METHODOLOGICAL REPORT

Impact measurement using the Value Balancing Alliance (VBA) method

Upstream calculation: Methodological background and data sources

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1 Methodological Background

This technical report describes the method of upstream impact calculation used and gives an overview of the required data sources and respective extrapolations which were necessary to meet the needs of the VBA method.

Upstream impacts can either be evaluated from bottom-up or top-down. One popular approach to measure impact from bottom-up is the process-based lifecycle assessment (LCA). Another one is the collection of suppliers and / or sales data. The advantage of this method is the predominant use of primary data. However, the results are product or vendor specific and represent only pieces of the company's overall impact. It is also considered a labour-intensive task. On the contrary, when measuring impact from top-down, mostly secondary data is used. A popular methodology is the Input-Output-Analysis (IO-Analysis). IO-Analysis can detect environmental and socio-economic hotspots with comparatively low effort. It is often used to estimate the up- and downstream impacts in the supply chain of a company or of an economic sector. The main difference to a process-based methodology is the scope. In Input-Output-Modelling, the entire value chain of the company can be accounted for. The estimations are based on primary financial data (a detailed list with region-specific information regarding the amount and type of goods purchased and sold) that are then translated into economic, socio-economic, and environmental indicators. As both approaches deliver valuable results, efforts were made to match bottom-up and top-down approaches (Beylot, Corrado, and Sala 2019). Integrating results from bottom-up assessments into the top-down Input-Output-Framework allows to enhance data quality while not restricting the scope of analysis.

Within this specific project, we used the IO-Analysis to quantify the upstream impact. Input-Output analysis was originally developed by Wassily Leontief (Leontief 1936) to describe the industrial structure of an economy and understand how changes in one economic sector may affect other sectors.

Leontief is known for his research on IO-Analysis and earned the Nobel Prize in Economics for his development of its associated theory in 1973. Applying the technique of IO-Analysis, it is possible to trace the inputs of production along the entire supply chain. This allows for the calculation of upstream impacts of a company. In addition to the direct effects, which describe the immediate effects directly generated by a company, input-output analysis allows for the calculation of (indirect) upstream effects. Upstream effects arise due to the input the company demands from other economic agents. Order placements result in an increase of economic activity at commissioned agents and their suppliers. This stimulus increases the gross value added (GVA) and other key figures along the supply chain, which are summarized under the term upstream effects. The model comes with an array of assumptions[1], however it is widely agreed that it is well suitable for impact analysis.

The basis for the calculation of indirect effects can be illustrated by the following equilibrium equation:

$$x = Ax + y \leftrightarrow x = (I - A)^{-1} y \qquad (1)$$

where x represents the vector of total gross output of a sector and y represents the vector of final demand and includes domestic consumer spending, assets, changes in inventories and exports. A represents the matrix of intermediate consumption per unit of output.

Equation (1), with $L = (I - A)^{-1}$ being the Leontief inverse, can be determined by the following mathematical transformation:

$$x = Ax + y$$

$$y = x - Ax$$

$$y = (1 - A)x$$

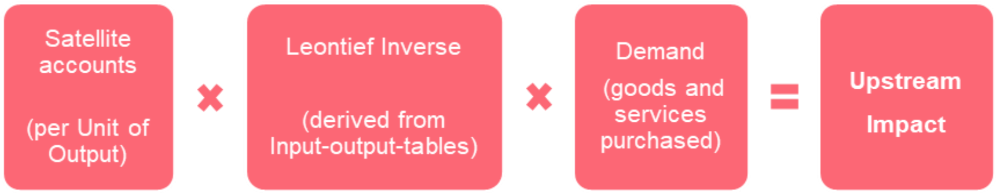
since $(I - A)^{-1} * (I - A) = 1$, with I being the identity matrix, $x = \frac{y}{1-A}$ equals

$$x = (1 - A)^{-1} y$$

[1] The assumptions of the Leontief model are: 1) Constant returns to scale, meaning that regardless of the level of production, the same quantity of inputs is needed per unit of output. 2)
No Supply Constraints, meaning there are no restrictions to raw materials, services or other inputs such as employment. 3) Fixed Input Structure: meaning that there is no input substitution in response to a change in output.

With x, the output triggered by a given demand y, the corresponding GVA can be derived using country and sector specific ratios of GVA to output. Other effects (eg. employment, air emissions, water pollution etc.) are calculated analogously using respective satellite accounts. In simple terms the indirect (upstream) impact of a company is the result of the multiplication of three components (see Figure 1).

Figure 1: Components of upstream calculation



Source: Own depiction

As shown in Figure 1, the calculation of upstream impacts requires input-output tables to derive the Leontief Inverse, corresponding satellite accounts, and a detailed purchasing list / spend of the company under investigation. The calculation is done by the calculation service implemented by Novartis and RedRooster. The next chapter describes the data sources used in more detail. The focus of this section is on the data sources used and the extrapolations performed.

2 Data Sources Base Year

2.1 Input-output-tables

When it comes to company-specific impact assessments using economic input output tables and the Leontief Inverse, the choice of the correct data source is very important. It determines the size and respective characteristics of the impact factor under study. There is no one fits all solution regarding the choice of the base data to use.

The compilation of input-output tables (IOT) is described in the System of National Accounts (European Commission et al. 2009). Similarly, the compilation of environmental satellite accounts is described in the System of Environmental-Economic Accounting (United Nations 2014). The provision of national input-output tables is thus a task which is carried out by national statistical offices. Such tables are very well suited to calculate the national economic footprint of an organization for example.

To analyze global value chains and the increasing international fragmentation of production, a multi-regional input-output table (MRIOT) is needed. These kinds of tables can be regarded as a set of national input-output tables that relate to each other by bilateral international trade flows. They provide comprehensive summaries of all transactions in the global economy between industries and final users across countries in a particular year.[2]
The estimation of a multi-regional IOT requires significant individual data and computation capability and is labor intensive. For a detailed multi-regional IOT, it would be necessary to measure worldwide economic transactions consistently and uniformly across all sectors and production stages of the economy. Since such an approach is not feasible, MRIOTs are constructed with the help of national accounts and trade data.

[2] Until now, statistical offices do not calculate official MRIOs. One exception are the experimental FIGARO MRIO tables produced by Eurostat.

The currently available tables differ with respect to the data sources, construction philosophy and the selection of countries. Not surprisingly, there are a lot of different approaches to deal with data gaps and inconsistencies. Each dataset was developed for specific questions with different intentions. Different methods were used in each case. This even leads to limited comparability of MRIOTs, which is a well-known and discussed phenomenon within the scientific community (Tukker and Dietzenbacher 2013; Arto, Rueda-Cantuche, and Peters 2014; Inomata and Owen 2014; Moran and Wood 2014; Owen 2017; Owen et al. 2014; 2016; Wieland et al. 2018; Giljum et al. 2019). Various data sources / models / IO Tables deliver different results (and operative conclusions) despite using the same model inputs (company spend and sales data).

The most prominent MRIO data sets (and related references) used for impact assessment are:

- FIGARO (Remond-Tiedrez and Rueda-Cantuche 2019; Eurostat and European Commission 2018; Eurostat 2008)
- OECD ICIO (Yamano and Webb 2018; Guilhoto et al. 2019)
- EORA (Lenzen et al. 2013; 2012)
- GTAP (Center for Global Trade Analysis, Purdue University et al. 2019; Walmsley, Aguiar, and Narayanan 2012)
- WIOD (Gouma et al. 2018; Timmer et al. 2016; 2015; Amores et al. 2019)
- ADB MRIO (Mariasingham 2011)
- EXIOBASE (Stadler et al. 2018; Tukker et al. 2013; Wood et al. 2014)
- Global MRIO Lab (Lenzen et al. 2017)

All selected databases have different methodical backgrounds and properties regarding regional, temporal, and sectoral coverage. Most of them are updated regularly and are therefore available in different versions, and they are differently equipped with additional information with respect to economic, environmental, and social satellite accounts (see Table 1 for an overview). A rigorous impact analysis framework relies on the choice of an appropriate model for the measurement and analysis of various impact factors of a company. The correct data choice makes it possible to adapt the modelling framework to the needs of the company more easily.

Table I: Overview of relevant MRIO Datasets

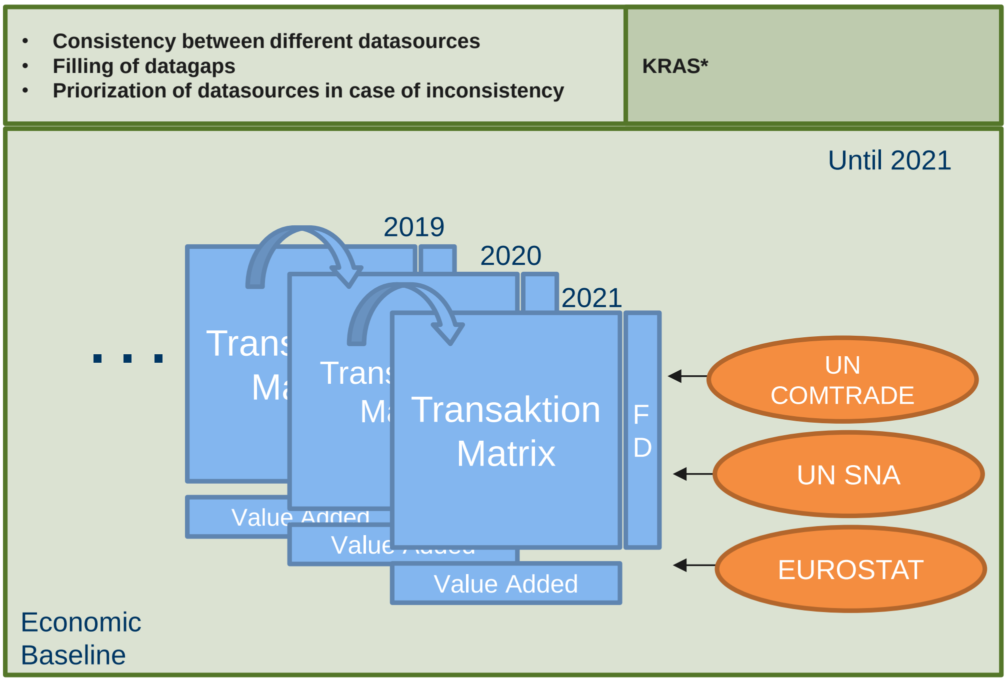
Source	Version	Resolution			sectoral classification standard	Satellite Accounts			License	Regular update	Institution	Info
		regional	temporal	sectoral		Economic	Environmental	Social				
FIGARO	experimental	27 Countries (EU-28 and USA)	2010 (production of time series in progress)	64 industries	ISIC Rev. 4	yes	not ready to use	not ready to use	free	experimental version, yearly updates and time-series planned	Eurostat	https://ec.europa.eu/eurostat/web/experimental-statistics/figaro
OECD ICIO	2018	65 Countries (37 OECD, 29 non-OECD, 1 RoW)	2005-2015	34 industries	ISIC Rev. 4	yes	not ready to use	not ready to use	free	yes	OECD	http://oe.cd/icio
EORA	EORA	187 countries	1990-2016	varying across countries; simplified version with 26 industries	ISIC Rev. 3	yes	good coverage (GHG, land, water, air pollution and biodiversity etc.)	no	not free	yes	KGM & Associates Pty (originally University of Sydney)	https://worldmrio.com/
EXIOBASE	3.8.1	44 countries, (5 RoW Aggregates)	1995-2024	163 industries, 200 products	ISIC Rev. 3	yes	very good coverage (Energy supply and use, GHG emissions, pollutants, water use, land use, material flows, nitrogen loads, phosphorus loads, LFC impact coefficients, etc.)	yes, few indicators are available (e.g. employment by skill-level and gender)	free	yes	Norwegian University of Science and Technologiy	http://exiobase.eu
GTAP	Version 10	121 Countries (20 RoW Aggregates)	2004, 2007, 2011, 2014	65 industries	ISIC Rev. 4	yes	good coverage (Co2 emissions, Energy volumes, land use)	Five labor skill categories	$320 - $6,240 (Versions 1 to 8 can be downloaded for free)	yes, on irregular basis	Center for Global Trade Analysis, Department of Agricultural Economics,Purdue University	https://www.gtap.agecon.purdue.edu/databases/v10/index.aspx
ADB MRIO	2019	62 countries (1 RoW)	2000, 2007-2018	varying SUT dimensions, harmonized to 35 industries	ISIC Rev. 3	yes	no	no	free	planned	Asian Development Bank	http://mrio.adbx.online/
WIOD	Release 2016	44 countries, 1 ROW	2000-2014	57 industries (some Zero-Sectors available)	ISIC Rev. 4	yes, full set of socio-economic variables	good coverage (GHG Emissions, Gross and emission relevant energy-use estimated by JRC, other environmental indicators just available for previous version)	labor by skill-level available for previous versions	free	yes, on irregular basis (depends on funding)	University Groningen	http://www.wiod.org
Global MRIO-Lab	-	All	as long as available	flexible (more than 5700 products)	flexibel	yes	covered (data availability depends on project purpose and sectoral resolution)	covered (data availability depends on project purpose and sectoral resolution)	depends on the workload	yes, realtime in nature	University of Sydney	https://ielab.info/

Source: Own depiction based on references and inspection of data.

To meet the needs of the VBA and the specifications given, we decided to use an own hybrid model which combines WIOD (high sectoral resolution and solid economic base-data), EORA (large number of countries included) and EXIOBASE (a lot of indicators available in the satellite accounts). In the current version, the WIOD database shows the global interdependence of 56 economies. It allows the analysis of the international interdependencies of 43 countries and an aggregate that summarizes the rest of the world. To be able to extend the impact analysis to other countries, this aggregate was distributed among the individual countries using the information from EORA. Due to the higher country resolution of EORA, a total of 188 countries and 57 sectors can be analyzed.

To capture the changes in World Trade over time and to consider current trends in international transactions occurred since the publication of the original tables, we additionally used data from UN COMTRADE[3], UN SNA[4] and Eurostat[5] to update the transaction matrices (see Figure 2). This was done using the KRAS balancing algorithm proposed by Lenzen (Lenzen, Gallego, and Wood 2009; Lenzen et al. 2014).

Figure 2: Update procedere with respect to the economic baseline of the base year



Source: Own depiction.

[3] https://comtrade.un.org/

[4] https://unstats.un.org/unsd/nationalaccount/madt.asp

[5] https://ec.europa.eu/eurostat/web/national-accounts/data/database

2.2 Satellite accounts

Satellite accounts are important extensions of MRIOT's and they are used to link the monetary flows of goods and services to other indicators of interest. The databases mentioned above already contain many economic, environmental, and social indicators, such as land- and sector-specific data on gross value added, employment, compensation of employees, greenhouse gas emissions, water consumption, land use, etc.
However, since the requirements of the VBA (see Table 2) could not be fulfilled with the help of the available MRIO datasets, we partially collected additional indicators from other sources and adapted them to the sectoral and geographical structure of the MRIO.

Table II: Scope of indicators for impact statement method, v0.2

Economic	• Gross value added (GDP contribution)
Human & Social	• Occupational Health & Safety • Training • Forced Labor • Child Labor • Living Wages
Environmental	• GHG emissions • Air emissions • Water consumption • Water pollution • Land use • Waste

Source: Value Balancing Alliance (2021, 11).

When creating the satellite accounts, we firstly checked whether the indicators and the respective specifications are available in a primary source / MRIO Database and mapped them onto the structure of our table. This was the case for GVA, GHGs, Air Pollution, Water Consumption, Land use and partially for supply of waste and water pollution. The indicators representing Occupational Health and Safety, Training, Forced Labor and Child Labor were not available, so we had to build the whole satellites on our own. We focus on the set of sources recommended by the VBA. This chapter describes the indicators and gives an overview of the relevant definitions and sources.

2.2.1 Economic

GVA (GDP contribution)

Definition

Output (at basic prices) minus intermediate consumption (at purchaser prices). GVA can be broken down by industry and institutional sector.
The sum of GVA across all industries or sectors plus taxes on products minus subsidies on products gives gross domestic product (GDP). The GVA thus captures the contribution to GDP.

Primary Sources

- World Input Output Database (WIOD)
- EORA

Additional Sources

- Eurostat National Accounts (Table “nama_10_a64”)
- OECD National Accounts (Table “SNA_TABLE6A”)

Data processing

There is full country coverage of economic variables by existing satellites of MRIO Sources. The additional sources are used to get the most recent values.

Change compared to previous year (financial year 2020)

No changes, just updates.

Employment

Definition

The employment level is defined as the number of people engaged in productive activities in an economy. The concept includes both employees and the self-employed.

Primary Sources

- World Input Output Database (WIOD)
- EORA
- ILO Database

Additional Sources

- Eurostat (Table “nama_10_a64e”)
- OECD (Table “SNA_TABLE7A”)

Data processing

There is nearly full country coverage of economic variables by existing satellites of MRIO Sources. Missing or implausible values in EORA were filled with the help of the ILO employment data. The additional sources are used to get the most current values.

Change compared to previous year (financial year 2020)

No changes, just updates.

2.2.2 Human rights and social

2.2.2.1 Occupational health and safety

Occupational health deals with all aspects of health and safety in the workplace and has a strong focus on primary prevention of hazards. The focus of this indicators is on the societal impacts arising from injuries and illnesses resulting from incidents that happen during the course of employment.

Injuries

Definition

A case of non-fatal occupational injury is the case of a worker incurring an occupational injury as a result of an occupational accident not leading to death. An occupational injury that is fatal is the result of an occupational accident where death occurred within one year from the day of the accident.

Specifications

Injuries by severity: short absence, long absence, partial incapacity, full incapacity, fatality

Primary Sources

- Eurostat (Tables “hsw_n2_01” and “hsw_n2_02”)
- Database of the International Labour Organization (ILO) - Occupational safety and health statistics (OSH): Incidence rates for fatal and non-fatal occupational injuries by economic activity

Additional Sources

- Study by Kharel (2016): The global epidemic of occupational injuries: Counts, costs, and compensation.
- Study by Hämäläinen et al (2017): Global Estimates of Occupational Accidents and Work-Related Illnesses
- Study of the Australia and National Occupational Health and Safety Commission (2015)
- Data on employment (see “Economic indicators”)

Estimation procedure

Eurostat and ILO data provide incidence rates for fatal and nonfatal injuries at different sector disaggregation levels and completeness. We calculated average incidence rates by income region to estimate missing values for entire countries and missing sectors. Incidence rates were then adjusted using academic studies to account for the well-recognized problem of underreporting. Furthermore, there was no data for all five severity levels. We used the ratios of the study of the Australia and National Occupational Health and Safety Commission (2015) to break down the non-fatal injuries according to the requested severity levels.

Change compared to previous year (financial year 2020)

Minor Change in estimation approach and use of additional sources.

Illness / Disease

Definition

An occupational disease is any disease caused primarily by exposure at work to a physical, organizational, chemical or biological risk factor or to a combination of these factors. Occupational diseases are mostly those listed in national legislation as resulting from exposure to risk factors at work. The recognition of an occupational disease may be linked to compensation if it is clear that there is a causal relationship between an occupational exposure and the disease. Many types of disease, including cancer, respiratory disorders, cardiovascular disease, skin diseases, musculoskeletal disorders and mental health problems, can be caused or made worse by work. Although the underlying causes of such diseases may be complex, certain workplace exposures are known to contribute to the development or progression of a disease, including:

- dangerous substances, such as chemical and biological agents, including carcinogens
- radiation, including ionizing radiation and ultraviolet radiation from the sun
- physical factors, including vibration, noise, manual lifting, and sedentary work
- work organizational and psychosocial risk factors, such as shift work and stress.

Specifications

Illness by severity: short absence, long absence, partial incapacity, full incapacity, fatality

Primary Source

- Study of the International Labour Organization (2014) with estimates on fatal occupational diseases for 227 countries
- Study of the European Agency for Safety and Health at Work (2019) for Germany, Netherlands, Finland, Italy and Poland. Australian Data is taken from Australia and National Occupational Health and Safety Commission (2015).

Additional Sources

- Sectoral incidence rates (The incidence rates represent the number of illnesses per 10,000 full-time equivalent workers) from US data on occupational illnesses by major industry sector and category of illness in 2018 (https://www.bls.gov/iif/oshwc/osh/os/snr07_00_2018.xlsx)

- Data on employment (see “Economic indicators”)

Estimation procedure

1. Estimation of cases fatal[6] illness for each country using the incidence rates from ILO (2014) (i.e., cases per 10.000 employees) and employment figures from the IO-Table. For Germany, Netherlands, Finland, Italy and Poland we use more recent estimates from the European Agency for Safety and Health at Work (2019), and for Australian the data is taken from the Australia and National Occupational Health and Safety Commission (2015).
2. The economy-wide fatality case estimates are allocated to sectors using US data on occupational illnesses by major industry sector and category of illness in 2018, mapped to WIOD-sectors (Assumptions: the sectoral distribution of fatal illnesses is the same as for all other illnesses; the relative incidence rate differences across sectors are similar between countries).
3. Estimate cases for the four other severity categories, applying the relation of non-fatal to fatal for each category in the Australian study as recommended by the Value Balancing Alliance. Check on plausibility of the relations, comparing the resulting global number of cases to the global estimates from ILO (2015).

Remarks

Numbers are not available in ILO-Database (like figures on injuries, which are updated regularly). Hard to compare between countries due to different definitions of “work-related diseases” and different compensation schemes. Underreporting / Underestimation is an issue here because there is a difference between reported and reality (diseases not accepted by authorities, different insurance-systems).

Change compared to calculation of previous year (financial year 2020)

No changes, just updates.

2.2.2.2 Training hours

[6] Unfortunately, this study provides no numbers on non-fatal incidence rates.

Definition

Time spent on continuing vocational training courses refers to paid working time (in hours) spent on Continuing vocational training (CVT) courses, i.e. the time that all participants have spent in total during the reference year. This only covers the actual training time, and only the time spent during the paid working time. Continuing vocational training (CVT) are training measures or activities which have as their primary objectives the acquisition of new competences or the development and improvement of existing ones and which must be financed at least partly by the enterprises for their employed persons who either have a working contract or who benefit directly from their work for the enterprise such as unpaid family workers and casual workers.

Primary Source

Eurostat: Hours spent in CVT courses by NACE Rev. 2 activity - hours per person employed in all enterprises (Table “trng_cvt_23n2”)

Additional Sources

Employment data.

Estimation procedure

In general, there is no dataset with global coverage. Eurostat provides datapoints for 30 countries and for the EU 28 on sectoral level. The data of the other countries were estimated based on the EU28 average training hours per person employed.

Change compared to calculation of previous years

No change: No newer data points were available.

2.2.2.3 Child labor

Definition

A case of child labor is defined as a child engaged in economic activities for more than one hour per week if aged 5-11, for more than 14 hours per week if aged 12-14, and for more than 43 hours per week if aged 15-17. This includes but is not limited to hazardous work but excludes household chores (ILO & UNICEF, 2021).

Primary Sources

- ILOSTAT (2021)
- UNICEF (2021)

Additional Sources

- ILO and UNICEF (2021)

Data processing

We combine country-level estimates of the percentage of children engaged in economic activity with estimates for the number of children aged 5 to 17 per country (UN DESA, 2019) to generate the absolute number of children working at the country level. We apply a recent estimate of the distribution across the three aggregate sectors agriculture, industry, and services by SDG region ILO and UNICEF (2021) and assume close to no child labor in 15 sectors with mainly high-skilled employment. Within the aggregate sectors, child labor cases are distributed proportionally to employment. Finally, we account for children working yet not engaged in supply chains. We assume that this is most relevant for the agricultural sector and thus exclude the percentage of children working as part of family operation according to regional estimates from ILO and UNICEF (2021). Finally, high-income countries are assumed to have no child labor.

New indicator for calculation of financial year 2020

Adjustments to the VBA approach:

- The method paper suggests applying the % of children in child labor as % to employees in low-skill labor. Instead, we estimate the total number of children in child labor and then distribute this number across sectors. Allocation to Novartis then follows as with other satellite accounts based on spend.
- The sector distribution uses regional data from ILO & UNICEF (2017) instead of Schulty & Strauß (2008).
- No cases of child labor in high income countries and specific sectors
- Adjustment of the number of children working in agriculture by an estimate for “contributing family workers” as these children are likely not integrated in supply chains.

2.2.2.4 Forced labor

Definition

Forced labor exploitation is defined as work forcefully imposed by private agents, including bonded labor, forced domestic work, and work imposed in the context of slavery or vestiges of slavery. Other forms of forced labor are forced sexual exploitation and state-imposed forced labor. The aggregate "modern slavery" further includes forced marriage (ILO and Walk Free Foundation 2017).

Primary Sources

- Walk Free Foundation (2018)

Additional Sources

- ILO and Walk Free Foundation (2017)

Data processing

The Global Slavery Index (GSI) provides country-level estimates for the number of people in modern slavery at the country level for 186 countries. For missing countries, the absolute number of modern slavery cases is estimated using the income region medians of Modern Slaves per Employees for the countries covered by the GSI dataset and the total number of employees in the country missing information.

As forced marriage, state-imposed forced labor and sexual exploitation are not driven by global supply chains, we exclude these using global and regional estimates from ILO and Walk Free Foundation (2017). The forced labor estimates are then allocated to sectors using the distribution of employees by country and excluding certain sectors (ILO and Walk Free Foundation 2017).

New indicator for the 2021 calculation

Adjustments to VBA approach:

- The Global Slavery Index estimates for modern slavery are adjusted to exclude types of modern slavery external to global supply chains.
- The method paper suggests applying the share of population in modern slavery to employees and further distributing this percentage by sector. Taking absolute cases and distributing these across the sectors, we ensure that the total number of cases matches estimates by the GSI.

2.2.2.5 Living Wages

Definition

The living wages indicator assesses the quality of employment by valuing the impact of the wages paid to employees on their quality of life. Specifically, it values the health utility of income, i.e. the contribution of income to an individual's well-being in a given location. For this purpose, wages are evaluated against a threshold, the "living wage". The living wage is defined as "a basic but decent level of life that allows a household to get good nutrition, housing, health and education" and is available at country level. Employees paid below the living wage cannot maintain a basic but decent level of life despite their work. They thus experience negative effects on quality of life and life expectancy. Wages above the living wage have a positive impact.

Comment

Valuation is done by Valuing Impact based on Estimation of Employees by skill level in the supply chain of Novartis using spend of 2021.

2.2.3 Environmental

2.2.3.1 GHG

Definition

A greenhouse gas (GHG) is a gas that absorbs and emits radiant energy within the thermal infrared range, causing the greenhouse effect. GHGs are in total seven gases of which we cover the three most impactful: carbon dioxide (CO2); methane (CH4) and nitrous dioxide (N2O). To harmonize the different gases to a universal metric, global warming potentials (GWP) are used. These potentials are factors describing the radiative forcing impact (degree of harm to the atmosphere) of one unit of a given GHG relative to one unit of CO2. The result is a universal unit of measurement named CO2e (CO2 equivalents) (GHG Protocol, 2015).

Primary Sources

- EXIOBASE 3.8.1.

- EORA

Additional Sources

- Eurostat Air Emission Accounts (Table: env_ac_ainah_r2)
- OECD Air Emission Accounts (Table “AEA”)
- Global Warming Potentials (based on the IPCC’s Fifth Assessment Report AR5)

Data processing

There is full country coverage of indicators by existing satellites of MRIO Sources. EXIOBASE has a higher sectoral disaggregation than WIOD (163 versus 57 sectors) such that we mapped the EXIOBASE sectors onto the WIOD classification. The additional sources were used afterwards to get the most current values.

Change compared to calculation of previous year (financial year 2020)

No changes, just updates.

2.2.3.2 Air Pollution

Definition

Air pollution is the presence of substances in the atmosphere that are harmful to the health of humans and other living beings, or cause damage to the climate or to materials. There are different types of air pollutants, such as gases, particulates, and biological molecules. Both human activity and natural processes can generate air pollution.

Primary Sources

- EXIOBASE 3.8.1.
- EORA

Additional Sources

- Eurostat Air Emission Accounts (Table: env_ac_ainah_r2)
- OECD Air Emission Accounts (Table “AEA”)
- Location mapping based on the recommendations of the VBA

Subindicators

- Ammonia (NH_3)
- Nitrogen Oxides (NO_x),
- Sulfur Oxides (SO_x)
- Volatile Organic Compounds (VOC)
- Particulates (PM 2.5, PM 10).

Specifications

Four locations:

- urban
- peri-urban
- rural
- transport

Data processing

There is full country coverage of indicators by existing satellites of MRIO Sources. EXIOBASE has a higher sectoral disaggregation than WIOD (163 versus 57 sectors) so that we had to map the EXIOBASE sectors into the WIOD classification. The additional sources were used afterwards to get the most current values. Depending on where emissions are released, the magnitude of air pollutants varies. Therefore, a split between four main locations (urban, peri-urban, rural and transport) was done, to fulfill the requirements of the VBA. The split recommended by the VBA is based on the assumption, that there is a high correlation between specific sectors and locations.

Change compared to calculation of previous year (financial year 2020)

No changes, just updates.

2.2.3.3 Water Consumption

Definition

Water consumption describes the proportion of water withdrawal, which is not returned to surface waters after use, as it is lost in the manufacturing process via evaporation, or incorporated into the finished product, byproducts, or solid waste. Water consumption refers to “blue water”, i.e. water sourced from surface or groundwater resources.

Primary Source

- EXIOBASE 3.8.1.
- EORA

Additional Sources

None.

Estimation procedure

There is full country coverage of indicators by existing satellites of MRIO Sources. EXIOBASE has a higher sectoral disaggregation than WIOD (163 versus 57 sectors) such that we had to map the EXIOBASE sectors into the WIOD classification.

Change compared to calculation of previous year (financial year 2020)

No changes, just updates.

2.2.3.4 Water Pollution

Definition

Water pollution is the contamination of water bodies, usually as a result of human activities. Water bodies include for example lakes, rivers, oceans, aquifers, and groundwater. Twelve different water pollutants are integrated in the analysis: Nitrogen, Phosphorus, Antimony, Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, PAHs and Zinc.

Primary Source

EXIOBASE HYBRID (Merciai and Schmidt 2018)

Additional Sources

- DESTATIS
- EEA WATERBASE – aggregated Database

Subindicators

- Nitrogen

- Phosphorus
- Antimony
- Arsenic
- Cadmium
- Chromium
- Copper
- Lead
- Mercury
- Nickel
- PAHs
- Zinc

Estimation procedure

The indicator distinguishes between three types of water bodies that get contaminated: freshwater, marine water, and unspecified water bodies. The availability of data on water pollution is highly restricted, both in terms of pollutant and impacted water bodies. Our primary data source features data on Nitrogen and Phosphorus in the sectoral granularity needed. These form the baseline to allocate the further ten pollutants to the respective countries and industries. The relation of Phosphorus and Nitrogen to the other ten Pollutants were taken from Destatis and EEA Waterbase and were used to extrapolate values for the missing pollutants, following the assumption of structural constancy. Unfortunately, just one specification was assessable (unspecified) with this approach and available datasets.

Change compared to calculation of previous year (financial year 2020)

No changes, just updates.

2.2.3.5 Land Use

Definition

Land use involves the management and modification of natural environment or wilderness into built environments such as settlements and semi-natural habitats such as arable fields, pastures, and managed woods. Most land use is due to agricultural activities. We distinguish between eleven types of land use, nine of them attributed to different forms of agricultural activity.

Subindicators

- Agriculture

- Forestry
- Paved

Specifications

- Wheat
- Vegetables,fruit,nuts
- Cereal grains nec
- Oilseeds
- Sugarcane,sugarbeet
- Plant-basedfibers
- Crops nec
- Animal rearing
- Paddyrice

Primary Source

- EXIOBASE 3.8.1.
- EORA

Additional Sources

- None

Estimation procedure

There is full country coverage of indicators by existing satellites of MRIO Sources. EXIOBASE has a higher sectoral disaggregation than WIOD (163 versus 57 sectors) such that we had to map the EXIOBASE sectors into the WIOD classification. EXIOBASE provides 20 types of Landuse[7], which were transferred / partially aggregated to the requested specifications.

Change compared to calculation of previous year (financial year 2020)

No changes, just updates.

General Remark

[7] For more information, see the supporting information S6 in Stadler et al. (2018) on the construction of the air emission accounts, available at: https://onlinelibrary.wiley.com/action/downloadSupplement?doi=10.1111%2Fjiec.12715&file=jiec12715-sup-0006-SuppMat-6.pdf

The quality of the data is not very good for some countries. Nevertheless, it is the best source available at the moment.

2.2.3.6 Waste

Definition

The indicator is defined as the weight of waste generated by a certain company. The quantity is expressed in kilogram.

Subindicators

- Hazardous waste
- Non-Hazardous waste

Specifications

- disposed (landfill)
- disposed (incinerated)
- recovered (recycling or downcycling)

Primary Source

EXIOBASE HYBRID (Merciai and Schmidt 2018)

Additional Sources

EUROSTAT Waste accounts (Table “env_wastrt”)

Estimation procedure

Because not all specifications requested by the VBA methodology for the indicator “waste” were given by EXIOBASEHYBRID, we used EUROSTAT to split the sub indicators to meet the specifications needed.

Change compared to calculation in 2019

No change.

2.2.4 Overview

Table III: Indicators and relevant sources

	Indicator	Subindicators	Specifications	Sources		
				Primary Datasource (MRIO Databases)	Additional Sources	comment on coverage
Economic	**GVA**	-	-	WIOD, EORA	Eurostat, OECD	full coverage by existing satellites of MRIO Source
	Employment	-	-			
Environmental	**Greenhouse gas emissions**	GHG's	-	EXIOBASE, EORA	Air Emission Accounts (Eurostat, OECD), GHG protocol to get actual GWPs	full coverage by existing satellites of MRIO Source
	Air Pollution	Six air pollutants: NH3, Nox, PM10, PM 2.5, Sox, VOC	Urban, Peri-Urban, Rural, Transport	EXIOBASE, EORA	Air Emission Accounts (Eurostat, OECD)	full coverage by existing satellites of MRIO Source
	Water consumption	-	-	EXIOBASE, EORA	-	full coverage by existing satellites of MRIO Source
	Water pollution	12 water pollutants: Nitrogen, Phosporus, Antimony, Arsenic, Cadmium, Chronium, Copper, Lead, Mercury, Nickel, PAHs, Zinc	Freshwater, marine, unspecified	EXIOBASE HYBRID	DESTATIS, EEA WATERBASE – aggregated Database	2 pollutants covered by MRIO Source (Nitrogen and Phosphorus) and the rest was estimated based on assumptions and other sources, one specification assessable (unspecified)
	Land use	Agriculture, forestry, paved	11 land types	EXIOBASE	-	full coverage by existing satellites of MRIO Source
	Waste	Hazardous waste, non-hazardous waste	disposed (landfill), disposed (incinerated), recovered (recycling or downcycling)	EXIOBASE HYBRID	EUROSTAT (env_wastrt)	specifications partially not covered by existing MRIO satellites

	Indicator	Subindicators	Specifications	Sources		
				Primary Datasource (MRIO Databases)	Additional Sources	comment on coverage
Human & Social	**Occupational health and safety**	Injury	short absence, long absence, partial incapacity, full incapacity, fatality	-	EUROSTAT(hsw_n2_01, hsw_n2_02), ILOSTAT, Kharel (2016), Hämäläinen, Takala, and Kiat (2017), Australia and National Occupational Health and Safety Commission (2015)	own research: no coverage via existing satellites so far, specifications were taken from Australia following guidelines of VBA
		Disease/Illness	short absence, long absence, partial incapacity, full incapacity, fatality	-	ILOSTAT, US BLS (TABLE SNR07), European Agency for Safety and Health at Work. et al. (2019), Australia and National Occupational Health and Safety Commission (2015),	
	Training	Training hours	not needed due to consistent reformulation of the proposed model	-	EUROSTAT (trng_cvt_23n2), World Bank, Enterprise Surveys (IC.FRM.TRNG.ZS)	no coverage via existing satellites so far, reformulation of the model allows for use of training hours only
	Child Labor	-	-	-	ILOSTAT (2021) UNICEF (2021) ILO and UNICEF (2021)	Own research: no coverage via satellites so far
	Forced Labor	-	-	-	Walk Free Foundation (2018) ILO and Walk Free Foundation (2017)	Own research: no coverage via satellites so far
	Living Wages	Living wages for low, medium, and high skill employees	-	WIOD, EORA	Living wage dataset (Valuing Impact) Health gap (Valuing Impact)	no coverage via existing satellites so far

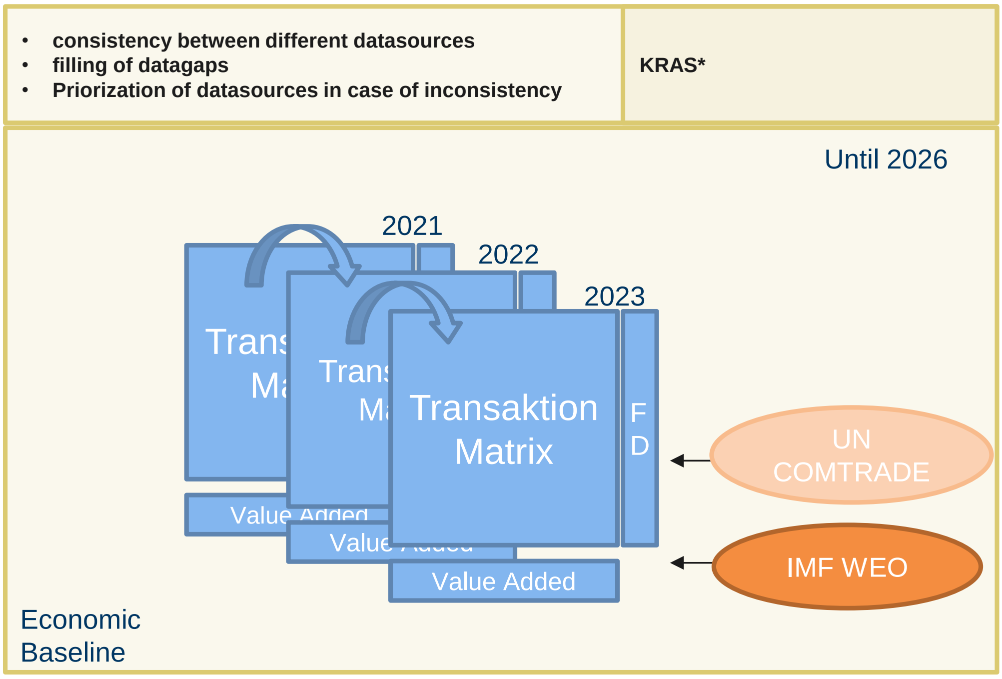
Source: Own depiction.

3 Data Sources Forecasting

3.1 Input-output-tables and economic Baseline

To produce a consistent and updated time series of IO tables spanning the time range from 2022 to 2026, we applied the KRAS, a RAS-type matrix balancing algorithm proposed by Lenzen (2009 and 2014), to the initial table of the base year 2021 (see figure 2). Using the resulting tables as initial input for the respective following year, we used economic Data (e.g., GDP development) given by World Economic Outlook from IMF as constraints for creating forecasted tables.

Figure 3: Update procedere with respect to the forecasted set of tables



Source: Own depiction.

The World Economic Outlook (WEO) database contains selected macroeconomic data series from the statistical appendix of the respective

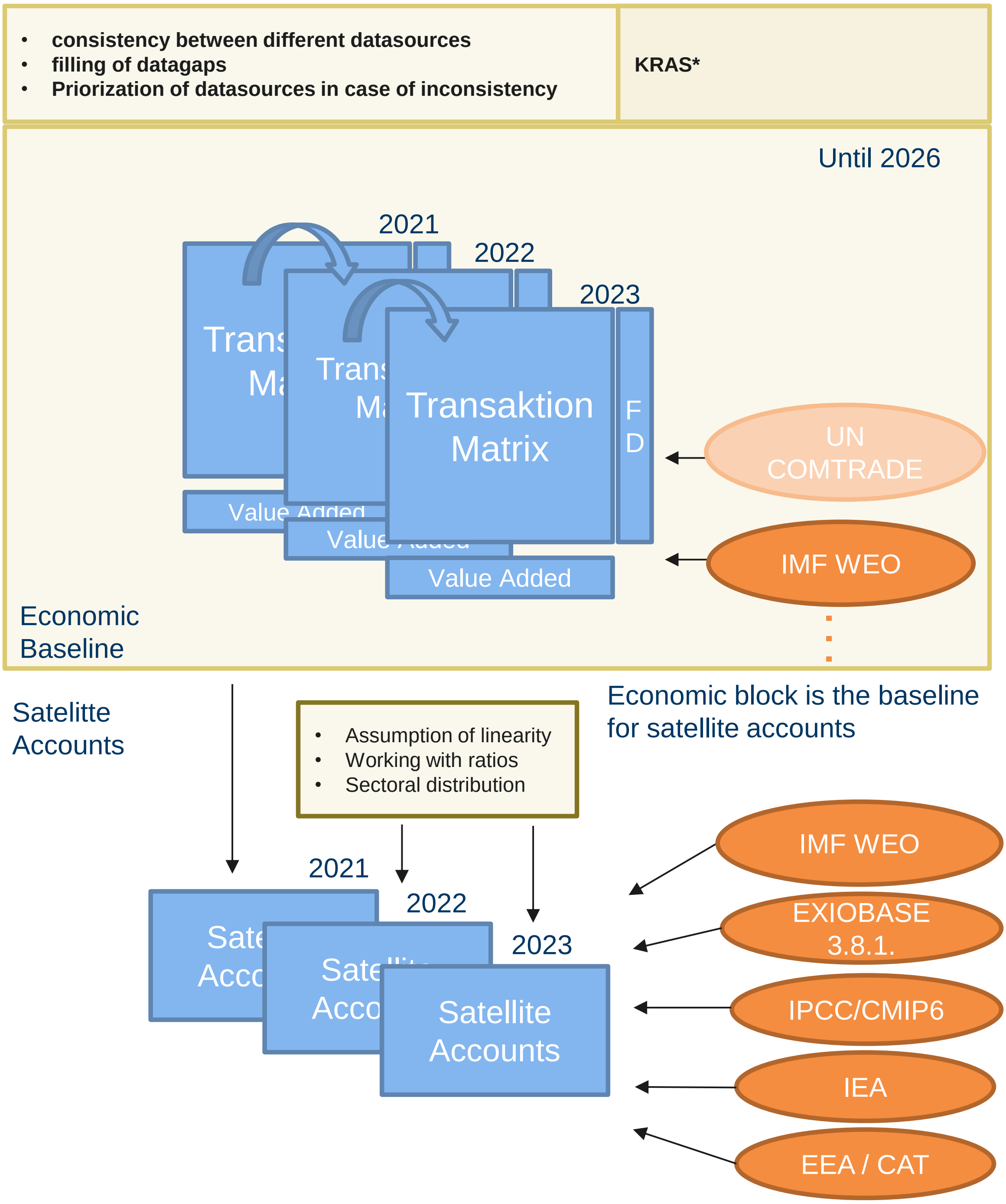
World Economic Outlook report (International Monetary Fund. Research Dept 2021), which presents the IMF staff's analysis and projections of economic developments at the global level, in major country groups and in many individual countries. The database[8] is created during the biannual WEO exercise, which begins in January and June of each year and results in the April and September/October WEO publication. Data and projections for 196 economies form the statistical basis of the IMF WEO database. The data are maintained jointly by the IMF's Research Department and regional departments, with the latter regularly updating country projections based on consistent global assumptions.
Although national statistical agencies are the ultimate providers of historical data and definitions, international organizations are also involved in statisti-cal issues, with the objective of harmonizing methodologies for the compilation of national statistics, including analytical frameworks, concepts, definitions, classifications, and valuation procedures used in the production of economic statistics. The WEO database reflects information from both national source agencies and international organizations.

3.2 Satellite Accounts

Satellite accounts are important extensions of MRIOT's and they are used to link the monetary flows of goods and services to other indicators of interest. To forecast the satellite accounts, we used different sources (see Table IV). We focused on the creation of forecasts for GHG emission accounts (see Chapter 3.2.1) since there are many studies and broad research on their possible future development. Except for the economic variables where we used the IMF WEO Database directly, very little research exists regarding the possible future developments of the remaining indicators on a global level. Here we mainly assumed proportionality to GVA or Employment and used the economic development as baseline indirectly. For some environmental Indicators we used Forecasts from EXIOBASE 3.81. and used sigma-clipped, linearly fitted extrapolations for the remaining years. The following figure summarizes the procedure and the sources used.

[8] https://www.imf.org/en/Publications/WEO/weo-database/2021/October

Figure 4: Simplified summary of the data processing procedure and the sources used



Source: Own depiction.

Table IV: Indicators and relevant sources

	Indicator	Subindicators	Specifications	Sources
Economic	**GVA**	-	-	IMF WEO (directly)
	Employment	-	-	
Environmental	**Greenhouse gas emissions**	GHG's	Baseline, Optimistic and Pessimistic Scenario	IPCC, CMIP6, IEA, EEA / CAT (see chapter 3.2.1)
	Air Pollution	Six air pollutants: NH3, Nox, PM10, PM 2.5, Sox, VOC	Urban, Peri-Urban, Rural, Transport	EXIOBASE 3.8.1 + sigma-clipped, linearly fitted extrapolations
	Water consumption	-	-	EXIOBASE 3.8.1 + sigma-clipped, linearly fitted extrapolations
	Water pollution	12 water pollutants: Nitrogen, Phosporus, Antimony, Arsenic, Cadmium, Chronium, Copper, Lead, Mercury, Nickel, PAHs, Zinc	Freshwater, marine, unspecified	IMF WEO (indirectly), proportionality assumption based on forecasted GVA
	Land use	Agriculture, forestry, paved	11 land types	EXIOBASE 3.8.1 + sigma-clipped, linearly fitted extrapolations
	Waste	Hazardous waste, non-hazardous waste	disposed (landfill), disposed (incinerated), recovered (recycling or downcycling)	IMF WEO (indirectly), proportionality assumption based on forecasted GVA
Human & Social	**Occupational health and safety**	Injury	short absence, long absence, partial incapacity, full incapacity, fatality	IMF WEO (indirectly), proportionality assumption based on forecasted Employment
		Disease/Illness	short absence, long absence, partial incapacity, full incapacity, fatality	IMF WEO (indirectly), proportionality assumption based on forecasted Employment
	Training	Training hours	not needed due to consistent reformulation of the proposed model	IMF WEO (indirectly), proportionality assumption based on forecasted Employment
	Child Labor	-	-	IMF WEO (indirectly), proportionality assumption based on forecasted Employment
	Forced Labor	-	-	IMF WEO (indirectly), proportionality assumption based on forecasted Employment

Source: Own depiction.

3.2.1 Optimistic, realistic, and pessimistic GHG forecasts

Three fundamental ways of thinking about future GHG emissions can be distinguished. Each is connected to different methods:

Scenario	Projections of what *can* happen by creating plausible, coherent, and internally consistent **descriptions of possible climate change futures**. *Not* a forecast of what will happen but used to compare different potential trajectories and implications of various developments and actions.	How *could* the future unfold?
Pathway	Plausible, coherent, and internally consistent descriptions of **pathways towards certain goals**, e.g., limiting global warming to 2°C, or achieving certain SDGs.	What *should* happen to reach a certain goal?
Near-term Projection	Projection of what is **likely** to happen in the coming years given current policies.	What will *likely* happen based on current status?

Near-term projections are used for developing the realistic forecast, as these reflect the implications for current policies. Scenarios are used to develop the best- and worst-case forecasts.

Studies on future GHG emissions are typically performed for sectors that are akin to emission *inventories*, i.e., they are process-based. For example, they distinguish between energy-based emissions, emissions due to specific industrial processes (not their energy use) or as cattle emit methane. In IO tables, however, the satellite accounts are emission *accounts,* i.e. based on economic activities. Emission accounts can include different emission inventory types. For example, the animal rearing activity has emissions through cattle as well as from tractors burning fossil fuels, which are two different processes. Absolute values in IO Satellite accounts can thus not be directly compared with sources on future emissions.

To generate forecasts for emission accounts, we first identify which process-sectors are the main drivers of emissions in each economic sector. We invert the “Eurostat Correspondence Table”, showing for each process-based category the NACE sectors in which they occur. This basic mapping can then be adjusted to the specific differentiations of emission inventories in the different data sources.

The forecast of emission accounts is then done based on the development of the dominating process-sectors. For this purpose, we calculate the percentage changes of the process-sectors’ emissions for each year relative to the latest year for which actual emissions are available.

3.2.1.1 Near-term projections

A variety of academic studies and governmental data can be used for the construction of a “likely” or “realistic” near-term forecast. A summary of relevant sources identified is provided in the table on the following page.

We use EEA (2019/2020) and CAT sectoral detail (2020) for the countries available. For all other countries, the IEA (2021) projections for CO2 and US EPA (2019) projections for CH4 and N2O are used. The resulting individual gas emissions are then aggregated using the same warming potentials as described for the base year. Missing years are interpolated linearly.

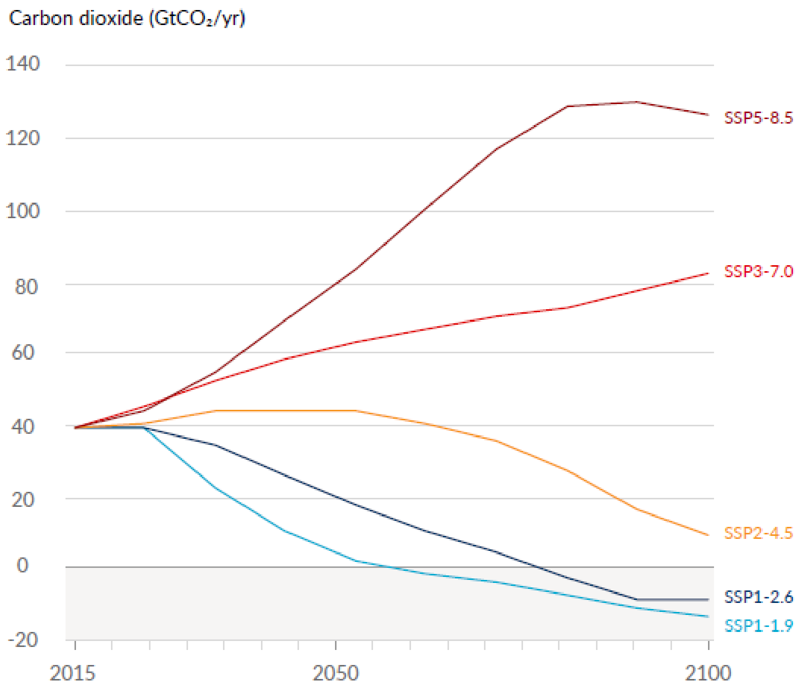
	Source	Description	Regional coverage	Sectors	Years
GHG	**European Environmental Agency (EEA)** (2019/20)	States' harmonized projections with ***existing measures***, taking into consideration any policies and measures adopted at Union level	EU 27, United Kingdom, Iceland, Norway, Liechtenstein	UNFCCC Common Reporting Framework (CRF) level 1	Yearly until 35
	Climate Action Tracker (CAT) sectoral detail (2020)	Projected emissions based on ***current policies*** (min & max estimates)	China, USA	Agriculture, Industry, Transport, Waste; Total fossil CO2 emissions	2020, 25, 30, 50
	Climate Action Tracker (CAT) total (2020/21)	Post-covid emission projections based on ***current policies*** (min & max estimates)	30 major economies not in EEA	Total	Yearly until 30
CO2	**IEA STEPS model** (from Net Zero 2050 Report 2021)	Stated Policies Scenario: takes account only of specific ***policies that are in place or have been announced*** by governments.	"Advanced" vs. "emerging & developing" countries	Electricity, Industry, Transport, Buildings, Other	2020-50 in 5-year steps
CH4 & N2O	**US EPA** (2019)	Harmonized ***BAU baseline*** with fixed emission factors. Does not model policies explicitly but does incorporate historic emission declines	175 countries	Agriculture, Energy, Industrial Processes, Waste	Yearly until 2050

3.2.1.2 Scenarios

As for the near-term projections, there is a large number of studies providing future emission scenarios for emission inventories. An overview of identified sources is provided in the table on the next page.

The CIMP6 scenarios have several advantages:

- Broad range of possible futures covered
- Scenarios form the basis for IPCC 6th Assessment Report, have been developed in long, comprehensive, collaborative, peer-reviewed process
- Region/country- and sector-specific projections for CO2, and CH4, global projection for N2O.
  Region/country- and sector-specific projections for other air pollutants (NH3, NOx, Sulfur, VOC) are also available.
- Further information available (e.g., GDP, population by education levels) which might be used to enhance economic and employment forecasts in the future.



We selected "'SSP1, 1.9" as optimistic scenario, which reflects a world of sustainability-focused growth and equality where global warming is limited to below 1.5°C. "SSP4, 6.0" was selected as pessimistic scenario, which reflects a world of ever-increasing inequality with global warming above 3°C.

Source	Description	Regional coverage	Sectors	Years	Emissions
EIA Energy Outlook (2019)	• Reference • High / Low oil price • High / low economic growth	• 8 regions • Specification of 10 countries	-	Yearly until 2050	CO_2
IEA Announced Pledges Case (from Net Zero 2050 Report 2021)	All announced national net zero pledges are achieved in full and on time, even if not underpinned by specific policies.	Global	Electricity, industry, transport, buildings, other	2020-50 in 5-year steps	CO_2
IEA net zero 2050 pathway (2021)	Pathway to net zero 2050 that relies on little carbon dioxide removal to stay below 1.5°	• Global • "Advanced" vs. "emerging&developing" countries only for industrial emissions	Electricity & heat; other energy, industry, transport, buildings		CO_2 CH_4 in energy-sector
CMIP6 (2017) Scenarios in preparation of next IPCC report	SSP1-19/26: "sustainability"	26 countries/regions	Agriculture, Energy, Industry, Residential Commercial, Transportation, Waste; Forest Burning, Peat Burning, Grassland Burning, and Agricultural Waste Burning	2020-50 in 5-year steps	CO_2 and CH_4 sectoral + regional, N_2O global; Other air pollution: NH_3, NO_x, Sulfur, VOC
	SSP2-45: "middle of the road"	10 countries/regions			
	SSP3-70: "regional rivalry"	17 countries/regions			
	SSP4 -34 and SSP4-60: "inequality"	32 countries/regions			
	SSP5-34-OS: "fossil fuel development"	11 countries/regions			
US EPA (2019)	% reductions relative to the projection baseline	175 countries	Agriculture, Energy, Industrial Processes, Waste	2015-50 in 5-year steps	CH_4, N20

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