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Environmental and Labour accounts for OECD Inter-Country Input-Output Tables 2010-2013

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Abstract
This report (final deliverable of project JRC/SVQ/2016/J.5/0054/OC) describes the methodology used to estimate the energy, environmental and labour accounts linked to the OECD ICIO tables and gives a short overview on the data available for the estimations. In addition, it contains the structure of the code used to for the estimations, including all concordance matrices and the data input and output formats.

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Abstract

This report (final deliverable of project JRC/SVQ/2016/J.5/0054/OC) describes the methodology used to estimate the energy, environmental and labour accounts linked to the OECD ICIO tables and gives a short overview on the data available for the estimations. In addition, it contains the structure of the code used to for the estimations, including all concordance matrices and the data input and output formats.

1 Introduction

Environmental and socio-economic accounts as extensions to input-output (IO) databases are datasets in physical units following the same industry and country classification and order as the inter-industry and final demand matrix of IO tables.

This report outlines the data sources and methodology used for the contract JRC/SVQ/2016/J.5/0054/OC: Production of energy, environmental and labour accounts (ELIOD). This project has an objective of creating energy, air emission and labour accounts for the OECD Inter-country Input-output (ICIO) table. The project specifically requires full coverage of all energy carriers; the account of six different types of emissions (CO_2, CH_4, N_2O, NO_x, SO_x and NH_3) presented according to source categories of combustion, non-combustion (process emissions), agricultural and waste emissions; and socio-economic accounts in the form of labour recorded by compensation of employees, total employment, employees and hours worked by skill levels (low, medium, and high).

The scope of the project is limited because of the comparison between the high ambition level (updated years, full global coverage including disaggregation of regions commonly aggregated in input-output analysis, highly detailed breakdown of energy, emission and labour indicators) and the resources available for the project. The report describes what is achievable commiserate with the state of the art in global multi-regional input-output accounting, whilst noting that the development of new approaches to improve the state of the art is well beyond the scope of this project.

The report follows this structure: In section 2 an overview on the relevant data and its availability across countries and time is provided. In Section 3, a general introduction to environmental and labour accounts as well as a detailed description of the methodology used to estimate those is given. Section 4 provides the pseudo-code showing the interrelations between the different source data and final results. Section 5 defines next steps.

2 Detailed description of the methodology

2.1 Environmental accounts

Environmental accounts as extensions to input-output databases are datasets in physical units following the same industry and country classification and order as the inter-industry and final demand matrix. Environmental accounts consist of a variety of different environmental pressures, including material use and supply (including energy), emissions, blue and green water, land and other resources. Here, the focus is on energy and emissions accounts. Full coverage of all energy carriers available in the IEA energy balances will be included, as well as six different types of emissions CO_2, CH_4, N_2O, NO_x, SO_x and NH_3 presented according to source category combustion, non-combustion (process emissions), agricultural and waste emissions.

For the environmental accounts, we follow a standard methodology as has been developed and employed in the European projects FP6 EXIOPOL (Tukker, de Koning et al. 2013), FP7 CREEA (Wood et al. 2015) and more recently in FP7 DESIRE (Stadler et al. 2016), with some adjustments on data used in allocation to bring in line with the current version of OECD emission accounts. In the following, we use the terminology as used by Eurostat (2009, 2013, 2014), EEA (2013), and UN (UNDESA 2015) to refer to the different formats used to compile data on physical energy flows and air emissions.[1]

The main steps are

1) Estimating energy accounts
2) Using TNO emission factors and apply those to the emission relevant energy use to estimate fuel combustion related emissions
3) Estimate non fuel combustion related emissions

2.1.1 Energy accounts

Task 1.1 is the compilation of energy accounts for the required energy commodities. The work consists of acquiring all necessary source data (including auxiliary data for allocation/disaggregation methods), and the conversion from the IEA energy balance flow classification under the territorial principle to the desired OECD ICIO industry classification under the residential principal. The three individual steps in the estimation of the energy accounts are

1) The differentiation between gross energy-use, net energy-use and emission-relevant energy use.
2) The reallocation from territorial to residential energy use of:
    a. Road transport fuels
    b. International aviation and marine bunkers
3) The reallocation from the IEA activity classification to the OECD-based ICIO industry classification.

This last point is an important consideration in that IEA energy balances are not recorded in an accounting framework synonymous with input-output (IO) analysis. The most critical point here is that energy balances are recorded by type of activity (e.g. all energy

[1] During the compilation process of the desired environmental extensions, we will use different concordance matrices. The term "concordance matrix" and "correspondence matrix" are hereafter used interchangeably. Correspondence matrix can refer to any matrix that relates one classification to another, i.e. it can refer to the relationship between activities and industries, energy commodities according to different classifications and different kinds of energy uses. Furthermore, concordance matrices can either be purely binary, i.e. consist of only zeros and ones, or can contain shares in case one classification is disaggregated into another.

use associated with road transport, no matter if it is a taxi, freight or private automobile use), which can differ from the industry/final consumption classification of IO analysis. We come back to this later.

2.1.1.1 *Source data*

The main data source for the compilation of the energy accounts will be the country-specific energy balances compiled by the IEA (IEA 2015a, IEA 2015b). These are available for all countries covered in the OECD ICIO and for all years required. They are updated on a regular basis.

	Source data	**Auxiliary data**
Energy accounts	IEA energy balances (IEA 2015a, IEA 2015b)	EUROSTAT Physical energy flow accounts EXIOBASE auxiliary data (res to terr) Various allocation matrices

2.1.1.2 *Gross, net and emission-relevant-energy accounts*

Energy use will be provided as both gross energy use (including, for example energy not combusted such as lubricants, and energy carriers such as heat and electricity), net energy use (not counting energy transformed) and emissions relevant energy use, which will only provide energy usage that we apply emission factors to (in general, emission factors are applied when fuel is combusted). The specification of emissions relevant energy use from gross energy use is done using the method applied in the EXIOBASE energy accounts (Kuenen, Fernández et al. 2013, Stadler, Wood et al. 2016). We report **gross energy use** as all energy use (both primary and secondary), and net energy use and emissions relevant energy use as a subset of the same flows.

The energy balances as available from the IEA allow for the clear delineation of emissions relevant energy use. This is aided by the accounting of energy separately for energy that is transformed by the energy industry, the energy used by the energy industry when transforming energy from one carrier to another, and the final consumption of fuels for energy (emissions relevant) purposes, and for non-energy purposes. As such, the allocation is done at the energy activity level (i.e. prior to disaggregation to industries). The primary breakdown for **emissions relevant energy use** is: 1) fuel used for electricity, CHP and heat is included for transformation industries; fuel transformed to secondary fuels by the transformation industry is excluded; 2) all fuel consumed by the energy transformation industry for its own purposes (i.e. not transformed into secondary fuels) is included; 3) all final consumption of fuels is included, except for the consumption for non-energy uses; 4) Electricity and heat is not included (as the fuel input is already counted). **Net energy use** follows the exact same structure as emissions relevant energy use, but in addition, includes final consumption of fuels for non-energy use. See Box 1.

In the net energy accounting of this project, we include all final use of energy, as well as energy own-use and exclude any transformation. For electricity, we include the quantity of energy consumed by the electricity generator by source (e.g. coal, wind, etc), that is we count the GJ of coal being consumed in electricity generators, and add the GJ of renewable electricity generation. Net energy accounts also include losses. An easier way to visualise the net energy accounts constructed in this project is to look at the data files provided for the relevant code (section 3.1)

Box 1. Oslo group on energy statistics
(http://unstats.un.org/oslogroup/meetings/vm-02)

"Gross energy accounts are … hybrid accounts as described in SEEA-2003 (chapter 4). The gross energy accounts are fully consistent with the National accounts, and are thus compiled according to the concepts described in chapter 2 of SEEA 2003. Gross energy accounts include all types of fuels, i.e. primary energy products as coal and crude oil on one hand and transformed/converted types of energy like petrol and heating and electricity. This as a disadvantage leads to a double counting of all uses of energy are added in the sense that the same energy is counted more than once.

Main characteristics of the gross energy flow accounts:

- …
- Supply equals use for each energy commodity
- Compiled according to the resident principle
- Direct link with the monetary accounts: fully consistent with National accounts
- Includes energy consumption for energetic and non-energetic purposes
- Gives total (or gross) energy production and total (or gross) energy use by industry
- Double counting (as energy products are converted into other energy products)
- …

Net energy accounts are still compiled according to the resident principle. Accordingly, the net energy consumption can be compared to economic parameters such as value added or labour force to calculate important indicators such as the energy intensity or the energy productivity…. Besides final energy use, also the energy that is lost during conversion processes is registered. Examples are the energy lost during refinery or during the generation of electricity from coal or gas…

The main characteristics of the net energy flow accounts:

- Supply and use tables for energy products by industry in physical terms
- Supply does not equal use for each energy commodity, only for the economy as a whole
- Compiled according to the resident principle
- …
- No direct link with monetary accounts: only physical accounts
- Includes energy consumption for energetic and non-energetic purposes
- …
- No double counting (net energy use and net energy supply)

Although emission relevant energy accounts are a sub group of net energy accounts it seems to make sense to treat them separately because of their role as core element of NAMEA air."

2.1.1.3 *Adjustment residential principle, handling of bunkers/international aviation*

Existing energy data can broadly be put into two categories: 'energy balances' and 'energy accounts'. The two main conceptual differences relate to

1) the difference between activities and consumer, where multiple different industrial and final consumers partake in an energy using activity (e.g. road transport), and
2) the difference between activities taking place on a territory, and those by consumers from a territory.

Energy balances follow the '**territory principle**' – i.e. they cover the activities occurring within a territory independent from the residence of the relevant consumers –, whilst **energy accounts** follow the '**residence principle**' – i.e. they report the energy flows associated with consumption by residents of a country independent from where the activities take place. This boundary issue mainly affects how international transport activities such as road tourism and freight transport, international navigation (marine bunkers) and international aviation (air bunkers) are allocated in the compilation process. Usubiaga and Acosta-Fernández (2015) have shown that severe differences in product and even country specific footprints arise from omitting this difference when compiling environmental accounts.

Country-specific energy balances are compiled by the International Energy Agency (IEA 2015a, 2015b), which relate supply and use of energy by different activities using the territorial accounting principle. In contrast, energy accounts relate supply and use of energy by consumer using the residential accounting principle. The data are available for the EU countries from EUROSTAT, but there is no set of country-specific energy accounts compiled by other international organisations yet covering countries outside the EU. Therefore, a new set of energy accounts, complying with the industry classification of the OECD ICIO tables needs to be compiled. To convert the data from the territorial principle (used in the energy balances) to the resident principle (used in the OECD ICIO), data from the compilation of the EXIOBASE database will be used (see below). By doing this, we build on already tested and quality ensured data. There is a significant lack of ready to use data at the international level for such adjustments (for example, even though Eurostat provides adjustments from residential to territorial for CO2 emissions, the data is missing for many countries that are impacted significantly such as Greece.

Affected fuels can be divided into two categories: a) those mainly for road transport: the fuels we are considering here are motor gasoline, gas/diesel oil, bio gasoline, biodiesel; and b) those fuels in international fuel bunkers: the fuels we are considering here are heavy fuel oil, kerosene, aviation gasoline and kerosene type yet fuel.

For bridging from territorial to residential fuel use, we use the following approach.

A. EU countries: use the IEA data and emission factors, and EXIOBASE data for adjustment territorial to residential. This approach applies total correction factors for each fuel and hence does not differentiate between correction made for road transport of households and industry the further steps were proposed (the point here is if there is data on whether the household sector or certain industries participate more in fuel tourism than others – we do not have access to any of this data, nor had planned on including it):

    - As a cross check of our approach to available statistics, there will be a comparison of a) the bridging factors of EU air emission accounts, b) the absolute air emissions by industry\household.
    - There is the possibility to adjust the territorial to residential factor from EXIOBASE to achieve closer comparability with EU air emission accounts. Note this is embodies many assumptions, as the EU air emission accounts have sometimes adopted very different approaches. There is of course variability in the other data used (energy use or emission factors). It is not possible to do this comparison without the full dataset on non-fuel combustion as the EU air emission accounts do not provide any breakdown. We will not compare against the Eurostat energy account (PEFA) territorial to residential adjustment because it is only available for 2014 for 10 countries. Hence, in order to take this approach, the territorial to residential factors from EXIOBASE will be compared only on CO2 emission quantities, which will then be used to make manual adjustments to the original factors to achieve better comparability. Details are provided in Annex 3.

B. Non-EU – EXIOBASE: use IEA data and emission factors, and only EXIOBASE data for adjustment territorial to residential (see step A)

C. Rest of World (Non-EU countries in ICIO, not detailed in EXIOBASE but only regions in EXIOBASE): use IEA data and emission factors, and only EXIOBASE data for adjustment territorial to residential. The adjustment for bunker fuels is done with the same share for all Rest of the World countries.

The available relevant data is:

1. Eurostat data on energy is available at (http://ec.europa.eu/eurostat/web/products-datasets/-/env_ac_pefa05) Austria (2014), Belgium (2008-2014), Bulgaria (2014), Czech Republic (2014), Estonia, Latvia, Romania (all 2014), Germany (2012-2014), and Slovenia (2013, 2014). This data does not distinguish modifications by type of fuel, and thus there is no distinction between bunker use and road transport fuels. Bridging factors are given at the country level. The main limitation of this data is the lack of geographical coverage for relevant years. Detailed adjustment factors are not available, so only high level comparisons can be made.
2. Air emission accounts from Eurostat (Note, emission, not energy) http://ec.europa.eu/eurostat/web/environment/emissions-of-greenhouse-gases-and-air-pollutants/air-emission-accounts/database. This provides air emission by pollutant, but does not provide product level detail (which energy products are responsible), or the type of emission (e.g. fuel combustion vs process emissions).
3. OECD approach based on data of spending by residents abroad only for road transport fuel use (bunkers were not considered). We mention this approach, despite source data not being readily available for use by others. The data on spending by residents abroad in the OECD ICIO tables is available by industry (in original ICIO tables, not in the preliminary ICIO tables made available in this project). The data in the original ICIO tables is sourced from tourism satellite accounts, which are not broadly publicly available (for example, Eurostat tables only report total expenditure by residents abroad, and not by industry or product). This data is for carbon dioxide emissions and only for all fuels aggregated, and not by individual fuels.
4. Territorial-to-residential bridges are available based on data used in EXIOBASE. The translation from territorial to residential fuel use has been done in EXIOBASE based on a detailed transport model individually for marine transport, fishing air and road transport. Full details about the procedure used in EXIOBASE will not be repeated here, but is available in the respective EXIOBASE deliverable (Kuenen, Fernández et al. 2013) (p29-31), at http://www.exiobase.eu/index.php/publications/documentation. We apply territorial to residential factors in EXIOBASE separately for bunker fuels and road transport fuels:
    a. **Road transport:** We compute country- and fuel-specific adjustment factors (but not sector specific) by calculating the total fuel-dependent difference (factor = exio/iea) between the IEA energy use balances and the EXIOBASE3.4 energy use accounts (which are according to the residential principle) per country. We do this for the fuels: motor gasoline, gas/diesel oil, bio gasoline, biodiesel. This factor is then scaled such as that the total (world) emission relevant energy use is kept constant. It is then applied to the usage of fuel in the energy data used in the ELIOD accounts. For example, first we calculate an adjustment factor, the % difference of usage of between e.g. gasoline in Luxembourg in EXIOBASE energy accounts (residential) and gasoline usage in Luxembourg in IEA energy balances. If

then the IEA reports 100GJ of gasoline used, and EXIOBASE reports 120 GJ of gasoline used, we obtain an adjustment factor for gasoline in Luxemburg of 1.2. This calculation is done for every relevant fuel in every country. For the ICIO countries not in EXIOBASE, the adjustment factors are based on the corresponding world region average. The adjustment factors will be made available as a data input, with the possibility to update in the future given resource availability (e.g. through international transport models) or via using other data. Of note is that we only have data for 44 EXIOBASE countries and five rest of the world regions, we apply the same adjustment factor for each country within a region.

b. **Bunkers**: Globally, we know the total amount of each fuel used from bunkers. We need to allocate this to individual country uses. We do this by separating out the bunker and non-bunker fuel use in the EXIOBASE data based on the value of the non-bunker fuel use in the IEA data. For the countries individually represented in EXIOBASE we subtract the non-bunker fuel use of the IEA from the EXIOBASE data, which gives the bunker-fuel use per country and fuel. For the countries not individually represented in EXIOBASE, we calculate the total fuel-specific bunker fuel use for all these countries combined by determining the differences between the IEA non-bunker fuel use for each of these countries combined and the EXIOBASE data from all ROW regions combined. This total bunker fuel use number is then allocate to the individual countries by assigning each individual country the same percentage change applied to its original IEA no-bunker fuel value. This percentage change is determined by calculating the share between the countries' total IEA value (including bunker supply) and the ROW regions total EXIOBASE value (including bunker use). Now we have obtained an absolute bunker value for each country and together with the value of the total bunker fuel in the world, each country's share of the global bunker-fuel use is then calculated. This country share is applied to the global bunker fuel use of the IEA data in the year that data is being prepared for. We thus assume that the share of bunker fuel use between countries is stable over time.

Note, the adjustment from the territorial to residential is purely a re-allocation of energy from country to country and from world bunkers to consuming country. The total global energy use must be conserved in such a process. We rescale the total adjustment of emission relevant energy use to ensure this occurs (see section 3.1).

2.1.1.4 ***Adjustment to OECD ICIO industry classification***

Only after the reallocation of fuels from territorial to residential, will the data be converted from the energy balance activities to the ICIO industries. The allocation is based on the correspondence matrices (that shows the corresponding IEA flows and MRIO industries) used in the construction of EXIOBASE/CREEA/DESIRE and the CO2 emission accounts at OECD (Wiebe and Yamano, 2016). The concordances has been discussed with the teams at OECD (Norihiko Yamano) and IEA (Roberta Quadrelli) to ensure the consistency with the data. The matrices will consist of zeros and ones and will be made available as an easily adjustable .csv file.

From these correspondence matrices, fuel-specific allocation matrices between the IEA activities and OECD ICIO industries (including final demand categories) are developed based on including proxy data from the ICIO tables to disaggregate the flows (see below) to give a matrix of allocation shares. The shares will always add up to 100% as to ensure no energy loss in the sector to industry conversion. For some fuel/activity/industry combinations, the mapping is straightforward. For others, such as road transport a more complex allocation is necessary. (See section 2.1.1.4.5 for the mathematics of the fuel specific allocation matrix).

2.1.1.4.1 Road transport

Road transport fuels for example should not be allocated wholly to the road transport industry in the ICIO, as all industries use road transport fuels. These are allocated to the industries and final demand according to their use of part of ISIC Rev 4 "19 Manufacture of coke and refined petroleum products". When doing this it is necessary to consider, that some industries, e.g. "20 Manufacture of chemicals and chemical products" also use other inputs from "19 Manufacture of coke and refined petroleum products", so that a correction of the shares is necessary. The algorithm applied here will take into account the findings in Annex B in Wiebe and Yamano (2016) on reallocation considering the use of primary and secondary fuels. We use EXIOBASE data and calculate the relative consumption of individual fuels (EXIOBASE has 60 different energy carriers detailed) by ICIO industry and final consumer. We aggregate this data to transport and non-transport fuels, and calculate the relative % of transport and non-transport fuel to total fuel use in each industry. This is used to disaggregate the ICIO consumption of fuels (monetary data) into two groups of fuels that are then used as the proxy value to allocate transport fuels to user. These values are provided as input data, and can be manually adjusted as required.

2.1.1.4.2 Auto producers

Auto-producers were allocated directly to the main electricity generation industry in EXIOBASE, despite the fact that by definitions, auto-producers have electricity production as a secondary output. In ELIOD, auto-producers are assigned to non-electricity producers. However, knowing which industry is responsible for auto-production of electricity is not straightforward or easily extracted from statistics. As such, this allocation is highly uncertain, and highly dependent on assumptions made about source data used. Theoretically, the monetary supply table of a country shows the quantity of electricity produced by different industries (in practice, the way this is handled differs from country to country, and note, it is not clear from the expertise within the consortium what happens when households are producing electricity). From the supply data, we make the basic assumption that those industries supplying electricity are those using the fuels needed to generate the electricity (generating a file of shares by industry, using EXIOBASE data - EXIOBASE_supply_YYYY.csv). By itself, this secondary supply information is not particularly useful, as it is unlikely that steel production is using photovoltaics. Hence, a correctional mask is used (concordance_prod_auto.csv) that can be edited to allow/disallow the allocation of certain fuels to certain industries (note, you might want nuclear to only go to government or research).

Data on electricity supply by auto producers is taken from the EXIOBASE dataset for 2011. The supply p40.11 is taken (all electricity producers aggregated). Distinction between different sources of electricity supply (e.g. that generated by coal vs wind, or combined heat and power plants) is not taken, as this was not modelled in EXIOBASE.

This creates a dataset of country specific electricity generation by non-auto producers in EXIOBASE classification.

Three steps are then undertaken:

1) Industries producing the electricity are remapped from EXIOBASE to ICIO classification
2) Countries in EXIOBASE are remapped to ICIO classification (e.g. Data from Rest of Asia in EXIOBASE is remapped to all ICIO Asian countries not in EXIOBASE).

3) An energy product dimension is introduced to the dataset, such that we end up with an allocation matrix for each IEA energy by product and for each ICIO country. As a default, the allocation matrix of each IEA energy product is the same as the country level total in step (2). This may be manually refined for example by setting the use of solar PV into Steel furnaces to 0.
4) Calculate shares at the end.

2.1.1.4.3 Losses

Losses are included in gross and net energy use. Losses due to primary fuels are allocated to the mining sector, losses due to refinery fuels are allocated to the refinery sector, and losses due to electricity are allocated to the electricity sector.

2.1.1.4.4 Further notes

"Transfers" are allocated to petroleum refineries (relevant for gross and net energy use)

"Statistical differences" are allocated to changes in inventories (relevant for gross and net energy use)

"International air and marine bunkers" are allocated to exports (relevant for gross and net energy use).

2.1.1.4.5 Allocation

In order to perform the actual allocation from IEA activities to ICIO industries, we obtain, by combining the two dimensional allocation matrix with the respective proxy, a three-dimensional concordance matrix G_c which is country specific, and has dimensions fuel, activity, industry. This G_c is adjusted for road transport and auto-producers as above, to essentially give three different versions. These three concordance matrices G_c will be applied to each country's IEA energy balance, converted to the residential principle, according to:

$$E_{ijk} = G_{c_{ijk}} * Ein_{ijk}$$

with fuel commodity *i*, OECD industry *j* and IEA energy flow *k*. E_{ijk} being the resulting energy and E_{in} the adjusted energy data from IEA energy balances. Allocation is done separately for energy supply, gross energy use, net energy use and emission relevant energy use. The concordance matrix G_c will be different for use and supply tables (due to different proxy data used – the 0 1 relationships that show which activity/ies corresponds to which industry/ies will remain unchanged). This will be done as matrix calculations to preserve all the original information as well as the data in the desired industry classification.

The resulting gross and net energy supply and use as well as the emission relevant energy use matrices will be aggregated to the proposed energy commodity classification (26 energy commodities and losses). This process will be mere additions of several of the IEA energy commodities into the required energy commodity classification of the OECD environmental extension.

Then the resulting matrix will be collapsed into two dimensions, summing over all the IEA energy flows, resulting in the desired energy supply and use extensions. The tables with emission relevant energy use data can then be multiplied by the TNO emission factors (by fuel type and gas) to obtain energy-related emissions (see below).

Note: gross and net energy use tables are the total quantity of energy used in a country, whether from domestic or imported sources. We do not include “exports” in gross and net energy use tables as it would be a form of double counting at the global level, and not commiserate to the structure of the ICIO table. Total domestic production and imports are not represented in the use tables explicitly. They would be represented in energy supply tables, which are not needed for the calculation of energy use or emissions.

2.1.2 Emission accounts

Global air emissions for each of the individual years 2010-2013 will be calculated using the TNO Emission Assessment Model (hereafter referred to as “TEAM”), which is an emission estimation model that explicitly models the use of certain technologies (Pulles, van het Bolscher et al. 2007). This is mainly important when longer time series are studied, allowing for the introduction of new, mostly cleaner technologies over time. The model uses state-of-the-art emission estimation methodologies from the IPCC Guidelines for National Greenhouse Gas Inventories, the EMEP/EEA Air Pollutant Emission Inventory Guidebook and the IIASA GAINS model (Amann 2009). Using the model, a complete overview of the emissions is obtained. Emissions are calculated on a per country, per year basis for all relevant sources.

These state-of-the-art emission estimation methodologies are those used by UNFCCC Annex I countries to annually report their GHG emissions to the UNFCCC and under the Kyoto Protocol, as well as those used by European and North American countries to annually report emissions of the air pollutants under the UNECE Convention on Long-Range Transboundary Air Pollution.

‘Air emission inventories’ follow the same accounting rules as the energy balances. Likewise, ‘air emission accounts’ share the same boundaries as energy accounts. Given that IO tables are also compiled according to System of National Accounts, which is based on the residence principle, only air emission accounts should be used as satellite accounts in EE MRIO models. Not doing so can lead to large discrepancies in the environmental extension itself and, as a result, in the footprint results (Usubiaga and Acosta-Fernández 2015). In this work, alignment is achieved by applying the air emission factors for fuel combustion emissions (kg emission per TJ energy) to the 3-dimensional emission relevant energy use matrix defined above, before collapsing to the industry level.

Task 1.2 is the compilation of emission accounts for 6 different emission types for 4 different source categories each. The work will be split in four phases, calculation of emission factors and the compilation of the combustion, non-combustion and agricultural/waste emission sets.

Using the TEAM model, developed by TNO, emissions for a variety of emissions can be calculated using state-of-the-art emission estimation methodologies as described earlier. Although the model is capable of calculating air emissions for many pollutants, in this project the focus will be put on calculating high quality emission factors for the six desired pollutants.

	Source data	**Auxiliary data**
Emission accounts (comb)	IEA energy balances (IEA 2015a, IEA 2015b)	TNO TEAM Model (Pulles et al. 2007)

2.1.2.1 ***Emission factors for combustion of fuels***

For the case of fuel combustion, air emissions are calculated based on the IEA energy balances which give the amount of fuel combusted per country, year, IEA flow and product. These are used as input to the TEAM model, which calculates the emissions for each of the 6 pollutants for each country, year, IEA flow and product.

The TEAM model builds on information on country and year specific emission factors derived from the IIASA GAINS model. This model provides 5-yearly data on activities (fuel combusted in TJ) and emissions resulting from that combustion. It should be noted that the GAINS data are not available for all countries considered, i.e. data are available for 44 out of 61 countries. For the missing 17 countries (these are located in Latin America, Africa and Asia) emission factors from representative other countries have been used instead (see details in Section 4.1.2).

Since only 5-yearly data are available, linear interpolation is used to estimate activity data and emissions between 2010 and 2015. From the interpolated activity data and emissions, country and year specific emission factors are calculated for all pollutants considered in this study (CO_2, CH_4, N_2O, NO_x, SO_x, NH_3), for each IEA flow and product.

To ensure consistency between the energy and environmental accounts, the resulting emissions from the TEAM model can then be directly applied to disaggregated energy balances from which emission accounts can then be extracted (see Task 1.2.4).

2.1.2.1.1 Source data for combustion emission factors

The main source data for the emission factors has been the IIASA GAINS model which has also been the main data source used for EXIOBASE3 combustion emission factors. From the model, sector/fuel specific data were extracted for each relevant pollutant/gas (CO_2, CH_4, N_2O, NO_x, SO_x, NH_3). The model provides both activity data (in the case of combustion this is the amount of energy consumed in TJ) and emissions. Both were extracted for the years 2010 and 2015, since GAINS provides data only at 5-yearly estimates. It should be noted that 2015 data are projected emissions as earlier years are not yet available. However the projections have been made recently in the framework of the revision of the EU National Emissions Ceilings Directive in 2015-2016.

It should be noted that the IIASA GAINS model does not cover all the countries included in this study. How this issue is addressed is described in the data processing section.

2.1.2.1.2 Processing of data for combustion emission factors

The IIASA GAINS model[2] calculates future emissions based on several future scenarios. The GAINS scenarios are largely based on economic model output from PRIMES[3] and agricultural forecast models, combined with a bottom-up estimation of emissions based on information from individual countries as well as scientific literature. The scenarios used for this study are:

- For Europe:
- [WPE_2014_CLE]: Current legislation scenario based on the PRIMES 2013 reference scenario, including the results of bilateral consultations between IIASA and countries (only for Europe) *(not available for CH4)*

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[2] http://www.iiasa.ac.at/web/home/research/researchPrograms/air/GAINS.en.html

[3] http://www.e3mlab.ntua.gr/e3mlab/index.php?option=com_content&view=category&id=35%3APRIMES&Itemid=80&layout=default&lang=en

- [TSAP_2013_CLE]: Current legislation scenario based on the 2012 PRIMES energy projections, developed in support of the development of the Thematic Strategy on Air Pollution *(only for CH4)*
- For other regions:
- [CP_WEO_2011_UPD]: Scenario for non-European Annex I countries developed under the ECLIPSE project
- [CP_WEO11_S10P50_v2]: Scenario for South/East Asian countries developed under the ECLIPSE project

Compared to the data used in EXIOBASE3, a more recent scenario for Europe was used, reflecting the most recent estimates of historical years and improved projections estimates for future years. Since CH_4 was not included in the latest scenario, here the data from the TSAP_2013_CLE have been used (this dataset was the basis for EXIOBASE3). For other regions, no updated scenarios were available. It should be noted that the GAINS data are only available at 5-yearly intervals, for 2010 and 2015 in this case. For the intermediate years, both activity data and emissions were estimated using linear interpolation at the most detailed level of sectors and fuels.

In order to create a global dataset of emissions, GAINS activities (amount of TJ combusted) and emissions (in kg) are extracted, from which implied emission factors (IEFs) are calculated (kg/TJ). A global dataset of emissions is then created by taking the IEA energy balances as a starting point, and allocate to each IEA sector, fuel and year an emission factor for each of the 6 pollutants. As some specific combinations of sector and fuel in the IEA database were not represented in the GAINS emission dataset, an alternative GAINS sector was selected with the same fuel (since the fuel type is the most important variable determining the EF value). In addition, the IEA database has all major countries in the world, while the combined GAINS dataset only contains 52 countries.

To create a complete set of emissions for all countries included in the IEA energy balances, a gap filling methodology has been developed. Option 1 is the preferred option, if not possible option 2 is chosen, etc. The gap filling options are:

- Take weighted average IEF from the same sector-fuel for the country group where the country is part of [see **Table 4**]
- Take weighted average IEF from the same fuel, taken from the country group where the country is part of [see **Table 4**], for a different sector
- Take weighted average IEF from the same sector-fuel, taken from the complete available set (global average)
- Take weighted average IEF from the same fuel, taken from the complete available set (global average), for a different sector

It should be noted that this choice is particularly important for the emissions of NO_x and SO_x since here the combustion activities are the key source of emissions. For the greenhouse gases, this choice is not of key importance, since for CO_2 the emission factors are dependent on fuel only (not on technology or abatement characteristics), and CH_4/N_2O as well as NH_3 emission factors from combustion are small compared to non-combustion sources such as agriculture or waste treatment.

Additionally, it should be noted that during this assessment, several outliers were identified in the IEFs extracted from the GAINS data, where the calculated emission factor was very high. In the GAINS model these were always applied only to very low activity rates, therefore the emission was OK. However, when applying these IEFs to other countries with higher energy consumption led to very high emissions. To exclude the outliers which were clearly wrong, upper limits were set to the implied emission factors. The IEFs that were above the threshold mentioned above were excluded for calculating the country group and global average IEFs, to avoid the outliers leading to unrealistic estimates when used in the gap filling process. The following thresholds for the IEFs were used:

- NO_x, NH_3: < 1000 kg/TJ
- SO_x: < 10 000 kg/TJ

Table 1. Percentage of the emission calculated by TEAM based on global average EF (orange: 5-10%, red: >10%)

	Country group	NOX	SOX	NH3		Country group	NOX	SOX	NH3
AUS	Annex I	0.9%	0.2%	1.9%	**TUR**	Annex I	0.6%	1.3%	0.5%
AUT	Annex I	0.7%	5.0%	0.8%	**GBR**	Annex I	0.6%	0.3%	0.0%
BEL	Annex I	0.7%	1.3%	1.0%	**USA**	Annex I	0.6%	0.3%	0.0%
CAN	Annex I	0.0%	0.0%	1.4%	**ARG**	Latin America	100.0%	100.0%	100.0%
CHL	Latin America	100.0%	100.0%	100.0%	**BGR**	Annex I	0.3%	0.0%	0.2%
CZE	Annex I	0.3%	0.8%	0.1%	**BRA**	Latin America	100.0%	100.0%	100.0%
DNK	Annex I	0.2%	0.5%	0.0%	**BRN**	Asia	100.0%	100.0%	100.0%
EST	Annex I	44.0%	96.9%	0.1%	**CHN**	Asia	1.2%	1.4%	0.0%
FIN	Annex I	1.0%	6.0%	0.1%	**COL**	Latin America	100.0%	100.0%	100.0%
FRA	Annex I	1.6%	0.6%	0.2%	**CRI**	Latin America	100.0%	100.0%	100.0%
DEU	Annex I	0.3%	0.7%	0.1%	**CYP**	Annex I	8.2%	0.1%	0.2%
GRC	Annex I	0.4%	0.0%	0.8%	**HKG**	Asia	21.2%	80.0%	4.8%
HUN	Annex I	1.4%	4.4%	0.2%	**HRV**	Annex I	1.2%	0.2%	0.2%
ISL	Annex I	21.9%	86.9%	1.7%	**IDN**	Asia	0.7%	0.1%	0.0%
IRL	Annex I	0.1%	0.3%	0.0%	**IND**	Asia	5.8%	3.5%	2.3%
ISR	Middle East	100.0%	100.0%	100.0%	**KHM**	Asia	100.0%	100.0%	100.0%
ITA	Annex I	0.5%	1.1%	0.2%	**LTU**	Annex I	0.6%	0.4%	0.2%
JPN	Annex I	1.7%	9.2%	0.1%	**LVA**	Annex I	0.5%	3.8%	0.1%
KOR	Asia	2.3%	2.1%	0.5%	**MLT**	Annex I	1.3%	3.2%	0.2%
LUX	Annex I	0.3%	3.9%	0.5%	**MYS**	Asia	100.0%	100.0%	100.0%
MEX	Latin America	100.0%	100.0%	100.0%	**PHL**	Asia	100.0%	100.0%	100.0%
NLD	Annex I	1.2%	11.4%	0.0%	**ROU**	Annex I	1.6%	0.1%	1.2%
NZL	Annex I	12.5%	44.0%	0.3%	**RUS**	Annex I	0.3%	0.2%	0.1%
NOR	Annex I	0.8%	1.9%	3.8%	**SAU**	Middle East	100.0%	100.0%	100.0%
POL	Annex I	0.8%	0.3%	0.0%	**SGP**	Asia	100.0%	100.0%	100.0%
PRT	Annex I	1.6%	1.8%	2.4%	**THA**	Asia	100.0%	100.0%	100.0%
SVK	Annex I	0.5%	0.3%	0.2%	**TUN**	Africa	100.0%	100.0%	100.0%
SVN	Annex I	0.3%	4.3%	0.0%	**TWN**	Asia	0.4%	3.1%	0.3%
ESP	Annex I	0.5%	0.7%	0.6%	**VNM**	Asia	100.0%	100.0%	100.0%
SWE	Annex I	0.2%	1.0%	0.0%	**ZAF**	Africa	100.0%	100.0%	100.0%
CHE	Annex I	0.7%	8.7%	0.8%	**ROW**				

Also in the emissions from greenhouse gases, several outliers were found, which was not expected given the relative stability of the emission factors of greenhouse gases from combustion (as the CO_2 emissions released depend only on the amount carbon in the fuel). Therefore, it was decided to replace the emission factors for combustion with the default emission factors per fuel type, as included in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006).

Table 1 provides country specific data on the amount of gap filling that was used per country and per pollutant (for NO_x, SO_x and NH_3 only, since for GHGs no gap filling is needed), where the percentage given corresponds to the sum of the four gap filling methods described above. Figure 1 distinguishes the importance of each of the gap filling methods, but then for the combinations of all emissions for the 61 countries. This shows that for all three pollutants between 85 and 90% of the emissions comes directly from GAINS (including interpolation for missing years). For the missing emissions, around 1/3 is based on a country group average, while 2/3 is based on a global average. The latter reflects mostly the emissions for the countries in Latin America and the Middle East, which are not represented in GAINS.

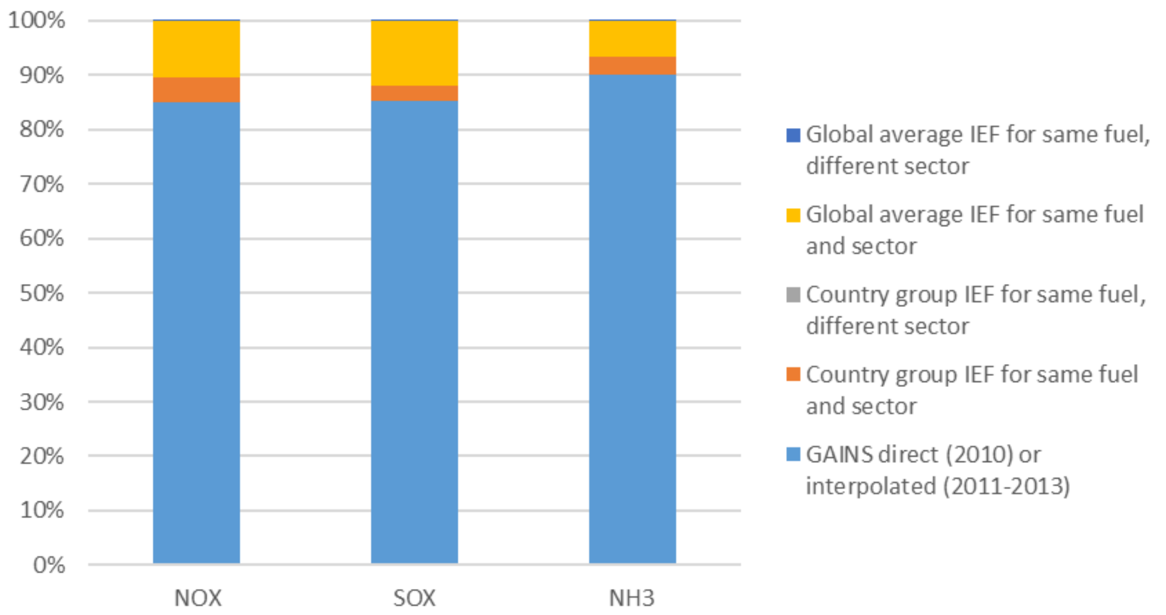


Figure 1. Data sources for global emissions per pollutant

2.1.2.2 ***Non-combustion emissions (Task 1.2.2)***

The calculation of non-combustion emissions from industrial activities and product use (defined as those emission sources included in IPCC sectors 1.B and 2), as well as agriculture and waste, uses emission data directly from other sources. Here, we use emission data reported by countries to UNFCCC, emission data estimated in the IIASA GAINS model and emission data reported in the EDGAR emission inventory, v4.3.1.

	Source data	**Auxiliary data**
Emissions accounts (non-comb)	Industrial production statistics	EDGAR emission inventory (http://edgar.jrc.ec.europa.eu/) UNFCCC and CLRTAP official reported emissions IIASA GAINS model (Amann 2009)

One data source is selected per country per pollutant. This way it is ensured that the same data source is used for all (non-combustion) sectors and for all years, thus avoiding any inconsistencies between years and any sector allocation issues between different datasets.

These datasets have been used in order from highest to lowest preference:

1. UNFCCC reported data (only for CO_2, CH_4, N_2O and only for Annex I countries);

2. IIASA GAINS emissions (for all pollutants, 5 year intervals, interpolated for the years in between);
3. EDGAR emission inventory (data only available up to and including 2010, years after estimated by extrapolating based on the 2005-2010 trend).

2.1.2.2.1 Source data

As mentioned in Section 2.1.2.4, the following data sources have been used for the compilation of non-combustion emissions:

- UNFCCC official reported emissions in CRF format: these have been used as the primary source: whenever available (for Annex I countries only) these data have been used. Only GHG emissions are taken from the UNFCCC submissions.
- The IIASA GAINS model is the second source of data, this has been used when no UNFCCC data were available (for non-Annex I countries)
- The third source is the JRC EDGAR emission inventory which provides emission estimates for all countries. However the latest version (v4.3.1) only provides emission estimates up to and including 2010. Therefore extrapolation (based on the trend 2005-2010) has been used to estimate emissions until 2013.

Table 2 highlights for which country which data source was selected.

Table 2. Detailed sources of the emissions for non-combustion activities

	Data source for CO2/CH4/N2O	**Data source for NOX/SOX/NH3**		**Data source for CO2/CH4/N2O**	**Data source for NOX/SOX/NH3**
AUS	UNFCCC	GAINS	**TUR**	UNFCCC	GAINS
AUT	UNFCCC	GAINS	**GBR**	UNFCCC	GAINS
BEL	UNFCCC	GAINS	**USA**	UNFCCC	GAINS
CAN	UNFCCC	GAINS	**ARG**	EDGAR	EDGAR
CHL	EDGAR	EDGAR	**BGR**	UNFCCC	GAINS
CZE	UNFCCC	GAINS	**BRA**	EDGAR	EDGAR
DNK	UNFCCC	GAINS	**BRN**	EDGAR	EDGAR
EST	UNFCCC	GAINS	**CHN**	GAINS	GAINS
FIN	UNFCCC	GAINS	**COL**	EDGAR	EDGAR
FRA	UNFCCC	GAINS	**CRI**	EDGAR	EDGAR
DEU	UNFCCC	GAINS	**CYP**	UNFCCC	GAINS
GRC	UNFCCC	GAINS	**HKG**	GAINS	GAINS
HUN	UNFCCC	GAINS	**HRV**	UNFCCC	GAINS
ISL	UNFCCC	GAINS	**IDN**	GAINS	GAINS
IRL	UNFCCC	GAINS	**IND**	GAINS	GAINS
ISR	EDGAR	EDGAR	**KHM**	EDGAR	EDGAR
ITA	UNFCCC	GAINS	**LTU**	UNFCCC	GAINS
JPN	UNFCCC	GAINS	**LVA**	UNFCCC	GAINS
KOR	UNFCCC	GAINS	**MLT**	UNFCCC	GAINS
LUX	UNFCCC	GAINS	**MYS**	EDGAR	EDGAR
MEX	EDGAR	EDGAR	**PHL**	EDGAR	EDGAR
NLD	UNFCCC	GAINS	**ROU**	UNFCCC	GAINS
NZL	UNFCCC	GAINS	**RUS**	UNFCCC	EDGAR
NOR	UNFCCC	GAINS	**SAU**	EDGAR	EDGAR
POL	UNFCCC	GAINS	**SGP**	EDGAR	EDGAR
PRT	UNFCCC	GAINS	**THA**	EDGAR	EDGAR
SVK	UNFCCC	GAINS	**TUN**	EDGAR	EDGAR
SVN	UNFCCC	GAINS	**TWN**	EDGAR	EDGAR
ESP	UNFCCC	GAINS	**VNM**	EDGAR	EDGAR
SWE	UNFCCC	GAINS	**ZAF**	EDGAR	EDGAR
CHE	UNFCCC	GAINS			

For the IIASA GAINS model, different scenarios were used for different world regions:

- For Europe, the latest available scenario (WPE14_CLE) was used (this is an update from the scenario used in the DESIRE project for EXIOBASE 3)
- For outside Europe, the scenarios used are: CP_WEO_2011_UPD for Australia, Canada, New Zealand, Russian Federation and United States; CP_WEO11_S10P50_v2 for China, Japan, Korea, Taiwan, India and Indonesia (all similar to what was used for EXIOBASE 3)

These scenarios are chosen because they reflect the latest available estimates and scenario projections for the specific countries.

2.1.2.2.2 Processing of non-combustion emissions

For non-combustion, similar to the combustion activities the GAINS data are only available at 5-year intervals (e.g. 2010 and 2015 are available, and not the years in between), therefore linear interpolation was used to estimate emissions for the years in between.

For the EDGAR emissions v4.3.1, data are only available up to (and including) 2010. Emissions for 2011-2013 have been estimated by using linear extrapolation based on the trend 2005-2010.

2.1.2.2.3 Allocation of non-combustion emissions to ICIO industry classification

The final step in the calculation of non-combustion emission accounts is linking of the emissions to the ICIO industry classification. Since the different input emission datasets use different classifications, this has been a challenging task.

The allocation will be based largely on the allocation that has been used in the earlier projects which fed emission data into EXIOBASE. This allocation will be adapted to fit with the ICIO industry classification. The allocation as it has been used between the NFR source category level and the ICIO industries is provided in Table 3 and Table 4 for the different sources that are used. It can be shown that the sectors are only linked to one ICIO industry, which is believed to be the main industry. However, it is likely that some emissions are also occurring in other industries. However, in the international emission datasets that we use here the information to make such a distribution over various industries is lacking, therefore only the main industry is selected in the allocation of emissions to ICIO industries.

Table 3. Allocation table for emissions from EDGAR (left) and GAINS (right)

EDGAR IPCC code	**ICIO industry**	**GAINS NFR code**	**ICIO industry**
1B1	D05T06	1.B	D05T06 / D35T39
1B2	D19	1.B.1.a	D05T06
1C1	D49T53	1.B.1.b	D24
1C2	D05T06	1.B.2.a	D05T06 / D19
2A	D23	1.B.2.b	D05T06 / D35T39
2B	D20T21	2.B.2	D20T21
2C	D24	2.B.3	D20T21
2G	D35T39	2.B.5.a	D20T21
3A	D45T47	2.C.1	D24
3B	D26	2.C.5	D24
3C	D22	2.D.1	D17T18
3D	D23	3.D.3	D49T53
4*	D01T03	4.*	D01T03
6*	D35T39	6.*	D35T39

Table 4. Allocation table for emissions from UNFCCC

UNFCCC CRF code	ICIO industry	UNFCCC CRF code	ICIO industry
1.B.1.a	D05T06	2.A.4	D20T21
1.B.1.b	D24	2.B.*	D20T21
1.B.1.c	D05T06	2.C.*	D24
1.B.2.a	D19	2.D.1	D29
1.B.2.b	D35T39	2.D.2	D10T12
1.B.2.c	D05T06	2.D.3	D49T53
1.B.2.d	D05T06	2.G.3	D49T53
1.C.1	D49T53	2.G.4	D35T39
1.C.2	D05T06	2.H	D10T12
2.A.1	D23	3.*	D01T03
2.A.2	D23	5.*	D35T39
2.A.3	D23		

As one way to verify the allocation shown in Table 3, it has been suggested to use the Eurostat Air Emission Accounts (AEA) for comparison in order to identify any possible outliers. An example is shown in Table 5 for CH_4. The table shows the results in the 2nd column against the Eurostat AEA in the 3rd column. It can be seen that for many industries where the Eurostat AEA has (mostly) small emissions, this study does not provide emissions, due to the allocation issues described above. A large discrepancy for CH_4 was observed for AEA industry B (Waste Management) where the Eurostat AEA value is nearly 3 times as high as the calculated emissions in this study. Looking into this reveals that the Eurostat AEA emissions are very different for a few countries with large emissions, in particular Poland, Romania, Turkey, Czech Republic, Germany and the UK. The reported values have been compared to the UNFCCC reported emissions for CRF source category 5 (Waste Management) which showed that these values were different again from both. The largest discrepancy was found for Poland, where the reported emissions in Eurostat AEA for the waste management sector (B) are 1709 kton CH_4 while the UNFCCC reported emissions for CRF source category 5 are only 477 kton. The different reported values can be interpreted as an indication of the uncertainty of the numbers, but understanding and resolving these differences is beyond the scope of this study.

As a means to improve the comparison between the resulting emissions from this study and the Eurostat AEA, it was decided to rescale the total calculated emissions from this study using the Eurostat AEA industries on a per country basis (only for the countries for which Eurostat data are available, other countries are not changed). This way, the distribution over industries becomes more in line with Eurostat, which is expected to better reflect reality. Because the scaling is done for each country and year individually, for some industries there are stronger deviations from Eurostat than for others, but generally the results are in better agreement compared to the situation before scaling.

In addition, this scaling is only performed for NH_3, CH_4 and N_2O since these pollutants originate mainly (>90%) from non-combustion activities. For CO_2, NO_x and SO_x the majority of emissions result from combustion, and therefore the non-combustion emissions cannot be compared to the Eurostat AEA.

A similar comparison can be made per country, this is shown in Figure 2, for NH_3. The comparison includes the NH_3 emissions calculated in this study and scaled with the Eurostat AEA as described above, the Eurostat Air Emission Accounts and the national inventory as submitted to the LRTAP Convention. What can be seen in the graph is that the totals reported in the Eurostat AEA and the national inventory are not always equal. In Bulgaria, Spain, Lithuania and Latvia, the relative difference is more than 20%. This is surprising, as it was expected that the AEAs and the inventories in each country would be based on the same dataset and thus add up to the same country total. What may play a role in this is the timing of reporting: emission inventories are being updated constantly, so historical emissions for a given year are different every year they are reported, due to new scientific insights, new data becoming available, etcetera.

Table 5. Comparison to Eurostat Air Emission Accounts for CH_4 emissions (values in kton)

AEA Industry	Resulting emissions before scaling	Eurostat AEA	Resulting emissions after scaling
A	10757.36	10919.37	10787.65
B	1502.30	4485.22	1495.84
C10-C12	0.51	66.95	62.33
C13-C15	0.00	6.56	6.32
C16	0.00	34.99	31.45
C17-C18	0.00	39.59	36.35
C19	177.57	102.06	100.50
C20-C21	57.01	122.55	115.05
C22	0.00	1.66	1.59
C23	0.00	15.64	14.76
C24	43.74	56.45	56.49
C25	0.00	2.32	2.21
C26	0.00	0.68	0.67
C27	0.00	0.81	0.78
C28	0.00	2.04	1.99
C29	0.03	2.25	2.15
C30	0.00	1.10	1.07
C31-C33	0.00	4.74	4.70
D-E	7213.67	6596.19	6477.13
F	0.00	5.98	6.01
G	0.00	42.20	44.02
H	0.06	305.46	412.09
I	0.00	10.02	9.82
J58-J60	0.00	1.22	1.19
J61	0.00	0.94	0.92
J62_J63	0.00	0.97	0.95
K	0.00	3.25	3.20
L	0.00	8.52	8.40
M-N	0.00	11.46	11.27
O	0.00	23.58	22.71
P	0.00	12.85	12.64
Q	0.00	10.37	10.14
R-S	0.00	8.67	8.50
T	0.00	1.35	1.33
	19752.24	**22907.99**	**19752.24**

Note: some industries were merged to facilitate the comparison between ICIO and AEA industries

From the comparison, problems in both national datasets can be observed. For instance, for Bulgaria, the AEA emission is too low, while for the inventory clearly Greece is wrong. Therefore, any correction based on these national reported datasets would have to be on a country by country basis. By doing that however, we would lose the consistent approach and therefore it was decided to stick with the scaled values as they are. Also, in many cases it is not directly clear whether the inventory or the AEA would be the better dataset. Therefore, it has been decided to stick with the emissions scaled by Eurostat AEA.

All in all, the mixed picture with different values in different reporting schemes confirms that there are still significant uncertainties around NH3 emissions from agriculture.
Similar results are found for CH4 and N2O, where the totals reported under the Eurostat AEA and to the UN Framework Convention on Climate Change / Kyoto Protocol are found to be different.

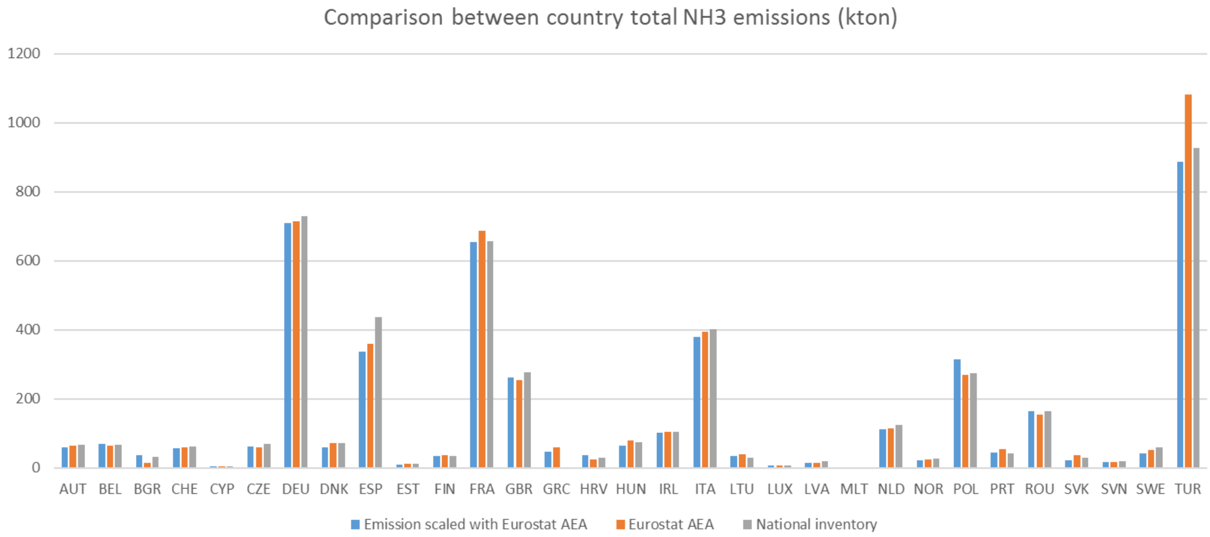


Figure 2. Country level comparison for CH4 between emissions

2.2 Labour accounts

Labour accounts are part of the socio-economic extensions of input-output tables, and as environmental extensions, they follow the same country and industry classification of the inter-industry matrix. In the context of this project, labour accounts comprise compensation of employees, total employment, employees and hours worked.

Data on compensation of employees (COE) comprises wages, salaries and employers' social contribution are often found in national accounts. It covers all gross remuneration to paid workers during the accounting period. In this project, COE was extracted from the ICIO tables provided to the NTNU team, and only its distribution in skill levels is part of the deliverable.

Total employment refers to total persons engaged in each industry. It covers both employees and self-employed persons. Employees are all persons with formal job attachment, even if in temporarily paid or in unpaid leave. Self-employed persons include employers, own-account workers, members of producers' cooperatives, unpaid family workers at work, and persons engaged in the production of economic goods and services for own household consumption. In this project, we will report total employment in total number of persons in work, in full-time employment (FTE), and in hours worked. Hours worked is a measure that includes regular work of full-time, part-time and temporary workers, as well as paid and unpaid overtime. It usually excludes hours not worked due to holidays, paid and unpaid leave, and other non-worked time. Full-time equivalent is a unit to normalize part-time workers according to the full-time working hours. For example, a part-time worker employed for 20 hours per week, in a place where a full-time work consists of 40 hours per week, would be counted as (a) 1 person in total employment and (b) 0.5 FTE.

Data for total employment and for compensation of employees is divided in three skill levels (high, medium, and low). Skilled work is based on either occupations or educational attainment levels. For occupations, we follow the definition from the International Standard Classification of Occupations (ISCO) (ILO 2012) and, for educational attainment, the International Standard Classification of Education (UNESCO 2012), which is the classification used in the KLEMS database (Timmer et al. 2007; WORLD KLEMS 2016). Whenever possible, we used occupation as the basis for distributing employment and COE in skill levels. The correspondence between the skill levels and occupations and education attainments is presented in Table 6.

Table 6. Correspondence between skill types and occupations or educational attainment levels

Occupations *(ILO ISCO classification)*	**Skill type *(k)***	**Educational attainment levels (UNESCO ISCED classification)**	**Educational attainment levels (KLEMS database)**
9 Elementary occupations	**Low-skilled**	0 Less than primary education 1 Primary education 2 Lower secondary education	3 No formal qualifications
8 Plant and machine operators, and assemblers 7 Craft and related trades workers 6 Skilled agricultural, forestry and fishery workers 5 Services and sales workers 4 Clerical support workers	**Medium-skilled**	3 Upper secondary education 4 Post-secondary non-tertiary education	2 Intermediate
3 Technicians and associate professionals 2 Professionals 1 Managers	**High-skilled**	5 Short-cycle tertiary education 6 Bachelor's or equivalent level 7 Master's or equivalent level 8 Doctoral or equivalent level	1 University graduates (ISCED 5 + 6)

Section 2.2.1 below describes the compilation of data for the labour accounts, while section 2.2.2. describes the adjustment of the downloaded data into the ICIO classification. A more detailed (step-by-step) description is found in section 2, where the codes for the processing, harmonization, gap filling and allocation of data are described.

2.2.1 Compilation of labour accounts

Data compilation and correspondence with the input-output model followed procedures applied for FP7 projects CREEA (Wood et al. 2015) and DESIRE (Stadler et al. 2017). These procedures are described in section 2.2.2 below. Country- and industry-specific labour accounts were compiled from national accounts (NA), labour force surveys (LFS) and earning surveys (ES), available from international statistics databases. Appendix 3 presents a summary of sources used per indicator and country. The compiled accounts are then adjusted to the ICIO industry classification.

The main databases used are Eurostat, OECD Statistics and ILOSTAT.

	Source data	**Auxiliary data**
Labour accounts	Systems of National Accounts, Labour Force Surveys, Earning Surveys, and other available statistics from international databases	EUROSTAT OECD Statistics ILOSTAT

Sector-level data were collected annually for the period between 2010 and 2013 for total employment, employees, hours worked, and skill level.

The compilation of data was done in three steps:

a) Quantification of labour inputs to the economy. The first step is to compile the number of workers, in total employment and employees, and hours worked per industry and per country for each year. Whenever available, data for labour inputs are from National Accounts (see Annex 4). Preference in labour inputs obeyed the following hierarchy: (1st) National accounts (NA) data; (2nd) Labour Force Surveys (LFS); (3rd) Combined data from diverse sources (including the World Input-Output Database – WIOD); and (4th) Estimated data based on proxies. Disaggregation of labour inputs into OECD ICIO industry classification and merge of data in different classification are described in section 2.2.3.

b) Qualification of labour inputs in skill levels. The second step involves the allocation of workers into three skill levels: high-, medium-, and low-skilled employment. This procedure is done by determining the share of workers per skill level in each industry. This step is detailed in section 3.2. The number of employees per occupation or per education attainment is available from LFS. Priority in qualifying labour per skill level is given to occupations. When information on occupations is not available or reliable, education will be used as a proxy for skilled work (see Table 6).

c) Distribution of compensation of employees in skill levels. The third step comprises the distribution of compensation of employees per skill level. This is done by combining the number of skilled workers in each industry with relative differences in wages between workers in different skill levels available from earning surveys (ES). This step is also detailed in section 3.2.

For the purpose of this project, we considered hours actually worked whenever available, since it reflects the productivity of the industry, and are the usual data available in labour accounts. When only average weekly hours worked by person for each sector is available for each industry, total hours are obtained by multiplying average weekly hours by the number of persons in work and by 52 weeks. When only data for hours worked in total employment or by employees were available, we assumed same hours worked per person in both labour types.

Employment in FTE was calculated for each sector as in:

$$FTE_i = \frac{e_i \times h_i^w}{h_i^{ft}}$$

Where e_i is total employment (in total numbers of persons in work in activity i), h_i^w is the total hours actually worked in sector i, and h_i^{ft} is the usual working hours for full-time work in sector i. Hours worked per week for full-time workers was collected from Eurostat, and covers 32 countries in the ICIO. For the remaining countries, we assumed the average of hours worked in full-time for the European countries.

2.2.2 Adjustment of labour accounts to OECD ICIO industry classification

Source labour data is available in a variety of industry classifications, in different degrees of detail. Sector classifications vary not only between different countries, but also between different years within one country. The first step in adjusting the data into the desired classification is the harmonization between the different datasets, obeying the hierarchy in data preference. The reliable data with higher industry classification serve as a basis for allocation of labour inputs in the highest disaggregation possible from the source data in the time series. This harmonization is described in detail in section 3.2.1.

The second step in the adjustment is disaggregating labour inputs into the OECD ICIO industry classification. This is done by distributing labour inputs from the source data into the different industries inside each broad sector according to the share of compensation of employees in each industry. For example, allocation is done between the broad sector ISIC Rev. 4 B (*Mining and quarrying*) to ICIO sectors D05T06 (*Mining and quarrying of energy producing material*), D07T08 (*Mining and quarrying except energy production materials*) and D09 (S*ervices to mining and quarrying*). This distribution is done according to the following equation:

$$e_j = \frac{e_B \times w_j}{\sum_{j \in B} w_j}$$

Where e_j is total employment (or labour inputs) in sector *j* (for example, *Mining and quarrying of energy producing material*), e_B is the total employment (or labour inputs) in broad sector *B* (for example, *Mining and Quarrying*), and w_j is the compensation of employees in each industry *j* which belongs to broad sector *B*. A more detailed explanation on allocation is given in section 3.2.2.

The adjustment of data for missing years (harmonization of time series) or missing indicators (gap filling) are described in section 3.2.1. and 3.2.3.

3 Main steps in the estimation of the Environmental and Labour accounts

This section shows the steps in the estimation of the environmental and labour accounts, using pseudo-code taken from the comments in the R-scripts and complemented by tables and graphs.

The first section in this chapter deals with the energy accounts and the energy-related emissions (or combustion emissions, these two terms are used interchangeably in the text below). The second section explains the estimation of the non-fuel-combustion emissions and the third section provides insights into the estimation of the labour accounts. The estimation of energy accounts and energy-related emission accounts have been pulled together, because the emission factors are applied to the energy accounts before the final step of the conversion into the ICIO industry classification.

Data for the energy accounts is readily available for all countries from the IEA energy balance data. The description of the estimation of the energy accounts is, thus, different from the subsequent description of the emission factor estimations and the labour account estimations.

3.1 Energy accounts and energy-related emission accounts

3.1.1 Estimation of energy accounts and energy-related emission accounts

The estimation of the energy accounts and energy-related emission accounts is done for each year separately as the source data is available for all years.

The code uses some concordance matrices and external data that have been prepared in Excel and are available as .csv files.

- auxData\countryConcordance.csv
  contains two columns with the country names used in the IEA data in the first column and the ISO-3 country codes in second column.
- indata_ICIO\countryNames_OECD.csv
  contains 4 columns with the country names in column one, A3 codes in column two, A2 codes in column 3 and corresponding EXIO A3 country/region code in column 4
- auxData\net_energy_mask.csv
  contains a matrix with rows for the IEA energy products and columns corresponding to the IEA energy activities. The matrix itself consists of 0’s and 1’s with the 1’s indicating the entries of net energy use.
- auxData\emission_relevant_mask.csv
  contains a matrix with rows for the IEA energy products and columns corresponding to the IEA energy activities. The matrix itself consists of 0’s and 1’s with the 1’s indicating the entries of emission-relevant energy use.
- auxData\concordanceIEAActivities.csv
  contains a concordance matrix that is only used to rearrange the IEA activities into a format suitable for the use and final demand tables of energy accounts. The concordance matrix essentially 1) re-arranges activities; 2) deletes subtotals of the IEA energy flows in the energy balances and 3) aggregates energy and transformation flows for the energy industry.
- auxData\concordance_prod_auto_icio.csv
  contains 0’s and 0’ indicating which fuel can be used for auto-producing electricity in which sector

- auxData\concordance_IEA_ICIO.csv
contains the concordance between the IEA activities and the ICIO industries.

- auxData\bunkerShares.
contains the share of each country for year 2011 in total global aviation and marine bunker fuels. The data is based on the data used in EXIOBASE. For those countries which are not available in EXIOBASE, the shares are scaled estimates from the EXIOBASE regions to which the country belongs. The estimation of the shares is described in Sections 2.1.1.1, 3.1.2 and 3.1.3.

- auxData\trans_fuel_percEXIO.csv
contains the adjustment factors for transport fuel use across industries and final demand categories. Rows are the ICIO countries and columns are the ICIO industries and final demand categories. The factors are sector-specific and represent the shares of road transport fuels (motor gasoline, gas diesel oil, biodiesel, biogasoline) in "Coke and refined petroleum products".

- emissionFactors\emissionFactorMatrix_YYYY.Rdata
The derivation of the emission factors for combustion emissions is explained in Section 4.1.2.

- auxData\EXIOBASE_supply_ICIOYYY.csv
contains the country specific energy that is supplied to each sector. The data is used to create a proxy for the country specific allocation to sectors for autoproducers.

- auxData\ terrRes_adjustment_YYYY.csv
contains the factors for the relevant fuels for the reallocation of territorial to residential. The factors describe how much each countries energy use from road transport fuels) must be adjusted in order to adjust the energy (use, net, emission relevant) to the residential principle. The estimation of the factors is described in Sections 2.1.1.1 and 3.1.2.

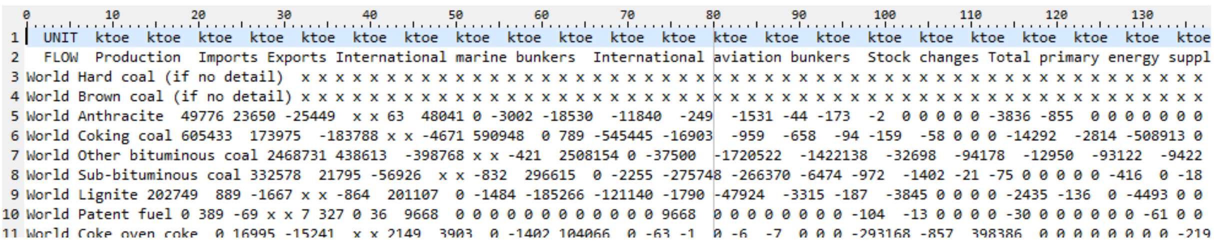
- results\Extensions_YYYY_ELIOD.Rdata

Step 0 - set paths and define variables and filenames

Step 1 - read in year invariant data:

a. Read in country concordance that relates IEA country names to A3 codes
b. Read in OECD country codes
c. Read in net and emission relevant mask, which relate energy use to net energy and emission relevant energy, respectively.
d. Read in concordance to relate to original IEA activity order to the activity order of the use table

Step 2 - Load IEA data (TJ data – the most right columns) by year in source format from file year_YYYY.txt



```
 UNIT  ktoe  ktoe  ktoe  ktoe  ktoe  ktoe  ktoe  ktoe  ktoe  ktoe  ktoe  ktoe  ktoe  ktoe  ktoe  ktoe  ktoe  ktoe  ktoe  ktoe  ktoe  ktoe  ktoe
  FLOW  Production  Imports Exports International marine bunkers  International aviation bunkers  Stock changes Total primary energy suppl
World Hard coal (if no detail)  x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x
World Brown coal (if no detail) x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x
World Anthracite  49776 23650 -25449  x x 63  48041 0 -3002 -18530  -11840  -249  -1531 -44 -173  -2  0 0 0 0 0 -3836 -855  0 0 0 0 0 0 0
World Coking coal 605433  173975  -183788 x x -4671 590948  0 789 -545445 -16903  -959  -658  -94 -159  -58 0 0 0 -14292  -2814 -508913 0
World Other bituminous coal 2468731 438613  -398768 x x -421  2508154 0 -37500  -1720522  -1422138  -32698  -94178  -12950  -93122  -9422
World Sub-bituminous coal 332578  21795 -56926  x x -832  296615  0 -2255 -275748 -266370 -6474 -972  -1402 -21 -75 0 0 0 0 0 -416  0 -18
World Lignite 202749  889 -1667 x x -864  201107  0 -1484 -185266 -121140 -1790 -47924  -3315 -187  -3845 0 0 0 0 -2435 -136  0 -4493 0 0
World Patent fuel 0 389 -69 x x 7 327 0 36  9668  0 0 0 0 0 0 0 0 0 0 0 0 9668  0 0 0 0 0 0 0 0 -104  -13 0 0 0 0 -30 0 0 0 0 0 0 -61 0 0
World Coke oven coke  0 16995 -15241  x x 2149  3903  0 -1402 104066  0 -63 -1  0 -6  -7  0 0 0 -293168 -857  398386  0 0 0 0 0 0 0 0 -219
```

The columns are energy activities. The rows are the energy products, for the country mentioned in the first column. All countries are below each other. Flows are the quantity of an energy product produced/consumed in a certain activity.

3.1.1.1 ***Code1: IEA raw energy balance data to energy use, net energy use and emission relevant energy use (IEA2energyuse_net_emissionrelevant.R)***

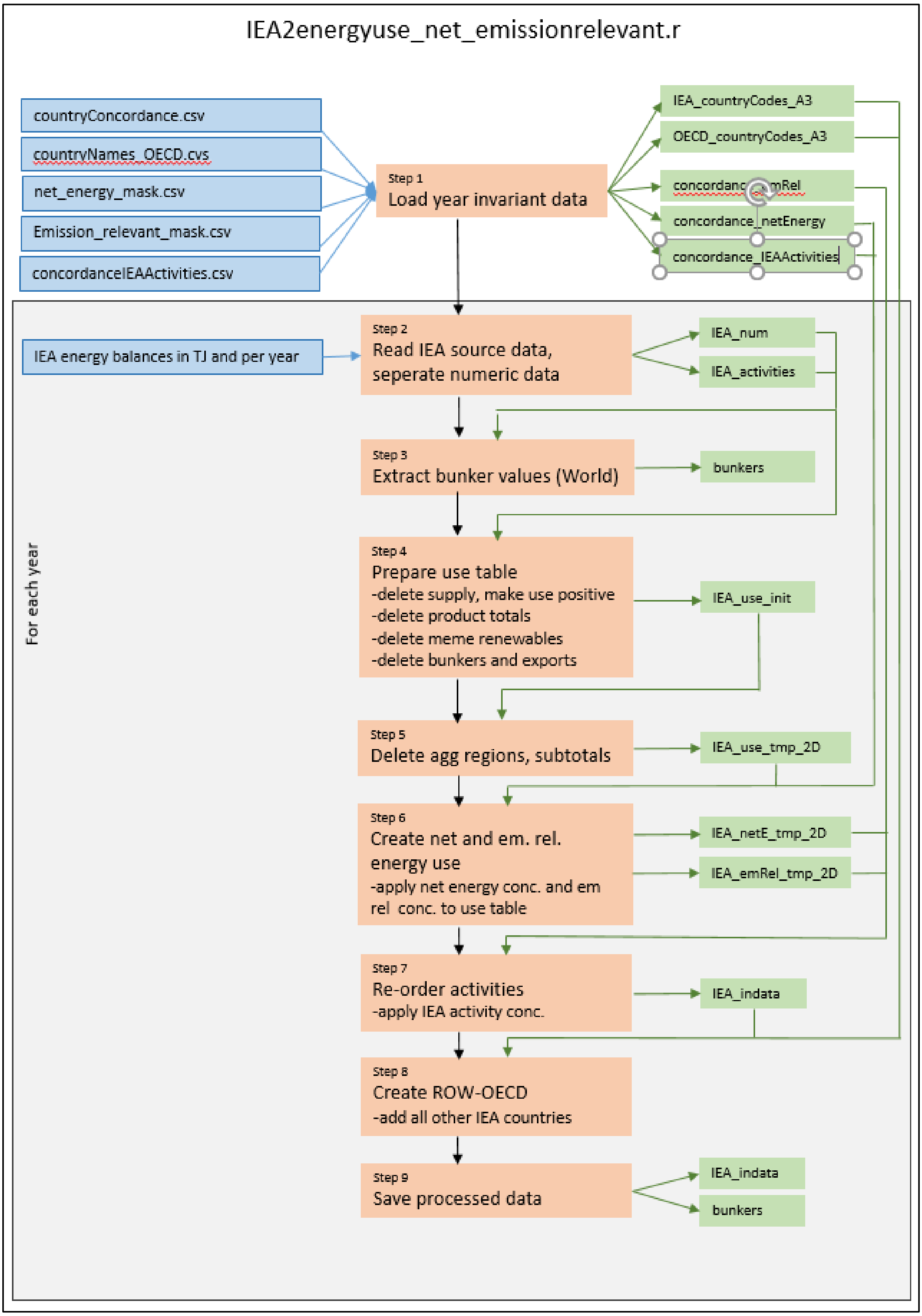


Figure 3. Flow diagram of IEA2energyuse_net_emissionrelevant.R

Step 3 - From country "WORLD" get total bunkers for 4 bunker fuels (aviation gasoline, kerosene, kerosene type jet fuel and heavy fuel oil

Step 4 - Prepare energy use data from the energy balances (gross energy use only)

a. For transformation and energy sector columns (from columns 10:50 of the data in TJ) everything that is larger than zero is assumed supply and thus set to zero Everything that is negative is use of energy, which we multiply by -1 for representation in gross energy use tables.
b. Stock changes, exports, int marine bunkers, distribution losses, transfers, and statistical differences are multiplied by -1 for representation in gross energy use tables.
c. Industry, commercial, and other final use of energy are positive in the energy balances and kept in the same representation of the gross use
d. remove bunkers from country data by setting corresponding columns to zero

Step 5 – Aggregated regions and subtotals are deleted

Step 6 – Get net energy use and emission relevant energy use

a. read net_energy_mask.csv and emission_relevant_mask.csv – these files are binary files that show whether IEA energy balance flows should be accounted for in Net Energy Indicator or in Emission Relevant Indicator.
b. multiply each country's energy_use by net_energy_concordance matrix to get net energy use
c. multiply each country's energy_use by emission_relevant_concordance to get emission relevant energy use

Step 7 – re-structure IEA data

4) multiply use countryConcordance.csv to adapt country names from IEA notation to 3digit country codes.
5) apply concordanceIEAActivities.csv to energy_use, net_energy_use and emis_rel_energy_use. This transforms the 85 IEA columns to 66 columns in an adjustment of the IEA activity classification so that we can apply emission factors later. Note: - we get rid of total flows, aggregate energy and transformation flows/activities and note, that "Memo: Feedstock use in petrochemical industry" are taken out of 'Non-energy use industry/transformation/energy' and treated as a separate activity.

Step 8 – create ROW_OECD table, by adding all other regions and countries from IEA

Step 9 – save the IEA use tables and bunkers

The outcome of this first step (IEA2energyuse_net_emissionrelevant.R) is energy data by energy product in IEA activity classification according to the territorial principle for each country. Note, losses are included as an "activity" in Gross energy use tables, but excluded from Net energy use and Emission relevant use.

3.1.1.2 *Code2: EnergyAndEmissionsExtensions_YYYY.r consists of adjustment from territorial to residential; calculation of combustion emissions; allocation to ICIO industries and final consumers.*

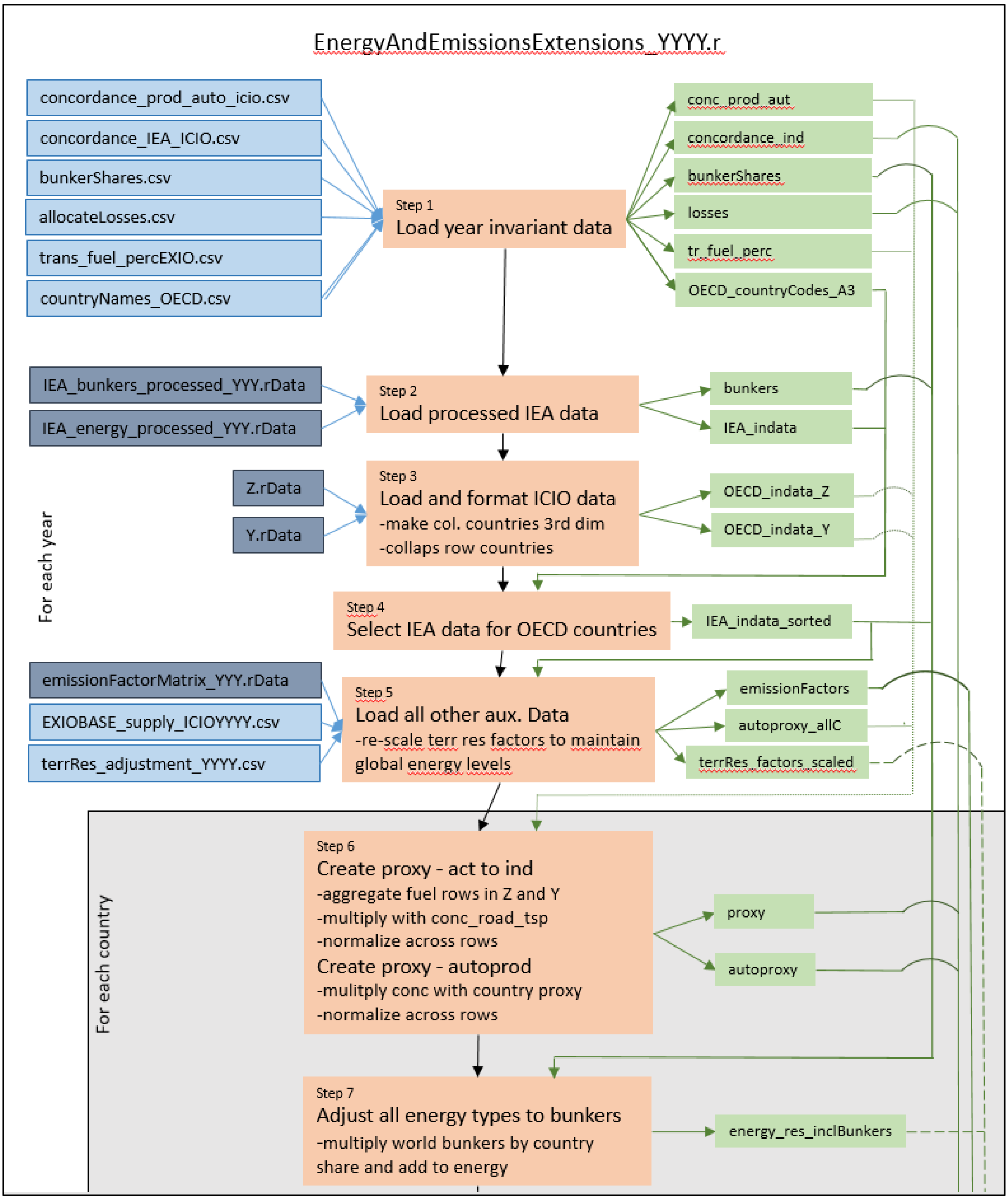


Figure 4. Flow diagram of EnergyAndEmissionsExtensions_YYYY.r

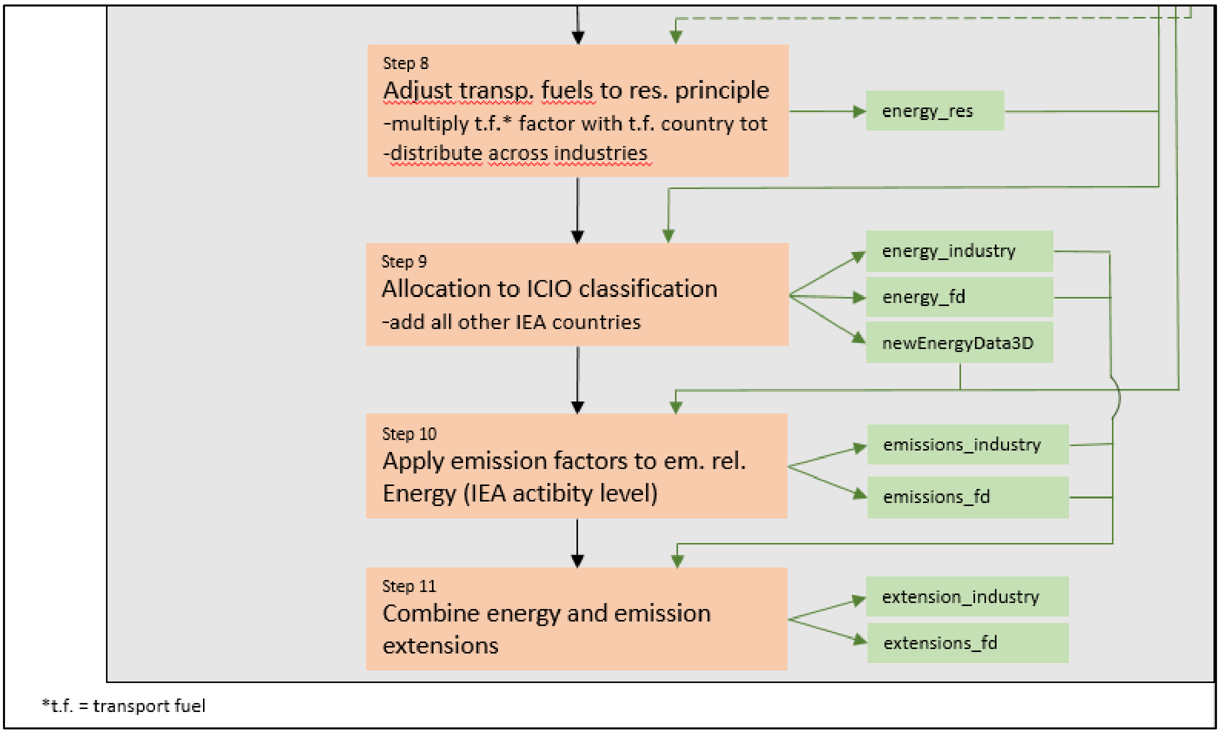


Figure 4. Flow diagram of EnergyAndEmissionsExtensions_YYYY.r (cont.)

Step 0 - define paths, variables and indices, such as: year range, number energy products, activities, extension sets indices for bunkers, transportfuels, energy commodities(rows) for proxy in the original MRIO

Step 1 - read in year invariant data:

6) concordances for autoproducer proxy
7) In order to do the relationship between IEA activities, and IO industries+final consumers, we need some concordance information. Here we read in a concordance matrix - that links the IO industries to the IEA activities via a binary (1|0) relationship matrix.
8) bunker country shares – percentage of total bunker fuel per country
9) information on to which industry losses should be attributed (fuel specific)
10) concordance for road transport fuel allocation (between industries and industry and final demand)
11) OECD country names and codes

Step 2 - load processed IEA source data, Input IEA_energy_processed_YYYY.rData and IEA_bunkers_processed_YYYY.rData (from IEA2energyuse_net_emissionrelevant.R)

Step 3 - load and format ICIO data

Step 4 - select IEA data for the ICIO countries and initialize final matrices

Step 5 - load aux data: emission factors, proxy for auto electricity prodcers and terr to res adjustment. Terr to res adjustment factors are scaled to ensure energy (emission relevant energy) conservation

Initialize final matrices

Step 6 - create proxies - based on monetary spendings on fuel (corresp. rows in Z and Y)

a. The proxy is adjusted –for road and non-road transport fuels - based on the share of road fuels in the fuel mix combination used as the proxy (fuel idx 9). This is based on EXIOBASE data (ICIO doesn't have the resolution to distinguish differential % of consumption across industries and households for individual fuels).

b. Create a proxy for autoproducers only based on EXIOBASE supply data with a masking matrix ('concordance_prod_auto_icio.csv') that can assign specific fuel inputs of autoproducers to specific industries.

Step 7 - select country data and adjust to bunkers. Here we add each countries marine and aviation bunker share for each fuel to the IEA bunker activities

Step 8 - adjust transport fuels to residential. Here we adjust each country's energy data to the residential principle by multiplying the country's road transport fuel use with the scaled terr to res adjustment factor.

Step 9 - allocate energy to the ICIO industry classification

12) Here we do the allocation for all 3 types of energy use. We multiply each row of the concordance matrix with the proxy and the multiply the energy_res data with the result. We obtain a three dimensional matrix, maintaining the original level of detail while having the new ICIO classification. We sum over the IEA activities to obtain the data only in ICIO classification.
13) We place that data into the energy extension

Step 10 - apply emission factors to the emission relevant energy use to calculate emissions and place them in the emission extensions

Step 11 - combine energy and emission extensions together and save

3.1.2 Validation of energy and energy-related emission accounts

Table 7 - Comparison world totals 2010 with IEA$_1$: IEA - source data, IEA$_2$: CO2EmissionsfromFuelCombustion_Highlights_2016, EDGAR$_3$: EDGAR_CO2_2000_2010

World Totals for 2010			
Total energy use (TJ)			
ELIOD	EXIOBASE	IEA	EDGAR
8,4E+08	8,5E+08	8,4E+08	-
Total emission relevant energy use			
ELIOD	EXIOBASE	IEA 1	EDGAR
4,4E+08	4,4E+08	4,4E+08	-
Total CO2 emissions from combustion (kg)			
ELIOD	EXIOBASE	IEA 2	EDGAR 3
3,0E+13	3,0E+13	3,0E+13	2,9E+13

Table 7 shows for year 2010 a comparison of the world total energy use, emission relevant energy use and CO2 emissions from combustion, indication only minor differences in absolute numbers between the produced data set and published datasets.

Figure 5, Figure 6 and Figure 7 show a comparison of the computed country, industry and finals demand total CO2 emissions with EUROSTAT and EXIOBASE3.4 data, respectively. Annex 5 shows the source data and more detailed information on the computed territorial, bunker adjusted and residential CO2 emissions. On average the difference between country totals computed and country totals supplied by EUROSTAT is less than 10%, with large countries like Germany and the UK diverging less.

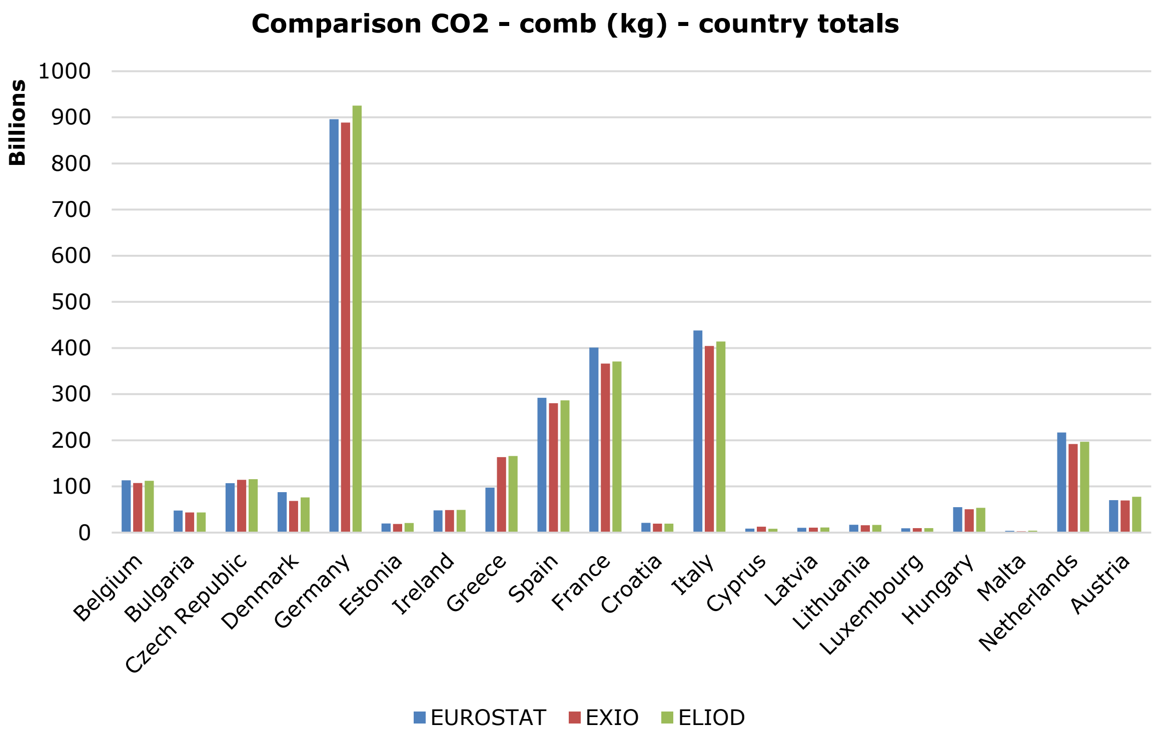


Figure 5. Comparison CO2 emission - country totals

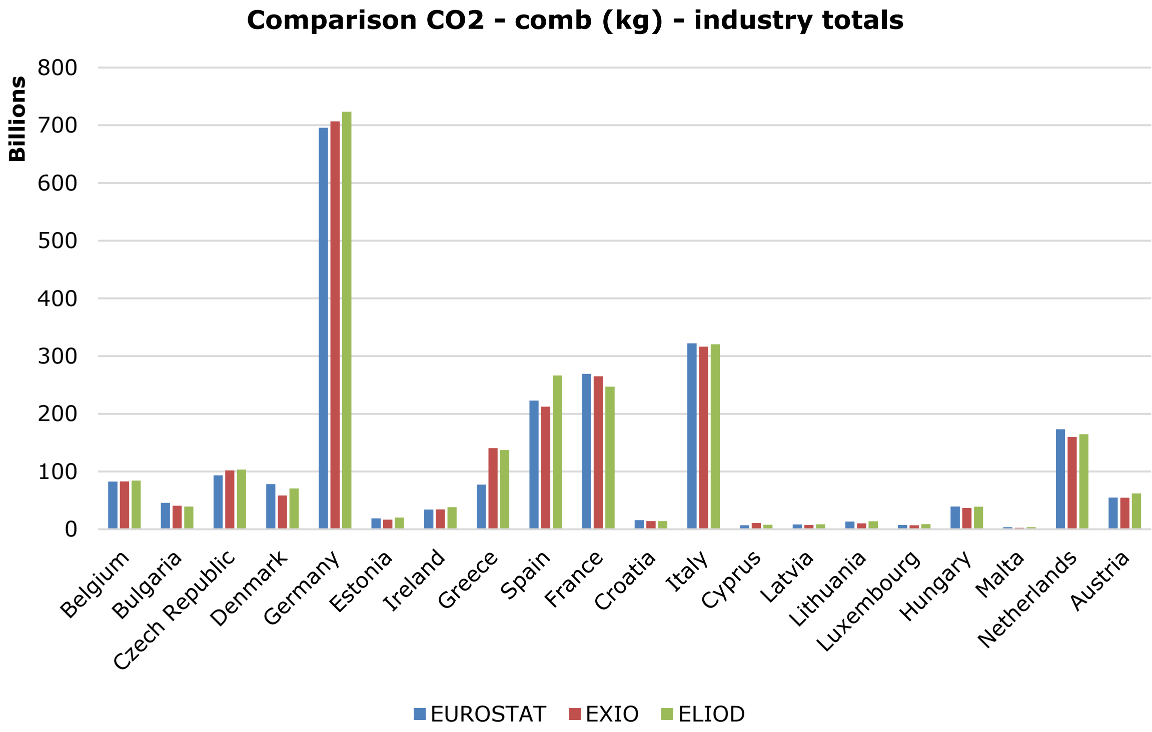


Figure 6. Comparison CO2 emission - industry totals

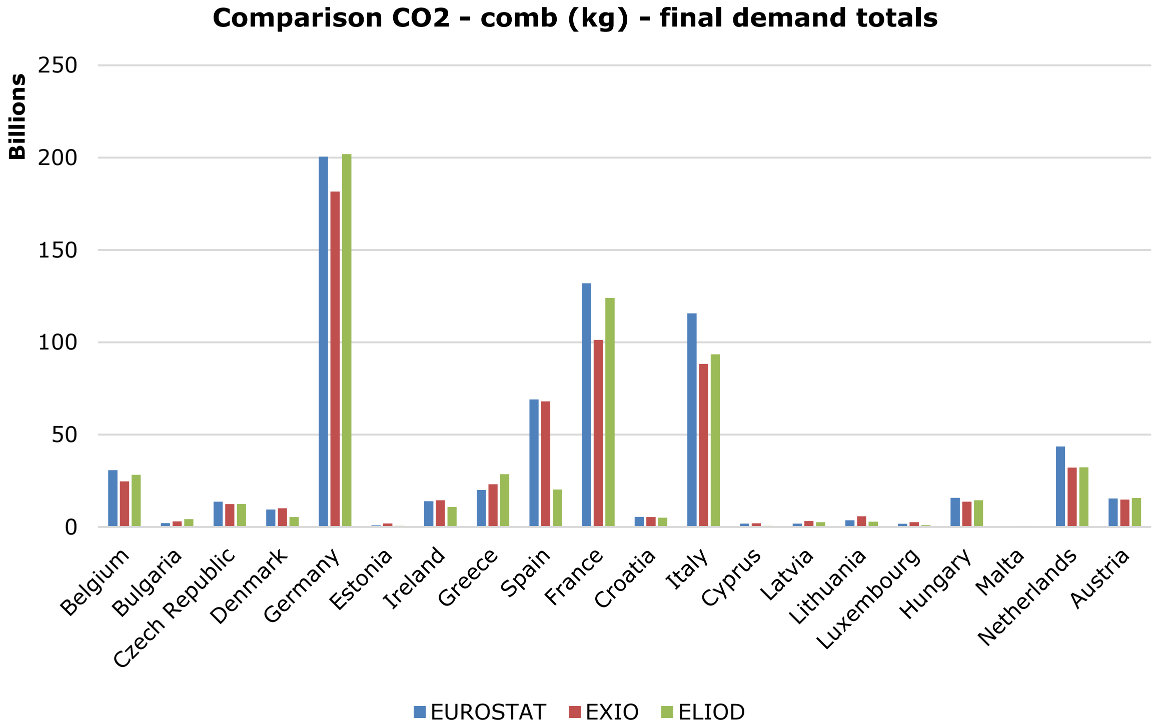


Figure 7. Comparison CO2 emission - final demand totals

3.2 Labour accounts

The overview of the full chain of data processing from raw data is detailed in Figure 5**.** The starting point for this procedure is the download of raw data, in csv format, from the main databases (Eurostat, OECD and ILO). This data is then cleaned, harmonized and processed to deliver harmonized time series for each country. This procedure is described in section 3.2.1 and Figure 6 and Figure 7.

The harmonized data is allocated form its source industry classification to the ICIO industry classification, following procedure described in section 2.2.2 and further explained in section 3.2.2 and Figure 8.

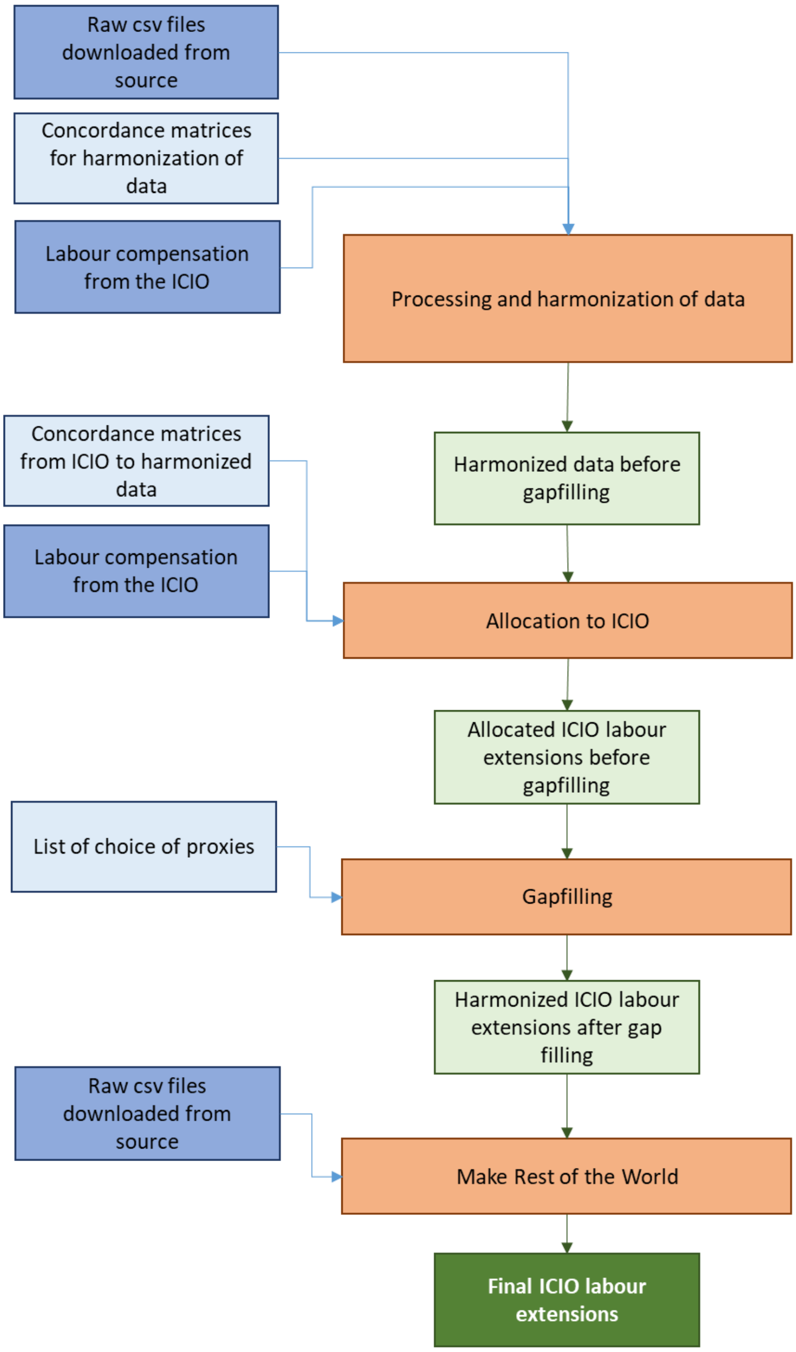


Figure 8. Workflow for estimating labour accounts

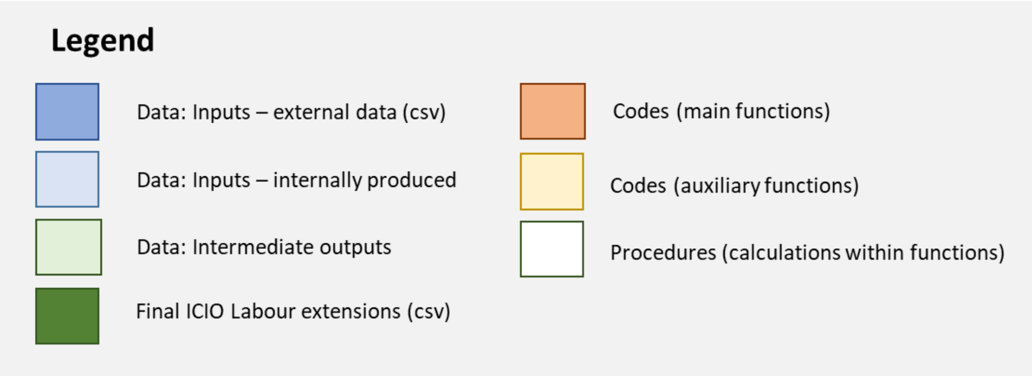


Figure 8. Workflow for estimating labour accounts (cont.)

The allocated labour data still has gaps for missing indicators. The following procedure is fill in those missing indicators using proxies, through the gap filling procedure explained in section 3.2.3 and Figure 9.

After the entire dataset is harmonized, allocated and gapfilled, we can proceed to estimate the Rest of the World (RoW) by using a weighted average of the distribution of employees in total employment, of skilled work, and of relative wages between skill levels for all other countries in the ICIO. This procedure is explained in section 3.2.4 and Figure 10.

3.2.1 Processing and harmonization of source data

The source data (also referred here as raw data) downloaded from the databases (Eurostat, OECD, ILOSTAT, WIOD) is not easily comparable. The first step to use this data is to prepare it, by processing it into a standardized, machine-readable format similar to all datasets. This step is the most resource (time and lines of code) intensive. It follows different procedures for each of the datasets, and different procedures for labour inputs (persons and hours worked) and labour types (distribution of work and wages in skill levels). Section 3.2.1.1 explains the processing and harmonization of labour inputs, and section 3.2.1.2 explains the processing and harmonization of labour types.

3.2.1.1 ***Processing and harmonization of data: labour inputs***

The bulk of the work in the compilation of labour accounts is in the processing of the data. This processing was necessary in order to achieve a data layout that could be read and allocated to the ICIO industries. The intermediate output from this process are tables with 8 columns:

code	industry	var_name	year_label	values	unit	source	notes

Figure 6 illustrates the simplified steps for processing of labour inputs. It first starts with the upload of the downloaded csv files into R. From there, a case-by-case (database dependent) code is used for processing these files into a similar format, units, and industry codes for handling in the next stages (intermediary output in the process: standardized raw data). From this stage, we harmonize available data from each database into a same industry classification throughout the entire time period (for the years available), using concordance matrices to do the correspondence between different industry sectors (and classifications). If harmonization occurs between years (i.e. disaggregating broader sectors from one year's classification to another year's more detailed industry classification) we maintain the relationship between compensation of employees per worker in each disaggregated industry inside the broader sector.

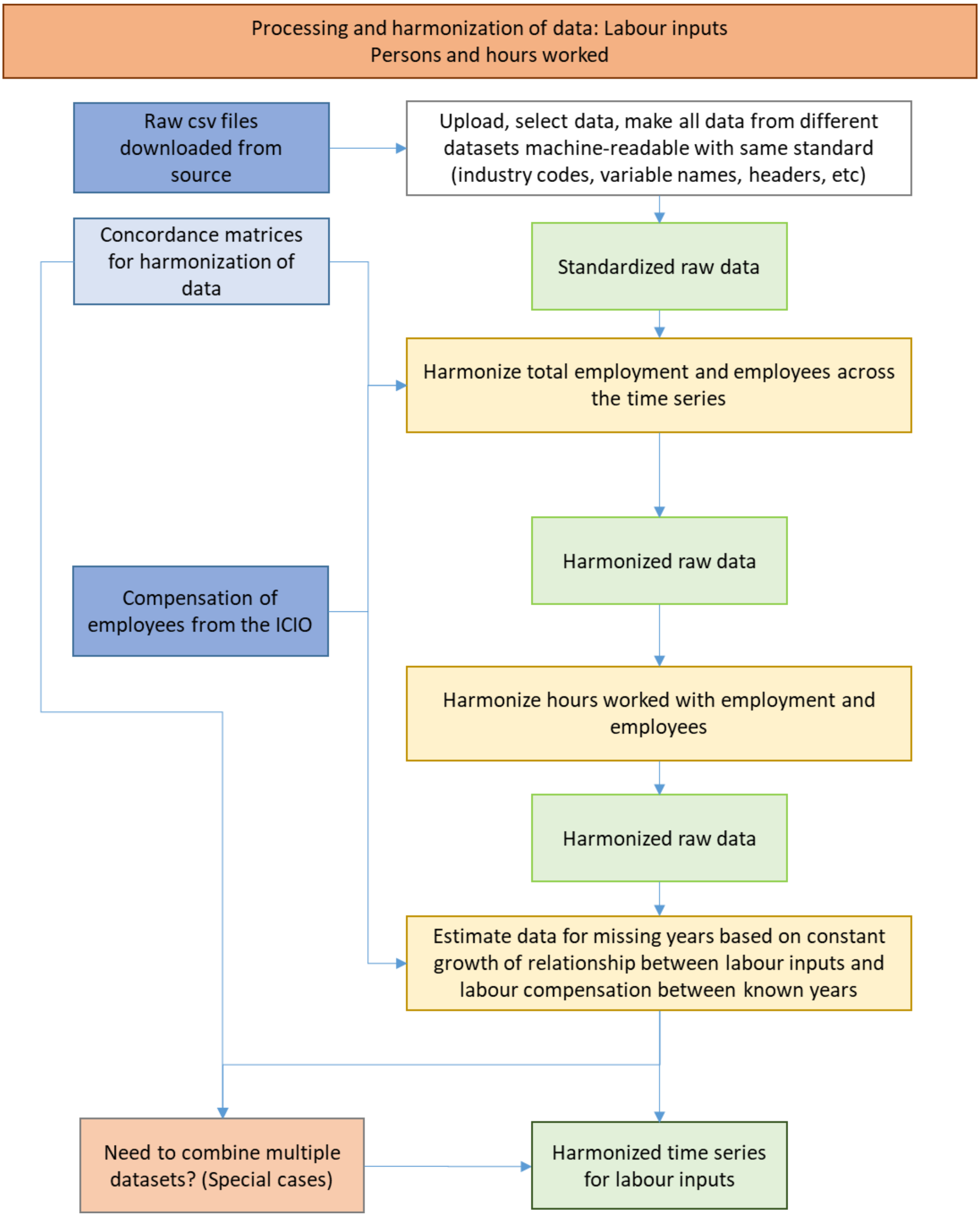


Figure 9. Procedure for processing and harmonization of labour inputs

In this stage we also estimate missing years in the time series for the available indicators. For this, we used fixed relationships:

- For estimating total employment, we use a constant ratio between COE and employment in the closest year (in both cases where this needed to be applied, there were no previous year to interpolate growth rates). This was the case for Singapore and New Zealand.
- For estimating employees or hours worked, we estimated growth rates of the ratio between employees per total employment or between hours worked per person, based on two closest years available: if the missing year was in between known years, we interpolated growth rates from the available data; otherwise, we extrapolated growth rates based on the growth between the next/previous two years available.
- In this stage, if only hours worked for one type of work (total employment or employee) were available, we estimated same hours worked for both employees and all other workers in the economy.

For data from Eurostat and OECD, the data available is total hours worked in the economy. For data from ILOSTAT, however, the indicator available is hours worked per week per person We then proceed to combine it with hours worked (when needed). In data from NA, this step is not necessary. However, data available from LFS is in hours worked per week, which then needs to be applied to the harmonized series of workers per industry.

Processing and harmonizing processes for Eurostat and OECD data is rather simple, as those sources provide a time series that is already harmonized and there are hardly any missing years (exception: New Zealand). The process (and thus, the codes) for the harmonization of data from ILOSTAT are more complex, as the following issues are encountered in the data:

1. Data is available from multiple sources: Need to find and select preferred source (partially manual, by selecting in the source csv data and deleting not-wanted data);
2. Data is available in multiple industry classification throughout the time series: Need to find the best one and distribute data from other years to the most detailed classification based on distribution of COE in the most detailed industries;
3. Data is available in different classification for indicators that are dependent on each other (for example, employees/total employment, or hours worked and employment in persons): Need to harmonize the industry classification between the indicators;

3.2.1.2 ***Processing and harmonization of data: skill level***

Like with the labour inputs, the first steps of this procedure is to upload the data and write it in the standard format as a table with eight columns and standard industry codes and units across the different datasets. Figure 7 illustrates the simplified steps for processing of skilled labour and wages. Unlike the labour inputs, for which the output is in physical amounts (thousand persons, million hours), the goal here is to have shares of employment and compensation per skill levels (es and ws) calculated for each industry and country. This is then multiplied by the absolute employment, hours and compensation of employees, generating the actual (physical and monetary) values for the indicators.

The source data for these indicators make a difference on the quality of the final data. For employment per skill level, priority was given to data on occupations. Hierarchy for the choice of data for each country was given to data from LFS (collected from Eurostat, OECD Statistics, and ILOSTAT); followed by data from WIOD (which is based on KLEMS), followed by estimation by proxy (detailed in section 3.2.3).

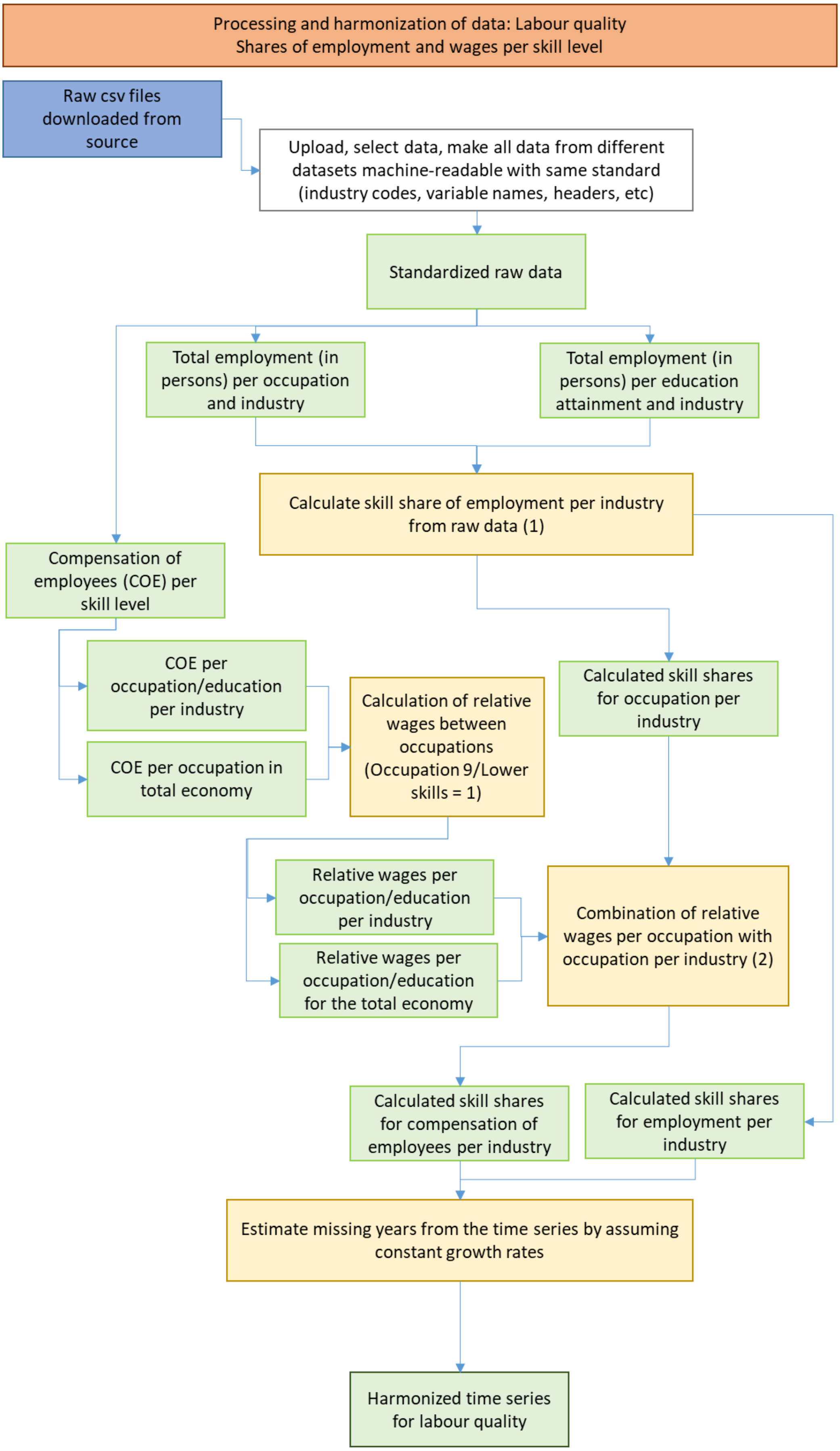


Figure 10. Procedure for processing and harmonization of labour quality (skills)

LFS provide labor distribution per occupation and industry, in thousands of people. While for Eurostat this dataset is harmonized for industries and time series, it is not the case for the ILOSTAT dataset. For Eurostat we calculate skill shares and wage shares directly from source data, but for non-European countries we first harmonize and estimate missing years using the procedures describes in the above section. Industry classification for skilled work is usually in top level ISIC Rev. 3 or 4, covering between 7 and 22 sectors.

The highest difference between sources, however, is for the distribution of wages in skill levels. Eurostat provides data from Earning Surveys, which comprise data for average hourly wages per occupation and industry. Industry classification is available in top ISIC4 level, and is available for 2010 and 2014. We estimated average hourly wages for the period between 2011 and 2013 as interpolation between the two years, using constant growth rates for the wages (as in % growth per annum). Wages for the agricultural sector are not available in Eurostat, and we use the average wage for all the non-agricultural activities instead.

For non-European countries, however, average wages are only available per occupation as per the entire economy, and not for each industry. This dataset presents average wages (in local currencies or dollar) paid to employees in different occupations, regardless of the industry sector they work. This is the most aggregated data available in the datasets, which mean that using this dataset estimates that differences in wages per occupation are constant across all industries in the economy. ILO provides data for average monthly wages per occupation in the economy, while the OECD (through the World Indicators of Skills for Employment – WISE – database) provide data on average annual wages per occupation for the entire economy. We prioritized wage data from ILO when available. The table in Annex 4 describes in detail the source used for each of the indicators for each country, as well as the year availability for these data.

If no data were available from the Eurostat, ILO or OECD databases for both skill shares and wages, we used the WIOD database. This was the case for China, Taiwan and the United States. The data in WIOD are available in shares of total employment and COE per skill level, and is available for 36 industries in ISIC Rev. 3 classification, and are calculated based on education attainment, in contrast with data for occupations used for the remaining countries. These data are already harmonized for both industries and time series. For countries not in the WIOD database, we used proxies to estimate distribution of skills in total employment and the relative wages, as described below in section 3.3.3.

From the standardized data in this procedure, we calculate the skill shares of employment (1) and the skill shares of compensation of employees (2) per industry. We detail these two steps below.

3.2.1.3 ***Skill share of employment per industry***

For each industry j, the sum of employment share (es) for the three skill levels in each sector is one (100%). This share is applied to every industry within each sector j, for example, for each industry within the manufacturing sector.

The data available from the source data are total employment per occupation (in thousands of persons). The employment shares (es) for each skill level k and sector j was obtained by summing the total employment, in thousands of persons, in each occupation (oc) correspondent to each skill level (see Table 6), and dividing by the sum of all workers in the dataset for that sector:

$$es_j^k = \frac{\sum_{oc} e_j^{oc}}{\sum e_j}; \sum_k es_j^k = 1$$

We maintain, however, data on employment per occupation disaggregated inside the procedure, as it is used to calculate the wage shares (*ws*).

The same procedure is applied to calculate the skill share of hours worked in total employment per industry. However, the only dataset that provides distinction between hours and persons in skilled employment is Eurostat (for 2010 and 2014, as mean monthly hours paid by sex, economic activity and occupation in non-agricultural activities. As with wages, we use the average of non-agricultural activities to estimate the shares of hours worked by agriculture workers). Thus, for European countries, the shares of hours worked in persons in different skill levels is different than of the share of persons in different skill levels, while for the remaining countries, these shares are equal.

3.2.1.4 ***Skill share of compensation of employees per industry***

As in the distribution of employment shares, the sum of wage shares (ws) in each sector j is one (100%) and this share is applied to every industry within sector j. The first step to calculate wage shares is to calculate relative wages within each occupation, where we quantify the actual difference between the wages, and not the absolute values. In this case, we estimate the relative wages per occupation as:

$$R_j^{oc} = \frac{w_j^{oc}}{w_j^{ISCO-9}}; R_j^{ISCO-9} = 1$$

Where the relative wage (R) in each occupation (oc) and sector j corresponds to the ratio of the average wage (w) in that occupation and sector, divided by the average wage of workers in occupation ISCO-9 (elementary occupations = low-skilled work) in that same sector. For data from Eurostat, this is done for each sector of the economy, while for data from ILO and OECD, the relative wages are applied only for the entire economy (so j would be the total economy).

For calculating the wage shares we combine relative wages with persons in occupation in each sector. For data from ES (i.e. industry—specific wages), we calculate wage shares by summing the product of total employment per occupation in each industry j (e_j^{oc}) and relative wages in the same occupation and industry (R_j^{oc}) for all occupations within a skill level k, and dividing by the sum of the product of all workers in each occupations in industry j and the relative wages for their occupation:

$$ws_j^k = \frac{\sum_{oc}\left(e_j^{oc} \times R_j^{oc}\right)}{\sum_k \sum_{oc}\left(e_j^{oc} \times R_j^{oc}\right)}; \sum_k ws_j^k = 1$$

This provides a weighted average taking into account the difference in wages for each occupation, and the distribution of people in each occupation inside each skill level. The total wages considered are without bonuses or other non-standard payments – that is, calculated as hourly wages multiplied by number of hours paid for per month.

For average wages from ILO or OECD (i.e. not industry-specific), we use the same approach, but instead of multiplying the persons in each occupation per industry with industry-specific relative wages, we multiply with the total economy-wide relative wages (R_T^{oc}). In that way, even though the difference of wages remains the same for workers in different occupations in every sector of the economy, the different distribution of occupations within each industry results in different wage shares per skill level for each sector:

$$ws_j^k = \frac{\sum_{oc}\left(e_j^{oc} \times R_T^{oc}\right)}{\sum_k \sum_{oc}\left(e_j^{oc} \times R_T^{oc}\right)}; \sum_k ws_j^k = 1$$

3.2.2 Allocation of processed and harmonized labour data to the ICIO industry classification

The output of the previous process is entire process, is a table for each country with data per indicator, industry and year. The first rows of the table for Spain are illustrated below for providing an example of the output from the previous step:

code	industry	var_name	year_label	values	unit	source
ISIC4_TOTAL	Total	EMP	2010	19639.5	Thousands	Eurostat National Accounts Database
ISIC4_A	Agriculture, forestry and fishi	EMP	2010	793.9	Thousands	Eurostat National Accounts Database
ISIC4_A_01	Crop and animal production, h	EMP	2010	725	Thousands	Eurostat National Accounts Database
ISIC4_A_02	Forestry and logging	EMP	2010	25	Thousands	Eurostat National Accounts Database
ISIC4_A_03	Fishing and aquaculture	EMP	2010	43.9	Thousands	Eurostat National Accounts Database
ISIC4_B_E	Industry including energy [B-E	EMP	2010	2559.2	Thousands	Eurostat National Accounts Database
ISIC4_B	Mining and quarrying [B]	EMP	2010	44	Thousands	Eurostat National Accounts Database
ISIC4_C	Manufacturing [C]	EMP	2010	2311.2	Thousands	Eurostat National Accounts Database
ISIC4_C_10_12	Food products, beverages and	EMP	2010	442.8	Thousands	Eurostat National Accounts Database
ISIC4_C_13_15	Textiles, wearing apparel, lea	EMP	2010	167.4	Thousands	Eurostat National Accounts Database
ISIC4_C_16_18	Wood and paper products, and	EMP	2010	218.6	Thousands	Eurostat National Accounts Database
ISIC4_C_16	Wood and products of wood a	EMP	2010	76.4	Thousands	Eurostat National Accounts Database
ISIC4_C_17	Paper and paper products	EMP	2010	47.3	Thousands	Eurostat National Accounts Database
ISIC4_C_18	Printing and reproduction of r	EMP	2010	94.9	Thousands	Eurostat National Accounts Database

The allocation procedure involves three steps:

14) **Removing double-counting**. As illustrated above, there is double counting in data for labour inputs from Eurostat and OECD (for example, A is the sum of A01-A03). This procedure is done by identifying and removing this double counting. First, we compare aggregated and disaggregated values. We incur in three scenarios: (a) If the sum of disaggregated matches the aggregated value, we remove aggregated value and keep the disaggregated values; (b) if the sum of disaggregated does not match the aggregated value and all disaggregated sectors are in the dataset, we re-scale disaggregated values to match the aggregated one and delete the latter; or (c) if the sum of disaggregated does not match the aggregated value and not all disaggregated sectors are in the dataset, we match the remaining from the aggregated value to the remaining disaggregated sectors. In this case, we keep the remaining (aggregated minus sum of disaggregated) in the row of the aggregated value and correct the row in the concordance matrix to remove the disaggregated sectors available in the dataset.
15) **Creating concordance matrices**. The concordance matrices are created within the function *AUX_RemoveDoubleCounting* and is comprised of a matrix of zeros and ones, with the industry classification in the source data in the rows, and the matching ICIO industries in the columns. All possibilities for concordance matrices are available in the file *AUX_files\Concordances_ICIO.csv*.
16) **Allocation of data from the source classification into the ICIO industry classification**. The allocation of industries from the source data in the ICIO industry classification is done using the COE values and the concordance matrices

that provide a correspondence between the industries available in the harmonized data and the ICIO industries.

Figure 11 illustrates the allocation procedure of labour data from an aggregated industry classification (ISIC 4 Industry B: Mining) into the ICIO disaggregated industries (D05T06, D07T08 and D09) according to their share of COE in the total mining sector.

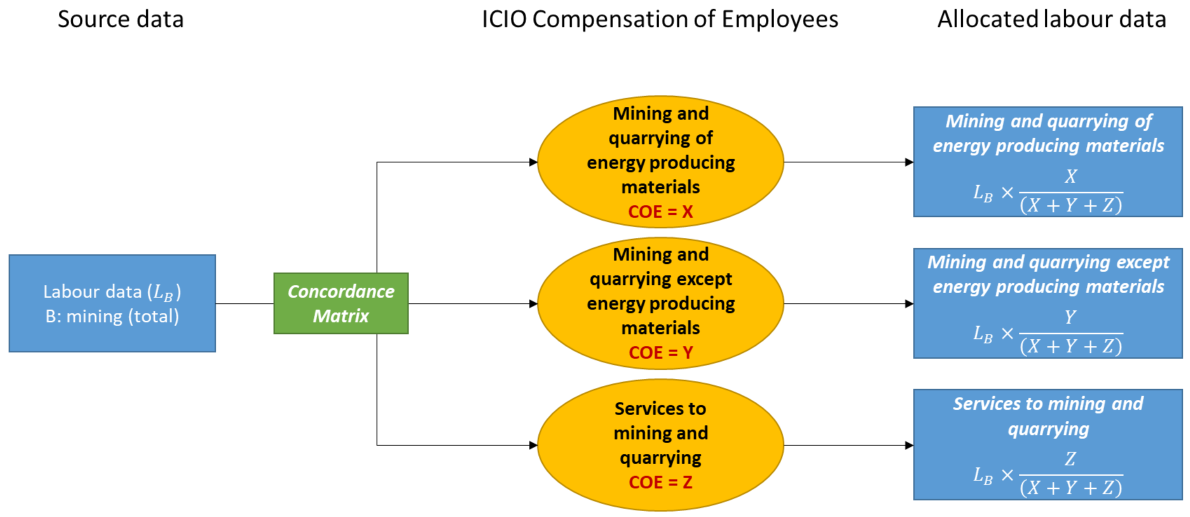


Figure 11. Illustrative example of allocation of labour data from an aggregated sector into ICIO disaggregated sectors

The output from this step is a table for each country with allocated data, before gap filling, in the same industry classification as the ICIO:

year	country	industry	values	unit	var_name	source
2010	ESP	D01T03	793.9	Thousands	EMP	Eurostat National Accounts Database
2010	ESP	D05T06	37.75704	Thousands	EMP	Eurostat National Accounts Database
2010	ESP	D07T08	0	Thousands	EMP	Eurostat National Accounts Database
2010	ESP	D09	46.57118	Thousands	EMP	Eurostat National Accounts Database
2010	ESP	D10T12	621.0409	Thousands	EMP	Eurostat National Accounts Database
2010	ESP	D13T15	266.5937	Thousands	EMP	Eurostat National Accounts Database
2010	ESP	D16	146.1663	Thousands	EMP	Eurostat National Accounts Database
2010	ESP	D17T18	263.8735	Thousands	EMP	Eurostat National Accounts Database
2010	ESP	D19	9.039537	Thousands	EMP	Eurostat National Accounts Database
2010	ESP	D20T21	411.8826	Thousands	EMP	Eurostat National Accounts Database
2010	ESP	D22	253.4552	Thousands	EMP	Eurostat National Accounts Database
2010	ESP	D23	214.4114	Thousands	EMP	Eurostat National Accounts Database
2010	ESP	D24	241.6495	Thousands	EMP	Eurostat National Accounts Database
2010	ESP	D25	595.778	Thousands	EMP	Eurostat National Accounts Database

During this step we also multiply the shares of skilled work and compensation of employees per skill level to the values (total employment, hours, and COE).

There can be errors in the distribution of data within sectors due to the COE data that was supplied to NTNU by the JRC. For example, sector D19 – Manufacture of coke and refined petroleum products (for 2019 BRN, 2013 DNK and 2013 BRN) presents negative compensation of employees, which resulted in negative distribution of COE per skill level and might have affected the distribution of employment indicators within the broader sector. This data is needed for the distribution of all gathered data, as well as harmonization and filling out missing years from the time series. Any fix to the COE data will demand a new run of the code from the *processing and harmonization of data* step.

3.2.3 Gap filling

The previous step provides allocated data from the source data to the industries. Every country has allocated values for total employment for all years, but there are still missing variables for some countries, as detailed in Table 7:

Table 8. Countries and variables that require gap filling for labour extensions

Country	Missing variables
BRN	EMPE, HEMP, HEMPE, SKILLS, COE_SKILLS
COL	COE_SKILLS
IDN	COE_SKILLS
IND	HEMP, HEMPE
ISL	HEMP, HEMPE
MEX	EMPE, HEMP, HEMPE, COE_SKILLS
NZL	SKILLS, COE_SKILLS
SAU	EMPE, HEMPE, SKILLS, COE_SKILLS
SGP	COE_SKILLS
TUN	EMPE, HEMP, HEMPE, SKILLS, COE_SKILLS
TWN	EMPE, HEMP, HEMPE

Legend: EMPE = Employees; HEMP = hours worked in total employment; HEMPE = hours worked by employees; SKILLS = distribution of employment/hours worked in skill levels; COE_SKILLS = distribution of compensation of employees in skill levels.

To fill those gaps, we use other countries' structure of employment as proxy for estimating labour inputs and labour quality. For this, we calculate the ratio between labour inputs and total employment (COE, in case of COE distribution per skill levels) and then apply these ratio of employees per total employment, as well as hours worked, from countries with similar characteristics. For example, for estimating employee data for a country r based on proxy countries p:

$$EMPE^r = \left(\frac{\sum_p EMPE^p}{\sum_p EMP^p} \right) EMP^r$$

If compensation of employees per skill level is not available for a country while the distribution of labour per skill level is, we do not use the relationship of COE per skill out of total COE. Instead, for each industry j we calculate the relative wages per R per skill level k for the proxy countries p by dividing the sum of COE per skill level in proxy countries p with sum of COE for low-skilled (LS) persons in the region. From there, we calculate the wage shares ws relative to the skilled work available for country r and apply to the COE from region r:

$$R_k^p = \left(\frac{\sum_p COE\_SKILL_k^p}{\sum_p COE\_SKILL_{LS}^p} \right)$$

$$ws_k^p = \left(\frac{R_k^p \times SKILL_k^r}{\sum_k \left(R_k^p \times SKILL_k^r \right)} \right); \sum_k ws_k^p = 1$$

$$COE\_SKILL_k^r = ws_k^p \times COE^r$$

A list of proxy countries is provided in the file *AUX_Files\Gap filling.xlsx*. For Brunei Darussalam, Saudi Arabia and Tunisia we used a similar approach to calculate the RoW, by using the average of all other (available) countries.

Figure 9 illustrates the method for gap filling.

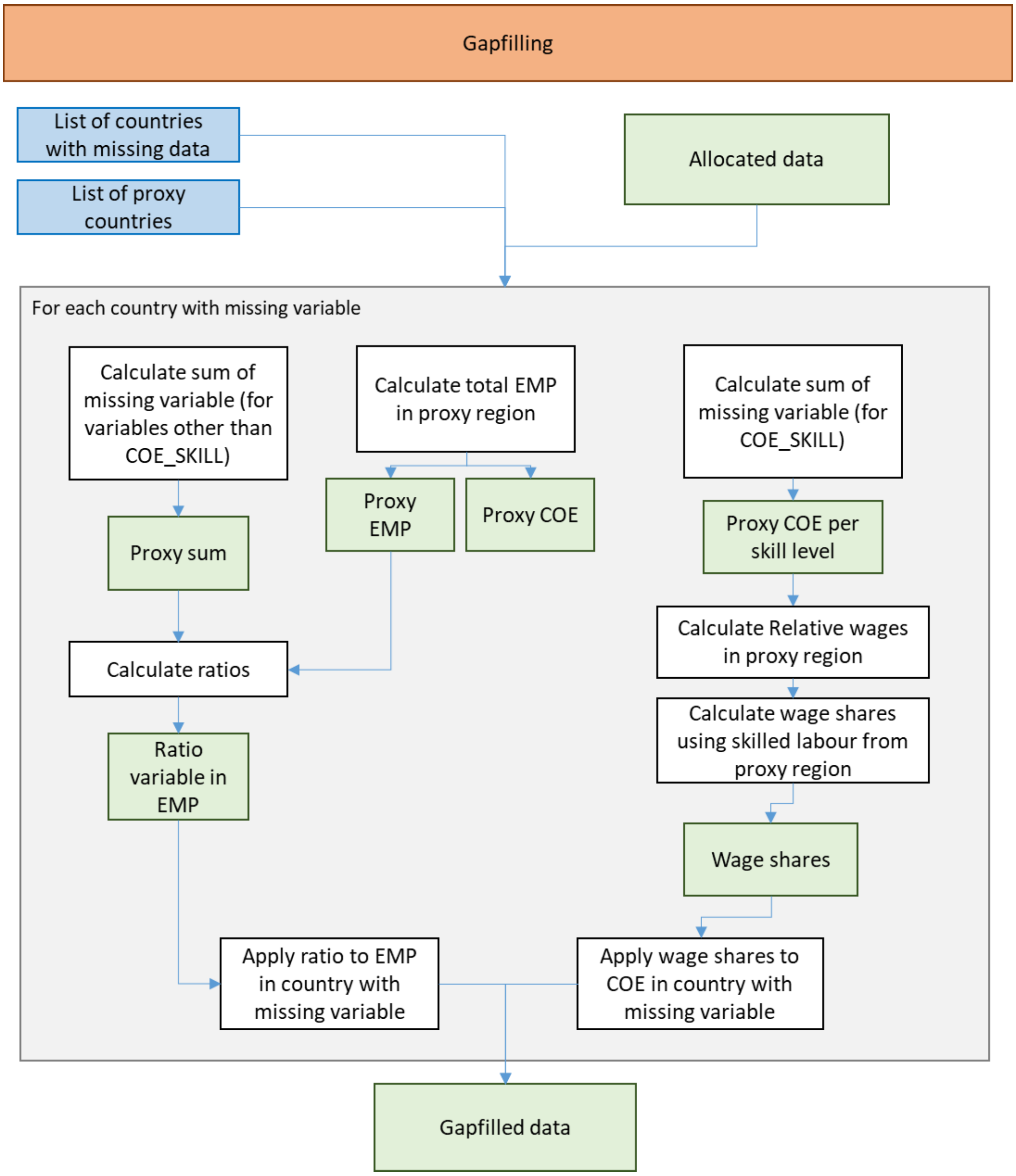


Figure 12. Procedure for gap filling for missing indicators

3.2.4 Estimating the Rest of the World

Estimating labour accounts for the rest of the word (RoW) is done in three steps, illustrated in Figure 10. First, we upload the total employment, in three broad sectors (agriculture, industry, services) for the entire world and organize it in the same format as previous processed and harmonized data as before. Then, we subtract all employment already covered by the countries in the ICIO, generating the total employment in the RoW region, and allocate it to the ICIO industries. Finally, we use the same gap filling function explained above to estimate the remaining indicators, using all other countries in the ICIO as proxies, following procedure used before in EXIOBASE (Stadler et al. 2014). However, the control of countries used as proxy is done outside the code, in the auxiliary files, and can easily be changed according to preferences.

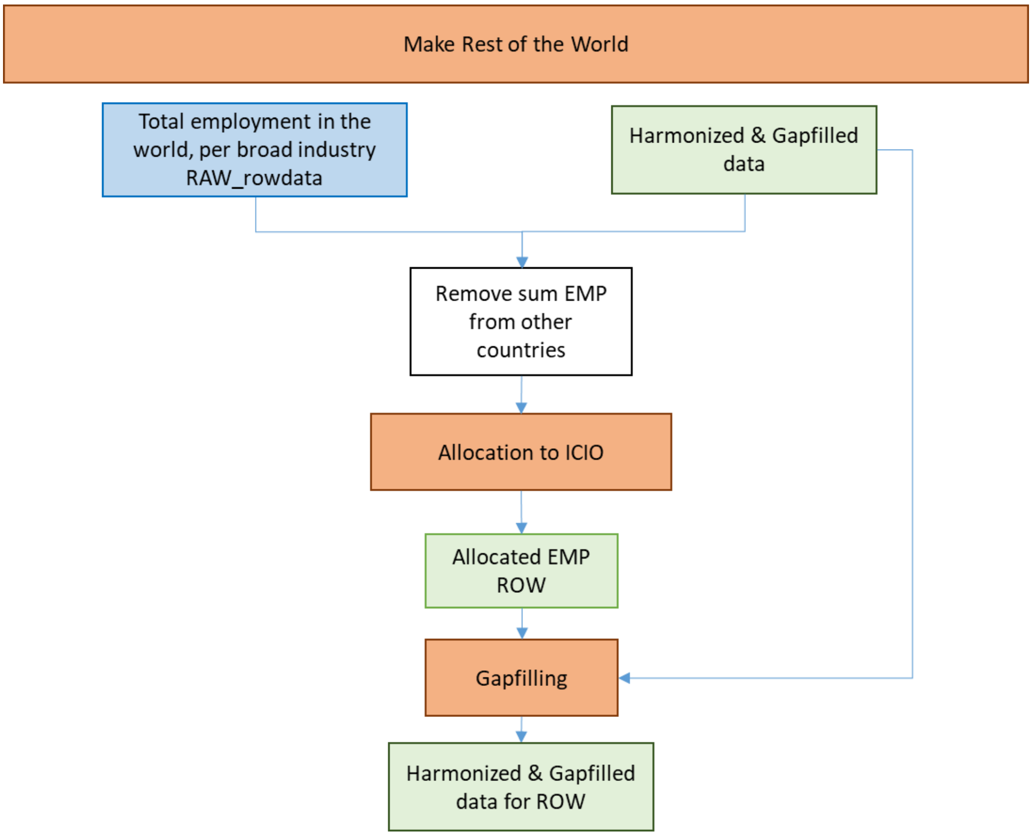


Figure 13. Procedure for estimating the Rest of the World labour accounts

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Annexes

Annex 1. Gross and emission relevant energy use

The list of energy commodities (following IEA classification) that we estimate emissions for are:

Table 9. Energy commodities used for combustion emission calculations

P_03	Anthracite	P_18	Natural Gas	P_36	White spirit & SBP
P_04	Coking coal	P_20	Crude oil	P_37	Lubricants
P_05	Other bituminous coal	P_21	Natural gas liquids	P_38	Bitumen
P_06	Sub-bituminous coal	P_24	Other hydrocarbons	P_40	Petroleum coke
P_07	Lignite	P_25	Refinery gas	P_41	Non-specified oil products
P_08	Patent fuel	P_26	Ethane	P_42	Industrial waste
P_09	Coke oven coke	P_27	Liquefied petroleum gases (LPG)	P_43	Municipal waste (renewable)
P_10	Gas coke	P_28	Motor gasoline	P_44	Municipal waste (non-renewable)
P_11	Coal tar	P_29	Aviation gasoline	P_45	Primary solid biofuels
P_12	BKB/peat briquettes	P_30	Gasoline type jet fuel	P_46	Biogases
P_13	Gas works gas	P_31	Kerosene type jet fuel	P_47	Biogasoline
P_14	Coke oven gas	P_32	Other Kerosene	P_48	Biodiesels
P_15	Blast furnace gas	P_33	Gas/diesel oil	P_49	Other liquid biofuels
P_16	Other recovered gases	P_34	Fuel oil	P_50	Non-specified primary biofuels and waste
P_17	Peat	P_35	Naphtha	P_51	Charcoal

IEA commodities with which we do not account for in emissions relevant energy use, see Table 9:

Table 10. Energy commodities not relevant for combustion emissions

P_01	Hard coal (if no detail)	Zero in all IEA Energy Balances
P_02	Brown coal (if no detail)	Zero in all IEA Energy Balances
P_19	Crude/NGL/feedstocks (if no detail)	Zero in all IEA Energy Balances
P_22	Refinery feedstocks	Feedstock, not combusted
P_23	Additives/blending components	Feedstock, not combusted
P_39	Paraffin waxes	Feedstock, not combusted
P_52	Elec/heat output from non-specified manufactured gases	Emission factor applied to input gas; No emission factor applied to electricity output
P_53	Heat output from non-specified combustible fuels	Emission factor applied to input fuel; No emission factor applied to heat output
P_54	Nuclear	No emission factor applied to electricity output
P_55	Hydro	No emission factor applied to electricity output
P_56	Geothermal	No emission factor applied to electricity output
P_57	Solar photovoltaics	No emission factor applied to electricity output
P_58	Solar thermal	No emission factor applied to electricity output
P_59	Tide, wave and ocean	No emission factor applied to electricity output
P_60	Wind	No emission factor applied to electricity output
P_61	Other sources	No emission factor applied to electricity output
P_62	Electricity	Emission factor applied to inputs where relevant; No emission factor applied to electricity output
P_63	Heat	Emission factor applied to inputs where relevant; No emission factor applied to heat output

Transformation sector

All fuel inputs into main-activity and auto-producer electricity, CHP and heat plants have emission factors applied. No further emission factors are applied to electricity or heat (see Table 9). No emission factors are applied to any other transformation activities, where transformation activities use energy in producing secondary fuels, this energy use is recorded in "Energy industry own use" (see Table 10).

Table 11. IEA activities in the transformation sector (emission and not emission relevant)

Emission factor applied	No emission factor applied
Main activity producer electricity plants	Heat pumps
Autoproducer electricity plants	Electric boilers
Main activity producer CHP plants	Chemical heat for electricity production
Autoproducer CHP plants	Blast furnaces
Main activity producer heat plants	Gas works
Autoproducer heat plants	Coke ovens
	Patent fuel plants
	BKB plants
	Oil refineries
	Petrochemical plants
	Coal liquefaction plants
	Gas-to-liquids (GTL) plants
	For blended natural gas
	Charcoal production plants
	Non-specified (transformation)

Energy industry own use

Emission factors are applied to use of fuel in all activities, except for losses and those only using electricity:

Table 12. Non emission relevant and emission relevant IEA energy commodities for energy industry own use

Emission factor applied	No emission factor applied
Coal mines	Pumped storage plants
Oil and gas extraction	Nuclear industry
Blast furnaces	Losses
Gas works	
Gasification plants for biogases	
Coke ovens	
Patent fuel plants	
BKB plants	
Oil refineries	
Coal liquefaction plants	
Liquefaction (LNG) / regasification plants	
Gas-to-liquids (GTL) plants	
Own use in electricity, CHP and heat plants	
Charcoal production plants	
Non-specified (energy)	

Total final consumption

Emission relevant energy use is considered for all final consumption of fuels in industry, transport and "other" (Residential, Commercial and public services, Agriculture/forestry, Fishing (used domestically), Non-specified (other)). Noting that the electricity and heat do not have emission factors applied. Non-energy usage component of final energy consumption is excluded from the emissions relevant energy use accounting.

Countries included in the EXIOBASE3 database

Table 13. EXIOBASE3 countries

Austria	Luxembourg	India
Belgium	Latvia	Mexico
Bulgaria	Malta	Russia
Cyprus	Netherlands	Australia
Czech Republic	Poland	Switzerland
Germany	Portugal	Turkey
Denmark	Romania	Taiwan
Estonia	Sweden	Norway
Spain	Slovenia	Indonesia
Finland	Slovakia	South Africa
France	United Kingdom	RoW Asia and Pacific
Greece	United States	RoW America
Croatia	Japan	RoW Europe
Hungary	China	RoW Africa
Ireland	Canada	RoW Middle East
Italy	South Korea	
Lithuania	Brazil	

Annex 2. Expected OECD ICIO ISIC Rev. 4 industry list

Table 14. Expected industry list for OECD ICIO ISIC Rev. 4

Full EUROSTAT A64 industry list		OECD ICIO (PRODUCT) (USED IN TRADE BALANCING and hopefully in international Use)	OECD ICIO (industry)	Section	Code i4 (product and industry)	LabelE	approx i3 (code)	ISIC A10
ISIC Rev. 4	Description							
A01	Crop and animal production, hunting and related	1	1	A	D01	Crop and animal production, hunting and related service activities	C01	
A02	Forestry and logging	2	1	A	D02	Forestry and logging	C02	A
A03	Fishing and aquaculture	3	1	A	D03	Fishing and aquaculture	C05	
B	Mining and quarrying							
		4	2	B	D05	Mining of coal and lignite	C10	
		5	2	B	D06	Extraction of crude petroleum and natural gas	C11	
		6	3	B	D07	Mining of metal ores	C12, C13	
		7	3	B	D08	Other mining and quarrying	C14	
		8	4	B	D09	Mining services		
C10-C12	Manufacture of food products, beverages and tob	9	5	C	D10T12	Food products, beverages and tobacco	C15T16	
C13-C15	Manufacture of textiles, wearing apparel and lea	10	6	C	D13T15	Textiles, textile products, leather and footwear	C17T19	
C16	Manufacture of wood and of products of wood an	11	7	C	D16	Wood and products of wood and cork	C20	
		12	8	C	D17T18	Pulp, paper, paper products, printing	C21T22	
C17	Manufacture of paper and paper products							
C18	Printing and reproduction of recorded media							
C19	Manufacture of coke and refined petroleum produ	13	9	C	D19	Coke, refined petroleum products and nuclear fuel	C23	
C20	Manufacture of chemicals and chemical products	14	10	C	D20	Chemicals and chemical products	C24X	
C21	Manufacture of basic pharmaceutical products an	15	10	C	D21	Pharmaceuticals	C2423	
C22	Manufacture of rubber and plastic products	16	11	C	D22	Rubber and plastics products	C25	
C23	Manufacture of other non-metallic mineral produ	17	12	C	D23	Other non-metallic mineral products	C26	B-E
C24	Manufacture of basic metals							
		18	13	C	D241T31	Iron and steel	C271	
		19	13	C	D242T32	Non-ferrous metals	C272	
C25	Manufacture of fabricated metal products, except	20	14	C	D25	Fabricated metal products	C28	
C26	Manufacture of computer, electronic and optical p	21	15	C	D26	Computer, Electronic and optical equipment	C30T33X	
C27	Manufacture of electrical equipment	22	16	C	D27	Electrical equipment	C31	
C28	Manufacture of machinery and equipment n.e.c.	23	17	C	D28	Machinery and equipment, nec	C29	
C29	Manufacture of motor vehicles, trailers and semi-	24	18	C	D29	Motor vehicles, trailers and semi-trailers	C34	
C30	Manufacture of other transport equipment	25	19	C	D30	Other transport equipment	C35	
		26	20	C	D31T33	Manufacturing nec; repair and installation services	C36T37	
C31_C32	Manufacture of furniture; other manufacturing							
C33	Repair and installation of machinery and equipm							
D35	Electricity, gas, steam and air conditioning supply	27	21	D	D35	Electricity and gas supply	C40	
		28	21	E	D36T39	Water supply; sewerage, waste management and remediation activities	C41, C90	
E36	Water collection, treatment and supply							
E37-E39	Sewerage; waste collection, treatment and dispo							
F	Construction	29	22	F	D41T43	Construction	C45	F
		30	23	G	D45T46	Wholesale trade and sale, maintenance and repair of motor vehicles	C50T51	
G45	Wholesale and retail trade and repair of motor ve							
G46	Wholesale trade, except of motor vehicles and m							
G47	Retail trade, except of motor vehicles and motorc	31	23	G	D47	Retail trade	C52	
H49	Land transport and transport via pipelines	32	24	H	D49	Land transport	C60	G-I
H50	Water transport	33	24	H	D50	Water transport	C61	
H51	Air transport	34	24	H	D51	Air transport	C62	
H52	Warehousing and support activities for transporta	35	24	H	D52	Other transport services	C63	
H53	Postal and courier activities	36	25	H	D53	Postal and courier services	C64	
I	Accommodation and food service activities	37	26	I	D55T56	Accomodation and food services	C55	
		38	27	J	D58T60	Publishing, video, broacasting and programming	C22, C72, (	
J58	Publishing activities							
J59_J60	Motion picture, video and television programme							J
J61	Telecommunications	39	28	J	D61	Telecommunications	C64	
J62_J63	Computer programming, consultancy and related	40	29	J	D62T63	Computer and related activities	C72	
		41	30	K	D64T66	Financial intermediation	C65T67	
K64	Financial service activities, except insurance and							K
K65	Insurance, reinsurance and pension funding, exce							
K66	Activities auxiliary to financial services and insur							
L68	Real estate activities	42	31	L	D68	Real estate activities	C70	L
		43	32	M	D69T71	Professional, scientific and technical activities	C74	
M69_M7	Legal and accounting activities; activities of head							
M71	Architectural and engineering activities; technica							
M72	Scientific research and development	44	32	M	D72	Scientific R&D	C73	
		45	32	M	D73T75	Advertising, marketing, other professional, scientific and technical activities	C74	
M73	Advertising and market research							M-N
M74_M7	Other professional, scientific and technical activi							
		46	32	N	D77T82	Administrative and support service activities	C71, C74	
N77	Rental and leasing activities							
N78	Employment activities							
N79	Travel agency, tour operator reservation service a							
N80-N82	Security and investigation activities; services to b							
O84	Public administration and defence; compulsory s	47	33	O	D84	Public administration and defence; compulsory social security	C75	
P85	Education	48	34	P	D85	Education	C80	
		49	35	Q	D86T88	Health and social work	C85	O-Q
Q86	Human health activities							
Q87_Q88	Social work activities							
		50	36	R	D90T93	Arts, entertainment and recreation	C92	
R90-R92	Creative, arts and entertainment activities; librari							
R93	Sports activities and amusement and recreation a							
		51	36	S	D94T96	Other service activities	C91, C93	
S94	Activities of membership organisations							R-U
S95	Repair of computers and personal and household							
S96	Other personal service activities							
T	Activities of households as employers; undifferen	52	37	T	D97T98	Private households with employed persons	C95	
U	Activities of extra-territorial organisations and bo	na in sna	na in sna	U	D99	Extra-territorial organizations and bodies	C99	

Annex 3. Manual adjustment of bunker shares

File: (bunkerShares.csv)

Latvia

For Latvia the EXIOBASE marine bunker adjustment factor results in the total adjustment of CO2 emissions being more than one order of magnitude lower than the adjustment of marine bunkers suggested by Eurostat. Hence, we decrease the total adjustment to match Eurostat's total adjustment, resulting in better compliance of the country's overall CO2-combustion emissions with Eurostat.

Cyprus

The EXIOBASE bunker adjustment for Cyprus results in almost a doubling of the country's energy. Eurostat assigns much less (marine) bunkers to Cyprus, hence we adjusted the bunker share of heavy fuel oil to match the total Eurostat adjustment instead, resulting in a better compliance of Latvia's total CO2-combustion emissions with Eurostat data.

Malta

Malta's total energy use is alignment with EXIOBASE data but only about 50% of the EUROSTAT value. For a country like Malta a very small change in bunker share (heavy fuel oil) has a huge impact. The total adjustment for (heavy) fuel oil for Malta is according to Eurostat almost 15 times higher than according to EXIOBASE. Increasing the bunker share to make the absolute adjustment match the Eurostat value results in better compliance of the country's overall CO2 combustion data with Eurostat.

Note 1

Greece, Sweden and Finland also show a larger discrepancy between the "ELIOD" CO2-combustion country total and Eurostat. However, in the case of Greece Eurostat does not report any adjustment made for marine bunkers. The obtained bunker fuel adjustment data is in compliance with the findings in Usubiaga & Acosta-Fernandez 2015, figure 3 (https://doi.org/10.1080/09535314.2015.1049126). In case of Sweden and Finland we found the IEA source data already to be significantly different (higher) to the EUROSTAT territorial energy data, which results in the higher CO2-combustion emissions for these countries.

Note 2

Both Singapore and Hong Kong show a large difference between the countries energy total provided by the IEA balances (including bunker sales) and ELIOD (with bunker use). Singapore and Hong Kong are within the largest countries for Bunker fuel sales (Singapur alone is responsible for about 25% of all the worlds bunker sales), hence a high discrepancy between the countries' total energy use when considering bunker sales and bunker use is anticipated.

Annex 4. Summary of labour data used by country and by indicator

Table 15. Data availability – labour. Explanation of colour coding below. EMP = total employment; EMPE = employees; HEMP = hours worked in total employment, HEMPE = hours worked by employees, SKILL = total employment per skill level; COE_SKILL = Compensation of employees per skill level (continues in the next page)

	EMP	EMPE	HEMP	HEMPE	SKILL	COE_SKILL
ARG	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS	
AUS	OECD-NA	OECD-NA	OECD-NA	OECD-NA	ILO-LFS	OECD-WISE
AUT	EURO-NA	EURO-NA	EURO-NA	EURO-NA	EURO-LFS	EURO-SES
BEL	EURO-NA	EURO-NA	EURO-NA	EURO-NA	EURO-LFS	EURO-SES
BGR	EURO-NA	EURO-NA	EURO-NA	EURO-NA	EURO-LFS	EURO-SES
BRA	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS
BRN	ILO-LFS					
CAN	OECD-NA	OECD-NA	OECD-NA	OECD-NA	ILO-LFS	ILO-LFS
CHE	EURO-NA	EURO-NA	EURO-NA	EURO-NA	EURO-LFS	EURO-SES
CHL	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS	OECD-WISE
CHN	ILO	ILO	ILO	ILO	WIOD	WIOD
COL	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS	
CRI	OECD-NA	OECD-NA	OECD-NA	OECD-NA	ILO-LFS	ILO-LFS
CYP	EURO-NA	EURO-NA	EURO-NA	EURO-NA	EURO-LFS	EURO-SES
CZE	EURO-NA	EURO-NA	EURO-NA	EURO-NA	EURO-LFS	EURO-SES
DEU	EURO-NA	EURO-NA	EURO-NA	EURO-NA	EURO-LFS	EURO-SES
DNK	EURO-NA	EURO-NA	EURO-NA	EURO-NA	EURO-LFS	EURO-SES
ESP	EURO-NA	EURO-NA	EURO-NA	EURO-NA	EURO-LFS	EURO-SES
EST	EURO-NA	EURO-NA	EURO-NA	EURO-NA	EURO-LFS	EURO-SES
FIN	EURO-NA	EURO-NA	EURO-NA	EURO-NA	EURO-LFS	EURO-SES
FRA	EURO-NA	EURO-NA	EURO-NA	EURO-NA	EURO-LFS	EURO-SES
GBR	EURO-NA	EURO-NA	EURO-NA	EURO-NA	EURO-LFS	EURO-SES
GRC	OECD-NA	OECD-NA	OECD-NA	OECD-NA	ILO-LFS	ILO-LFS
HKG	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS
HRV	EURO-NA	EURO-NA	EURO-NA	EURO-NA	EURO-LFS	EURO-SES
HUN	EURO-NA	EURO-NA	EURO-NA	EURO-NA	EURO-LFS	EURO-SES
IDN	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS	
IND	ILO-LFS	ILO-LFS			ILO-LFS	ILO-LFS
IRL	EURO-NA	EURO-NA	EURO-NA	EURO-NA	EURO-LFS	EURO-SES
ISL	EURO-NA	EURO-NA			EURO-LFS	EURO-SES
ISR	OECD-NA	OECD-NA	OECD-NA	OECD-NA	ILO-LFS	ILO-LFS
ITA	EURO-NA	EURO-NA	EURO-NA	EURO-NA	EURO-LFS	EURO-SES
JPN	OECD-NA	OECD-NA	(1)	OECD-NA	ILO-LFS	OECD-WISE
KHM	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS
KOR	OECD-NA	OECD-NA	OECD-NA	OECD-NA	ILO-LFS	ILO-LFS
LTU	EURO-NA	EURO-NA	EURO-NA	EURO-NA	EURO-LFS	EURO-SES
LUX	EURO-NA	EURO-NA	EURO-NA	EURO-NA	EURO-LFS	EURO-SES
LVA	EURO-NA	EURO-NA	EURO-NA	EURO-NA	EURO-LFS	EURO-SES
MEX	ILO-LFS				ILO-LFS	
MLT	EURO-NA	EURO-NA	EURO-NA	EURO-NA	EURO-LFS	EURO-SES
MYS	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS
NLD	EURO-NA	EURO-NA	EURO-NA	EURO-NA	EURO-LFS	EURO-SES
NOR	EURO-NA	EURO-NA	EURO-NA	EURO-NA	EURO-LFS	EURO-SES
NZL	OECD-NA	OECD-NA	OECD-NA	OECD-NA		OECD-WISE
PHL	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS
POL	EURO-NA	EURO-NA	EURO-NA	EURO-NA	EURO-LFS	EURO-SES
PRT	EURO-NA	EURO-NA	EURO-NA	EURO-NA	EURO-LFS	EURO-SES
ROU	EURO-NA	EURO-NA	EURO-NA	EURO-NA	EURO-LFS	EURO-SES
ROW	ILO-LFS					
RUS	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS
SAU	ILO-LFS		ILO-LFS			
SGP	ILO-LFS	ILO-LFS	ILO-LFS		ILO-LFS	
SVK	EURO-NA	EURO-NA	EURO-NA	EURO-NA	EURO-LFS	EURO-SES
SVN	EURO-NA	EURO-NA	EURO-NA	EURO-NA	EURO-LFS	EURO-SES
SWE	EURO-NA	EURO-NA	EURO-NA	EURO-NA	EURO-LFS	EURO-SES
THA	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS
TUN	ILO-LFS					
TUR	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS	EURO-LFS	EURO-SES
TWN	ILO-LFS				WIOD	WIOD
USA	OECD-NA	OECD-NA		OECD-NA	WIOD	WIOD
VNM	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS
ZAF	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS	ILO-LFS

2010; 2012	2010; 2014	2011; 2013	2012-2013	Only 2013
2010; 2012-2013	2010-2011	2011-2012	Only 2011	no data available for any year
2010; 2013	2010-2012	2011-2013	Only 2012	

Annex 5. Validation of CO2 combustion emissions

Table 16. Comparison computed CO2 emission data with Eurostat data for country totals, industry totals and final demand totals.

CO2 (t)	tot					ind					fd				
	ELIOD res	ELIOD terr incl. bunker	ELIOD terr	Eurostat	ELIOD res / EUROSTAT	ELIOD res	ELIOD terr incl. bunker	ELIOD terr	Eurostat	ELIOD res / EUROSTAT	ELIOD res	ELIOD terr incl. bunker	ELIOD terr	Eurostat	ELIOD res / EUROSTAT
Belgium	1,12E+08	1,14E+08	1,07E+08	1,13E+08	99 %	8,42E+07	8,51E+07	7,82E+07	8,26E+07	102 %	2,83E+07	2,90E+07	2,90E+07	3,07E+07	92 %
Bulgaria	4,38E+07	4,50E+07	4,45E+07	4,78E+07	92 %	3,95E+07	4,01E+07	3,97E+07	4,57E+07	87 %	4,28E+06	4,89E+06	4,82E+06	2,10E+06	204 %
Czech Republic	1,16E+08	1,16E+08	1,14E+08	1,07E+08	108 %	1,03E+08	1,03E+08	1,02E+08	9,36E+07	110 %	1,25E+07	1,24E+07	1,24E+07	1,36E+07	91 %
Denmark	7,61E+07	7,31E+07	5,44E+07	8,77E+07	87 %	7,08E+07	6,83E+07	4,96E+07	7,83E+07	90 %	5,36E+06	4,81E+06	4,81E+06	9,47E+06	57 %
Germany	9,25E+08	9,02E+08	7,92E+08	8,96E+08	103 %	7,24E+08	7,13E+08	6,04E+08	6,96E+08	104 %	2,02E+08	1,89E+08	1,89E+08	2,00E+08	101 %
Estonia	2,08E+07	2,06E+07	1,99E+07	1,97E+07	105 %	2,02E+07	2,00E+07	1,94E+07	1,88E+07	107 %	6,01E+05	5,83E+05	5,83E+05	9,11E+05	66 %
Ireland	4,91E+07	5,12E+07	3,95E+07	4,82E+07	102 %	3,83E+07	3,97E+07	2,80E+07	3,42E+07	112 %	1,08E+07	1,15E+07	1,15E+07	1,40E+07	77 %
Greece	1,66E+08	1,56E+08	8,39E+07	9,73E+07	170 %	1,37E+08	1,34E+08	6,17E+07	7,73E+07	178 %	2,86E+07	2,22E+07	2,22E+07	2,01E+07	143 %
Spain	2,87E+08	2,82E+08	2,71E+08	2,92E+08	98 %	2,66E+08	2,62E+08	2,51E+08	2,23E+08	119 %	2,03E+07	2,01E+07	2,01E+07	6,91E+07	29 %
France	3,71E+08	3,80E+08	3,55E+08	4,01E+08	92 %	2,47E+08	2,51E+08	2,26E+08	2,69E+08	92 %	1,24E+08	1,29E+08	1,29E+08	1,32E+08	94 %
Croatia	1,93E+07	1,97E+07	1,83E+07	2,12E+07	91 %	1,43E+07	1,45E+07	1,30E+07	1,57E+07	91 %	5,06E+06	5,25E+06	5,25E+06	5,47E+06	93 %
Italy	4,14E+08	4,20E+08	4,04E+08	4,38E+08	95 %	3,21E+08	3,24E+08	3,08E+08	3,22E+08	99 %	9,35E+07	9,60E+07	9,60E+07	1,16E+08	81 %
Cyprus	8,33E+06	7,97E+06	7,32E+06	8,66E+06	96 %	7,69E+06	7,36E+06	6,71E+06	6,86E+06	112 %	6,40E+05	6,11E+05	6,11E+05	1,80E+06	35 %
Latvia	1,12E+07	9,80E+06	9,13E+06	1,02E+07	110 %	8,64E+06	7,88E+06	7,21E+06	8,44E+06	102 %	2,60E+06	1,92E+06	1,92E+06	1,79E+06	145 %
Lithuania	1,67E+07	1,39E+07	1,35E+07	1,71E+07	98 %	1,39E+07	1,19E+07	1,16E+07	1,34E+07	104 %	2,82E+06	1,97E+06	1,97E+06	3,63E+06	78 %
Luxembourg	9,77E+06	1,47E+07	1,08E+07	9,25E+06	106 %	8,86E+06	1,31E+07	9,19E+06	7,51E+06	118 %	9,11E+05	1,62E+06	1,62E+06	1,74E+06	52 %
Hungary	5,36E+07	5,20E+07	5,13E+07	5,50E+07	98 %	3,92E+07	3,82E+07	3,75E+07	3,93E+07	100 %	1,45E+07	1,38E+07	1,38E+07	1,57E+07	92 %
Malta	4,05E+06	4,16E+06	2,57E+06	3,95E+06	103 %	3,62E+06	3,70E+06	2,34E+06	3,72E+06	97 %	4,36E+05	4,64E+05	2,37E+05	2,23E+05	196 %
Netherlands	1,97E+08	1,95E+08	1,76E+08	2,17E+08	91 %	1,65E+08	1,63E+08	1,44E+08	1,73E+08	95 %	3,23E+07	3,18E+07	3,18E+07	4,36E+07	74 %
Austria	7,78E+07	8,21E+07	7,93E+07	7,03E+07	111 %	6,21E+07	6,43E+07	6,15E+07	5,48E+07	113 %	1,57E+07	1,78E+07	1,78E+07	1,54E+07	102 %
Poland	3,30E+08	3,23E+08	3,21E+08	3,40E+08	97 %	2,74E+08	2,69E+08	2,66E+08	2,86E+08	96 %	5,60E+07	5,43E+07	5,43E+07	5,41E+07	104 %
Portugal	5,36E+07	5,41E+07	5,06E+07	5,37E+07	100 %	4,36E+07	4,39E+07	4,04E+07	4,34E+07	100 %	1,00E+07	1,02E+07	1,02E+07	1,03E+07	97 %
Romania	7,43E+07	7,65E+07	7,57E+07	8,49E+07	88 %	6,31E+07	6,45E+07	6,38E+07	7,25E+07	87 %	1,12E+07	1,20E+07	1,19E+07	1,24E+07	91 %
Slovenia	1,56E+07	1,64E+07	1,59E+07	1,72E+07	90 %	1,03E+07	1,05E+07	9,93E+06	1,37E+07	75 %	5,26E+06	5,96E+06	5,96E+06	3,52E+06	149 %
Slovakia	3,51E+07	3,63E+07	3,63E+07	3,85E+07	91 %	2,92E+07	2,99E+07	2,99E+07	3,59E+07	81 %	5,86E+06	6,38E+06	6,38E+06	2,59E+06	227 %
Finland	8,20E+07	8,24E+07	7,73E+07	6,80E+07	121 %	7,68E+07	7,71E+07	7,21E+07	6,08E+07	126 %	5,15E+06	5,25E+06	5,25E+06	7,19E+06	72 %
Sweden	7,17E+07	7,49E+07	6,98E+07	6,17E+07	116 %	5,74E+07	5,86E+07	5,35E+07	5,12E+07	112 %	1,42E+07	1,63E+07	1,63E+07	1,05E+07	135 %
United Kingdom	5,54E+08	5,50E+08	4,90E+08	5,59E+08	99 %	4,07E+08	4,05E+08	3,45E+08	4,11E+08	99 %	1,47E+08	1,45E+08	1,45E+08	1,47E+08	100 %
Norway	6,29E+07	6,06E+07	3,87E+07	6,03E+07	104 %	5,78E+07	5,59E+07	3,40E+07	5,50E+07	105 %	5,08E+06	4,64E+06	4,64E+06	5,30E+06	96 %
Switzerland	4,92E+07	5,07E+07	4,38E+07	4,85E+07	102 %	3,14E+07	3,22E+07	2,52E+07	2,75E+07	114 %	1,78E+07	1,86E+07	1,86E+07	2,10E+07	85 %
Turkey	2,81E+08	2,81E+08	2,66E+08	3,22E+08	87 %	2,29E+08	2,29E+08	2,13E+08	2,47E+08	93 %	5,22E+07	5,22E+07	5,22E+07	7,52E+07	69 %
TOT	**4,59E+09**	**4,56E+09**	**4,14E+09**	**4,62E+09**	**99 %**	**3,65E+09**	**3,64E+09**	**3,21E+09**	**3,57E+09**	**102 %**	**9,35E+08**	**9,25E+08**	**9,25E+08**	**1,05E+09**	**89 %**

Table 17. Comparison computed CO2 emission data with EXIOBASE3.4 data for country totals, industry totals and final demand totals.

CO2 comb (t)	Tot			Ind			FD		
	ELIOD	EXIO3.4	ELIOD/EXIO	ELIOD	EXIO3.4	ELIOD/EXIO	ELIOD	EXIO3.4	ELIOD/EXIO
Austria	7,78E+10	6,96E+10	112 %	6,21E+10	5,47E+10	114 %	1,57E+10	1,48E+10	106 %
Belgium	1,12E+11	1,08E+11	105 %	8,42E+10	8,29E+10	102 %	2,83E+10	2,47E+10	115 %
Bulgaria	4,38E+10	4,37E+10	100 %	3,95E+10	4,07E+10	97 %	4,28E+09	3,00E+09	143 %
Cyprus	8,33E+09	1,29E+10	64 %	7,69E+09	1,09E+10	70 %	6,40E+08	1,98E+09	32 %
Czech Republic	1,16E+11	1,14E+11	101 %	1,03E+11	1,02E+11	101 %	1,25E+10	1,24E+10	100 %
Germany	9,25E+11	8,89E+11	104 %	7,24E+11	7,07E+11	102 %	2,02E+11	1,82E+11	111 %
Denmark	7,61E+10	6,87E+10	111 %	7,08E+10	5,85E+10	121 %	5,36E+09	1,02E+10	53 %
Estonia	2,08E+10	1,86E+10	111 %	2,02E+10	1,67E+10	121 %	6,01E+08	1,92E+09	31 %
Spain	2,87E+11	2,80E+11	102 %	2,66E+11	2,12E+11	125 %	2,03E+10	6,80E+10	30 %
Finland	8,20E+10	6,74E+10	122 %	7,68E+10	6,29E+10	122 %	5,15E+09	4,55E+09	113 %
France	3,71E+11	3,66E+11	101 %	2,47E+11	2,65E+11	93 %	1,24E+11	1,01E+11	122 %
Greece	1,66E+11	1,64E+11	101 %	1,37E+11	1,41E+11	98 %	2,86E+10	2,31E+10	124 %
Croatia	1,93E+10	1,96E+10	99 %	1,43E+10	1,42E+10	100 %	5,06E+09	5,39E+09	94 %
Hungary	5,36E+10	5,07E+10	106 %	3,92E+10	3,69E+10	106 %	1,45E+10	1,37E+10	106 %
Ireland	4,91E+10	4,90E+10	100 %	3,83E+10	3,45E+10	111 %	1,08E+10	1,45E+10	75 %
Italy	4,14E+11	4,05E+11	102 %	3,21E+11	3,16E+11	101 %	9,35E+10	8,83E+10	106 %
Lithuania	1,67E+10	1,59E+10	105 %	1,39E+10	1,02E+10	137 %	2,82E+09	5,78E+09	49 %
Luxembourg	9,77E+09	9,59E+09	102 %	8,86E+09	7,00E+09	127 %	9,11E+08	2,59E+09	35 %
Latvia	1,12E+10	1,08E+10	104 %	8,64E+09	7,56E+09	114 %	2,60E+09	3,23E+09	81 %
Malta	4,05E+09	2,86E+09	142 %	3,62E+09	2,53E+09	143 %	4,36E+08	3,37E+08	129 %
Netherlands	1,97E+11	1,92E+11	103 %	1,65E+11	1,60E+11	103 %	3,23E+10	3,22E+10	100 %
Poland	3,30E+11	3,17E+11	104 %	2,74E+11	2,68E+11	102 %	5,60E+10	4,91E+10	114 %
Portugal	5,36E+10	5,10E+10	105 %	4,36E+10	4,26E+10	102 %	1,00E+10	8,33E+09	120 %
Romania	7,43E+10	7,34E+10	101 %	6,31E+10	6,39E+10	99 %	1,12E+10	9,49E+09	118 %
Sweden	7,17E+10	4,79E+10	150 %	5,74E+10	4,07E+10	141 %	1,42E+10	7,22E+09	197 %
Slovenia	1,56E+10	1,50E+10	103 %	1,03E+10	9,81E+09	105 %	5,26E+09	5,24E+09	100 %
Slovak Republic	3,51E+10	3,35E+10	105 %	2,92E+10	2,90E+10	101 %	5,86E+09	4,43E+09	132 %
United Kingdom	5,54E+11	5,44E+11	102 %	4,07E+11	4,09E+11	99 %	1,47E+11	1,35E+11	109 %
United States	5,53E+12	5,46E+12	101 %	4,25E+12	3,98E+12	107 %	1,28E+12	1,48E+12	87 %
Japan	1,19E+12	1,21E+12	99 %	1,05E+12	1,04E+12	101 %	1,42E+11	1,72E+11	82 %
China	7,86E+12	7,35E+12	107 %	7,53E+12	7,00E+12	108 %	3,26E+11	3,50E+11	93 %
Canada	5,42E+11	5,27E+11	103 %	4,15E+11	4,39E+11	94 %	1,28E+11	8,74E+10	146 %
Korea	5,89E+11	5,89E+11	100 %	5,37E+11	5,28E+11	102 %	5,28E+10	6,10E+10	87 %
Brazil	4,02E+11	3,98E+11	101 %	3,37E+11	3,51E+11	96 %	6,51E+10	4,65E+10	140 %
India	1,60E+12	1,72E+12	93 %	1,45E+12	1,56E+12	93 %	1,57E+11	1,53E+11	103 %
Mexico	4,43E+11	4,19E+11	106 %	3,67E+11	3,17E+11	116 %	7,61E+10	1,02E+11	75 %
Russian Federatio	1,56E+12	1,56E+12	100 %	1,41E+12	1,41E+12	100 %	1,44E+11	1,47E+11	97 %
Australia	4,02E+11	4,07E+11	99 %	3,43E+11	3,64E+11	94 %	5,87E+10	4,26E+10	138 %
Switzerland	4,92E+10	4,95E+10	99 %	3,14E+10	3,06E+10	103 %	1,78E+10	1,89E+10	95 %
Turkey	2,81E+11	2,81E+11	100 %	2,29E+11	2,24E+11	102 %	5,22E+10	5,73E+10	91 %
Chinese Taipei	2,85E+11	2,85E+11	100 %	2,74E+11	2,66E+11	103 %	1,10E+10	1,89E+10	58 %
Norway	6,29E+10	6,19E+10	102 %	5,78E+10	5,75E+10	101 %	5,08E+09	4,44E+09	115 %
Indonesia	3,93E+11	4,17E+11	94 %	3,55E+11	3,69E+11	96 %	3,73E+10	4,75E+10	79 %
South Africa	3,65E+11	3,70E+11	99 %	3,31E+11	3,39E+11	97 %	3,45E+10	3,10E+10	111 %

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