Wilshire

Paris-Aligned Benchmarks

Carbon Emissions Model

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Contents

1 Introduction

The Wilshire Carbon Emissions model provides comprehensive data on Scope 1 and Scope 2 emissions for any company and on Scope 3 emissions for companies from Energy and Mining sectors, during a fiscal period, according to this specific framework. The emissions data results from a rigorous hierarchical selection process that combines both reported and estimated data (when no reported data is available or validated). The process and input data used are detailed in the next sections.

2 Definitions

2.1 Common Definitions

For the following definitions, the main and extensive source can be retrieved from the GHG Protocol[1].

GHG (Greenhouse Gas): GHG are gases in the atmosphere such as carbon dioxide, methane and nitrous oxide that absorbs and emits radiant energy, causing the greenhouse effect.

Carbon emissions: in our case, it represents the GHG emissions caused by a company, and are expressed in terms of to the CO2 equivalent (CO2eq) unit, according to IPCC and related official documentation

Scope 1: direct carbon emissions emitted by a company during the production process.

Scope 2: indirect carbon emissions of a company linked to its energy-use during the production process. Note that Scope 2 emissions can be either "location-based" (calculated from the energy that the company has physically got via the energy grid) or "market-based" (calculated on the proportion and type of energy purchased by the company on the market)[2]. For reporting companies, the sustained value is "market-based". For non-reporting companies, estimates are "location-based".

Scope 3: indirect GHG emissions that occur upstream or downstream of the production chain of a company. For example, it consists in emissions required to produce raw material used by a company or emissions associated with using products sold by a company. Scope 3 emissions are divided into 15 categories as detailed in Appendix C.

Reported carbon emissions: carbon emissions figures disclosed by a company.

Carbon intensity: it measures how much carbon emissions are produced per unit of monetary or physical metrics. With regards to carbon intensity in terms of monetary unit, the most widespread metrics are carbon intensity of sales or revenues, market value (MV), or enterprise value (EV or EVIC if cash included).

Fiscal year: it represents a one-year period that companies use for accounting purposes to prepare financial statements. Note that not all fiscal years correspond with the calendar year.

NAICS (North American Industry Classification System)[3]: The North American Industry Classification System (NAICS) is the standard used by Federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy. NAICS was developed under the auspices of the Office of Management and Budget (OMB), and adopted in 1997 to replace the Standard Industrial Classification (SIC) system. It was developed jointly by the U.S. Economic Classification Policy Committee (ECPC), Statistics Canada, and Mexico's Instituto Nacional de Estadistica y Geografia, to allow for a high level of comparability in business statistics among the North American countries.

[1] https://ghgprotocol.org/standards

[2] https://ghgprotocol.org/scope_2_guidance

[3] https://www.census.gov/naics/

NACE[4]*:* The Statistical classification of economic activities in the European Community, abbreviated as NACE, is the classification of economic activities in the European Union (EU); the term NACE is derived from the French "Nomenclature statistique des Activités Economiques dans la Communauté Européenne". Various NACE versions have been developed since 1970.

Multi-Regional Input Output (MRIO) model: a MRIO model gathers all monetary flows between major economic sectors of geographic regions. It is one of the most powerful tool used in macroeconomy to illustrate, calculate, and predict the interrelations between various activities and economic players

Environmentally-Extended MRIO (EE-MRIO) model: an EE-MRIO model associates environmental accounts to monetary flows from MRIO, such as direct GHG emitted by each economic sector of each geographic region during the production process.

2.2 Specific Definitions

Specific definitions are the definitions that are used by Wilshire in its internal processes.

Self-Reported data: carbon emission data that is publicly disclosed by the emitters (companies), whether they have been quality-checked or not by external third-party. Self-reported data is collected from time by time by various data providers & vendors, and is usually attached to a specific fiscal year.

Reported-Derived Data: data that is not directly disclosed by emitters, but derived directly from self-reported data using basic interpolation (between two years) or extrapolation (derived from the year immediately before), according to a general proxy (net sales or revenues). Reported-derived data is considered as part of the Reported data family, and not Estimated data. Reported-Derived data only depends on data specifically linked to the emitter (net sales or revenues, previous carbon emissions).

Estimated data: estimated carbon data encompasses all data that is neither self-reported nor reported-derived. In other words, Estimated data is the output of specific modelling based on macro-economic perspectives or statistical analysis of peer-groups.

Final dataset: refers to the final dataset which assigns emission data to a company and a fiscal year, either reported or estimated.

3 Sources and Input Data

3.1 Reported Carbon Emissions Data

3.1.1 Self-Reported Carbon Data

Self-reported corporate carbon emissions data is sourced from the ISS Climate Core dataset. It contains self-reported emissions data collected by ISS from all available sources, including company CSR and annual reports, and other direct sources of emissions data. The dataset also integrates carbon emissions data from the Carbon Disclosure Project (CDP).

3.1.2 Reported-Derived Carbon Data

To expand the coverage of reported carbon emissions, reported-derived emissions data is computed either by interpolating data between two reported years or by extrapolating previous carbon emission data, using computed revenue carbon intensity and current net sales or revenue in USD from no earlier than two years previously.

3.2 Company and Industry Taxonomy System (CITS)

CITS is Wilshire companies' classification system. This classification relies on the breakdown of revenues generated by the various products and services offered by a company. As the classification tends to be product & services centric, there is no

[4] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Statistical_classification_of_economic_activities_in_the_European_Community_(NACE)

specific distinction relative to economic cycles or types of clients (consumer versus businesses). Besides, the general philosophy is also to discriminate whenever practically possible between the ESG (environmental, social, and governance) profiles of such products and services. As an example, revenues from electric power generation will be split according to the different sources of power, provided that this information is available. This has a hierarchical structure:

- 11 industries
- 30 supersectors
- 59 sectors
- 176 subsectors.

Through an automated process:

1. Raw product segments[5] disclosed by companies are translated into NAICS segments.
2. NAICS segments are aggregated at subsector level.
3. The primary subsector assigned to a company is the subsector from which its revenue mainly comes.

For more details, see the CITS methodology.

3.3 Fundamentals Data

3.3.1 Net Sales or Revenues in USD

Companies' revenues data used in the process are currently sourced from various well-known, global databases that are publicly available, including but not limited to Refinitiv Worldscope, which collect information as disclosed by companies.

For industrials, "Net Sales or Revenues" represents gross sales and other operating revenue less discounts, returns and allowances. For banks, insurance and other financial companies, it represents the total operating revenue of the company.

Note that all the financial statements reported by companies in local currency are reported to USD using the exchange rate given in the statements, or where it is not available, using the fiscal year end exchange rate linked to the country of primary listing of shares traded by the company.

3.3.2 NAICS Segments

See section 3.2.

3.3.3 Other Data

Companies are assigned to a single country u which represents the country in which the corporate office of a company is located.

Fiscal years and associated fiscal periods start and end dates that are used in the process are initially sourced from Refinitiv Worldscope. However, when there are missing fiscal years for a company, a fiscal period is created which starts at the end of the latest available fiscal period and ends at the beginning of the next available one. Note that before applying this, checks are made to ensure that the company is active during the created period and that the dates of the initial periods are not consecutive.

3.4 Environmentally Extended Multi-Regional Input Output model (EE-MRIO)

The Exiobase[6] v.3 dataset is the Environmentally Extended Multi-Regional Input Output model (EE-MRIO) used, in part, to estimate non-reported carbon emissions. Key features of this dataset can be found in the table below:

[5] Raw product segments represent the revenue as disclosed by a company from each of its product lines.

[6] Exiobase is a global, detailed Multi-Regional Environmentally Extended Supply-Use Table (MR-SUT) and Input-Output Table (MR-IOT). It was developed by harmonizing and detailing supply-use tables for a large number of countries, estimating emissions and resource extractions by industry. Exiobase was developed by a consortium of several research institutes in projects financed by the European research framework programs. Three version of Exiobase are available. (https://www.exiobase.eu/)

Key features of Exiobase 3

Number of countries and geographic regions	Number of economic sectors	Economic sectors classification	Currency of monetary data
44 countries* **5 Rest of World regions***	163 industries	NACE Rev. 1.1 except energy-linked sectors	EUR[7]

*Source: Exiobase. *See Appendix F for a detailed list of Exiobase countries and regions.*

4 Methodology

4.1 Overview

There is a variety of models and approaches available for estimating missing carbon emission data. The fundamental reason why these models are still employed lies with the limited portion of companies reporting and disclosing their emissions for the various scopes. Despite significant progress over time and increased regulation asserting the material risk either in producing emissions (climate change risk) or failing to report such emissions (transparency & litigation risk), investors wanting a comprehensive view on the investment universe must continue to make substantial use of models that estimate non-reported emission data.

Such models are usually characterized according to two perspectives:

1. Is the model derived from a top-down, macro-economic view linking economies, sectors, and emitters together, or is it derived from bottom-up observations related to some peer-group average?
2. Regarding the potential breakdown of activities of the emitter and their specific carbon intensity factors, is the emitting company considered as a portfolio of separate activities (multi-segment) or as a pure play of its own (one-segment only)?

Broadly this is summarized in the following table.

Crossing the modelling strategies

	Top-Down Approach	Bottom-Up Approach
Corporates as One-Segment Only	Examples: - Meta Sector Analysis (factor coefficients)	Examples: - Median/Mean - 1Factor / Multifactor Regression analysis
Corporates as Multi-Segment Portfolio	Examples: - EE-MRIO	Examples: - Interpolation (IDWI)

Source: Wilshire (NB. The list of solutions presented here is not exhaustive and displayed only for illustrative purpose)

[7] To make Exiobase data, in EUR, comparable with segments data, in USD, the EUR to USD exchange rate from OECD (https://data.oecd.org/conversion/exchange-rates.htm) is applied to the Exiobase monetary figures.

The Wilshire model covers the two main, complimentary types of solutions:

- A Bottom-Up Approach applied to companies viewed as One-Segment Only, with Multi-level Weighted adjusted-median estimates, and
- A Top-Down Approach applied to companies viewed as Multi-Segment Portfolios, with the EE-MRIO-based estimated data and the model for estimating Scope 3 emissions for companies from Energy and Mining sectors.

Additionally, a third-party estimate (from ISS) is also introduced into the final estimate computation, to increase the stability across sectors and over time.

4.2 Notational Definitions

The following definitions will be used throughout this methodology document:

$C_{i,t}^{r}$: self-reported r carbon emissions of a company i for the fiscal year t

$C_{i,t}^{rd}$: reported-derived rd carbon emissions of a company i for the fiscal year t (see section 3.1.2)

$C_{i,t}^{e}$: estimated e carbon emissions of a company i for the fiscal year t

$Revenue_{i,t}$: Net Sales or Revenue in USD of a company i for the fiscal year t

$CI_{i,t}^{emissions\ type} = \frac{C_{i,t}^{emissions\ type}}{Revenue_{i,t}}$: revenue carbon intensity of a company i for the fiscal year t. Note that "emissions type" may be either self-reported, reported-derived or estimated.

Each symbol can refer to scope 1, scope 2 or scope 3 emissions.

4.3 Quality Control of Reported Data

Before integrating reported data into the Final Dataset, extreme carbon data is discarded. To achieve this, a winsorization process is performed at CITS sector level 3:

- For each CITS sector, lower and upper bounds are set at the 1st and 95th percentiles of the CITS sector. A count of companies within the sector for which a reported revenue carbon intensity is available is also performed.
- For each company with a reported carbon intensity, we compute the absolute distance to either the lower or the upper bound of its associated CITS sector.

The reported carbon intensity of a company is replaced by the lower or upper bound of its CITS sector only if the sector counts at least 2 companies with available reported carbon intensity and if the absolute distance to the boundaries is greater than 95%.

4.4 Estimated Data from Third Party

The ISS Climate Core dataset includes estimated carbon emissions data for non-reporting companies. These estimates are based on ISS own classification system which allows benchmarking of non-reporting companies against their reporting peers. They are denoted below by $C_{i,t}^{iss}$.

For more details, see an overview of the methodology.

4.5 Estimated Data from Wilshire

In addition to third-party data, Wilshire has developed its own estimation model for assigning carbon emissions data to non-reporting companies. Data is estimated using a process based on the combination of three strategies detailed below.

Note that the process estimates Scope 1 and Scope 2 location-based emissions for companies from all sectors, and Scope 3 emissions for companies from Energy and Mining sectors. In particular, Scope 2 emissions estimates are mainly derived from intensity factors based on the location of the company.

4.5.1 Median-based estimated data for Scope 1 and Scope 2

This estimation strategy is based on the various medians of reported revenue carbon intensity computed at each CITS sectoral level, whether it is industry, supersector, sector, or subsector.

The principle is that each company carbon intensity can be approximated by various peer groups that can be considered again at different level of granularity (industry, supersector, sector and subsector).

A wider peer group (e.g. at industry level) will give a carbon intensity proxy which will be more stable, while a narrower peer group will give carbon intensity proxy (median) likely more representative of the specific characteristics of similar companies but less stable over time.

With a multi-level weighted median (described below), a corporate carbon intensity will be simultaneously approximated by the four sector level intensity (medians), according to the merits (peer group size, representativeness) of each level.

Adjusted median of reported carbon intensity

Based on controlled reported revenue carbon intensities, we compute medians for each sectoral activity s at each CITS level l ($Median\ CI^{s_l}$). We also count the overall size of each sectoral activity in each CITS level ($Size^{s_l}$) as well as the number of companies with an available controlled reported revenue intensity figure ($Reported\ Size^{s_l}$).

As mentioned in section 3.2, CITS has a hierarchical structure with four sectoral levels: $l = [1,2,3,4]$. Therefore, a company is assigned a unique subsector s_4 at level 4, a unique sector s_3 at level 3, a supersector s_2 at level 2 and an industry s_1 at level 1.

For a company i and a fiscal period t, we derive from the size and the number of companies with reported data in each of the sectoral levels s_l assigned to the company, an adjustment coefficient regarding the size of its subsector s_4:

$$Adjustment\ Size_{i,t}^{s_l} = \frac{Size_{i,t}^{s_4} * Reported\ Size_{i,t}^{s_l}}{(Size_{i,t}^{s_l})^2}$$

This coefficient reflects the representativeness of each sector in each CITS level regarding the corresponding subsector. Please see Appendix A for a detailed example of the computation.

Furthermore, to minimize the impact of potential abnormal changes of the sectoral median from one fiscal period to another, we use a 3-year trailing average to smooth every median of each sectoral level assigned to a company:

$$Smooth\ Median\ CI_{i,t}^{s_l} = \frac{\sum_{t=1}^{3} Median\ CI_{i,t}^{s_l}}{3}$$

The adjusted median of reported carbon intensity of company i for a fiscal period t is then the average of the smoothed medians of the four sectoral levels assigned to it, weighted by the corresponding adjustment size coefficients:

$$Adjusted\ Median\ CI_{i,t} = \frac{\sum_{l=1}^{4} Adjustment\ Size_{i,t}^{s_l} * Smooth\ Median\ CI_{i,t}^{s_l}}{\sum_{l=1}^{4} Adjustment\ Size_{i,t}^{s_l}}$$

Multi-level Weighted adjusted-median estimates

The median-based estimated carbon emissions data for a company i and a fiscal period t is the product of its adjusted median of reported carbon intensity and its net sales or revenue in USD:

$$C_{i,t}^{e\ median} = Adjusted\ Median\ CI_{i,t} * Revenue_{i,t}$$

4.5.2 EE-MRIO-based estimated data for Scope 1 and Scope 2: overview

The second carbon model used to compliment Multi-level Weighted adjusted-median estimates comes from the range of macro-economic tools. In that perspectives, the model built up here is directly based on one of the already existing Environmentally-Extended Multi-Regional Input-Output tables (Exiobase), which allows for linking up sectors / country to each other with an overlay on Greenhouse Gas generated and exchanged in-between.

On this base, a vector of carbon coefficients per monetary unit can be computed for each sector / country in the table and then applied to the vector of revenues (revenue segment breakdown) of each and every company. The multiplication of those two vectors is then computed and aggregated for assessing and estimating the total GHG (in CO2eq) corresponding to the total revenues generated by the company.

The sector classification here is NAICS, the US industrial classification that supports CITS.

For technical details on how Exiobase is unfold and used for matrices computation, please see Appendix B.

Adjusted MRIO estimates

The final set of MRIO-based carbon emissions data are derived from the raw MRIO estimates by adjusting them by their distance with reported peers at the industry level. More precisely, based on the companies with both reported and MRIO-based figures in each CITS industry (level 1), a MRIO adjustment coefficient ($\beta^{industry}$) is derived from the distance between MRIO-based figures and their reported peers.

Finally this adjustment coefficient is applied to the raw MRIO estimates to obtain the final MRIO-based carbon emissions:

$$C_i^{e\ mrio} = Raw\ C_i^{e\ mrio} * \beta_i^{industry}$$

where $industry$ is the CITS industry assigned to the company i and $\beta_i^{industry}$ the adjustment coefficient associated to the company i.

4.5.3 Estimated data for Scope 3 (Energy and Mining sectors)

The following section describes the model for estimating Scope 3 emissions for companies within in the Energy and Mining sectors.

Scope 3 emissions for such companies occur mostly downstream of the value chain at two stages of the lifecycle:

- Use of sold products: combustion of fossil fuels (coal, oil, natural gas) for electricity generation or to power vehicles
- Processing of sold products: combustion of fossil fuels for processing bauxite and iron ores into aluminium and crude steel respectively

These two categories (see Appendix C) are considered material in the Energy and Mining sectors. Associated emissions are estimated using relevant emission factors. Emission factors are coefficients that allow conversion of units of activities (sales, km travelled) into GHG emissions released because of these activities.

Hereafter, we use the quantity of Energy and Mining products sold with corresponding emission factors to estimate corporate emissions. The quantity of products sold in year t by company j is approximated using segment revenues divided by commodity prices sourced from the World Bank for corresponding segment j.

$$Q_{j,i,t} = \frac{Revenue_{j,i,t}}{P_{j,t}}$$

To calculate Scope 3 GHG emissions $C_{i,t}^{e\ Wilshire}$ of company i at fiscal period t, we multiply the quantity of product j sold by its corresponding emission factor. The formula is given below:

$$C_{i,t}^{e\ wilshire} = \sum_{j=1}^{J} EF_j^{\cdot}\ Q_{j,i,t}$$

where:

- $C_{i,t}^{e\ wilshire}$ are Scope 3 (indirect) emissions of company i in year t expressed in tCO2e
- $EF_j^{\cdot}$ is the emission factor of goods j
- $Q_{j,i,t}$ is the quantity of goods j sold in year t by company i

4.6 Final Estimated Data

4.6.1 Final estimated data for Scope 1 and Scope 2

The final estimated carbon emissions data for Scope 1 and Scope 2 assigned to a non-reporting company i for a fiscal period t results from the combination of the estimates of the 3 modelling strategies such as:

$$C_{i,t}^{e} = \frac{C_{i,t}^{e\ iss} + C_{i,t}^{e\ median} + C_{i,t}^{e\ mrio}}{3}$$

4.6.2 Final estimated data for Scope 3

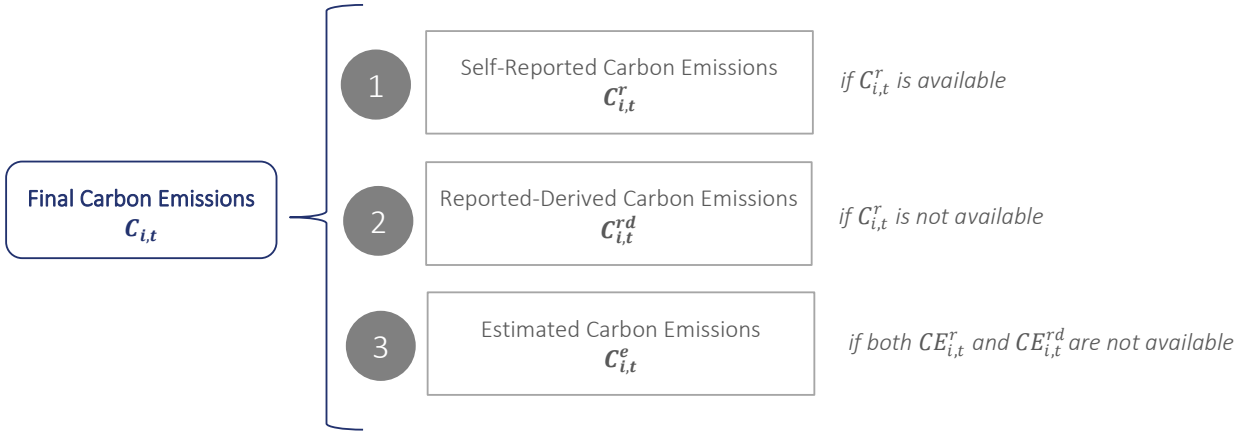
The final estimated Scope 3 GHG emissions $C_{i,t}^{e}$ is defined below:

$$C_{i,t}^{e} = \begin{cases} C_{i,t}^{e\ iss} & \text{if} \quad C_{i,t}^{e\ wilshire} < C_{i,t}^{e\ iss} \\ \frac{1}{2}\left(C_{i,t}^{e\ iss} + C_{i,t}^{e\ wilshire}\right) & \text{otherwise} \end{cases}$$

4.7 Selection Algorithm

The final carbon emissions data for a company and a fiscal period is selected as below:

Final carbon emissions data selection process



Appendix A: Example of the Adjustment Size from the Median-based modelling strategy

This Appendix comprises an example of the computation of the Adjustment Size coefficient for a company which is associated to the CITS subsector "Electronic Entertainment Goods". This subsector is linked to the sector "Digital and Electronic Goods" which is related to the supersector "Digital Goods and Services". The industry associated to this supersector is "Digital Information and Services".

Example of the Adjustment Size Process

CITS level	CITS name	Size	Reporting Proportion Size	Adjusted Size weighting coefficient
Subsector (4)	Electronic Entertainment Goods	40	14	0.35 $40*(14/(40)^2)$
Sector (3)	Digital and Electronic Goods	65	36	0.34 $40*(36/(65)^2)$
Supersector (2)	Digital Goods and Services	112	53	0.16 $40*(53/(112)^2)$
Industry (1)	Digital Information and Services	434	161	0.03 $40*(161/(434)^2)$

Source: Wilshire.

Appendix B: From Exiobase to carbon intensity coefficients by NAICS sector

As set out in section 2.1, EE-MRIO details monetary values Z exchanged and user demand Y between the economic sectors of each geographic region with other sectors and regions during the whole production process and the direct GHG emissions associated to the consumption of these quantities E.

Note that Z and Y are sparse matrices while E is a vector such as:

$$Z = \begin{pmatrix} z_{i,j}^{1,1} & \cdots & z_{i,j}^{1,m} \\ \vdots & z_{i,j}^{r,k} & \vdots \\ z_{i,j}^{m,1} & \cdots & z_{i,j}^{m,m} \end{pmatrix}$$ where $z_{i,j}^{r,k}$ is the monetary input from sector i in region r to sector j in region k.

$$Y = \begin{pmatrix} y_{i}^{1,1} & \cdots & y_{i}^{1,m} \\ \vdots & y_{i}^{r,k} & \vdots \\ z_{i}^{m,1} & \cdots & z_{i}^{m,m} \end{pmatrix}$$ where $y_{i}^{r,k}$ is the final demand of region k of the product of sector i in region r.

$$E = \begin{pmatrix} e_{i}^{1} \\ \vdots \\ e_{i}^{m} \end{pmatrix}$$ where e_{i}^{m} is the direct GHG emissions demand of sector i in region m.

EE-MRIO GHG intensity factors

From the initial matrices, the gross output GO vector can be derived, which is the overall monetary quantities consumed both as intermediary input by other sectors and regions and by final users of other regions:

$$GO = \begin{pmatrix} go_{i}^{1} = z_{i,j}^{1,1} + \cdots + y_{i}^{1,1} + \cdots + y_{i}^{1,m} \\ \vdots \\ go_{i}^{m} = z_{i,j}^{m,1} + \cdots + y_{i}^{m,1} + \cdots + y_{i}^{m,m} \end{pmatrix}$$

The key assumption in a MRIO framework is that the gross output vector must be equal to the total input one. Because of this, a matrix of technical coefficients A can be derived, which gathers the monetary quantities from a sector in a region used to produce one unit of total input:

$$A = \begin{pmatrix} \frac{z_{i,j}^{1,1}}{go_{i}^{1}} & \cdots & \frac{z_{i,j}^{1,m}}{go_{i}^{m}} \\ \vdots & \frac{z_{i,j}^{r,k}}{go_{i}^{k}} & \vdots \\ \frac{z_{i,j}^{m,1}}{go_{i}^{1}} & \cdots & \frac{z_{i,j}^{m,m}}{go_{i}^{m}} \end{pmatrix}$$

Using the total input vector, the GHG direct multiplier vector MD can be derived, which represents the direct GHG emitted from the production of one unit of total input:

$$MD = \begin{pmatrix} md_{i}^{1} = \frac{e_{i}^{1}}{go_{i}^{1}} \\ \vdots \\ md_{i}^{m} = \frac{e_{i}^{m}}{go_{i}^{m}} \end{pmatrix}$$

The rows of the MD matrix constitute the Scope 1 MRIO intensity factors for a sector i a region m: $Scope\ 1_{i}^{m} = md_{i}^{m}$.

In economic analysis, MRIO is used to track the ripple effects in an economy where sectors and regions are fully interconnected. These interconnections are shown in the so-called "Leontief inverse" matrix L. This matrix gathers all direct and indirect effects on output in one sector from one region required to produce a unit of output from another sector of another region. In other words, it summarises the entire production chain (direct and indirect). It is defined by:

$L = (I - A)^{-1}$ where I is the identity matrix and A the matrix of technical coefficients.

Therefore, the dot product of the Leontief inverse matrix and the GHG direct multiplier vector gives both direct and indirect GHG emissions associated to each sector and region of the whole production chain:

$$MT = (L * MD) = \begin{pmatrix} l_{i,j}^{1,1} md_i^1 & \cdots & l_{i,j}^{1,m} md_i^m \\ \vdots & \ddots & \vdots \\ l_{i,j}^{m,1} md_i^1 & \cdots & l_{i,j}^{m,m} md_i^m \end{pmatrix}$$

Note that, by construction, the direct GHG multipliers vector is only included into the diagonal of MT.

Based on the MT matrix, we deduce Scope 2 MRIO intensity factors for a sector i of a region m as the sum of all the rows of MT associated with energy producing sectors j:

$$Scope\ 2_i^m = \sum_j l_{i,j}^{m,m} md_i^m$$

where j includes only energy producing sectors of the production chain of the sector i.

Raw MRIO estimates

The first set of MRIO-based estimates are obtained by combining the previous MRIO outcomes with NAICS segments data.

Before computing estimated carbon emissions, we associate each NAICS activity to a single Exiobase industries and each country to an Exiobase region thanks to tables of correspondence provided by the Exiobase working group[8].

Note that an Exiobase industry can be associated to various NAICS activities. From these tables, we derive intensity factors for each NAICS activities $naics$ and country c as:

$$MRIO\ GHG\ {}_{naics}^{c} = \frac{\sum_i go_i^m * GHG_i^m}{\sum_i go_i^m}$$

where GHG represents either $Scope\ 1$ or $Scope\ 2$ intensity factors, m is the Exiobase region associated to the country c and i are all Exiobase sectors associated to the $naics$ activities.

For a company i, the raw MRIO-based carbon emissions results from the sum of its NAICS segments weighted by the associated NAICS-Country MRIO intensity factors:

$$Raw\ C_i^{e\ mrio} = \sum_{naics}^{NAICS} MRIO\ GHG\ {}_{naics}^{c} * segment_{naics}$$

where $segment_{naics}$ represents the revenue of the company i in the segment $naics$, $NAICS$ represents all of its $naics$ segments and c the Worldscope country associated to the company.

[8] https://ntnu.app.box.com/s/ziox4zmkgt3cdsg549brr0qaecskgjsd

Appendix C: Scope 3 Categories

Below are Scope 3 GHG emissions categories as referred to by the GHG Protocol.

Upstream categories	Downstream categories
1. Purchased goods and services	9. Downstream transportation and distribution
2. Capital goods	10. Processing of sold products
3. Fuel – and energy – related activities	11. Use of sold products
4. Upstream transportation and distribution	12. End of life treatment of sold products
5. Waste generated in operations	13. Downstream leased assets
6. Business travel	14. Franchises
7. Employee commuting	15. Investments
8. Upstream leased assets	

Source: GHG Protocol.

Appendix D: Emissions Factor Sources

Commodity	Emission Factor Source
Coal	IPCC Emissions Factor Database[9]
Crude Oil	IPCC Emissions Factor Database
Natural Gas	IPCC Emissions Factor Database
Iron	Song, J.; Jiang, Z.; Bao, C.; Xu, A. Comparison of Energy Consumption and CO_2 Emission for Three Steel Production Routes—Integrated Steel Plant Equipped with Blast Furnace, Oxygen Blast Furnace or COREX. *Metals* **2019**, *9*, 364.
Bauxite	International Aluminium Institute, Appendix A Life Cycle Inventory Data and Environmental Metrics, **2018**

[9] See IPCC Emissions Factor Database | Greenhouse Gas Protocol (ghgprotocol.org)

Appendix E: List of activities covered as Energy and Mining according to EU Regulation PAB

Per the regulation[10], as of 23 December 2020, Scope 3 GHG emissions data shall be included for the following sectors[11]:

Section B – Mining and Quarrying	Section C - Manufacturing
Division 05: Mining of coal and lignite	
Division 06: Extraction of crude petroleum and natural gas	Division 19: Manufacture of coke and refined petroleum products
Division 07: Mining of metal ores	Division 20: Manufacture of chemicals and chemical products
Division 08: Other mining and quarrying	
Division 09: Mining support service activities	

Source: European Commission.

[10] Delegated Act

[11] Regulation (EC) No 1893/2006

Appendix F: Countries and Geographic Regions from Exiobase

F.1 Countries

Exiobase Code	ISO3 Code	Name
AT	AUT	Austria
AU	AUS	Australia
BE	BEL	Belgium
BG	BGR	Bulgaria
BR	BRA	Brazil
CA	CAN	Canada
CH	CHE	Switzerland
CN	CHN	China
CY	CYP	Cyprus
CZ	CZE	Czech Republic
DE	DEU	Germany
DK	DNK	Denmark
EE	EST	Estonia
ES	ESP	Spain
FI	FIN	Finland
FR	FRA	France
GB	GBR	United Kingdom
GR	GRC	Greece
HR	HRV	Croatia
HU	HUN	Hungary
ID	IDN	Indonesia
IE	IRL	Ireland
IN	IND	India
IT	ITA	Italy
JP	JPN	Japan

KR	KOR	South Korea
LT	LTU	Lithuania
LU	LUX	Luxembourg
LV	LVA	Latvia
MT	MLT	Malta
MX	MEX	Mexico
NL	NLD	Netherlands
NO	NOR	Norway
PL	POL	Poland
PT	PRT	Portugal
RO	ROM	Romania
RU	RUS	Russia
SE	SWE	Sweden
SI	SVN	Slovenia
SK	SVK	Slovakia
TR	TUR	Turkey
TW	TWN	Taiwan
US	USA	United States
ZA	ZAF	South Africa

Source: Exiobase.

F.2 Rest of World regions

Exiobase Code	Name
WA	RoW Asia and Pacific
WE	RoW Europe
WF	RoW Africa
WL	RoW America
WM	RoW Middle East

Source: Exiobase.

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