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Handbook for estimating raw material equivalents

of imports and exports and RME-based indicators on the country level – based on Eurostat's EU RME model

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Preface

This handbook accompanies Eurostat's country raw material equivalents (RME) tool to estimate country-level raw material equivalents of product flows. The tool has been developed to support national statistical institutes at conducting country level estimates in a convenient manner by a model which is closely linked to the EU model in terms of methodological foundations and of data.

The calculation tool allows the user to estimate country-level estimates of flows in raw material equivalents (RME), such as imports and exports in RME, raw material input (RMI) and raw material consumption (RMC).

The tool is presented as a combined set which includes the handbook, the Excel-based tool and the auxiliary data files (data pool). The data pool is providing all necessary data for the individual countries. Detailed technical instructions are directly attached to the excel workbook of the tool.

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Abbreviations

CN8	Combined Nomenclature 8-digit detail
CPA	Classification of Products by Activity
DE	domestic extraction
DMC	domestic material consumption
DMI	direct material input
EU	European Union
EUR	Euro
EW-MFA	economy-wide material flow accounts
EXP	exports
FIGARO	Full International and Global Accounts for Research in input-Output analysis
GCV	gross calorific value
IMP	imports
IO	input-output
IOT	input-output table
LCI	life-cycle inventory
M3	cubic metres
NACE	Nomenclature statistique des activités économiques dans la Communauté européenne (Statistical classification of economic activities in the European Community)
rev.	revision
RMC	raw material consumption
RME	raw material equivalents
RMEEX	raw material equivalents of exports
RMEIM	raw material equivalents of imports
RMI	raw material input
SBS	structural business statistics
SIOT	symmetric input-output table
SUT	supply and use tables
t	tonne
TJ	Terajoule

1 Introduction

In 2019, the European Commission released the European Green Deal. The framework of the Green Deal sets out a new growth strategy that aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy. The transition of the EU also implies that there are no net emissions of greenhouse gases in 2050 and that economic growth is decoupled from resource use.[1]

The Green Deal is an integral part of the European Commission's strategy to implement the United Nation's 2030 Agenda and the sustainable development goals (SDGs). SDG 8 and 12, amongst others, specifically include material footprints as an indicator to monitor the development.[2]

Further, the EU set out a new circular economy action plan that will help modernise the EU's economy and benefit from the opportunities of the circular economy domestically and globally. A key aim of the new circular economy policy framework will be to stimulate the development of lead markets for climate neutral and circular products, in the EU and beyond. The action plan will focus in particular on resource-intensive sectors such as textiles, construction, electronics and plastics where the potential for circularity is high.[3]

In October 2019, the Council of the European Union adopted a set of conclusions regarding the development of an eight (8th) Environment Action Plan (EAP). The 8th EAP will be guiding European environment and climate change policies for 2021-2030.[4] The Commission proposal was published on 14 October 2020[5]. One key objective of the 8th EAPis to advance towards a regenerative growth model, decoupling economic growth from resource use and environmental degradation, and accelerating the transition to a circular economy.

Against this backdrop, Eurostat developed and regularly publishes annual results on raw material equivalents (RME) of product flows at EU-28 level ([6]). "Raw Material Consumption" (RMC) is the main indicator provided by RME accounting. That indicator describes the amount of raw materials which are embodied (over the whole production chain) in the products of domestic final uses of an economy.

The results are generated by a specific IOT-based calculation model which is denoted as ADTA-IO model (adapted domestic technology assumption input output model). The calculation approach provides detailed annual results on product flows in RME in a breakdown by the following dimensions:

- Categories of final uses and imports
- 182 product groups
- 51 raw material categories (without aggregates)

A previous version of this model, which was based on the NACE Rev 1.1 classification, was published in 2012 (see Schoer, K. et al. (2012)). The results of that model (2000-2013) were annually updated

[1] https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF
[2] https://sustainabledevelopment.un.org/post2015/transformingourworld
[3] https://ec.europa.eu/environment/circular-economy/
[4] https://www.europeansources.info/record/8th-environment-action-programme-council-adopts-conclusions/
[5] https://ec.europa.eu/environment/strategy/environment-action-programme-2030_en
[6] Eurostat: EU RME Model, December 2016

and published on Eurostat's online database. The current Eurostat EU RME model represents a revised version of the NACE Rev 1.1 based model. The major change is the migration from the NACE Rev 1.1 to NACE Rev. 2 classification. In addition, a number of methodical improvements were introduced with the primary aim of improving the estimates for RME of imports, such as increasing the degree of resolution of the IOT, improving the price concepts and the utilization of further regionalized information.

In order to make full use of that indicator, it is desirable to supplement the figures on EU-level by corresponding information for member countries. Therefore, Eurostat also developed a so-called country tool for estimating results of RME accounting at country level ([7]). Establishing the full EU calculation model on country level would be rather resource-consuming and would suffer from limited data availability. Therefore, applying the full Eurostat RME model or another model with similar degree of detail would only be an option for a few countries. It was the purpose of that tool to assist national statistical institutes to produce country-level estimates of RME with a manageable amount of effort. The handbook presents a simplified Excel based calculation tool (template) which is coherent with Eurostat's EU RME model.

Due to the migration of the EU-level RME model the supplementary country tool for estimating RME at country level had to be revised accordingly. The revised tool which is presented in this handbook is harmonised with the revised Eurostat RME model, which is following the NACE Rev. 2 activity classification. It is replacing the earlier version of this tool, which was based on NACE Rev. 1.1 classification for the years 2008 and onwards. The revised tool is based on a so-called coefficient approach (estimates for RME of imports are based on EU-level import and export coefficients) which is similar to the coefficient approach of the unrevised tool. However, for the new version an adjusted coefficient is applied, which is taking account of significant country-specific differences in the production technology.

For the previous version of the tool, a combined coefficient-IOT approach was offered in addition to the coefficient approach, in order to account for country-specific production conditions. However, with respect to the revised model, the approach was not able to produce convincing results under the new revised data settings. It can be assumed that the major problem is resulting from the new classification of the standard IOT. In the new IOT, all mining activities comprising the most crucial raw products are lumped together as one product group. Therefore, in this handbook only an improved coefficient approach could be offered. More research is needed for developing a suitable IOT-based approach at country level.

[7] Eurostat: Handbook for estimating raw material equivalents of imports and exports of imports and exports and RME - based indicators on country level – based on Eurostat's EU RME model, October 2015

2 Calculation model - overview

2.1 General remarks

The attached calculation model for estimating RME at country level was developed for conducting the estimation of RME of product flows at country level. The aim was to develop an approach which is satisfying the following conditions:

- Comparatively low resource requirement
- Sufficient degree of accuracy
- Compliance with the concepts, methods and data of the EU-level RME model
- Harmonized approach for all member countries

2.2 Calculation model

Figure 1 presents a schematic description of the calculation model. The chart shows the data inputs, the major calculation steps and the different types of results.

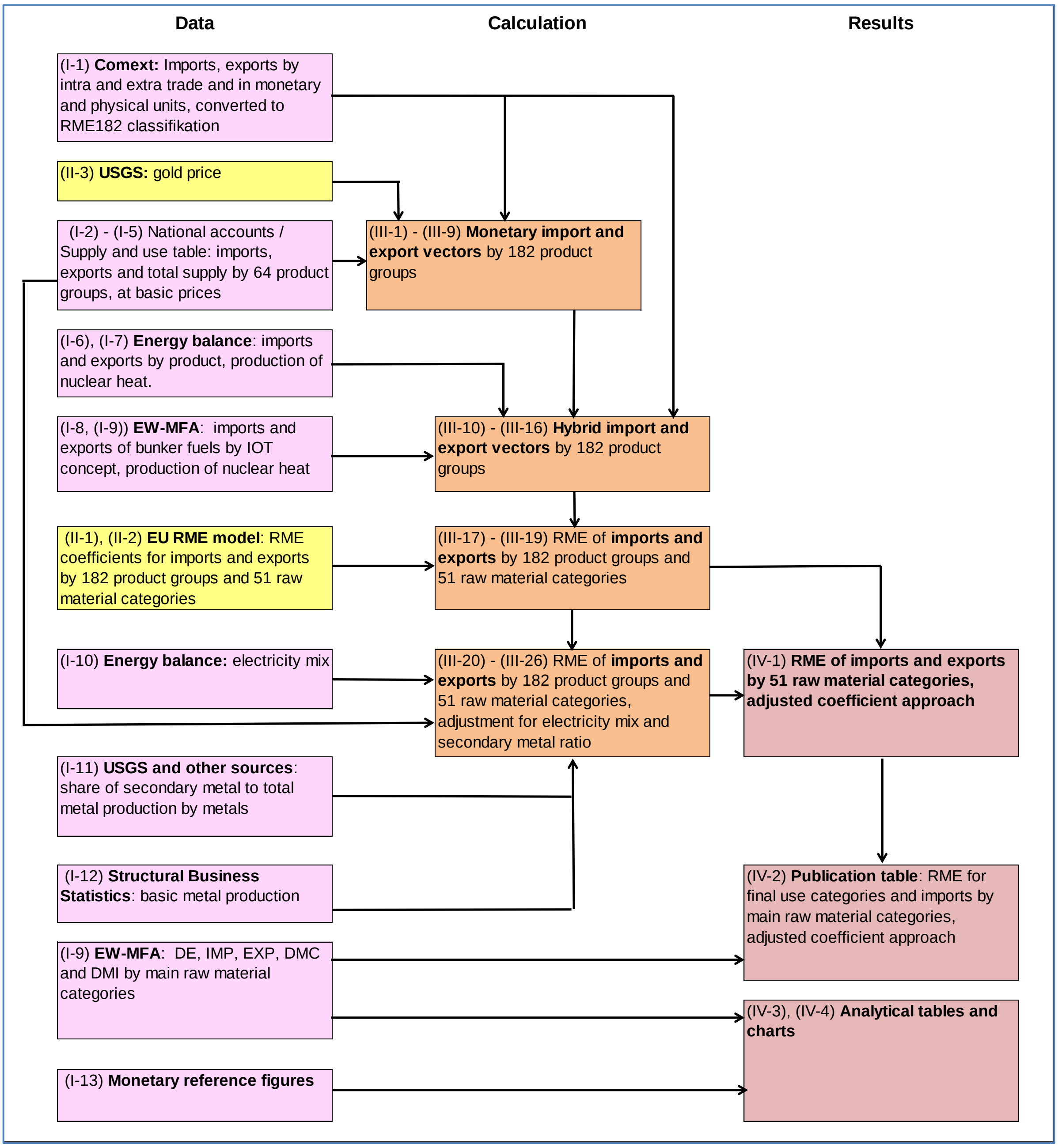
The following data sources are used:

- Country-level data: Comext, National Accounts/Supply and use tables; Energy Balance, economy-wide material flow accounts (EW-MFA), USGS and other sources, Structural Business Statistics
- Data valid for all countries: Eurostat's RME model (Annual RME coefficient matrices for imports and exports, EU-level), USGS (gold prices). The EU model is applying a hybrid IOT matrix, i.e. selected sales structures are expressed in physical units and not in monetary units. Accordingly, also the RME coefficients from that model are based on mixed units for the denominator.

The calculation method of the adjusted coefficient approach combines annual **EU-level RME coefficient matrices** for imports and exports with hybrid **country-level import and export vectors.** The mix of units of the hybrid trade vectors is fully matching the mix of units for the EU coefficients.

In a first principal calculation step (II-1 to III-9), country-level monetary imports and export vectors are estimated in a breakdown by 182 product groups. In a second step (III-10 to III-16), hybrid (mixed monetary and physical units) trade vectors are calculated, which correspond to the mix of units of the EU-level RME model. In a third step (III-20 to III-26), country-level RME of imports and exports are calculated by multiplying EU coefficients with country-level trade vectors. The results for RME of exports are adjusted regarding differences in country-specific and EU production technologies. In a final set of steps (IV-1 to IV-3), the calculation results and some supporting analytical results are presented.

Figure 1: Schematic description of estimation of country-level RME by the "adjusted coefficient approach"



2.3 Calculation of RMI and RMC

The indicators Raw Material Input (RMI) and Raw Material Consumption (RMC) correspond to Direct Material Input (DMI) and Direct Material Consumption (DMC) of EW-MFA respectively. These indicators are obtained in the same way as the EW-MFA indicators. They combine the numbers on domestic extraction (DE) from EW-MFA with RME of imports (RMEIM) and exports (RMEEX) in the following manner:

RMI = DE + RMEIM

RMC = RMI – RMEEX

2.4 Eurostat's estimates at country level ("Python country RME tool")

Eurostat estimates RMC for those EU Member States not providing their own estimate. To do so, an estimation tool, using Python, was developed which calculates indicators in RME for all EU countries. The "Python country RME tool" closely follows implements the estimation method described in this handbook. However, there are a few modifications that are explained in this chapter.

First of all, monetary imports and exports were derived from the FIGARO EU-ICIOT[8] for all countries. A balanced trade data set at HS6 level[9] constructed by the FIGARO team was used to disaggregate the monetary data on trade. In the Excel tool, on the other hand, ESA national input-output tables and supply and use tables[10] are used as starting point for the different countries depending on which dataset has the least number of gaps, and Comext is used for deriving disaggregated vectors.

As the "Python country RME tool" processes a full dataset for all EU Member States, a calibration can be carried out to ensure that imports within the EU are equal to exports within the EU and that the country-level material footprints (RMC) sum up to the EU-level material footprint. The calibration is carried out in two steps, at the level of input data and at the level of results:

Adjustment at the level of input data (country-level imports and exports of 182 products in hybrid units)

- **Intra-EU**: The 27 country-level (monetary and physical, i.e. hybridized) intra-EU trade vectors at the level of 182 products are scaled to ensure that total intra-EU imports are equal to total intra-EU exports. This is done in the following manner: We have given:
  - IMP_c,182 – intra-EU-import vector of Member State c
  - EXP_c,182 – intra-EU-export vector of Member State c
  - IMP_{eu},182 – intra-EU-import vector aggregated to EU, i.e. sum of 27 Member States
  - EXP_{eu},182 – intra-EU-export vector aggregated to EU; i.e. sum of 27 Member States

[8] URL: https://ec.europa.eu/eurostat/web/esa-supply-use-input-tables/figaro
[9] For a description of the methodology to construct the balanced trade dataset, see chapter 6 in: Remond-Tiedrez & Rueda-Cantuche (Ed.): EU inter-country supply, use and input-output tables: Full international and global accounts for research in input-output analysis (FIGARO). 2019 edition. URL: https://ec.europa.eu/eurostat/documents/3888793/10109187/KS-TC-19-002-EN-N.pdf/8d9af6c5-efbf-9da5-e2cc-e4a74d616c08?t=1568878682000
[10] URL: https://ec.europa.eu/eurostat/web/esa-supply-use-input-tables/overview

IMP_{eu},182 does not equal EXP_{eu},182. To ensure that they do, both vectors are adjusted to the mean between IMP_{eu},182 and EXP_{eu},182 for each of the 182 products by scaling the country-level vectors proportionally.

- **Extra-EU (EU-RME results)**: New RME coefficients are calculated based on the adjusted hybrid extra-EU trade vectors resulting from the “Python country RME tool” and the results of the EU-RME model. For the products for which a price adjustment is carried out in the original Excel country tool, physical coefficients were calculated – thus, more sectors are hybridized and the price adjustment is made obsolete. This adjustment ensures that the sum of all country-level material footprints equals.

Adjustment at the level of results (country-levels imports and exports in RME for 51 materials)

After running the model calculation with the adjusted input data, imports in RME and exports in RME for 51 materials are obtained. Using data on domestic extraction for 51 materials, RMC by 51 material classes can be calculated for each country. Especially for smaller countries, some negative values for RMC at the level of 51 materials were observed. As negative values are implausible, they need to be adjusted. The correction is done by setting the negative values to zero and by modifying the RME of exports accordingly for that particular material class.

Due to the correction of negative RMC values, the results become unbalanced again. That is the intra EU imports in RME of the 27 Member States may not match the intra-EU-exports in RME of 27 Member States, and extra-EU-trade in RME of the 27 countries may not match the results of the EU RME model. To remove the imbalances, an additional adjustment at the level of results is necessary:

- **Intra-EU**: Intra-EU imports in RME at the level of 51 materials are proportionally scaled to match intra-EU exports in RME.
- **Extra-EU** (EU-RME results): Extra-EU imports and exports in RME at the level of 51 materials are proportionally scaled to match the exports and imports in RME from the EU-RME model.

In addition, the following changes were implemented compared to the Excel country RME tool:

- Monetary export vectors are adjusted for differences in purchasing powers (using ppp-factors[11]) to account for differences in export prices between countries.
- As the FIGARO EU-ICIOT timeseries starts with the year 2010, the results for 2008 and 2009 are generated by applying change rates from the calculation in 2021 (based on ESA input-output tables) at the detailed raw material level.
- The differentiation between intra and extra-EU-trade is directly taken from the EU-ICIOT in the Python tool, while the share of intra- and extra-trade are estimated using Comext ratios in the Excel version.
- Gold smoothening is done using a moving average over 3 time periods instead of using a manual procedure.
- In the Excel tool, the energy balance data is disaggregated into intra-EU and extra-EU trade using Comext data. In the Python tool, data from the energy balance on trade by trading partner is used instead. Remaining gaps were filled with Comext data.

[11] Eurostat database, Purchasing power parities (PPPs), price level indices and real expenditures for ESA 2010 aggregates, URL: https://ec.europa.eu/eurostat/databrowser/view/prc_ppp_ind/default/table?lang=en

3 Data input to the model

Table 1 presents an overview of the data input to the calculation model. More detailed technical descriptions are directly attached to the Excel workbook for the calculation tool. The source and the extraction format for each dataset are shown in the attached data pool.

Table 1: Data inputs

Section	Worksheet of the country RME tool	Description
I. Data input country-level	I-1-COMEXT-182	**Comext**: Imports, exports by intra and extra-trade in EUR and tonnes. Data converted to RME182 classification
	I-2-Tot IMP EXP Nat Acc	Data of national accounts on total imports and exports of goods and of services
	I-3-IMP SUPPLY 64	Data of supply table of national accounts for imports and supplies by 64 product groups
	I-4-EXP 64	Data of use table of national accounts for exports by 64 product groups, basic prices
	I-5-IMP SERVICES	Data of supply table of national accounts for imports of services by intra and extra trade by 43 product groups, basic prices
	I-6-Energy balance IMP EXP	Data of energy balance: imports and exports by product
	I-7-Energy balance: nuclear heat	Data of energy balance on primary production of nuclear heat
	I-8-Bunker fuels IOT concept	Data of EW-MFA on imports and exports of bunker fuels by IOT concept (residence principle)
	I-9-EW-MFA	Data of EW-MFA on DE, IMP, EXP, DMC and DMI by main raw material categories and for nuclear fuel
	I-10-Electricity mix	Data of energy balance on electricity mix.
	I-11-Secondary metal ratio	Data of USGS and other sources on share of secondary metal production to total metal production by metals
	I-12-SBS basic metals	Data of Structural Business Statistics (SBS) on basic metal production
	I-13-Monetary reference figures	Data of national accounts on total GDP, EXP and IMP, chain linked volumes
II. Data inputs EU-level	II-1-EU RME coeff IMP	Annual data from EU model: RME coefficients for IMP, valid for all countries
	II-2-EU RME coeff EXP	Annual data from EU model: RME coefficients for EXP, valid for all countries
	II-3-USGS gold price	Annual data from USGS on gold price, valid for all countries
	II-4 EU Unit prices	EU unit prices from COMEXT data (EU RME Tool) based on monetary value per mass weight

For the tool, two different categories of data inputs are required.

- Country-specific data (items I-1 to I-13)
- EU-level data which are used for all countries (items II-1 to II-3)

As the tool is calculating all years (2008 to currently 2023) the input data are needed as time series as well. The tool is prefilled with data for the pilot country France to showcase the required layout of the data. Please replace data for France by your country data.

Country-level data: The preparation of the data input for the individual countries has to follow a number of principal steps: data extraction, gap filling and plausibility check.

- **Data extraction**: The worksheets for data input of the tool show the source and format of the required data. Refer also to the data pool (see below).
    - Core data input to the model is EU-level data on RME coefficients of imports and exports. Those coefficients are valid for all countries. Further data from USGS (United States Geological Survey) on annual gold prices are needed, which are also valid for all countries.
    - The required annual country level data (I-1 to I-13) can completely be derived from EUROBASE, with the exception of the data I-11 on secondary metal ratios which originate from USGS and some other sources. As an alternative to EUROBASE, national data sources could be utilized, provided that data are entered to the tool according to the prescribed format.
    - For your convenience, an accompanying data pool with prefilled data was attached to the tool. In the workbook "Other data" all required input data items for all countries and all years, except for Comext data, are provided. The complete data pool can be downloaded in conjunction with the country tool. Data from Comext which are needed by the tool in a model-specific classification by 182 product groups can be obtained on request from Eurostat. As an alternative, the procedure of converting Comext CN8-digit data to RME classification by 182 product groups could be made available to users on request.[12]
    - The data for the data pool have been extracted at the time of publication of this tool. It is intended to update the data once a year. If you want to use the most recent data at the time of running the tool you have to do your own extraction.
- **Gap filling**: The tool is only able to work properly if all data gaps (missing values) are closed. As far as data for complete years are missing (usually: data are not available), automatic gap filling procedures were established within the tool (see below III. Calculation steps). As far as applicable, ":" tags where replaced by "0"in the data pool in order to enable automated gap filling procedures.
    - Users may decide to improve upon this gap-filling by using additional data or other methods.
    - Manual gap filling is necessary for missing sectoral values. As a rule those data are missing due to suppression for confidentiality reasons (see attached information on flags and footnotes to each data table). That is, in case the tool is run within a statistical institute confidential data could usually be filled in. If missing data are definitely not available gaps should be closed by simple assumptions.
- **Plausibility check**: Beyond filling data gaps, the input data should also be checked for plausibility. In case of implausible values, data should be corrected. There may also be feedbacks from plausibility checks at the level of calculation results which may give reasons for correcting input data ([13]).

EU coefficient matrices: EU-level RME coefficients are derived from the Eurostat RME model by dividing the matrices (product groups by raw material categories) on RME of imports and exports in

[12] Please refer to Nuno.DOS-SANTOS-BAPTISTA@ec.europa.eu.

[13] Chapter 5 discusses potentially relevant country-specific adjustments

tonnes by the import and export vectors of the hybrid IOT (HIOT 182). Those coefficients measure cumulated raw material requirement in tonnes RME per unit of product. The denominator of the different products is measured in different (hybrid) units (EUR, tonnes and other physical units).

4 Calculation method

The coefficient approach combines annual **EU-level RME coefficient matrices** for imports and exports with **country-level trade vectors**. RME of imports and exports at country level are obtained by multiplying the coefficient matrix with the corresponding country-level hybrid import and export vectors.

Table 2 gives an overview of the detailed calculation procedure. For more technical details refer to the workbook for the country tool.

Table 2: Adjusted coefficient approach calculation procedure

Sections	Worksheet of the country RME tool	Description
III. Calculation steps for adjusted coefficient approach	III-1-COMEXT-182 form ad	Comext 182 format adjustment: totals for IMP and EXP are added
	III-2-Gold smoothing	Gold smoothing: The data on imports and exports of gold show for some countries rather erratic movements over time. It is recommended to smoothen the time series for gold.
	III-3-COMEXT182 gold smoothened	Comext 182: correction for gold smoothing of monetary flows is added.
	III-4-IMP 64 gap filling	Automated gap filling for IMP 64 for missing years.
	III-5-EXP 64 gap filling	Automated gap filling for EXP 64 for missing years.
	III-6-IMP sectoral disaggr	Sectoral disaggregation of gap filled IMP 64 to IMP 182 by Comext relationships
	III-7-EXP sectoral disaggr	Sectoral disaggregation of gap filled EXP 64 to EXP 182 by Comext relationships
	III-8-IMP services gap filling	Estimation of share extra trade for services. Automated gap filling for missing values
	III-9-IMP disag intra-extra	Disaggregation of IMP into intra and extra trade.
	III-10-IMP EXP EB (2)	Energy balance: imports, exports, international bunkers. Assignment of energy products (classification for energy balance) to items of RME 182 classification. Estimation of imports of uranium and thorium ores in 1000 t RME.
	III-11-IMP EXP EB bunker fuels	Adjustment of IMP and EXP of energy balance to IOT concept.
	III-12-IMP EXP EB format ad	Expansion of energy balance IMP and EXP data to RME 182 format
	III-13-IMP EB intra extra	Disaggregation of the energy balance data on IMP into intra and extra-trade by Comext relationships
	III-14-IMP EXP hybrid vector	Merging of SUT/IOT, Comext and energy balance data for establishing annual hybrid country-level vectors for IMP extra-trade, IMP intra-trade and EXP by 182 product groups
	III-14a price corr IMP-extra	Unit prices at country and at EU level can differ significantly for coefficients which are based on a monetary denominator. In that case, applying the EU coefficients may not generate accurate RME results. In order to cope with that problem, these sheets contain a semi-selective unit price adjustment module. The adjustment is carried out separately for intra-trade imports, for extra-trade imports and for exports. Each correction sheet contains four blocks
	III-14a price corr IMP-intra	
	III-14a price corr EXP-total	

	III-14d IMP EXP price corr	Hybrid country-level vectors for IMP extra-trade, IMP intra-trade and EXP by 182 product groups. Including semi-selective adjustment to EU Unit prices.
	III-15-IMP EXP hybr vect form a	Format adjustment annual hybrid IMP and EXP vectors: removal of sub-totals
	III-16-Hybrid vectors transp	Annual hybrid IMP and EXP vectors are transposed: transposing is required for the next calculation step III-17
	III-17-RME IMP EXTRA	Annual calculation of country-level RME of IMP extra trade: EU-level RME IMP coefficients x hybrid country level vector IMP extra trade.
	III-18-RME IMP INTRA	Annual calculation of country-level RME of IMP intra trade: EU-level RME EXP coefficients (= RME coefficients for final use) x hybrid country-level vector IMP intra trade.
	III-19-RME EXP	Annual calculation of country-level RME of total EXP: EU-level RME EXP coefficients (= RME coefficients for final use) x hybrid country-level vector total EXP
	III-20-Share of OUTPUT	Calculation of the share of output at total supply for total economy. Automatic gap filling for missing years. The share is used for weighting the impact of imports and domestic production on the average electricity mix of exports in step III-22
	III-22-Electricity mix adjustment factor	Estimation of adjustment factors for fossil energy carriers to regard differences in electricity mix for EU and country under review
	III-23-Energ cont EXP electr	Annual calculation of energy content of exported products, adjusted for the energy mix of electricity generation
	III-24-SBS basic metals	Format adjustment of SBS for basic metals
	III-25-IMP EXP OUTP basic met	Calculation of the share of output at total supply for basic metals by metal category. The share is used for weighting the impact of imports and domestic production on the average primary metal content of exported products
	III-26-Secondar metal adjm fact	Annual estimation of adjustment factors for differences in primary metal ratios for EU and country under review for major metal categories.

The calculation procedure follows a number of principal steps.

Hybrid trade vectors: The following operations are needed for deriving country-level hybrid trade vectors:

- **Preparation of Comext data**: The data of Comext have to undergo further preparations, such as format adjustments and a correction of gold statistics (gold smoothing) in order to meet the requirements for the next calculation steps (III-1 to III-3).
- **SUT/IOT gap filling for missing years**: Main starting point for establishing the trade vectors are the monetary import and export figures of SUT/IOT in a breakdown by 64 product groups. As for most countries, the complete period 2008 to 2014 is not covered by SUT/IOT data. A procedure of automated gap filling for missing years was developed (III-4 to III-5).
- **Sectoral disaggregation**: The monetary trade vectors by 64 product groups are disaggregated to the level of 182 product groups by using Comext relationships (III-6 to III-7).
- **Breakdown by intra and extra-trade**: The monetary vector for imports is subdivided into intra and extra-trade by using mainly Comext relationships (III-8 to III-9).
- **Preparation of the energy balance**: Energy balance data are required for expressing the imports and exports of energy carriers in physical units. In order to comply with the IOT concept (residence principle), energy balance data have to be adjusted for the flow of bunker fuels. Imports as reported by the energy balance have to be subdivided further into intra-EU and extra-EU trade. Finally the imports of uranium ores in physical units have to be estimated in

accordance with the energy balance information of production of nuclear heat (III-10 to III-13).

- **Hybrid trade vectors**: Hybrid trade vectors by 182 product groups are established by merging the physical information from the energy balance (energy carriers), physical information from Comext (raw materials excluding metal ores) and monetary information from disaggregated SUT/IOT for all other product groups (III-14 to III-16).

RME of imports and exports: As already described above, RME of imports and exports are estimated by multiplying EU-level RME coefficients with country-level hybrid trade vectors (III-17 to III-19).

The EU-level coefficients represent cumulated raw material requirement (embodied raw materials) per unit of product. The EU import coefficients are designed for approximating the average production technology of the countries of origin of imports to EU[14]. The EU export coefficients are representing the domestic EU production technology.

The following average production technologies by 182 product groups are assumed for country-level imports and exports:

- **Extra-trade imports**: Average production technology of countries of origin for EU imports (country-level extra-trade imports x EU import coefficients)
- **Intra-trade imports**: Average EU production technology (country-level intra-trade imports x EU export coefficients)
- **Exports**: Average EU production technology (country-level exports x EU export coefficients), adjusted

The rather detailed sectoral breakdown of the model assures that structural differences between EU and countries down to the level of 182 product groups are fully regarded. Further structural effects below that level may limit the accuracy of the calculation results to some extent.

A much more important issue, however, is that the assumptions about the production technology could be inadequate. With respect to RME of imports, the assumptions about the production technology can be considered to be quite realistic. That is, the model is able to provide fairly accurate results for RME of imports.

Adjustment of RME of exports: Unlike for imports, the assumption on the production technology for exports tends to be a weak point. The calculation for exports is based on EU average production technology. It has to be considered, however, that the production technologies of member countries might differ significantly from the EU average, at least for some product groups. Most obvious and quantitatively important cases in terms of raw material requirement are the production of electricity (different mix of energy carriers) and metal production (differences in the share of secondary metal production). Electricity and metals are embodied in almost all exported products. For taking account of those important country specific differences, a method for adjusting the coefficients for exports of metals and of energy carriers was developed, the so-called adjusted coefficient approach.

For the adjusted approach, the following corrections are regarded:

- **Electricity mix**: adjustment of embodied exports of fossil energy carriers for differences of country specific electricity mix to EU average electricity mix (III-20 to III-23).
- **Secondary metal ratio**: adjustment of embodied exports of metals for differences of country specific secondary metal ratios to EU average ratios (III-24 to III-26).

[14] See ADTA-IO approach for the EU RME model. See Eurostat: EU RME Model, December 2016

5 Country-specific adjustments

5.1 Introduction

Country experiences with applying the standard RME country tool suggest that the tool is able to provide quite reasonable results for most member countries. In some cases, however, it may be useful to modify the standard tool for coping with certain country-specific peculiarities.

For that purpose, the following topics for adjustments were identified:

- Coping with data gaps
- Disruption of time series
- Excluding re-export
- Treatment of gold
- Price effect

5.2 Data gaps

In case of missing data for complete years, the standard tool already offers automated procedures for bridging those gaps. In remaining cases of data gaps (mainly missing individual values that can lead to division-by-zero errors or non-plausible individual values), an intervention by the user is required to close those gaps by inserting estimated values that are either based on additional information or on simple assumptions.

The current country tool calculates RME estimates for the time series 2008 to 2023.

Country tool users also have the possibility to calculate preliminary RME estimates for 2024 if wanted. The respective year columns in the tool already contain relevant calculation links. However, users have to close data gaps for this year independently within the data input file. Also, for RME coefficients of imports and exports for 2024 estimation values have to be used. It has to be noted that simply using values from 2023 RME coefficients is not reliable since price changes have to be considered. Official RME coefficients for 2024 will only be calculated with the up-coming EU RME model 2026 and, thus, only by then available for the country tool. Users of the country tool that are estimating 2024 estimates should be aware of above mentioned shortcomings and ‘flag’ the estimation results accordingly.

5.3 Disruption of time series

Under specific circumstances, the tool may not lead to meaningful results for a country. An example is Ireland. An obvious disruption of the RME time series can be observed when using the standard tool based on the SUT/IOT framework of SNA for Ireland. Imports and exports show a sharp increase for the years 2014 and 2015, which is reflected by the results of the tool on RME of imports and exports. In addition, the increase is much more pronounced for exports than for imports. As an effect, the model reports a considerable decline of RMC for both years for Ireland, resulting in a negative RMC for 2015.

In comparison to the SUT/IOT framework, international trade statistics (Comext) show much less pronounced developments for imports and exports. The reason is a conceptual difference. Comext reports only real physical flows crossing the border, whereas in the SNA, in some cases imports or exports of goods are reported which are not accompanied by a corresponding physical flow. An important example is the treatment of contract manufacturing ("goods sent for processing").

For physical flow accounting, the SEEA-CF explicitly deviates from the SNA concept, favouring to report the real physical flows. In the case of Ireland, massive shifts of economic ownership to and from other countries to Ireland occurred. As result, in the SNA, the capital stock of the company (e.g. aircrafts, intellectual property) was re-assigned to the new country. That shift is regarded as an export-import flow, while there might not be any movement in physical terms. For generating results that are more meaningful by the country tool under those specific conditions, it is suggested to replace SUT/IOT-based developments by corresponding monetary information from Comext for critical product groups. By following that approach, the results for Ireland would be more plausible.

5.4 Re-exports

Especially for the Netherlands, re-exports account for an extremely high share of imports and exports. Rather high shares can also be found for Belgium and some smaller countries. Re-exports are not related to the production and consumption activities of an economy. As the RME approach is preliminary designed for monitoring the impact of domestic final use activities on raw material requirement, it might be an appropriate option to deduct re-exports. Therefore, the Dutch CBS has developed a specific approach for applying the country tool by excluding re-exports. The method is fully based on the basic version of the tool, but input data from Comext and SUT/IOT are adjusted to exclude re-exports.

5.5 Treatment of gold

The time series of imports and exports of gold show a rather discontinuous pattern. Unfortunately, the impact of gold on total development of RME of imports and exports can be rather distinctive, due to an extremely high RME factor. The gold issue is predominantly a problem for RME calculations for the UK, as the UK has very high imports of gold. Gold imports are also at a significant level for Austria, Germany and Italy.

The tool offers a smoothing module for gold data in order to cope with the discontinuous pattern of the time series. However, due to the dominant role of gold flows in terms of RME for the UK, applying the tool for smoothing would not be advisable, due to the high impact of the smoothing assumptions on the results for total RME.

Regarding the case of basic metals for the UK, exceptionally strong divergences between Comext and SUT data were noticed. Those differences are originating most likely from the different treatment of gold imports and exports by Comext and SUT.

Comext is reporting the physical flows which are crossing the border, whereas SUT is following the SNA concept, which is reporting the change of economic ownership. That is, goods which are crossing the border without change in ownership are not regarded as imports or exports by the SNA concept. It can be assumed that the difference is highly relevant in case of gold flows for the UK. Other reasons for differences are corrections, which are made in line with Balance of Payments adjustments (such as removal of transport costs) or Supply-Use balancing.

It has to be recalled that, for the purpose of the country tool, the SUT data on imports and exports are disaggregated from 64 product groups to 182 product groups by applying the Comext relationships as an indicator (see steps III-6 and III-7 of the calculation procedure). However, that approach cannot work properly in case of strong differences between Comext and SUT, as it can be observed for basic metals in the case of the UK. In those extreme cases, it is recommended to adjust the Comext values before they are entered to the disaggregation procedure.

5.6 Price effect

For the country tool, the following simplifying assumption is used: Import and export prices (EUR per tonne) for the country under review are identical to the corresponding EU prices at the level of 182 product groups. It is assumed that the amount of imprecision for individual product groups is not likely to impair the accuracy of the aggregated indicators significantly, as long as there is no systematic deviation in one direction.

However, in reality, country import and / or export prices at the level of 182 product groups can differ from the corresponding EU prices. An example is the Czech Republic. Export and probably also import prices tend to be systematically lower than the corresponding EU prices ([15]). Two factors can be behind that effect:

a. Different compositions of products within a product group.

b. Different prices for identical products.

In principal, the effect can be compensated by adjusting Czech prices for imported and exported products to EU level. But in practice, it turned out that implementing such an approach is not easy.

Also for Denmark a number of price differences could be identified. The most striking example was the high difference in unit price for other animal products. This is a structural effect as, in the case of Denmark, the imports and exports of that product group are strongly dominated by the item of fur skins. Fur skins are very high priced in comparison to other sub-items of that product group. As it can be assumed that those price differences certainly do not reflect differences in RME content, applying the equal-price assumption will lead to overstating the RME-content of Danish flows for other animal products.

However, a price correction approach is only suitable under some specific conditions. In case of rather homogeneous product groups, like basic metals, price adjustment may work quite well. Those product groups are composed of unwrought metal (low unit price) and different first processed metals (higher unit prices). In case of the individual sub-groups of basic metals, the mass weight is likely to represent the ore content quite adequately. That may also apply for other product groups of first processing of raw materials and for some other product groups, for which the mass weight is heavily determined by non-energy raw material inputs.

Yet, for other product groups the opposite may be the case. An example are energy intensive products. Usually, the use of energy carriers does not contribute to the mass weight. In those cases, the energy content may be represented more adequately by the monetary value of the product. Another example is milk products. The fodder crop content per unit of mass is much lower for fresh milk than for cheese and other products with lower water content.

[15] See: Jan Kovanda, Jan Weinzettel, Karl Schoer: What Makes the Difference in Raw Material Equivalents Calculation Through Environmentally Extended Input-Output Analysis? Ecological Economics 149 (2018) 80–87.

Generally, the more one moves up the production chain, the more it can be expected that the raw material content is not adequately represented by the mass of the product. Therefore, in many cases, price adjustment is not suitable for improving the calculation results in terms of RME.

Therefore, in order to cope with that problem in the country tool, a **semi-selective price adjustment module** was developed, tested and incorporated (sheets III-14a; III-14b; III-14c). This module includes a price correction for 22 selected product groups for which it is assumed that a price adjustment is suitable. Those product groups were selected based on knowledge and experiences with the RME model of the DeteRess-project[16] and a further project (REFINE[17]) on behalf of the German Environment Agency. For both models, a higher degree of hybridization was developed than for the Eurostat RME-model. The selection of the product groups, thus, contain commodities for which the raw material content is better represented by the physical denominator than by the monetary ones. The adjustment is carried out separately for intra-trade imports, for extra-trade imports and for exports.

The selection of product groups was tested for six countries: France, Germany, Netherlands, Ireland, Finland and Romania, based on the country tool version 2020. The results are suggesting that implementing the correction sheet for 22 selected product groups leads to fine-tuning of RME estimates. Therefore, in the current version of the country tool, the price adjustment is set as a default value. Yet, if users do not want to implement the price adjustment, given their specific country environment, the selected product groups can be unselected manually.

Another finding of the testing was that selecting more than the pre-selected 22 product groups can lead to implausible RME estimates. This holds true for all countries that were investigated. Selecting all (monetary) product groups has a rather strong effect on RME estimates of metals and fossils. This is not surprising if one considers the above statements regarding the deep processing of metal products and the energy intensity of certain commodities.

For rather small countries like Ireland and the Netherlands, even the selection of 22 products groups must be taken with caution, especially for metallic commodities.

Therefore, as a validation, users can analyse the impact of the price adjustment by the percentage change of RME estimates in the default setting (price adjustment for 22 pre-selected product groups) compared to RME estimates with manual selection (not all 22 or none of the 22 product groups are selected) in the summary sheets (IV-1 summary IMP EXP and IV-2 Summary publication), respectively.

The structure of the new price adjustment module is as follows: Each correction sheet in the country tool (III-14a; III-14b; III-14c) contains four blocks:

- Block I: These columns provide users with information on the share of product groups at total RME for 22 selected product groups. This information might be helpful if users want to use the semi-selective adjustment and select other (less) than the 22 pre-selected product groups.

[16] Monika Dittrich, Karl Schoer, Claudia Kämper, Sabrina Ludmann, Jürgen Giegrich, Christoph Lauwigi, Christian Sartorius, Thorsten Hummen, Frank Marscheider-Weidemann (2018): Strukturelle und produktionstechnische Determinanten der Ressourceneffizienz: Untersuchung von Pfadabhängigkeiten, strukturellen Effekten und technischen Potenzialen auf die zukünftige Entwicklung der Rohstoffproduktivität (DeteRess), Umweltbundesamt (https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2018-04-11_texte_29-2018_deteress.pdf)

[17] REFINE - Analysis of raw material demand and environmental impacts of the energy transition in a resource efficient and greenhouse gas neutral Germany. On behalf of German Federal Environmental Agency (UBA) https://www.ifeu.de/en/project/refine/

- Block II: Semi-selective correction of unit prices: In this column users can modify a semi-selective adjustment for unit prices. In the default mode, for all 22 selected product groups an adjustment is conducted. Users can manually select if correction of unit prices should not be applied by selecting "-" in the dropdown list of the respective cells. Information from block I can be used for decision-making.
- Block III: Ratio of unit price differences at the product groups level: The relation of country-level unit prices to EU unit prices for IMP Intra, IMP Extra and EXP total according to Comext are presented.
- Block IV: Correction factors to EU unit price (marked yellow): selected correction factors are displayed. Value=1 implies no correction.

6 Data output of the model

Table 3 describes the presentation of the calculation results of the model. For more details, refer to the workbook of the country tool.

Table 3: Adjusted coefficient approach calculation procedure

Sections	Worksheet of the country RME tool	Description
IV. Results	IV-1-Summary IMP EXP'	Presentation of annual results RME of imports and exports by raw material categories. 1st step: results by unadjusted coefficient approach. 2nd step: of RME of exports by adjusted coefficient approach Percentage change on RME results of semi-selective price adjustment is illustrated.
	IV-2-Summary publication	Annual results for publication for DE, IMP, RMI, EXP and RMC by main material categories Percentage change on RME results of semi-selective price adjustment is illustrated.
	IV-3-Summry analysis	Analytical tables with reference figures (used for charts)
	IV-4 Charts	Charts

The output tables show:

- Results for imports and exports in a full breakdown by 51 raw material categories. For exports, the unadjusted and the adjusted results are presented (IV-1).
- Annual results for publication for DE, IMP, RMI, EXP and RMC by main material categories (IV-2)
- Analytical tables with reference figures (IV-3)
- A set of charts with summary results (IV-4).

Figures 2 to 5 provide summary results for the pilot country France. The country RME tool has been populated with publicly available data for France for illustrative purposes. Please note that the RME-based indicators reported in the country RME tool, the data pool and in Section 5 of the handbook do not constitute official estimates.

Figure 2: RME country tool – summary results France; RMC, DMC and GDP (index 2010 = 100)

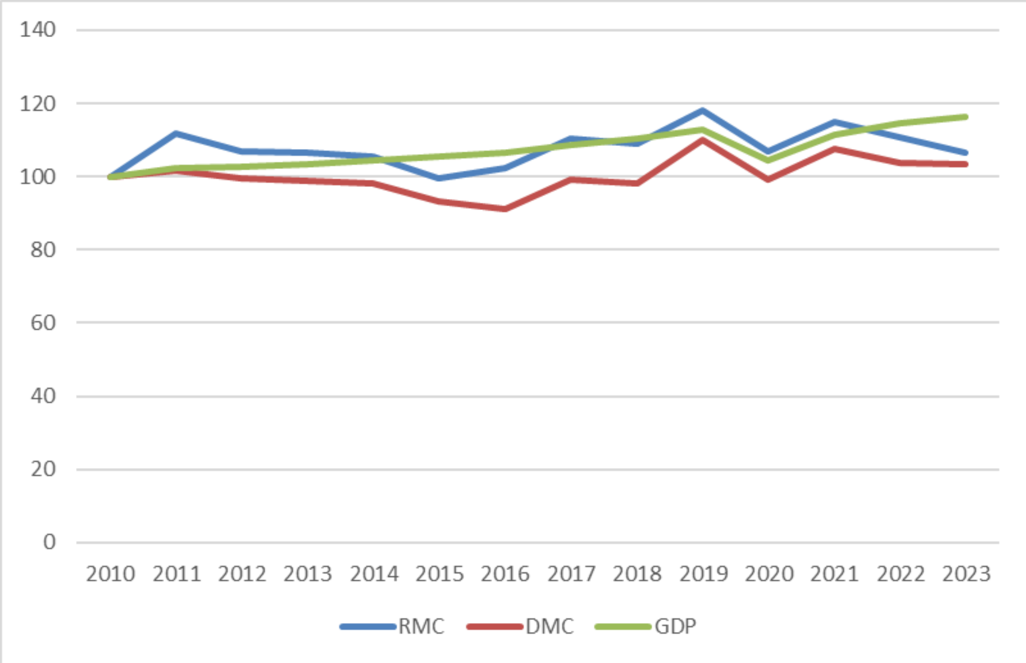


Figure 3: RME country tool – summary results France; RMI, DMI, DE and GDP (index 2010 = 100)

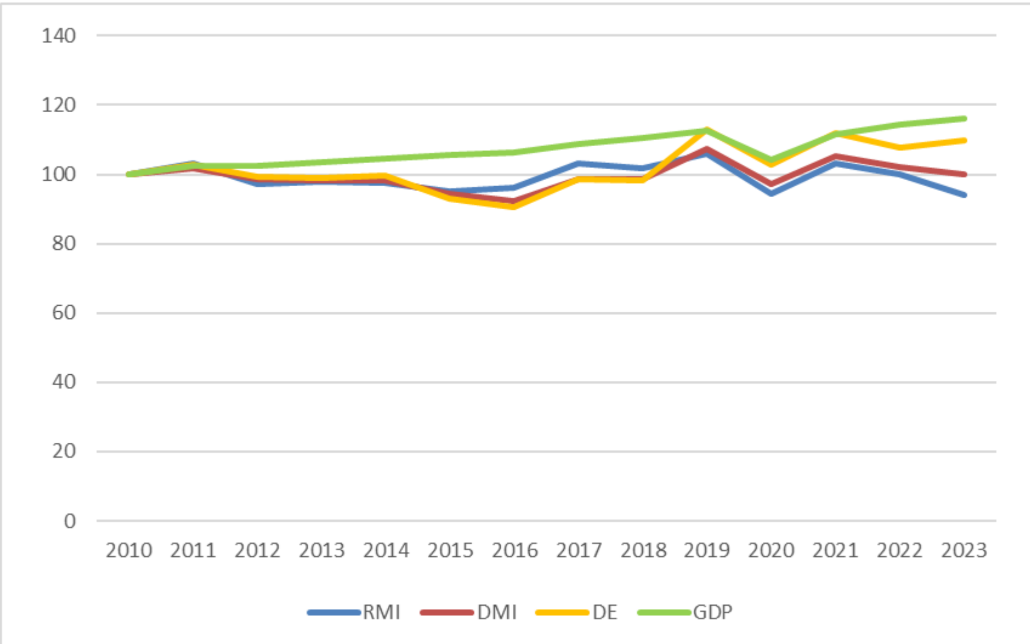


Figure 4: RME country tool – summary results France; imports (index 2010 = 100)

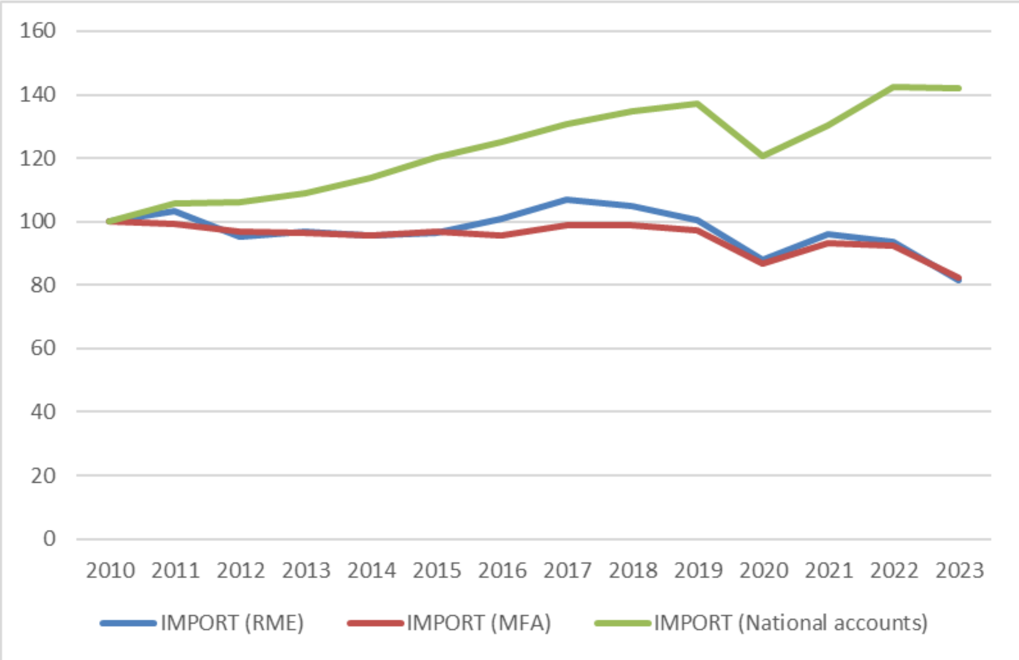
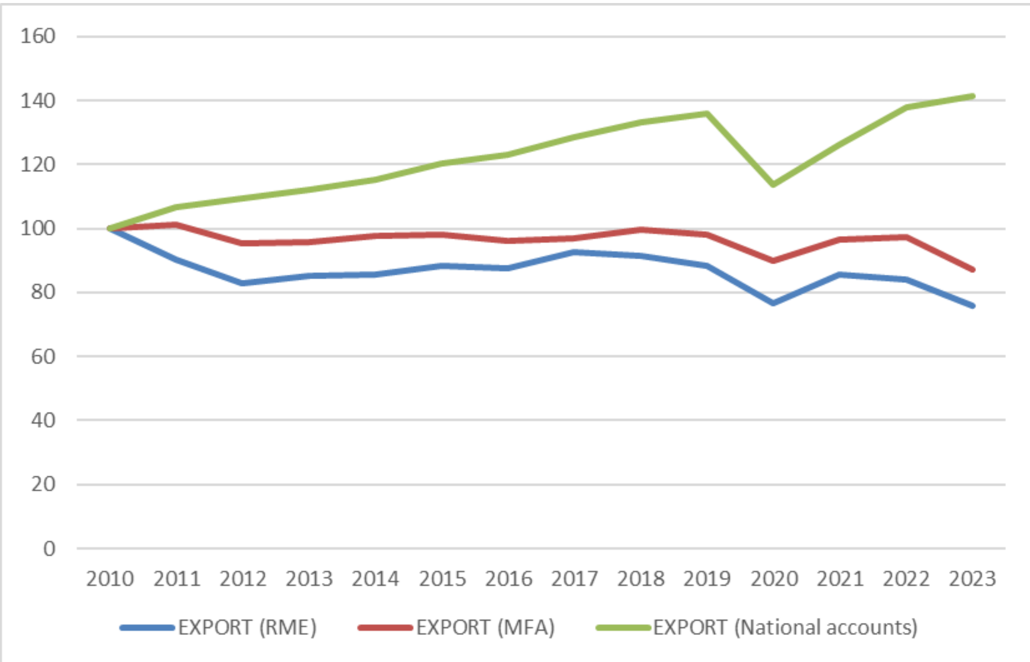


Figure 5: RME country tool – summary results France; exports (index 2010 = 100)



7 Future work

With the previous version of the country tool, a combined coefficient-IOT approach was offered in addition to the coefficient approach in order to cope for country-specific differences in production technology. However, that type of IOT-based approach was not able to produce convincing results with the revised data. It can be assumed that the major problem is resulting from the new classification of the standard IOT. According to the new classification for the IOT, all mining activities comprising the most crucial raw products are lumped together as one product group.

Therefore, in this handbook, only an improved coefficient approach could be provided. It would be desirable to have a supplementary IOT-based approach for estimating RME of exports as an alternative to the adjusted coefficient approach. In principle, an IOT-based approach would reflect the specific production conditions of the country under review more accurately than a coefficient approach, provided that an IOT of good quality could be established with an adequate degree of sectoral resolution. More research will be done in the future to determine whether an IOT model can be developed which is suitable and manageable for at least a larger number of member countries.