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Macro-economic material flow indicators for Flanders 2002-2018

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Macro-economic material flow indicators for Flanders 2002-2018

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Summary

This report contains the background data concerning the update of four macro indicators taking a central position in the monitoring of the circular economy: DMC, DMI, RMC and RMI. The update has been performed based on the most recently available data and extends up to and including the year 2018. At the end of the report a number of considerations on the way in which these indicators can be used for policy have been included.

Samenvatting

Dit rapport bevat de achtergrondgegevens met betrekking tot de update van vier macro-indicatoren die een centrale plaats innemen in het monitoren van de circulaire economie: DMC, DMI, RMC en RMI. De update is uitgevoerd op basis van de meest recent beschikbare data en loopt tot en met het jaar 2018. Het rapport besluit met een aantal beschouwingen over de manier waarop beleidsmatig met deze indicatoren omgegaan kan worden.

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Introduction

In recent years, Europe has put more emphasis on a sustainable approach to material use. This resulted in a number of initiatives and programs, and a focus on appropriate indicator sets to identify material use, for example the resource efficiency scoreboard (EC, 2016a) and the raw materials scoreboard (EC, 2016b). The resource efficiency scoreboard is a framework for presenting key indicators relating to natural resources. The lead indicator of this framework provides a focus on resource productivity, and is defined as the ratio between gross domestic product (GDP) and domestic material consumption (DMC) (EC, 2016a). Also, the DMC is part of the raw materials scoreboard, listed in the topic 'material flows in the circular economy' (EC, 2016b). Raw material consumption (RMC) has been identified as a candidate for a follow-up indicator to monitor the productivity of raw materials. The 'European Resource Efficiency Platform' also called to formulate objectives based on the RMC (EREP, 2012).

Eurostat provides a manual to the member countries to compile economy-wide material flow accounts (EW-MFA)[1]. The general purpose of EW-MFA is to describe the interaction of the domestic economy with the natural environment and the rest of the world economy in terms of flows of materials (excluding water and air). EW-MFA is a statistical framework conceptually embedded in environmental-economic accounts and fully compatible with concepts, principles, and classifications of national accounts – thus enabling a wide range of integrated analyses of environmental, energy and economic issues e.g. through environmental-economic modelling. To facilitate the compilation of extended material flow accounts at the country level, Eurostat has published the "country RME tool", accompanied by a handbook and a file with input data. This tool supports the country-level estimations of flows in raw material equivalents (RME), such as imports and exports in RME, raw material input (RMI) and RMC.

The RME-factors developed by Eurostat denote the upstream requirements of used extraction associated with imports and exports. Indirect material use is linked to both domestic and imported products. Converting traded products into its RME equivalent includes the indirect use of resources in the weight of that product. RME are introduced to account for the correct weight of raw materials needed to produce manufactured products. Usually this weight is a few times larger than the weight of the products themselves. When import and export are expressed in RMEs, they comprise all the raw materials needed worldwide to produce the imported and exported commodities. Import is considered as an environmental pressure shifted abroad; export is considered as environmental pressures shifted from the producing country to the demanding country (Kovanda & Weinzettel, 2013).

In this study, the EW-MFA methodology is applied to Flanders to estimate the indicators DMC and RMC. Also, the input indicators, direct material input (DMI) and RMI, are estimated and explained. Next to applying the EW-MFA methodology, the material footprint of Flanders is estimated via input-output (IO) calculations. This study addresses the difference between the indicators: DMI, DMC, RMI, RMC and material footprint. The differences in methodology, data and scope are explained. In the report, these indicators are explained in function of their potential policy support in Flanders. Also, the study elaborates on the question how policy should deal with indicators of which an update implies that the values for previous years also

[1] https://ec.europa.eu/eurostat/web/environment/material-flows-and-resource-productivity#

change along (because of error corrections in input data, changed definitions and changing conversion factors, etc.).

In 2016, VITO already assessed the indicators DMC and RMC for Flanders over the period 2002-2015 in a project funded by the Flemish department LNE (2016)[2]. In the conclusions of this study, it was recommended to estimate these indicators in long time series (+10 periods) as seasonal effects and economy-related factors may have an impact, for example, annual average temperatures and natural fluctuations, temporary disproportionately large infrastructure projects, short-term trends and trend breaks like an economic crisis. The goal of that study was to determine the material productivity of the Flemish economy expressed by the ratio GDP to the primary material use (in DMC and RMC). The indicator measures the material productivity of a region: it's ability to meet the same consumption requirements with less primary material use. An increase in the material productivity, for example, indicates an improvement of the environmental (primary material) performance of production chains. The results from the 2016 study differ from the results presented here. The main reason for these differences is a different methodology used for the domestic extraction (DEU), the use of updated (and improved) RME-coefficients and updates in the data input (e.g. updated trade statistics). The results from the 2016 study will be presented next to the updated results. The main differences are explained. In 2017, VITO calculated the material footprint of Flemish consumption via IO-analysis. The footprint was derived and analysed for the year 2010. Currently, VITO is assessing the material footprint for the years 2010, 2012, 2014, 2015 and 2016 using an updated input-output model[3]. Results will be published by the end of 2020.

In this report an update is provided on the material flows and indicators for Flanders. In Chapter 1, the definition of DMI, DMC, RMI, RMC and MF are given, together with their 'position' in the framework of macro-economic indicators.

In Chapter 2 the bottom-up estimation of the indicators DEU, import, export, DMI and DMC are derived (2002-2018 data, including a recalculation of the 2002-2015 indicators). The estimation follows the definitions and concepts of EW-MFA-handbook by Eurostat, enabling the comparability of the indicators with other countries. The results are available at the level of 60 individual material flows. The conversion of both import and export in their RMEs allows to derive the indicators RMI and RMC for the period 2008[4]-2018.

In Chapter 3 the material footprint (2010 data) is reported via input-output analysis (IOA). The material footprint is linked to final consumption categories: household consumption, non-profit institutions serving households, governmental spending, investments and changes in inventories. The household consumption is further specified using the consumption domains.

Chapter 4 brings together the information from the previous chapters to develop an overview of macro-economic material flows in Flanders. The chapter focusses on the role of the DMI, DMC, RMI, RMC and MF in support of policies in Flanders.

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[2] Project resulted in a report: 'Indicatoren voor een groene economie. Update van datafiche en Exceltabellen DMC en RMC' (Christis, et al., 2016). The results and conclusions are used in a publication by the Flemish Government 'Hoe groen is de Vlaamse economie?' (departement LNE, 2016).

[3] Model is developed in the project 'Koolstofvoetafdruk van de Vlaamse consumptie' commissioned by VMM-MIRA (2020) and in the annual program of VITO commissioned by OVAM (2019).

[4] Only 2008 onwards, as there are no RME-coefficients are available before 2008.

Chapter 1: Macro-economic material flow indicators

The overview presented in Figure 1 provides the structure and relationships between the material-based indicators. On the input side (far left) of an economy are the domestic extraction of materials and the cultivation of crops and other biomass (e.g. grazed biomass) (DEU, Domestic Extraction Used) on the one hand, and the import of goods and services on the other (IMP). The sum of DEU and IMP is displayed as the input indicator DMI. By reducing DMI with all exports (EXP), the consumption indicator DMC is obtained. By converting both IMP and EXP to RMEs[5], the input indicator RMI and the consumption indicator RMC are obtained. By adding the Unused Domestic Extraction (UDE) to DEU and expressing IMP and EXP in RMEs including UDE, the TMR (Total Material Requirement) and TMC (Total Material Consumption) are obtained. UDE contains overloading and separated materials in mining, by-catch and harvest losses from biomass production and soil excavations, as well as dredging material from construction activities that are not used in economic activities.

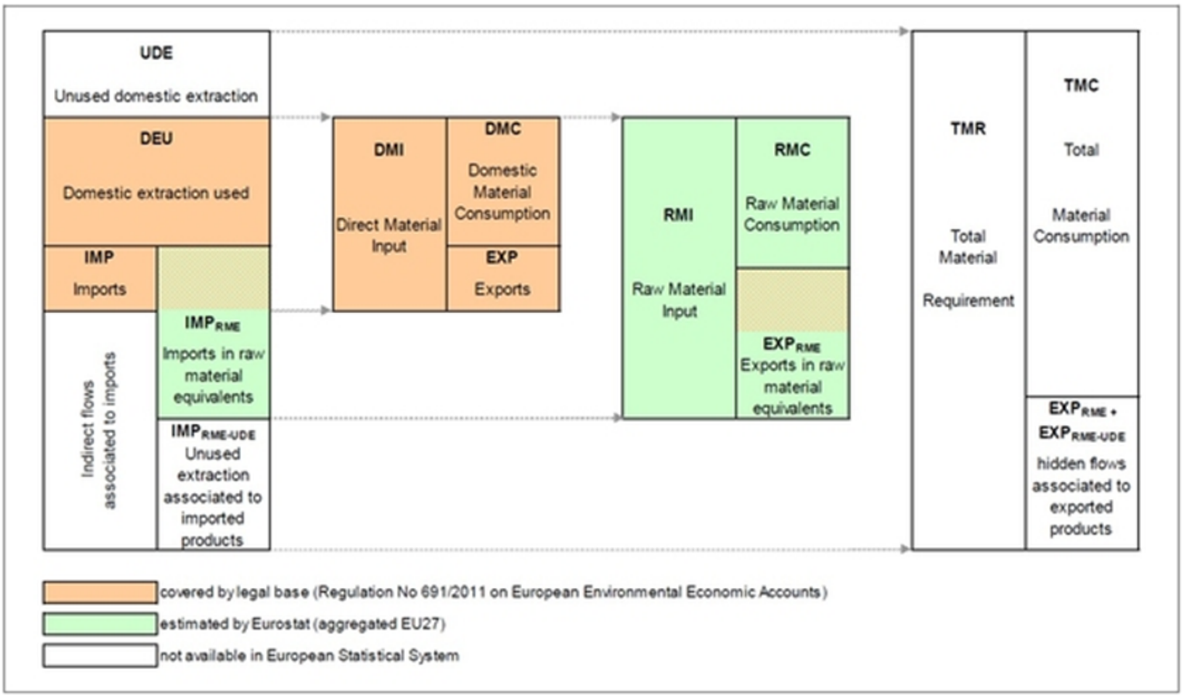

Figure 1: Overview on macro-economic material flow related indicators. (Eurostat, 2014).

DMI and RMI are so-called input indicators. DMI represents materials supply into the economy. It measures the direct input of materials for use, i.e. all materials that are of economic value and are used in production and consumption activities; DMI equals domestic extraction used plus imports. RMI is defined as the sum of DEU and imports expressed in RME. It measures the global use of resource linked to the input into the domestic economy by converting the import into RME. By including the indirect flows of import, the RMI is robust against outsourcing.

[5] The RMEs are used to convert import and export in their raw material equivalents. Eurostat provides these RMEs as average conversion factors for Europe (country-independent).

DMC and RMC (absolute, in kg) are so-called consumption indicators. The RMC and DMC (partly) are based on the value chain approach, which means that the use/consumption of raw materials throughout the chain can be linked to the end-product of this chain. They describe the materials used during economic activities throughout the value chain, starting from the consumption of end users (i.e. domestic consumption of end products). This is an important advantage over input indicators, which only consider the amount of material used in an economy, regardless of whether this is for own (domestic) use or for export.

A frequently heard criticism of DMC is that it is not robust against so-called outsourcing. For example, with the same domestic demand that is satisfied by more imports and the same production structure, the DMC indicator will decrease. This is due to the asymmetrical nature of DMC, more specifically due to the difference in weighting between domestic extraction of raw materials and imports. Domestic extraction is weighed in terms of ores or harvests, while imports are measured by the weight of goods that cross-country borders regardless of how they are produced. The DMC indicator offers an assessment of the absolute amount of use of raw materials with a clear focus on domestic consumption. Likewise, local production in function of export will increase the DMC as the weight of exported product is lower compared to (the sum of) its input. For example, the use of energy products in the production process will not be part of the exported product.

The RMC indicator measures the use of raw materials associated with domestic demand in the same way as DMC, except that import and export flows are expressed or converted into their RMEs. RMC is therefore robust against so-called outsourcing. It displays the total, global amount of used/spent mining and harvesting to provide domestic consumption with goods and services. In contrast to RMI, RMC avoids double counting of raw materials in international statistics because the exports and related flows are allocated to the consumer country. It provides a fundamental understanding of the accounting of raw materials. Trends of this type of indicator help to understand the evolution of consumption of raw materials over time. However, the indicator only gives an impression of the mass of primary raw materials and does not contain any information about scarcity or its impact.

The so-called efficiency or productivity indicators relate economy-wide indicators (as a measure of material input: DMI or RMI, and material footprint: DMC or RMC) to economic output (e.g. GDP). They are a measure of the material productivity or intensity of an economy or sector: the ability to produce the same output or meet the same consumption needs with less material indicates an improvement in environmental and economic performance (and therefore competitiveness). Because these indicators can be defined at the level of material groups or even individual materials, they also offer the option of the most important materials for an economy. Resource productivity is a 'lead' macro-indicator and was selected in the RE scoreboard (Eurostat) to measure the main objective of the Roadmap. It is defined as the ratio of GDP/DMC. Also, DMC (and in recent years RMC) is increasingly defined in other indicator sets as a relevant indicator, for example in the Green Growth Indicators from the OECD.

To fully exploit the potential of these indicators, they can be broken down by material categories. Expressing the indicators in absolute, per capita, per area or per GDP values delivers valuable information from different perspectives and allows country comparison. For example, the per capita expression summarizes environmental justice issues because all people should have equal rights to extract and consume resources and allows a better cross-regional comparison. Per GDP points to the economy's efficiency of resource transformation into economic output and allows for assessing the intensity of material use in the economy. Expressing DMI or RMI in relation with GDP gives insight into the metabolic performance of nations and shows results on the relative decoupling material use from economic growth.

DEU per area delivers easily interpretable results as it expresses environmental pressure per square kilometre of a given country associated with mining and production of biomass. It can be directly related to regional population and GDP to allow for inter-regional comparisons. A change in DEU per capita or per GDP can be related to two effects (along with demographic changes etc.): the technology effect and the structural effect. The technology effects include the use of new technologies with improved material and energy performance per unit of economic output. Structural changes in economies includes the growth towards service sectors characterised by less material input per unit of output[6].

The import and export indicators define the physical quantity of all imports and exports, including raw materials, semi-manufactured products and finished products. In the case of countries, imports and exports refer to international trade while in the case of cities and regions they refer to material flows crossing the boundaries of such administrative units. Imports are an environmental pressure exerted on a spatial unit over the importing one, i.e. the pressure related to production of imports is shifted from production regions to the importing region. The same reasoning applies to exports, but conversely.

Other indicators like the ratios DEU to DMI, DEU to DMC, import to DMI, import to DMC, export to DMI or export to DMC support policies on resource and trade dependencies. The DEU to DMI or DEU to DMC ratio indicates the dependence of the physical economy on domestic raw material supply, denoting the domestic resource dependency. The ratios between imports and exports to DMI or export to DMC indicate the physical intensity of import and export.

The material footprint (MF) indicators are closely related to the RMC-indicator. Both indicators capture global primary material use linked to domestic consumption. The MF uses a consumption-based approach to measure the material use across the upstream production chain of a consumed product. The difference between the two indicators is mainly their calculation methodology. The RMC-indicator, based on the Eurostat methodology, is calculated as the sum of DEU and imports expressed in raw material equivalents minus exports expressed in raw material equivalents. The MF indicator starts from consumption (e.g. final demand of households) and calculates the total primary material use upstream in the global production network. In contrast to indicators of standard economy-wide material flow accounting, which are based on apparent physical consumption, the MF does not record the actual physical movement of materials within and among countries but, instead, enumerates the link between the beginning of a production chain (where raw materials are extracted from the natural environment) and its end (where a product or service is consumed) (Wiedmann et al., 2015).

[6] In this context, one must consider the possible growth of imports. If an economy changes towards a service-based economy, the final demand does not automatically move in the same direction. To comply with domestic consumer needs, imports may increase meaning an extra pressure on the 'foreign' environment.

Domestic Material Consumption (DMC): DMC represents domestic materials use. DMC measures the total amount of materials directly used in an economy (i.e. the direct apparent consumption of materials, excluding indirect flows), like biomass, metal ores, fossil energy carries and non-metallic minerals. It equals domestic extraction used plus imports minus exports. It is an important measurement of future domestic waste and emissions as all materials consumed will be converted into waste sooner or later.

Raw Material Consumption (RMC): RMC measures the global material use associated with domestic production and consumption activities, including indirect flows related to imports and excluding exports and associated indirect flows of exports. RMC equals domestic material consumption plus imports minus exports both expressed in raw material equivalents (RME). Hidden flows or unused extraction (e.g. mining overburden and harvesting losses) are not counted by RMC. Thereby, it represents the global amount of used extraction to provide products for domestic final demand.

Material footprint (MF): MF measures the global material use associated with domestic consumption activities, including indirect flows related to imports and excluding exports and associated indirect flows of exports. Stated otherwise, it is the global allocation of used raw material extraction to the final demand of an economy.

Chapter 2: Economy-wide material flow analysis [bottom-up]

2.1 Method and data

The indicators DMI, DMC, RMI and RMC are estimated for Flanders using the EW-MFA methodology provided by Eurostat. The estimation follows the compilation guidelines in Chapter 4 of the 2018 edition handbook ‘Economy-wide material flow accounts’ from Eurostat. A summary from the handbook is given below, together with the sources used to compile the Flemish EW-MFA. To improve the readability of this report, several definitions are copied from the handbook. Deviations from this handbook are also explained below. This process implies a bottom-up estimation of DEU, import and export to estimate the DMI and DMC and a conversion of import and export in RMEs to estimate the RMI and RMC. The conversion of physical import and export in trade in raw material equivalents follows the Eurostat ‘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’ (2018).

Domestic extraction used of biomass records material flows from the environment to the economy related to the human appropriation of cultivated and non-cultivated biomass. While the latter (e.g. wild fish catch, hunting and gathering, logging from natural forests) can be measured straightforwardly at the boundary between environment and economy, the former cannot and by convention the so-called harvest approach is used. Applying the harvest approach implies that cultivated forests and agricultural plants are treated as if they were part of the environment. EW-MFA recognise the flow from environment to economy at the point of harvest rather than as growth occur. Amounts harvested from cultivated biological resources are available from agriculture and forestry harvest statistics. Note that cultivated livestock (e.g. cows, pigs) is not a natural input and hence excluded from the EW-MFA’s domestic extraction.

Annual crop production for Flanders is derived from the STATBEL-statistics on agriculture:

- Definitieve raming van de productie van de landbouwteelten – 2002 -2018; and
- Tab A: landbouwcijfers 2018 - Resultaten volgens uitgebreide lijst van variabelen: voor België, de Gewesten, de Provincies, de Landbouwstreken.

The first source provides production volumes on ca. 20 crops (in tons), while the second source provides cultivated land on ca. 200 crops (in acres). The latter needs an extra conversion step using production estimates per acre per crop to enable a derivation of production volumes (in tons). Around 60-70% of the total crop production volumes (in tons) is derived from the first source, meaning it encompasses the most imported (in terms of volume) crops. The yield figures (2002-2008) come from the ‘vakgroep Plantaardige Productie van de Faculteit Landbouwkundige en Toegepaste Biologische Wetenschappen’ of the UGent, from the ‘Provinciaal Onderzoek- en Voorlichtingscentrum voor Land- en Tuinbouw en het Proefcentrum Fruitteelt’, from the background document ‘Achtergronddocument Materiaalstromen’ and from the manual of 'Eurostat EW-MFA compilation guide 2013'. The yield figures of2009 till 2018 are an extrapolation on this.

Biomass production by households for own consumption cannot be included because no data is available. The same applies for biomass waste from management of parks, infrastructure areas, gardens etc. If these streams are used in the economy (e.g. energy production), they should be included in the DEU, however, no data is available on this flow.

Fodder crops and grazed biomass need extra attention during their estimation as their significance is high. On average in the EU about 30% of the domestic extraction of biomass is fodder crops and grazed biomass. Here we used the supply-side approach which implies the use of pasture area times pasture yield. Both permanent and temporary pasture area are provided by the second source. An alternative approach, which we did not use, is the demand-side approach estimating the amount of fodder crops and grazed biomass based on statistics on the number of animals.

Wood records the biomass harvested from cultivated (and non-cultivated) forests. In the case of cultivated forests, EW-MFA records by convention the harvested amounts of wood, following the harvest approach. The estimation of the domestic extraction of wood is based on the total forest surface in Flanders (in ha) multiplied by a harvest factor (in m^3/ha) and a density factor (in t/m^3). The density factor is from the Eurostat handbook (non-coniferous: 0.64 t at 15% moisture content/m^3). The harvest factor is from 'bosinventaristatie'[7] (3.1 m^3/ha). The forest surface in Flanders is taken from the 'boswijzer'[8] of Natuur en Bos.

Wild fish catch, aquatic plants/animals, hunting and gathering is all non-cultivated biomass. The data sources used are: annual reports from the fishery[9] and data from INBO on 'grofwildjacht'[10].

Domestic extraction of non-metallic minerals records material flows from the environment to the economy related to mining and quarrying of mineral material other than metal and fossil energy carriers such as stone, sand, clay, salt, etc. It refers to the extraction from a mine or quarry, but also dredging of alluvial deposits, rock crushing and the use of salt marshes. Non-metallic minerals are used most notably in construction, manufacture of mineral products, or manufacture of chemicals. The intention of the EW-MFA is to measure domestic extraction of non-metallic minerals at the point where the respective mineral-containing material crosses the boundary between the natural environment and the national economy. The so-called run-of-mine amount is accounted for which is the mineral containing material before any further separation or concentration. Official statistics, however, may be only available for the production output of quarrying activities. In the case of non-metallic minerals statistics on the production output from non-metallic mineral quarrying can be used to approximate the run-of-mine amounts. It is assumed that there is not much quantitative difference between the amounts extracted and those leaving the gate of the quarry in form of ready-to-sale products.

In Flanders, only a few non-metallic minerals are mined or quarried: clays and kaolin, and sand and gravel. Data is taken from the annual reports on MDO 'monitoringsysteem duurzaam oppervlaktedelfstoffenbeleid'[11]. These reports mention extraction data for most years. Missing years are estimated via intra- and extrapolation.

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7 https://www.natuurenbos.be/beleid-wetgeving/natuurbeheer/bosinventarisatie

8 https://www.natuurenbos.be/beleid-wetgeving/natuurbeheer/wat-de-boswijzer

9 https://lv.vlaanderen.be/nl/voorlichting-info/publicaties-cijfers/studies/sectoren/visserijrapport-2018

10 https://www.inbo.be/nl/pers/statistieken-over-grofwildjacht-online-raadpleegbaar

11 https://www.ovam.be/mdo

Domestic extraction used of metal ores and **domestic extraction of fossil energy materials and carriers** is non-existent in Flanders.

In Table 1 the composition of the material category of biomass is given, together with examples of DEU per subcategory. In Table 2 the composition in DEU of the material category of non-metallic minerals is shown. Table 3 to Table 12 show the composition per material category of import and export, respectively. The composition and the accompanying examples are those with the largest quantity of the year 2016. We choose the year 2016 as values for 2017 and 2018 might be updated due to updates in the trade database. This potential update is explained in the description of import and export. These examples should help the reader in understanding the type of trade flows that are behind the graphs and numbers through this report.

*Table 1: The compostion of **DEU** including examples of flows per material subcategory, **biomass**, Flanders, 2016. Only the top determining flows are metnioned in the list of examples, including their share in the total flow.*

Material category	Flow quantity (in tons)	Examples
A.1 Biomass	**14,357,650**	
A.1.1 Crops, raw and processed	**6,460,563**	
A.1.1.1 Cereals, raw and processed	1,062,860	winter wheat (36%); grain maize (32%); winter barley (8%)
A.1.1.2 Roots, tubers, raw and processed	1,874,607	storage potatoes (69%); early potatoes (15%)
A.1.1.3 Sugar crops, raw and processed	1,284,380	sugar beets (100%)
A.1.1.4 Pulses, raw and processed	35,115	green beans (60%); peas (35%)
A.1.1.5 Nuts, raw and processed	0	
A.1.1.6 Oil-bearing crops, raw and processed	1,777	rapeseed (92%)
A.1.1.7 Vegetables, raw and processed	1,419,268	carrots (24%); tomatoes (21%), leek (8%); cauliflowers (6%); spinach (5%)
A.1.1.8 Fruits, raw and processed	463,382	pears (46%); apples (37%); strawberries (8%); cherries (3%)
A.1.1.9 Fibres, raw and processed	28,818	fibre flax (100%)
A.1.1.10 Other crops n.e.c., raw and processed	289,905	ornamental trees (59%); forest plants (10%); perennials (8%)
A.1.2 Crop residues and fodder crops	**7,543,667**	
A.1.2.1 Crop residues (used), raw and processed	1,261,167	
A.1.2.1.1 Straw	308,979	straw from winter wheat (75%); straw from winter barley (18%)
A.1.2.1.2 Other crop residues	952,189	leaves from sugar beets (92%); leaves from fodder beets (8%)
A.1.2.2 Fodder crops	6,282,798	
A.1.2.2.1 Fodder crops	4,170,804	feed maize (94%); fodder beets (6%)
A.1.2.2.2 Grazed biomass	2,111,995	
A.1.3 Wood and wood products	**328,451**	
A.1.3.1 Timber, raw and processed	245,158	

A.1.3.2 Wood fuel and other extraction, raw and processed	83,292	
A.1.4 Fish capture and other aquatic animals and plants, raw and processed	**24,669**	
A.1.4.1 Fish capture	20,010	plaice (45%); sole (12%); gurnard (8%); squid (6%); codfish (5%)
A.1.4.2 All other aquatic animals and plants	3,451	shrimp (32%); langoustine (23%)
A.1.4.3 Hunting and gathering	1,208	hare (15%); roe deer (14%); pheasant (13%); pigeon (10%); wild boar (10%)

*Table 2: The compostion of **DEU** including examples of flows per material subcategory, **non-metallic minerals**, Flanders, 2016. Only the top determining flows are metnioned in the list of examples, including their share in the total flow.*

Material category	Flow quantity (in tons)	Examples
A.3 Non-metallic minerals	**32,470,000**	
A.3.7 Clays and kaolin	1,448,000	clay (74%); kaolin (26%)
A.3.8 Sand and gravel	7,535,000	construction sand (49%); quartz (23%); gravel (17%); fine sand (11%)
A.3.10 excavated earthen materials	23,487,000	excavated earthen materials (71%); dredge spoil (29%)

The **physical imports and exports** are recorded as material flows into and out of an economy. Physical trade flows are flows of products that have mass and volume and can be measured in tons. In EW-MFA the physical imports and exports are classified in two ways: by type of material and by stage of manufacturing. Employing a classification by type of material has implications. The main data source is international trade in goods statistics which employ product classifications (i.e. Combined Nomenclature, CN). To compile the EW-MFA one needs to transpose the CN codes toward MF classes. Each single CN product group is composed of many types of material. For compiling physical imports and exports a simplified approach is taken: each CN code is assigned to one and only one MF code according to the dominant material (i.e. the material with the highest share in terms of mass weight) in the material composition of the CN product group. For example, the international trade of a car (see A.2.3 in Table 4 and in Table 9) is linked to the material group of metal products, although the car is composed of metals, glass, plastics, rubber, etc. A one-to-one correspondence between the EW-MFA classification of materials and the Combined Nomenclature is provided by Eurostat. The majority of the more than 20,000 CN product groups is assigned to the four main material categories. Still, a considerable number of CN products cannot be assigned to one of these, so categories MF.5 (other products) and MF.6 (waste for final treatment and disposal) are introduced.

Another option could be to allocate each trade flow to multiple material categories. However, this requires a massive amount of information to allocate the more than 20,000 product groups to multiple (detailed) material categories. Also, this allocation would need a regular revision as product composition changes over time. An interim solution could be to focus on a small list of substantial product flows. None of these options is implemented in this study.

*Table 3: The compostion of **import** including examples of flows per material subcategory, **biomass**, Flanders, 2016. Only the top determining flows are metnioned in the list of examples, including their share in the total flow.*

Material category	Flow quantity (in tons)	Examples
A.1 Biomass	**48,476,851**	
A.1.1 Crops, raw and processed	**22,656,894**	
A.1.1.1 Cereals, raw and processed	10,232,335	wheat and meslin (42%); barley (19%); corn maize (18%)
A.1.1.2 Roots, tubers, raw and processed	1,856,333	potatoes (91%)
A.1.1.3 Sugar crops, raw and processed	1,111,120	molasses resulting from the extraction or refining of sugar (52%); cane or beet sugar and chemically pure sucrose (48%)
A.1.1.4 Pulses, raw and processed	85,113	dried leguminous vegetables (99%)
A.1.1.5 Nuts, raw and processed	68,751	prepared or preserved nuts (53%); fresh or dried nuts (30%); coconuts, Brazil and cashew nets (17%)
A.1.1.6 Oil-bearing crops, raw and processed	3,971,041	rape or colza seeds (70%); linseed (14%): soya beans (9%)
A.1.1.7 Vegetables, raw and processed	2,101,156	frozen vegetables (27%); carrots, turnips, salad beetroot, salsify, celeriac, radishes and similar edible roots (16%); fresh or chilled leguminous vegetables (9%); alliaceous vegetables (6%); tomatoes 6%)
A.1.1.8 Fruits, raw and processed	2,281,529	fruit juices (34%); bananas (22%); citrus fruit (7%); apples, pears and quinces (7%)
A.1.1.9 Fibres, raw and processed	104,461	flax (85%); cotton (8%); vegetable textile fibres (7%)
A.1.1.10 Other crops n.e.c., raw and processed	845,057	chocolate (26%); cocoa beans (18%); cocoa butter (15%); coffee (14%); cocoa paste (10%)
A.1.2 Crop residues and fodder crops	**147,398**	
A.1.2.1 Crop residues (used), raw and processed	68,501	
A.1.2.1.1 Straw	68,501	cereal straw and husks (100%)
A.1.2.1.2 Other crop residues	0	
A.1.2.2 Fodder crops	78,897	
A.1.2.2.1 Fodder crops	78,897	swedes, mangolds, fodder roots, hay, Lucerne, clover, and other forage products (100%)
A.1.3 Wood and wood products	**4,718,934**	
A.1.3.1 Timber, raw and processed	4,477,658	fuel wood (41%); fibreboard (19%); packing cases, boxes, crates and similar packings (13%); particle board (11%)
A.1.3.2 Wood fuel and other extraction, raw and processed	241,275	natural rubber and similar natural gums (43%); fuel wood (39%); wood charcoal (16%)
A.1.4 Fish capture and other aquatic animals and plants, raw and processed	**177,407**	
A.1.4.1 Fish capture	110,739	fish fillets and other fish meat (48%); prepared and preserved fish and fish eggs (29%)
A.1.4.2 All other aquatic animals and plants	66,668	crustaceans (44%); molluscs (41%)

A.1.5 Live animals other than in 1.4., and animal products	**5,173,666**	
A.1.5.1 Live animals other than in 1.4.	955,006	poultry (70%); swine (13%); bovine animals, swine, sheep, goats, horses, asses, mules or hinnies (13%)
A.1.5.2 Meat and meat preparations	873,052	poultry meat (41%); edible offal from bovine animals, swine, sheep, goats, horses, asses, mules or hinnies (16%); meat of swine (9%); sausages (6%)
A.1.5.3 Dairy products, birds eggs, and honey	2,199,394	milk and cream (not concentrated or not containing added sugar, 51%); cheese and curd (11%); milk and cream (concentrated or containing added sugar, 9%); birds' eggs (7%)
A.1.5.4 Other products from animals (animal fibres, skins, furs, leather etA.)	1,146,214	bones and horn-cores (28%); animal fats of bovine animals, sheep or goats (17%)
A.1.6 Products mainly from biomass	**15,602,552**	preparation of a kind used in animal feeding (11%); oilcake and other solid residues resulting from the extraction of soya-bean oil (8%); recovered paper or paperboard (8%); residues of starch manufacturing, beet pulp, bagasse and other waste of sugar manufacturing, brewing or distilling dregs and waste (7%)

*Table 4: The compostion of **import** including examples of flows per material subcategory, **metal ores**, Flanders, 2016. Only the top determining flows are metnioned in the list of examples, including their share in the total flow.*

Material category	Flow quantity (in tons)	Examples
A.2 Metal ores (gross ore)	**26,579,336**	
A.2.1 Iron ores and concentrates, iron and steel, raw and processed	**16,164,700**	iron ores and concentrates (44%); ferrous waste and scrap (18%): flat-rolled products of iron and non-alloy steel (16%)
A.2.2 Non-ferrous metal ores and concentrates, raw and processed	**3,023,151**	
A.2.2.1 Copper	653,061	copper waste and scrap (47%); unrefined copper, copper anodes for electrolytic refining (34%); refined copper and copper alloys (12%)
A.2.2.2 Nickel	15,442	unwrought nickel (66%); nickel plates, sheets, strip and foil (18%); nickel waste and scrap (6%)
A.2.2.3 Lead	122,806	lead ores and concentrates (55%); lead waste and scrap (24%); unwrought lead (16%)
A.2.2.4 Zinc	774,272	zinc ores and concentrates (66%); unwrought zinc (29%); zinc waste and scrap (3%)
A.2.2.5 Tin	14,205	unwrought tin (82%); tin ores and concentrates (9%); tin waste and scrap (7%)
A.2.2.6 Gold, silver, platinum and other precious metal	80,824	waste and scrap of (containing) precious metals (>99%)
A.2.2.7 Bauxite and other aluminium	905,724	unwrought aluminium (42%); aluminium waste and scrap (28%); aluminium plate, sheets and strip (20%)
A.2.2.8 Uranium and thorium	470	radioactive chemical elements and radioactive isotopes and their compounds (88%)

A.2.2.9 Other n.e.c.	456,347	slag, ash and residues containing metals (66%); titanium ores and concentrates (21%)
A.2.3 Products mainly from metals	**7,391,484**	motor cars and vehicles for passenger transport (32%); structures and part of structure of iron and steel (5%); motor vehicles for transport of goods (5%)

*Table 5: The compostion of **import** including examples of flows per material subcategory, **non-metallic minerals**, Flanders, 2016. Only the top determining flows are metnioned in the list of examples, including their share in the total flow.*

Material category	Flow quantity (in tons)	Examples
A.3 Non-metallic minerals	**38,510,976**	
A.3.1 Marble, granite, sandstone, porphyry, basalt, other ornamental or building stone (excluding slate)	902,021	worked monumental or building stone, mosaic cubes of natural stone, artificially coloured granules, chippings and powder of natural stone (55%); setts, curb stones and flagstones of natural stone (25%); granite, porphyry, basalt, sandstone and other monumental or building stone (15%)
A.3.2 Chalk and dolomite	289,567	chalk (91%); dolomite (9%)
A.3.3 Slate	34,280	slate (100%)
A.3.4 Chemical and fertilizer minerals	4,535,359	nitrogenous mineral or chemical fertilisers (41%); potassic mineral or chemical fertilisers (25%); sulphur (12%); natural (aluminium calcium phosphates and phosphatic chalk (10%)
A.3.5 Salt	1,301,862	salt (100%)
A.3.6 Limestone and gypsum	1,085,328	gypsum (96%): limestone (4%)
A.3.7 Clays and kaolin	2,029,533	non-expanded clays (44%); ceramic building bricks, flooring blocks, support or filler tiles and the like (34%); roofing tiles, chimney pots and liners, cowls, architectural ornaments and ceramic constructional goods (9%); kaolin (6%)
A.3.8 Sand and gravel	17,020,749	natural sands of all kinds (80%); pebbles, gravel, broken or crushed stone (20%)
A.3.9 Other n.e.c.	826,494	slag and ash, kelp, ash and residues from the incineration of municipal waste (29%); granulated slag from the manufacture of iron and steel (20%); slag-wool, rock-wool and similar mineral wools, expanded clays, foamed slag and expanded mineral materials (14%); natural steatite (13%)
A.3.10 Excavated earthen materials (including soil), only if used	0	
A.3.11 Products mainly from non metallic minerals	10,485,782	cullet and other waste and scrap of glass (49%); cement (21%); articles of cement or concrete (12%)

*Table 6: The compostion of **import** including examples of flows per material subcategory, **fossil energy carriers**, Flanders, 2016. Only the top determining flows are metnioned in the list of examples, including their share in the total flow.*

Material category	Flow quantity (in tons)	Examples
A.4 Fossil energy materials/carriers	**126,044,302**	
A.4.1 Coal and other solid energy products, raw and processed	**4,974,304**	
A.4.1.1 Lignite (brown coal)	158,394	lignite (100%)
A.4.1.2 Hard coal	4,250,697	coal (100%)

A.4.1.3 Oil shale and tar sands	51	bitumen and asphalt (100%)
A.4.1.4 Peat	565,162	peat (100%)
A.4.2 Liquid and gaseous energy products, raw and processed	**104,718,787**	
A.4.2.1 Crude oil, condensate and natural gas liquids (NGL)	72,852,350	petroleum oils and oils obtained from bituminous minerals (non-crude, 50%); crude petroleum oils and oils obtained from bituminous minerals (44%)
A.4.2.2 Natural gas	30,988,808	petroleum gases and gaseous hydrocarbons (>99%)
A.4.2.3 Adjustment for residence principle: Fuel bunkered by resident units abroad	877,629	
A.4.2.3.1 Fuel for land transport	792,802	
A.4.2.3.2 Fuel for water transport	84,826	
A.4.2.3.3 Fuel for air transport	0	
A.4.3 Products mainly from fossil energy products	**16,351,211**	cyclic hydrocarbons (18%); acyclic hydrocarbons (14%); polymers of ethylene (9%); acyclic alcohols (9%); polymers of propylene (4%)

*Table 7: The compostion of **import** including examples of flows per material subcategory, **other products and waste imported for final treatment and disposal**, Flanders, 2016. Only the top determining flows are metnioned in the list of examples, including their share in the total flow.*

Material category	Flow quantity (in tons)	Examples
A.5 Other products	**9,860,474**	ammonia (13%); biodiesel (9%); carbonates and peroxocarbonates (6%): sodium hydroxide and potassium hydroxide (5%)
A.6 Waste imported for final treatment and disposal	**43,715**	residual products of the chemical or allied industries, municipal waste, sewage sludge and other waste not specified in A.1 to A.4 (96%)

*Table 8: The compostion of **export** including examples of flows per material subcategory, **biomass**, Flanders, 2016. Only the top determining flows are metnioned in the list of examples, including their share in the total flow.*

Material category	Flow quantity (in tons)	Examples
A.1 Biomass	**40,195,516**	
A.1.1 Crops, raw and processed	**14,914,023**	
A.1.1.1 Cereals, raw and processed	4,703,725	malt (24%); wheat and meslin (18%); bread, pastry, cakes, biscuits and other bakers' ware (14%); wheat and meslin flour (11%)
A.1.1.2 Roots, tubers, raw and processed	3,131,397	potatoes (44%)
A.1.1.3 Sugar crops, raw and processed	383,461	cane or beet sugar and chemically pure sucrose (65%): molasses resulting from the extraction or refining of sugar (35%)
A.1.1.4 Pulses, raw and processed	40,419	dried leguminous vegetables (97%)
A.1.1.5 Nuts, raw and processed	34,218	prepared or preserved nuts (75%); fresh or dried nuts (22%); coconuts, Brazil and cashew nets (3%)

A.1.1.6 Oil-bearing crops, raw and processed	447,606	rape or colza seeds (32%); linseed (31%); soya beans (29%)
A.1.1.7 Vegetables, raw and processed	2,993,951	frozen vegetables (51%); tomatoes (12%); carrots, turnips, salad beetroot, salsify, celeriac, radishes and similar edible roots (6%), alliaceous vegetables (4%)
A.1.1.8 Fruits, raw and processed	2,121,619	apples (30%); fruit juices (28%); bananas (20%)
A.1.1.9 Fibres, raw and processed	167,951	flax (89%); jute and other textile bast fibres (5%): cotton waste (3%)
A.1.1.10 Other crops n.e.c., raw and processed	889,675	chocolate (76%); coffee (8%); cocoa beans (6%)
A.1.2 Crop residues and fodder crops	**30,149**	
A.1.2.1 Crop residues (used), raw and processed	18,998	
A.1.2.1.1 Straw	18,998	cereal straw and husks (100%)
A.1.2.1.2 Other crop residues	0	
A.1.2.2 Fodder crops	11,151	
A.1.2.2.1 Fodder crops	11,151	swedes, mangolds, fodder roots, hay, Lucerne, clover, sainfoin, forage kale, lupines, vetches and similar forage products (100%)
A.1.3 Wood and wood products	**2,493,198**	
A.1.3.1 Timber, raw and processed	2,472,060	particle board, OSB and similar board (39%); fibreboard of wood or other ligneous materials (18%); packing cases, boxes, crates, drums and similar packings of wood (16%); fuel wood (13%)
A.1.3.2 Wood fuel and other extraction, raw and processed	21,138	fuel wood (71%); natural rubber, balata, gutta-percha, guayule, chicle and similar natural gums (20%)
A.1.4 Fish capture and other aquatic animals and plants, raw and processed	**114,411**	
A.1.4.1 Fish capture	69,530	fresh or chilled fish, excluding fillets (45%), fish fillets and other fish meat (30%); prepared or preserved fish (22%)
A.1.4.2 All other aquatic animals and plants	44,881	crustaceans (53%); prepared or preserved crustaceans, molluscs and other aquatic invertebrates (27%); molluscs (19%)
A.1.5 Live animals other than in 1.4., and animal products	**5,396,459**	
A.1.5.1 Live animals other than in 1.4.	533,323	swine (45%); poultry (34%); bovine animals (19%)
A.1.5.2 Meat and meat preparations	2,122,229	meat of swine (42%); meat and edible offal of poultry (26%);
A.1.5.3 Dairy products, birds eggs, and honey	2,142,794	milk and cream
A.1.5.4 Other products from animals (animal fibres, skins, furs, leather etA.)	598,113	milk and cream (not concentrated or not containing added sugar, 26%); buttermilk, curdled milk and cream, yogurt, kephir and other fermented or acidified milk and cream (16%); milk and cream (concentrated or containing added sugar, 13%); cheese and curd (12%); birds' eggs (7%)

A.1.6 Products mainly from biomass	**17,247,275**	preparations of a kind used in animal feeding (13%); beer made from malt (10%); animal or vegetable fertilisers, fertilisers produced from mixing or chemical treatment of animal of animal or vegetable products (7%): recovered paper of paperboard (7%)

*Table 9: The compostion of **export** including examples of flows per material subcategory, **metal ores**, Flanders, 2016. Only the top determining flows are metnioned in the list of examples, including their share in the total flow.*

Material category	Flow quantity (in tons)	Examples
A.2 Metal ores (gross ore)	**19,150,860**	
A.2.1 Iron ores and concentrates, iron and steel, raw and processed	**10,645,641**	flat-rolled products of iron and steel or non-alloy steel (46%); ferrous waste and scrap (21%)
A.2.2 Non-ferrous metal ores and concentrates, raw and processed	**1,744,366**	
A.2.2.1 Copper	383,742	copper wire (58%); copper waste and scrap (19%); unrefined copper, copper anodes for electrolytic refining (8%); copper mattes, cement copper (5%)
A.2.2.2 Nickel	13,279	nickel waste and scrap (63%); unwrought nickel (23%); nickel bars, rods, profiles and wire (7%)
A.2.2.3 Lead	182,143	unwrought lead (82%); lead ores and concentrates (13%); lead waste and scrap (5%)
A.2.2.4 Zinc	309,380	unwrought zinc (57%); zinc ores and concentrates (35%)
A.2.2.5 Tin	13,105	unwrought tin (92%); tin waste and scrap (7%)
A.2.2.6 Gold, silver, platinum and other precious metal	108	base metals, silver and gold, clad with platinum (54%); waste and scrap of precious metals or of metal clad with precious metals and waste and scrap containing precious metals (28%); platinum (16%)
A.2.2.7 Bauxite and other aluminium	716,936	aluminium plates (33%); aluminium waste and scrap (28%); aluminium bars, rods and profiles (17%); unwrought aluminium (14%)
A.2.2.8 Uranium and thorium	116	radioactive chemical elements and radioactive isotopes and their compounds (67%); compounds of rare-earth metals (28%)
A.2.2.9 Other n.e.c.	125,557	slag, ash and residues containing metals (84%); titanium ores and concentrates (10%)
A.2.3 Products mainly from metals	6,760,853	motor cars and vehicles for passenger transport (28%); structures and parts of structure of iron and steel (12%); parts and accessories of motor vehicles (9%); motor vehicles for the transport of goods (6%); tractors (4%)

*Table 10: The compostion of **export** including examples of flows per material subcategory, **non-metallic minerals**, Flanders, 2016. Only the top determining flows are metnioned in the list of examples, including their share in the total flow.*

Material category	Flow quantity (in tons)	Examples
A.3 Non-metallic minerals	**28,697,591**	

A.3.1 Marble, granite, sandstone, porphyry, basalt, other ornamental or building stone (excluding slate)	204,079	worked monumental or building stone, mosaic cubes of natural stone, artificially coloured granules, chippings and powder of natural stone (37%); granite, porphyry, basalt, sandstone and other monumental or building stone (36%); setts, curb stones and flagstones of natural stone (24%)
A.3.2 Chalk and dolomite	33,012	dolomite (81%); chalk (19%);
A.3.3 Slate	1,587	slate (100%)
A.3.4 Chemical and fertilizer minerals	5,905,147	nitrogenous mineral or chemical fertilisers (68%); mineral or chemical fertilisers containing two or three of the fertilising elements nitrogen, phosphorus and potassium (28%)
A.3.5 Salt	106,046	salt (100%)
A.3.6 Limestone and gypsum	49,189	gypsum (93%): limestone (7%)
A.3.7 Clays and kaolin	3,020,831	ceramic building bricks, flooring blocks, support or filler tiles and the like (89%)
A.3.8 Sand and gravel	4,523,784	natural sands of all kinds (68%); pebbles, gravel, broken or crushed stone (32%)
A.3.9 Other n.e.c.	608,892	slag-wool, rock-wool and similar mineral wools, expanded clays, foamed slag and expanded mineral materials (70%); natural steatite (12%); slag, dross, scalings and other waste from the manufacture of iron or steel (8%)
A.3.10 Excavated earthen materials (including soil), only if used	0	
A.3.11 Products mainly from non metallic minerals	14,245,023	cullet and other waste and scrap of glass (74%); articles of cement or concrete (14%); cement (4%)

*Table 11: The compostion of **export** including examples of flows per material subcategory, **fossil energy carriers**, Flanders, 2016. Only the top determining flows are metnioned in the list of examples, including their share in the total flow.*

Material category	Flow quantity (in tons)	Examples
A.4 Fossil energy materials/carriers	**67,787,451**	
A.4.1 Coal and other solid energy products, raw and processed	**775,228**	
A.4.1.1 Lignite (brown coal)	110,112	lignite (100%)
A.4.1.2 Hard coal	337,321	coal (100%)
A.4.1.3 Oil shale and tar sands	19,359	bitumen and asphalt (100%)
A.4.1.4 Peat	308,436	peat (100%)
A.4.2 Liquid and gaseous energy products, raw and processed	**49,518,142**	
A.4.2.1 Crude oil, condensate and natural gas liquids (NGL)	43,602,356	petroleum oils and oils obtained from bituminous minerals (non-crude, 90%); oils and other products of the distillation of high temperature coal tar (5%)
A.4.2.2 Natural gas	4,654,496	petroleum gases and gaseous hydrocarbons (100%)
A.4.2.3 Adjustment for residence principle: Fuel bunkered by resident units abroad	1,261,290	
A.4.2.3.1 Fuel for land transport	1,219,137	

A.4.2.3.2 Fuel for water transport	42,153	
A.4.2.3.3 Fuel for air transport	0	
A.4.3 Products mainly from fossil energy products	**17,494,081**	polymers of ethylene (15%); saturated acyclic monocarboxylic acids and peroxyacids (7%); polymers of propylene (6%)

*Table 12: The compostion of **export** including examples of flows per material subcategory, **other products and waste exported for final treatment and disposal**, Flanders, 2016. Only the top determining flows are metnioned in the list of examples, including their share in the total flow.*

Material category	Flow quantity (in tons)	Examples
A.5 Other products	**13,080,619**	prepared binders for foundry moulds or cores, chemical products and preparations of the chemical or allied industries (9%); sodium hydroxide, potassium hydroxide (9%); biodiesel (9%); organic surface-active agents, washing and cleaning preperations (6%)
A.6 Waste exported for final treatment and disposal	**104,355**	residual products of the chemical or allied industries, municipal waste, sewage sludge and other waste not specified in A.1 to A.4 (98%)

The main source for the physical imports and exports in Flanders is the trade database[12] from the National Bank of Belgium. A drawback is that it provides only trade statistics using the national concept, while EW-MFA should be compiled using the residential concept[13]. Therefore, one needs to adjust the data to the residential principle. This adjustment concerns mainly the import and export of transport fuels: transport fuel bunkered by resident units abroad need to be added to the physical imports of fuel, while transport fuel bunkered by non-resident units on the territory need to be added to the physical exports. The deliveries of fuels to vessels and aircrafts of non-resident operators at domestic harbours or airports are already included in the exports of the international trade databases of goods and services. The adjustments for Flanders to the residential principle are a copy from the national (Belgian) economy-wide material flow accounts[14].

The trade statistics from the NBB provide the Flemish trade with non-Belgian trade partners. The trade with Brussels Capital Region and the Walloon Region is added to the trade data using the interregional input-output table for the year 2010. The international trade per product is augmented for interregional trade via the 2010-share of interregional trade in the interregional input-output model.

The trade statistics report imports and exports of goods both in monetary and physical units. The standard physical unit is 100 kilograms measured at the point in time when a good crosses an administrative border. For some commodities, data are reported in other physical units such

[12] https://www.nbb.be/nl/statistieken/buitenlandse-handel

[13] For many activities, the difference between the two principles will be limited, but this is not the case for activities related to tourism and transport. The economic activity of foreign transport companies in Flanders, as well as the movements of foreign tourists in Flanders, are not covered by the residential principle. However, it does include the economic activity of transporting firms from Flanders abroad..

[14] https://www.plan.be/databases/database_det.php?lang=nl&ID=44

as length, area, volume, numeric units or kilowatt-hours. In these cases, they need to be converted into kilograms. Eurostat provides these conversion factors.

The 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 tons by the import and export vectors of the hybrid input-output tables (IOT). Those coefficients measure cumulated raw material requirement in tons RME per unit of product. The denominator of the different products is measured in different (hybrid) units (e.g. EUR, tons, TOE). EUROSTAT provides in the 2018 version of the handbook RME-coefficients in timeseries 2008-2016. **In this report, we use the same timeseries, and extend to 2018 via the use of the 2016-coefficients for the years 2017 and 2018.**

To estimate the RMC, each import and export flow is expressed in its RME. The RMC is the main indicator provided by the RME-accounting. The RME-coefficients help to convert a trade flow into the quantity of raw materials that has been (direct and indirect) needed during the production process of that trade flow. The RMEs are derived by a specific IOT-based calculation which is donated as an adapted domestic technology assumption input-output model. The method combines annual EU-level RME-coefficients with country-level trade vectors. The calculation method of trade in RMEs makes use of these RME-coefficients together with the Flemish international trade statistics, which were augmented to include interregional trade. Following the Eurostat handbook, specific corrections and estimations are applied for energy-related products.

Flemish import and export statistics, including trade with EU and non-EU partners, are available at a high level of detail for the period 2002-2018. For example, in 2015 there are approximately 9,000 import flows described in the trade database. This database is supplemented with data on trade in services[15] from the Belgian interregional input-output model (share of the year 2010 is extrapolated over the 2002-2018 period) and supplement with specific data from the Belgian and European input-output model (e.g. on uranium use). The conversion to their RME is performed based on only 182 coefficients: the coefficients are not provided at the level of individual products, but only at the level of aggregated product groups (i.e. each trade flow is allocated to one of the 182 product groups). Although Eurostat also provides the conversion of CN-classification to the RME-coefficients (via CPA-codes), this results in a lower reliability of the indicator RMC due to this aggregation step compared to DMC which is determined at the disaggregated data level (for example, 9,000 import flows in 2015).

Each of the 182 coefficients is given using a specific unit. In general, trade flows of goods are converted using a conversion factor expresses in tons RME per ton of trade product, while trade flows of services are converted using a conversion factor expressed in tons RME per euro of trade product. Trade flows of energy related products (e.g. electricity, natural gas) are converted using a conversion factor expressed in tons RME per TOE of trade product.

The RMC-compilation unavoidably includes many over- and underestimations. Therefore, the RMI and RMC indicator trends are expressed using the moving average approach. This method calculates the average of the estimation for the current year and the estimation of the previous

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[15] The physical trade (import, export, DMC) includes no services (as the trade flow is immaterial). However, in its conversion in RME this trade flow includes indirect material uses (e.g. energy use, ICT, etc.). Therefore, the trade in services is included to estimate the trade expressed in RME's.

2 years. The reason for using this method is to put emphasis on the trend, and not on year to year fluctuations in the data or conversion factors.

2.2 Domestic extraction used

The DEU in Flanders fluctuates and slightly decreases from 53 million tons in 2002 to 45 million tons in 2018, which is 8.8 to 7.1 tons per capita. The highest DEU reached is 57 million tons in 2012, which approximates 9.0 tons per capita. Ca. 65% of the DEU is non-metallic minerals and ca. 35% is biomass. Metal ores and fossil energy carriers are not extracted in Flanders. A detailed composition of the 2016 DEU is provided in Table 1 and Table 2.

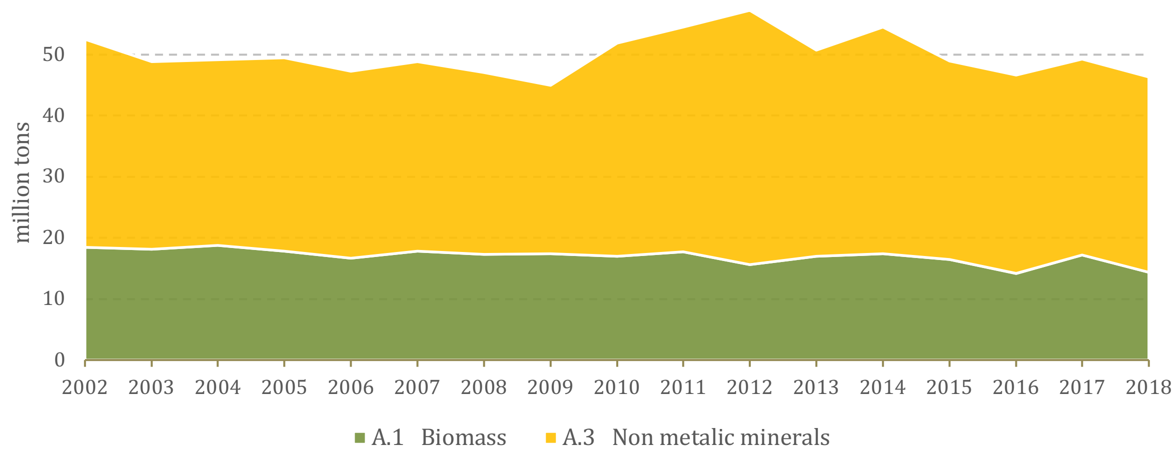

Figure 2: Domestic extraction used in Flanders per material category, 2002-2018.

The domestic extraction used of biomass is dominated by the cultivation of crops, crop residues and fodder crops. The data is illustrated in Figure 3. In 2018, 52% of the DEU of biomass are crop residues and fodder crops. Crop residues are counted only if they are subjected to further economic use. A large fraction of crop residues is used as bedding material in livestock husbandry, but crop residues may also be used as feed, for energy consumption, or as industrial raw material. 45% of the DEU of biomass is raw and processed crops (i.e. biomass mainly for human feeding but requiring further processing). The shares of wood (A.1.3) and fish capture (A.1.4) are low, 2% and 0.2%, respectively.

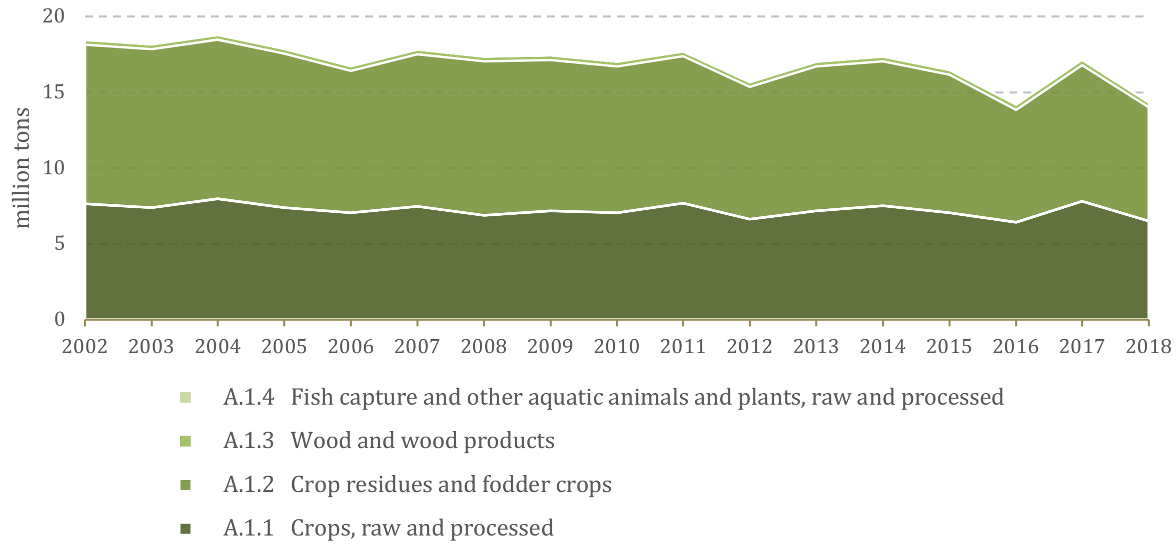

Figure 3: Domestic extraction used of biomass in Flanders, 2002-2018.

The non-metallic minerals only include excavated earthen materials (A.3.10), sand and gravel (A.3.8) and clays and kaolin (A.3.7). Excavated earthen material (including soil) is, in physical terms, a relevant category within the DEU. The Eurostat manual provides this category, but only as an optional category as there are too many countries in the EU which do not provide data for this variable. However, in Flanders is (part of) the excavated and dredged material used in the economy as an alternative raw material (see for example the Annual Report 2013 'monitoringsysteem duurzaam oppervlaktedelfstoffenbeleid' by LNE, OVAM and VITO) these flows are included in the 'A.3.8 sand and gravel' category. A smaller fraction is left in the excavated earthen material category itself. This inclusion of this data is different compared to the allocation in the previous study of 2016 resulting in a higher DEU for Flanders.

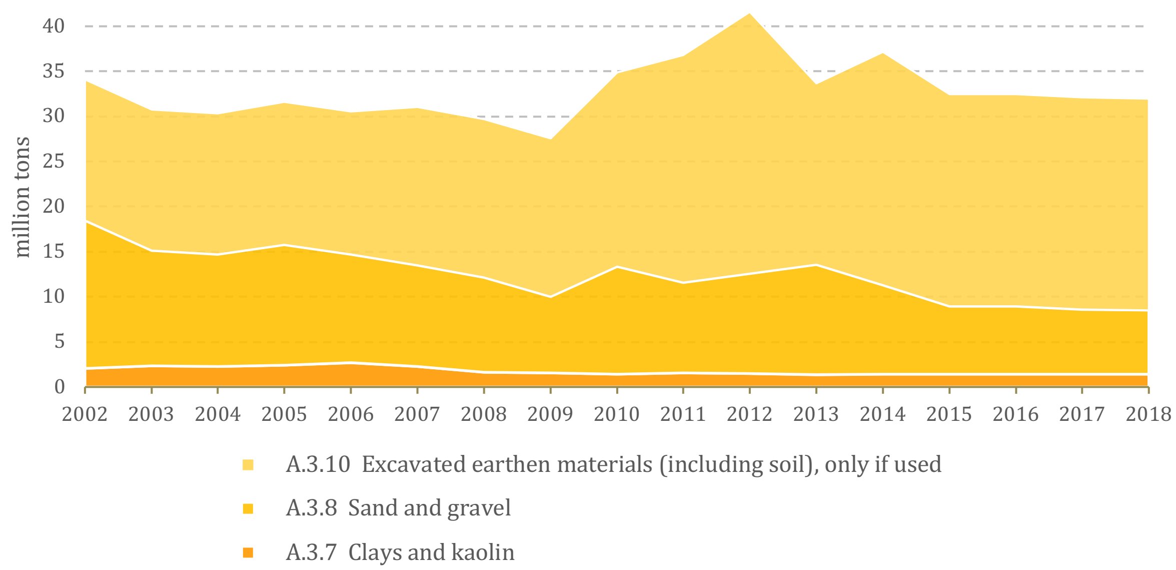

Figure 4: Domestic extraction used of non-metallic minerals in Flanders, 2002-2018.

2.3 Import and export

The material groups used to define import and export flows are equal to those used in defining DEU, except the addition of material categories A.5 and A.6. These extra categories define other products and waste imported and exported for final treatment and disposal. Especially for import and export the allocation of traded goods to material categories should be considered with care, as traded products are often composed heterogeneous. Although they can be composed of different materials, in this classification they are assigned to their main component (i.e. the highest weight share). This has no impact on total trade flow, but it might affect the internal relations of material groups in import and export. It is assumed that the potential error is larger within the four main material categories (biomass, non-metallic minerals, metal ores and fossil energy categories) than between these categories. For example, products can be composed of different minerals (e.g. glass) hampering the allocation to a subcategory, but it is correctly allocated to the material category of non-metallic minerals.

Product flows within category A.5 are, for example, starches from milling, chemicals like iodides fluorine, bromine and sulphur, vitamins, blood, vaccines, medication, certain fabrics and textile products, instruments like thermometers, watches, music instruments, toys, etc. Products within category A.6 are, for example, municipal waste, sewage sludge, clinical waste, waste organic solvents, etc.

As an example, the detailed composition of the import and export in 2016 is provided in Table 3 to Table 12. Based on the trade statistics, the interpretation is limited to the quantities of import and export. The database provides no details on the purpose of the import (e.g. for local consumption). To get this information, a value chain analysis is required, for example based on input-output analysis. Such an analysis is not part of this study.

2.3.1 Import

The Flemish import varies between 229 and 295 million tons. This corresponds to 37 and 45 tons per capita in the period 2002-2018. The material category fossil energy carriers is the largest category (by weight) in imports with a share of 46%, followed by biomass with a share of 25%. Metal ores and non-metallic minerals have a lower and comparable share of 12% and 13%, respectively. The share in total weight of imported goods attributed to the material categories A.5 and A.6 is low. The material category other products (A.5) has a share of 4%, and waste imported for final treatment and disposal has a share lower than 1%.

The total weight of the Flemish import is fairly stable in the 2002-2016 period, showing a small increasing trend. The 2017-2018 data show a sharp increase in the total weight of imports. Looking at a more detailed level of the data, shows this is (partly) due to an increase in the categories of wood and wood products, products mainly from metals and crude oil and natural gas liquids. Also, other material categories show smaller increases which accumulate to the perceived 2017-2018 increase. Looking at the monetary counterpart of the trade data, these increases are not always perceived, or not at the same level. An option could be to correct the weight of all import and export flows individually based on their monetary trend. Within the scope of this study, it was not possible to review all 9,000 trade flows individually, so, no corrections are applied to the input data or conversion factors. Also, based on our experience from the previous study, we see updates are more frequent on trade data from the more recent years. Therefore, at this moment we cannot draw any conclusions from the 2017-2018 increase.

Data corrections in the input data or conversion factors might (partly) rule out or even strengthen this increase in the future.

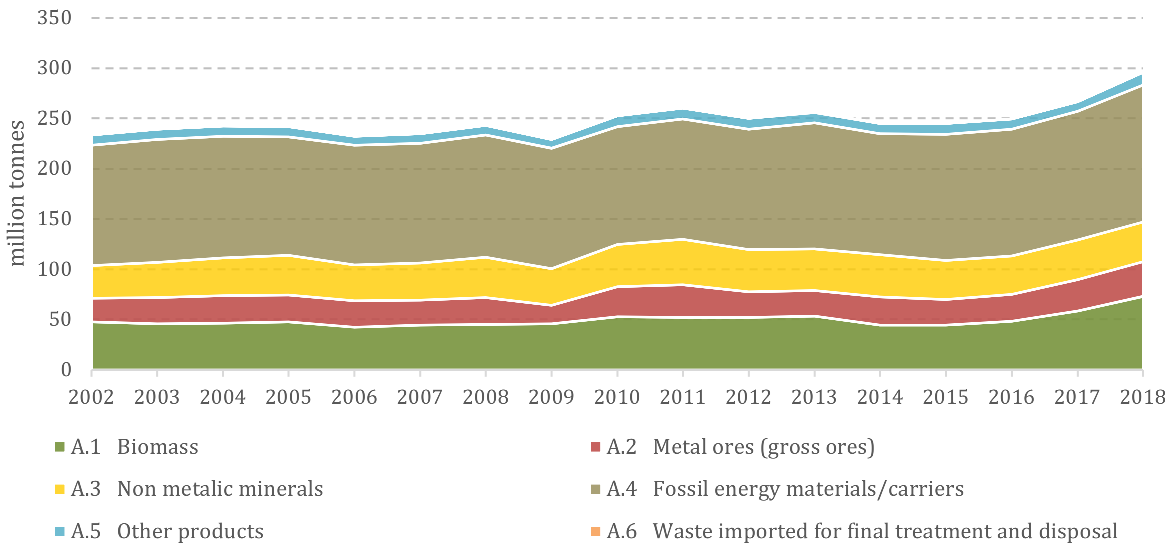

Figure 5: Import in Flanders per material category, 2002-2018.

The import of goods in the material category of biomass are mainly assigned to crops (A.1.1), products mainly from biomass (A.1.6) and wood products (A.1.3), with a share of 32%, 30% and 27%, respectively. The data is visualised in Figure 6. Import of goods in the material category 'products mainly from biomass' (A.1.6) are all kind of seeds and flour thereof. Live animals (A.1.5) has a stable share of 10% in the total biomass material category.

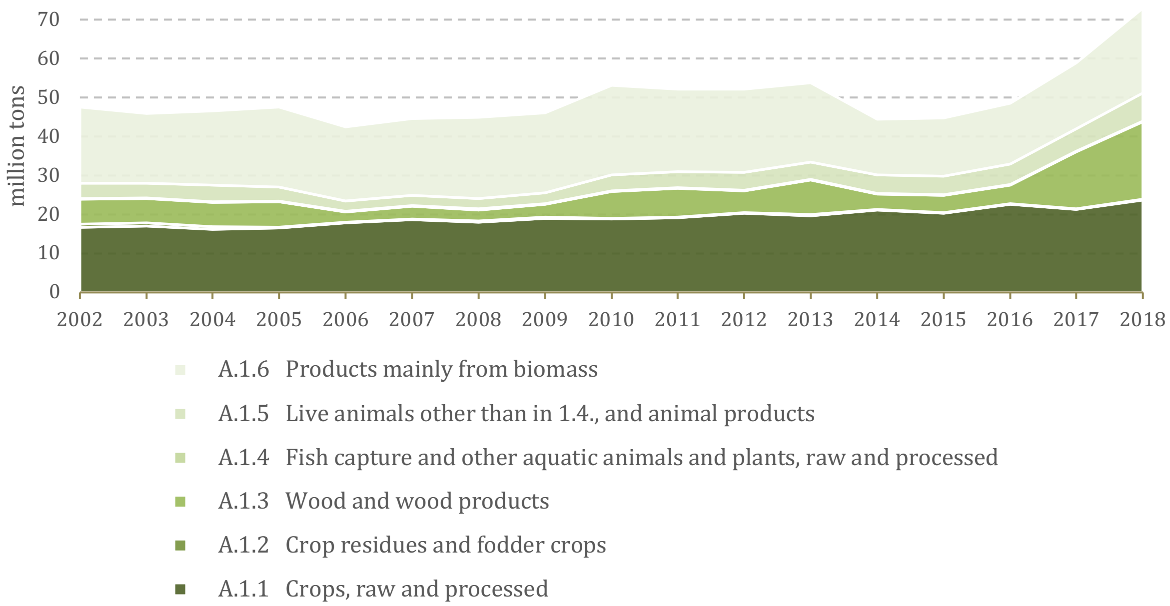

Figure 6: Import of goods assigned to the biomass material category, Flanders, 2002-2018.

The metal material category is named 'metal ores'. The metal containing materials extracted in metal mining is a composite material including metals and other non-metal material. It is the same run-of-mine concept that is applied here in comparison to the material category non-metallic minerals. It is the amount of raw mined metal containing material as it is delivered by the mine cars, skips, ore conveyors and prior to treatment of any sort. Although the gross ore run-of-mine is a material conglomerate, it excludes any non-metal-containing-material that has been (re-)moved to access the metal containing material layers. In the context of import and export, the weight of traded goods is used.

The import of goods in the material category of metal ores (see Figure 7) is dominated by imports of iron ores and concentrates, iron and steel, raw and processed (A.2.1). In 2018, this material category has a share of 50%. 41% are imported goods which cannot be assigned to a single metal material, meaning they are assigned to the products mainly from metals category (A.2.3; e.g. vehicles, containers and printing machinery). The division of the non-ferrous metals (A.2.2) is shown in Figure 8. In 2018, several metals determine this non-ferrous metal group: bauxite and other aluminium (a share of 31%), copper (23%) and zinc (19%).

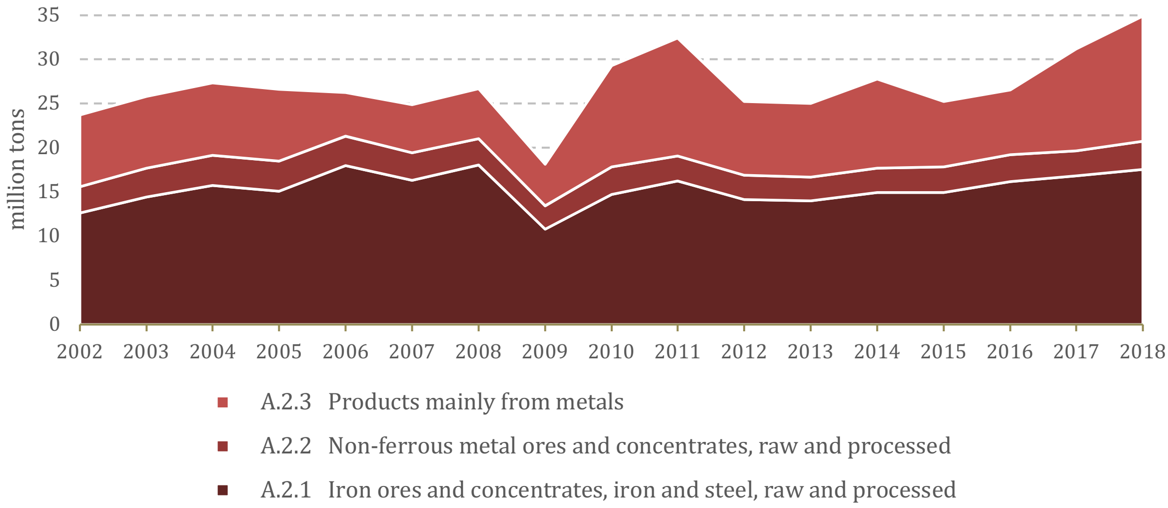

Figure 7: Import of goods assigned to the metal ores material category, Flanders, 2002-2018.

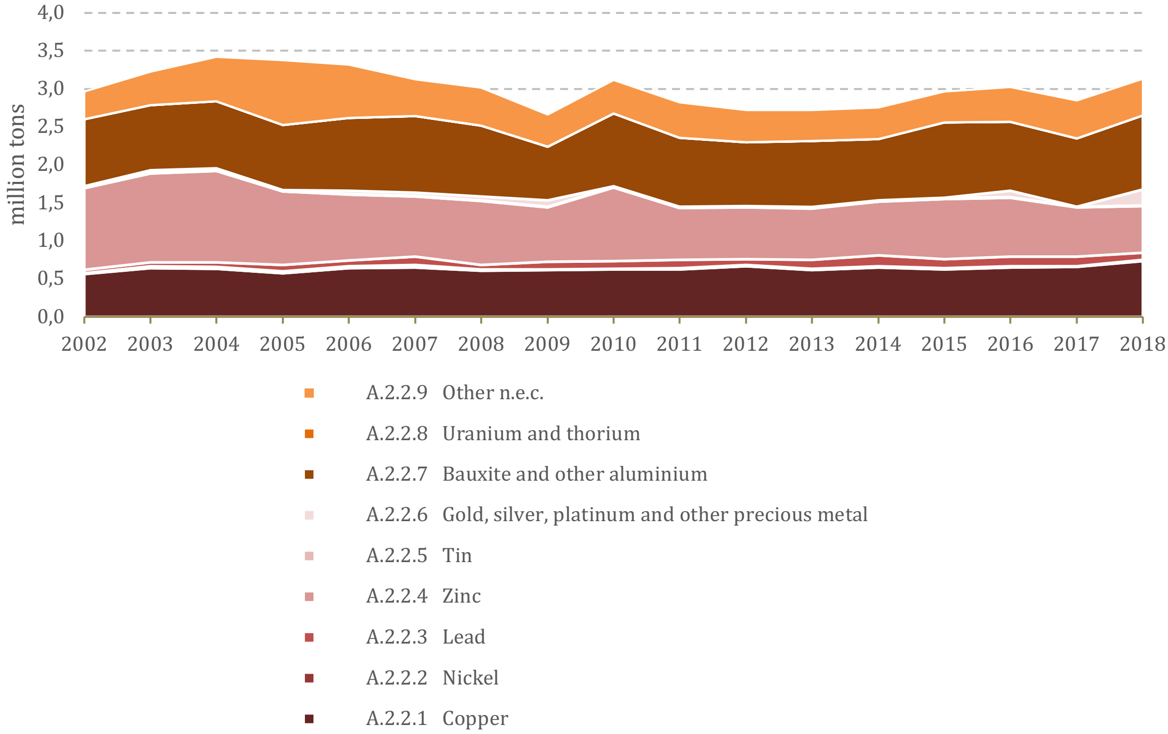

Figure 8: Import of goods assigned to the non-ferrous metal ores and concentrates, raw and processed (A.2.2) material category, Flanders, 2002-2018.

The import of goods in the material category of non-metallic minerals (see Figure 9) are mainly sand and gravel (A.3.8), products mainly from non-metallic minerals (A.3.11), chemical and fertilizer minerals (A.3.4) and clays and kaolin (A.3.8), with a share of 43%, 24%, 13% and 8%, respectively. Import of excavated earthen materials (A.3.10) is excluded from the figures, as its import quantity is zero in the period 2002-2018. Import of goods in the material category 'products mainly from non-metallic minerals' (A.3.11) are, for example, all kind of cements, construction elements from cement, concrete or artificial stone, goods fabricated from ceramics and glass products.

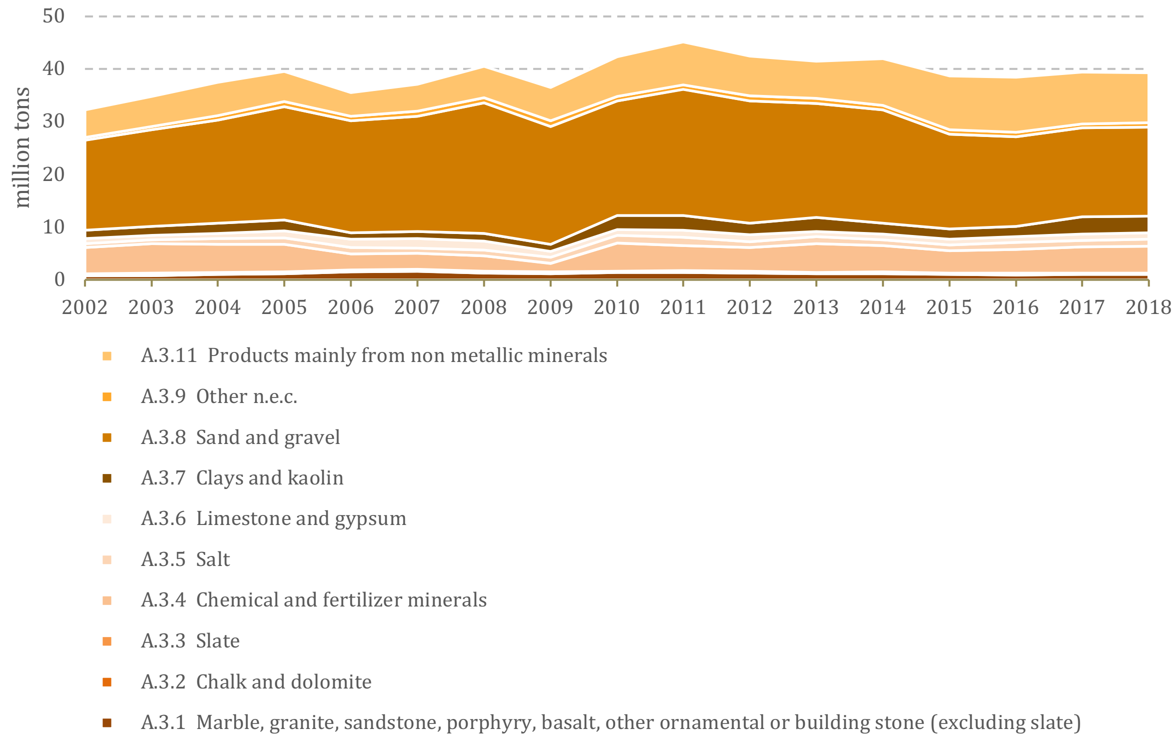

Figure 9: Import of goods assigned to the material category non-metallic minerals, Flanders, 2002-2018.

The import of goods in the material category of fossil energy carriers (see Figure 10) are liquid and gaseous energy products (A.4.2), products mainly from fossil energy products (A.4.3, e.g. organic chemicals like ethylene and benzene) and coal and other solid energy products (A.4.1). In 2018, 82% are liquid and gaseous energy products, followed by products mainly from fossil energy products (15%) and coal and other solid energy products (3%). The import of liquid and gaseous energy products consists out of the import of crude oil, condensate and natural gas liquids (NGL) (72%) and import of natural gas (28%). The weight of the import of fossil energy carriers is fairly stable in the period 2002-2018, although from 2013 onwards a small increasing trend is perceived.

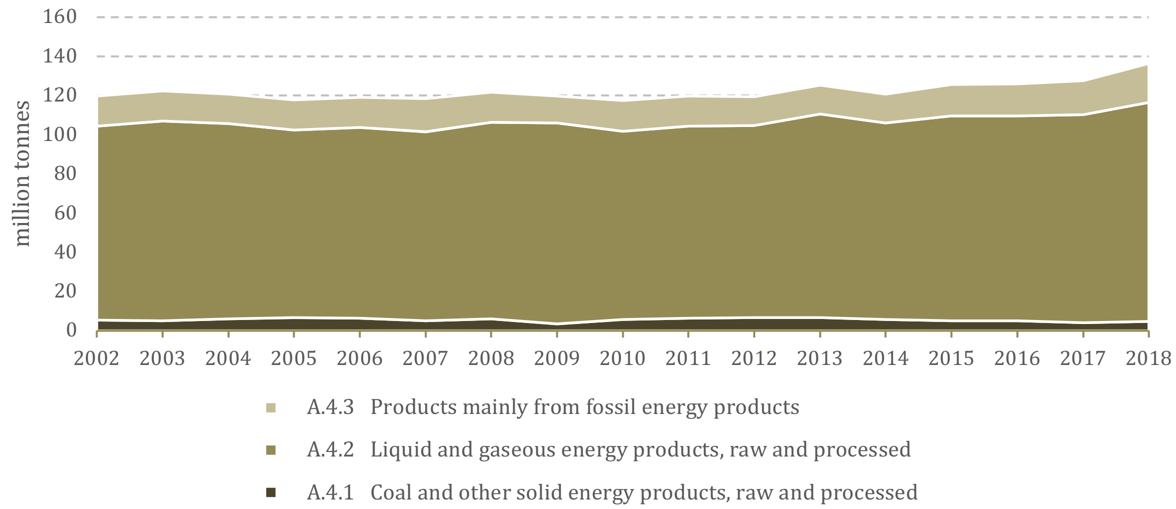

Figure 10: Import of goods assigned to the fossil energy carriers material category, Flanders 2002-2018.

2.3.2 Export

The Flemish export varies between 134 and 210 million tons. This corresponds to 22 and 32 tons per capita in the period 2002-2018. This is considerably lower than the weight of the imported goods, meaning Flanders has a negative trade balance (based on weight). The fossil energy carriers are the main category (by weight) in exports with a share of 38%, followed by biomass with a share of 28%. Metal ores and non-metallic minerals have a lower and comparable share of 12% and 16%, respectively. The material category other products (A.5) has a share of 7%, and waste exported[16] for final treatment and disposal has a share lower than 1%.

Comparable to the import (see Figure 5), the weight of export is stable in the 2002-2016 period and showing a sharp increase in the 2017-2018 period. Again, we cannot draw any conclusions from the 2017-2018 increase. Data corrections in the input data or conversion factors might (partly) rule out this increase in the future.

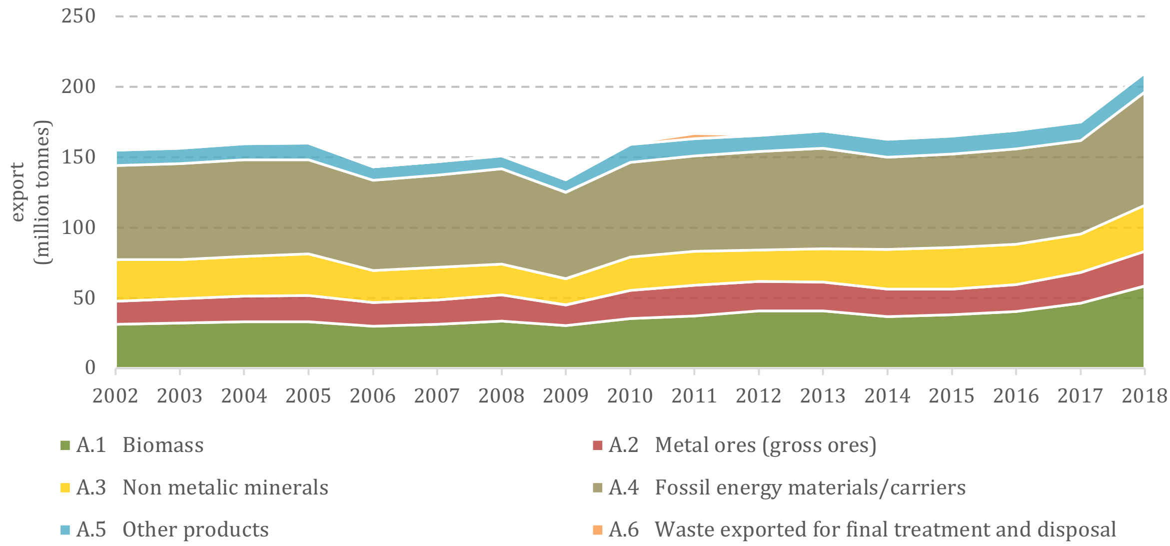

Figure 11: Export in Flanders per material category, 2014-2018.

The export of goods in the material category of biomass are mainly assigned to products mainly from biomass (A.1.6), crops (A.1.1), wood products (A.1.3) and live animals (A.1.5), with a share of 35%, 29%, 22% and 14%, respectively. The data is visualised in Figure 12.

The mass of imported goods assigned to the biomass material category is higher compared to the export thereof. The difference is fairly stable and ranges between 7 and 18 million tons or 1.0 and 2.8 tons per capita in the 2002-2018 period.

[16] The trade flows are only included in case at least one residential company is included. Transit is excluded.

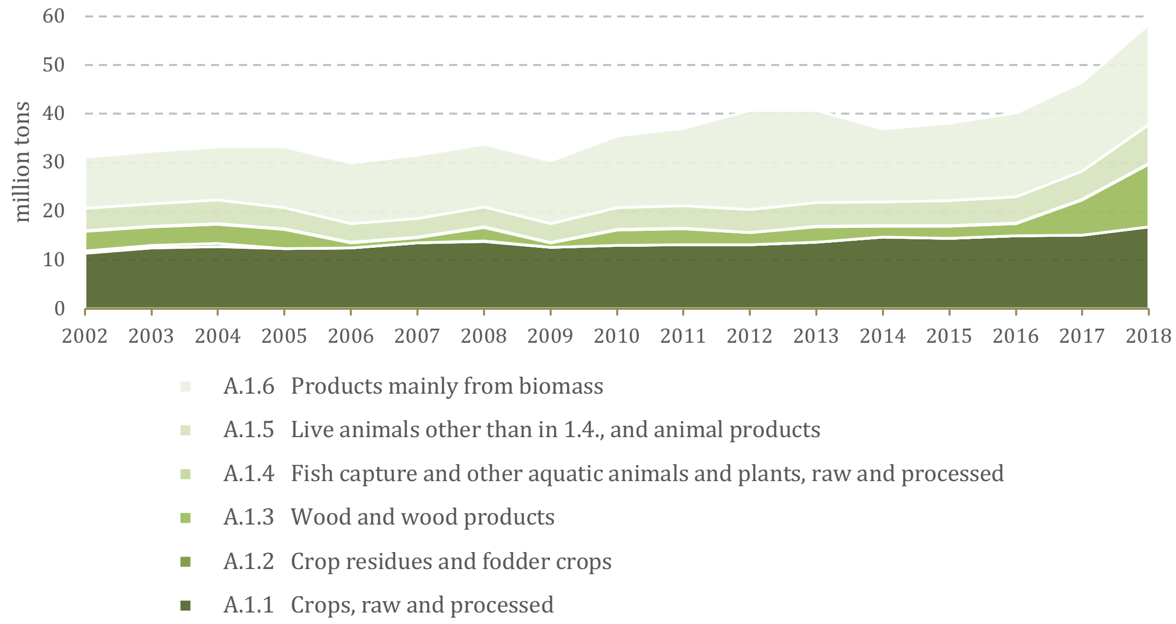

Figure 12: Export of goods assigned to the biomass material category, Flanders, 2002-2018.

The export of goods in the material category of metal ores (see Figure 13) is dominated by export of iron ores and concentrates, iron and steel, raw and processed (A.2.1). In 2018, this material category has a share of 49%. 42% are exported goods which cannot be assigned to a single metal material, meaning they are assigned to the products mainly from metals category (A.2.3). The division of the non-ferrous metals (A.2.2) is shown in Figure 14. In 2018, several metals determine this non-ferrous metal group: bauxite and other aluminium (a share of 34%), copper (27%), zinc (22%) and lead (7%).

The mass of imported goods assigned to the metal ores material category is higher compared to the export thereof. The difference is fairly stable and ranges between 3 and 10 million tons or 0.5 and 1.6 tons per capita in the 2002-2018 period.

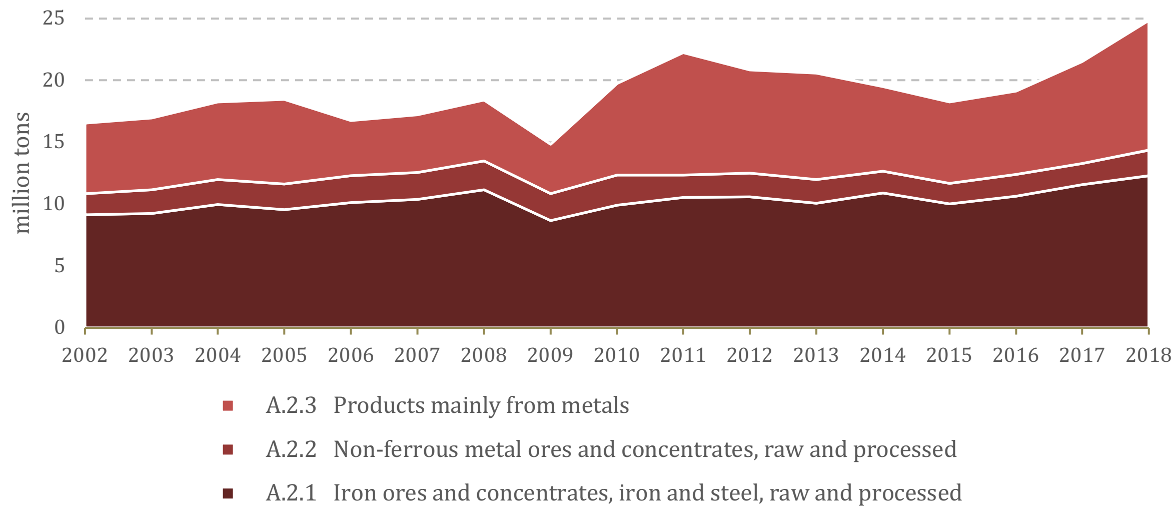

Figure 13: Export of goods assigned to the metal ores material category, Flanders 2002-2018.

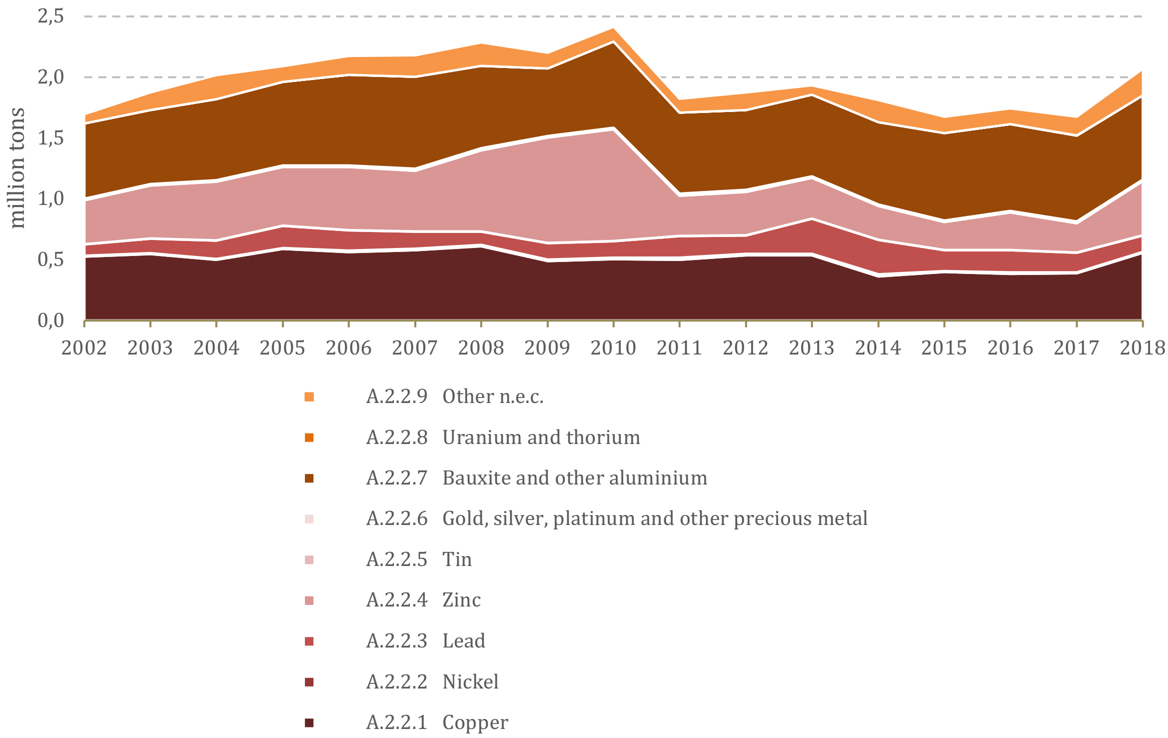

Figure 14: Export of goods assigned to the non-ferrous metal ores and concentrates, raw and processed (A.2.2) material category, Flanders, 2002-2018.

The export of goods in the material category of non-metallic minerals (see Figure 15) are products mainly from non-metallic minerals (A.3.11), chemical and fertilizer minerals (A.3.4), sand and gravel (A.3.7) and clays and kaolin (A.3.8), with a share of 44%, 21%, 19% and 12%, respectively. Export of excavated earthen materials (A.3.10) is excluded from the figures, as its import quantity is zero in the period 2002-2018.

The mass of imported goods assigned to the non-metallic mineral material category is higher compared to the export thereof. The difference, however, is less stable. It ranges between 3 and 21 million tons or 0.5 and 3.4 tons per capita in the 2002-2018 period.

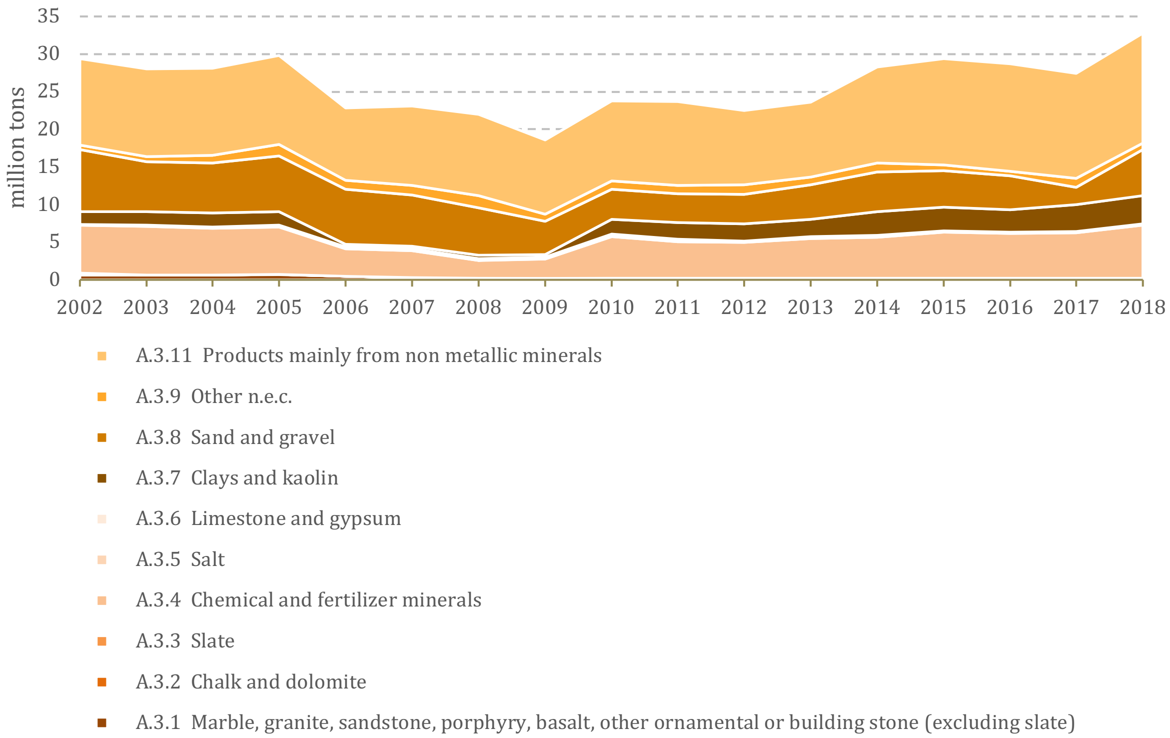

Figure 15: Export of goods assigned to the non-metallic minerals material category, Flanders, 2002-2018.

The export of goods in the material category of fossil energy carriers (see Figure 16) are liquid and gaseous energy products (A.4.2) and products mainly from fossil energy products (A.4.3). In 2018, 72% are liquid and gaseous energy products, followed by products mainly from fossil energy products (27%). The export of liquid and gaseous energy products consists mainly out of the export of crude oil, condensate and natural gas liquids (NGL) (85%).

The mass of imported goods assigned to the fossil energy carriers material category is higher compared to the export thereof. The difference is mainly increasing between 2002-2018. It ranges between 49 and 61 million tons or 7.8 and 9.4 tons per capita in the 2002-2018 period.

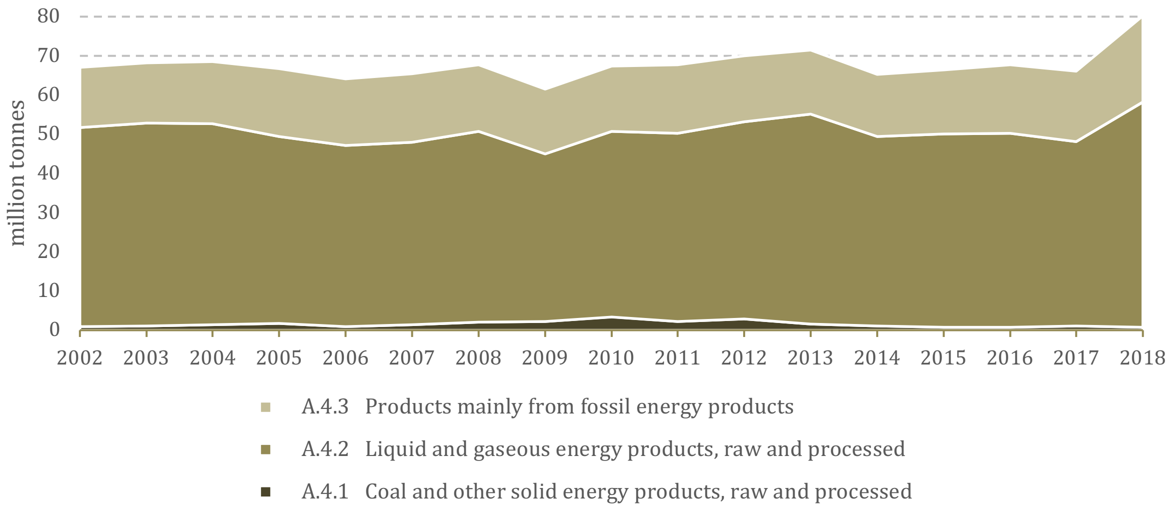

Figure 16: Export of goods assigned to the fossil energy carriers material category, Flanders 2002-2018.

2.3.3 Stage of manufacturing

The manufacturing stage of traded goods in import and export varies widely (see Table 13). Traded goods can be grouped according to the following three levels of manufacturing:

- **Raw products (SM_RAW)**: products produced by primary industries such as agriculture, forestry, fishing and mining;
- **Semi-finished products (SM_SFIN)**: products which are further processed raw products but do not yet constitute finished products; they obviously need to be further processed; and
- **Finished products (SM_FIN)**: products which are finalised in the sense that they are not further processed or transformed.

Eurostat considers the stage of manufacturing to be useful to assess the resource requirements (in terms of domestic material extraction needed) behind the traded product flows. The lower the stage of manufacturing the closer is the product's weight to the domestic material extractions required for its manufacture. Insofar the results of the level of manufacturing can serve as a first approximation of the RMEs.

The import is dominated by products with a lower level of manufacturing. The average share in the period 2002-2018 is 45.5%. The share of imported products with a high level of manufacturing is, on average, 32.8%. The share of imported products which are semi-finished have a share of, on average, 21.7%. The level of manufacturing of exported products is dominated (on average a share of 61.7%) by the products with a high level of manufacturing, followed by the export of semi-finished products (26.0%) and products with a low level of manufacturing (12.3%). The division in raw products, semi-finished products and finished products, both for import and export, is stable in the period 2002-2018.

Table 13: Stage of manufacturing of traded products in Flanders, 2002-2018.

	import SM_RAW	import SM_SFIN	import SM_FIN	export SM_RAW	export SM_SFIN	export SM_FIN
2002	45.8%	21.9%	32.3%	13.6%	28.6%	57.8%
2003	46.1%	22.7%	31.1%	11.5%	28.9%	59.7%
2004	43.8%	23.5%	32.7%	12.2%	29.4%	58.4%
2005	44.3%	23.2%	32.5%	12.6%	29.0%	58.4%
2006	47.3%	22.3%	30.4%	14.0%	26.4%	59.6%
2007	45.2%	22.7%	32.0%	12.7%	26.1%	61.1%
2008	45.8%	22.2%	31.9%	15.0%	26.0%	59.0%
2009	44.7%	22.3%	33.1%	13.1%	26.4%	60.5%
2010	43.9%	19.2%	37.0%	12.0%	23.6%	64.5%
2011	46.5%	20.5%	33.0%	10.9%	25.0%	64.2%
2012	48.1%	20.8%	31.1%	11.2%	23.7%	65.2%
2013	45.9%	21.3%	32.9%	11.8%	22.8%	65.4%
2014	48.1%	20.7%	31.2%	10.5%	24.9%	64.6%
2015	45.5%	21.4%	33.1%	10.1%	24.1%	65.8%
2016	46.1%	21.4%	32.5%	10.8%	24.9%	64.3%
2017	44.9%	21.7%	33.4%	12.1%	26.7%	61.2%
2018	41.5%	21.0%	37.5%	15.2%	25.3%	59.5%

This difference in the average stage of manufacturing between import and export has a significant impact on the indicators DMC and RMC. The length of the production chain of imported products is, on average, shorter than the production chain of exported products. This result will lead to a difference in the ratio between import and export and the ratio of import in RME and export in RME and affects the relationship between DMC (based on import and export) and RMC (based on import in RME and export in RME).

2.4 Direct Material Input and Domestic Material Consumption

The DMI and DMC are calculated by adding the quantities of imported products to the quantities of DEU. In case of the DMC the quantities of exported products are subtracted. The DMI of Flanders varied between 274 to 342 million tons in the 2002-2018 period, or 44 and 53 kilograms per capita. It shows an increasing trend, meaning the decrease in DEU is countered by a larger increase in import. Also, Figure 17 shows the GDP per DMI in euro per kilogram. GDP is expressed in chain linked volumes. This ratio has an increasing trend in the periods 2002-2009 and 2010-2016, with a drop in 2010. Also, the values of 2017 and 2018 are lower, due to the sharp increase in the estimated weight of import[17].

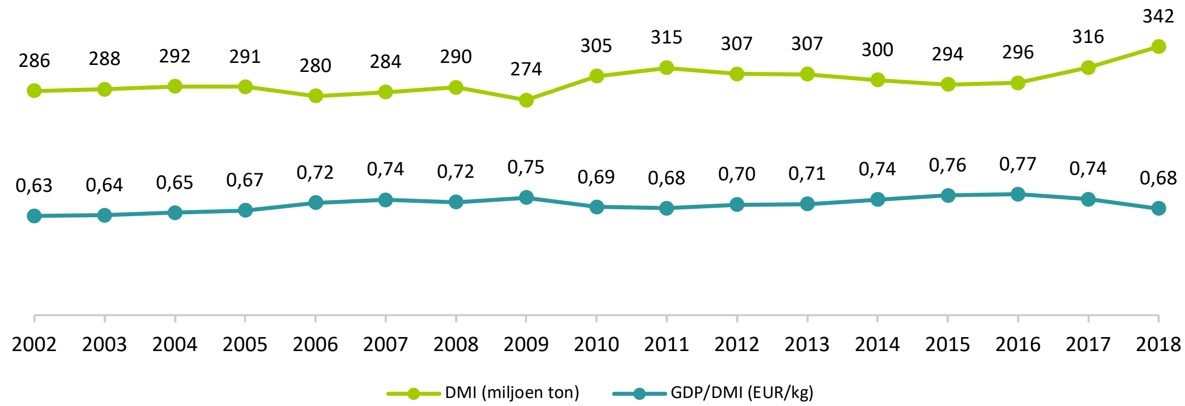

Figure 17: The DMI and GDP per DMI (in EUR per kilogram), Flanders, 2002-2018. GDP in chain linked volumes.

The physical quantities of import and export follow the same path with import consistently being around 15 ton per capita higher. The domestic material extraction decreases in the 2002-2018 period from 9.0 to 7.1 tons per capita. Adding the difference between physical import and exports to the DEU results in estimation of the DMC-indicator.

17 Remind that the values for 2017 and 2018 might be corrected due to updates in trade data.

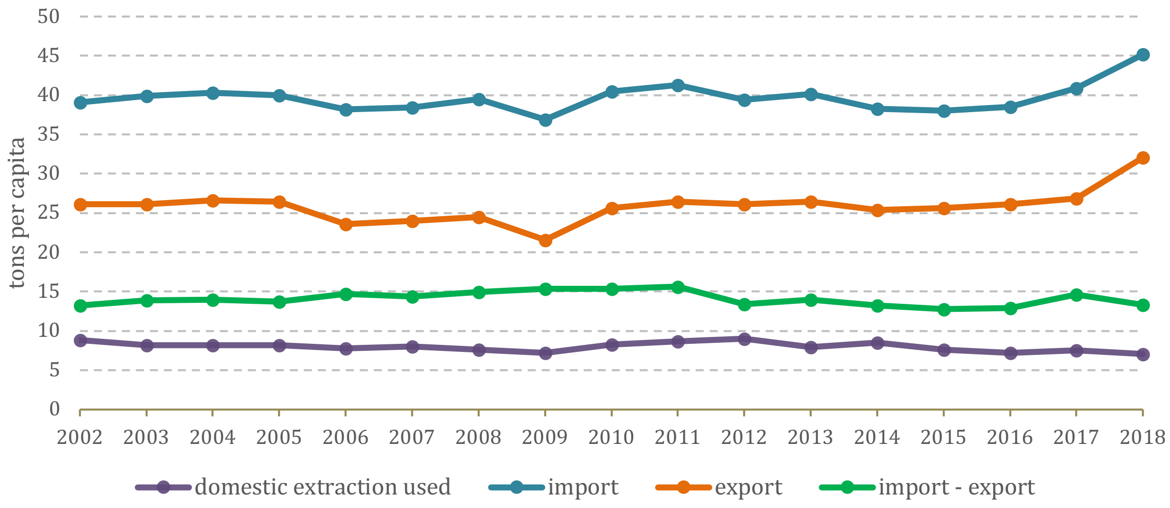

Figure 18: The building blocks of the domestic material consumption indicator, Flanders, 2002-2018.

The DMC in Flanders varies between 130 and the 148 million tons or 19.6 and 23.5 tons per capita in the period 2002-2018. The estimation shows an increasing material use between 2002 till 2011 from 21.8 to 23.5 tons per capita. After 2011 the domestic material uses decreased, with again an increase in 2017. The results are visualised in Figure 19. In Figure 20 the per capita results are shown for the four biggest material groups, meaning the other products (A.5) and the waste imported for final treatment and disposal (A.6) are excluded.

In 2018, the largest material category are the fossil energy carriers with 8.6 tons per capita, followed by non-metallic minerals with 5.9 tons per capita, biomass with 4.4 tons per capita and the metal ores with 1.5 tons per capita. Looking at the time series 2002-2018, the contribution of the fossil energy carriers continuously fluctuated between 8 and 10 tons per capita. The DMC of goods assigned to the material category of non-metallic minerals increased from 2002 till 2012 from 6.2 to 9.7 tons per capita, after which it decreased until 2018 to 5.9 tons per capita. The domestic material consumption of goods assigned to the biomass materials category slightly decreased in the 2002-2018 period from 5.8 to 4.4 tons per capita, with a minimum of 3.5 tons per capita in 2016. The domestic material consumption of goods attributed to the metal ores material category is low and stable, varying between 0.5 and 1.6 tons per capita.

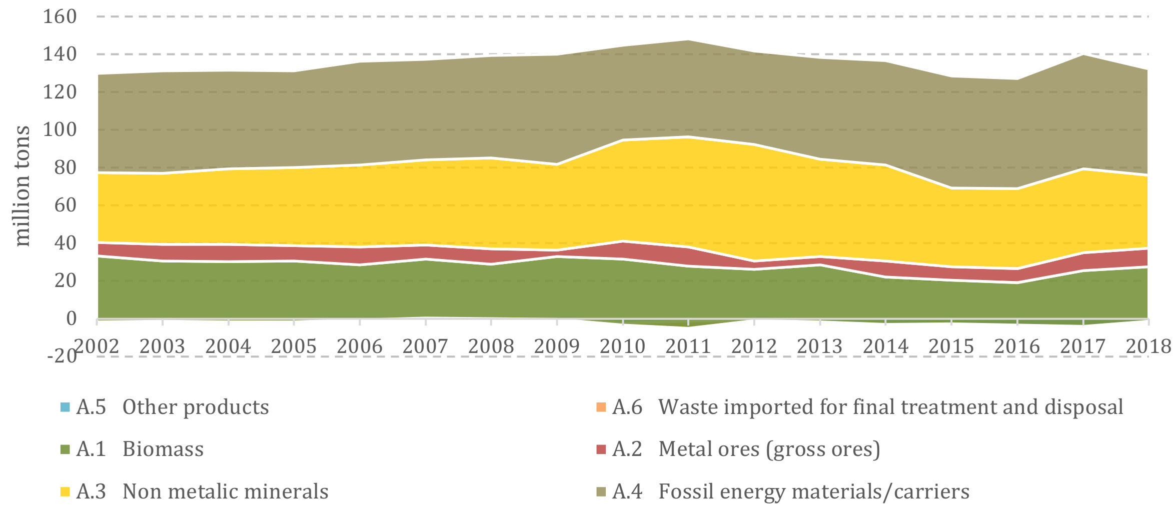

Figure 19: Domestic material consumption (DMC) per material category in Flanders, 2002-2018.

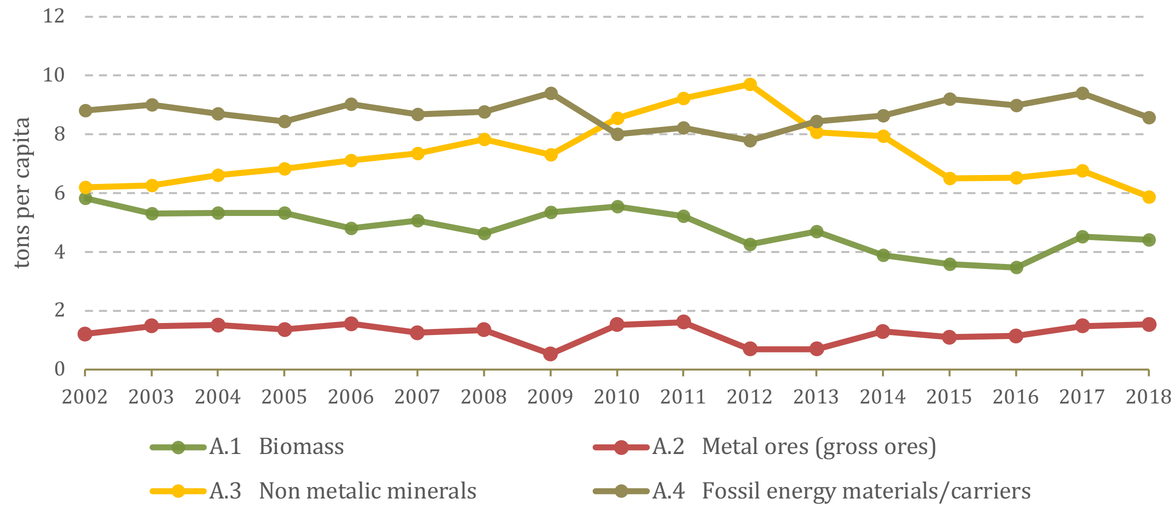

Figure 20: Domestic material consumption per material category in Flanders, 2002-2018.

It is considered not useful to further elaborate on the detailed material categories within the four broader defined material categories, due to the increasing uncertainty at the level of subcategories. The Flemish industries use DEU and imported goods in their production (chains). Their output might be differently attributed to a detailed material category compared to the attribution of the originally used DEU and imports. For example, a Flemish ceramic brick manufacturer uses amongst others mainly sand, clay and energy to produce bricks. While the input is attributed to clays and kaolin (A.3.7), sand and gravel (A.3.8) and fossil energy materials (A.4), the output is attributed to products mainly from non-metallic minerals (A.3.11).

2.5 Import and export in raw material equivalents

2.5.1 Import in raw material equivalents

Expressing import in RMEs[18] results in a Flemish import between 476 and 657 million tons or 77 to 100 tons per capita, in the period 2008-2018. So, the physical import of 37 and 45 tons per capita in the same period is accompanied by a material rucksack of 40 to 55 tons per capita.

In 2018, 37% of the raw material required in the production networks of Flemish imported products are fossil energy carriers. 244 million tons of fossil energy materials are globally extracted, while only 136 million tons effectively cross the Flemish border leaving 108 million tons of fossil energy materials already used abroad to provide products to Flanders. 32% or 207 million tons of the raw material required in the production networks of Flemish imported products are metal ores. The direct input of goods assigned to the metal ore material group is only 35 million tons. 21% of the raw materials required are non-metallic minerals and 10% is biomass.

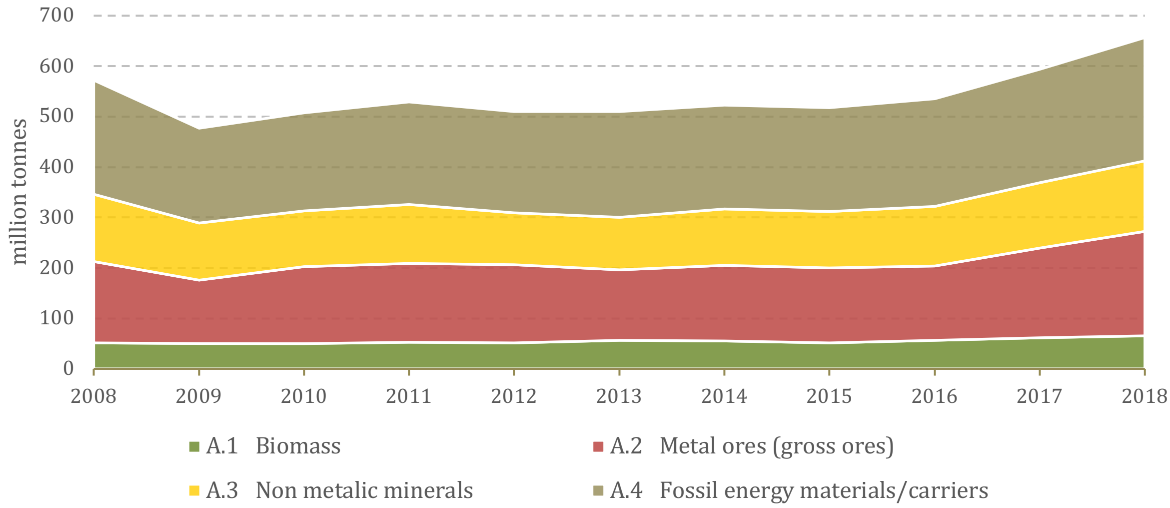

Figure 21: Import expressed in raw material equivalents in Flanders per material category, 2008-2018.

The ratio of import expressed in RME to physical import for the period 2008-2018 is on average 1.1 for biomass, 5.7 for metal ores, 2.9 for non-metallic minerals and 1.7 for fossil energy carriers. The average total ratio is 2.1. This ratio expresses the amount of raw materials used or consumed in the production chain of imported products. A ratio equal to 1 represents a market product that is an unprocessed raw material. The higher the level of manufacturing, the greater this ratio. Note that the denominator (physical import) is incomplete (except for the total ratio) as material categories other products (A.5) and waste imported for final treatment and disposal (A.6) are excluded.

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18 Physical trade flows are allocated to their main material component, while expressed in RME they consist out of multiple material categories.

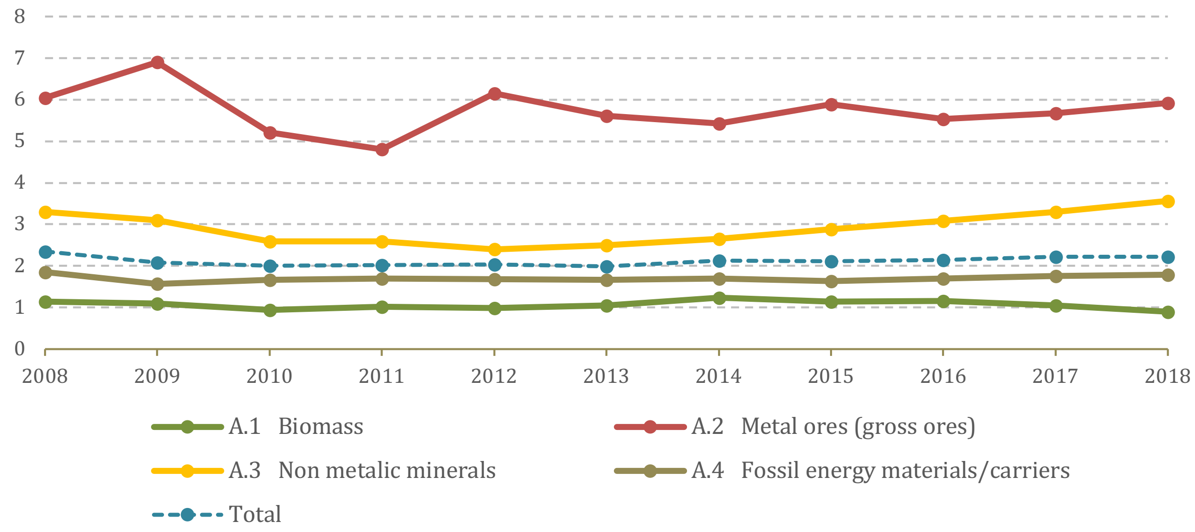

Figure 22: Ratio between import expressed in raw material equivalents and physical import, per material category, Flanders, 2008-2018.

2.5.2 Export in raw material equivalents

Expressing export in RMEs results in a Flemish export between 359 and 521 million tons or 57 to 80 tons per capita, in the period 2008-2018. So, the physical export of 22 and 32 tons per capita in the same period is accompanied by a material rucksack of 31 to 47 tons per capita.

In 2018, 35% of the raw material required in the production networks of Flemish exported products are fossil energy carriers. 180 million tons of fossil energy materials are globally extracted, while only 80 million tons effectively cross the Flemish border leaving 100 million tons of fossil energy materials already used abroad to enable Flanders to export. 27% or 142 million tons of the raw material required in the production networks of Flemish exported products are metal ores. The direct input of goods assigned to the metal ore material group is only 25 million tons. 24% of the raw materials required for exports are non-metallic minerals and 14% is biomass.

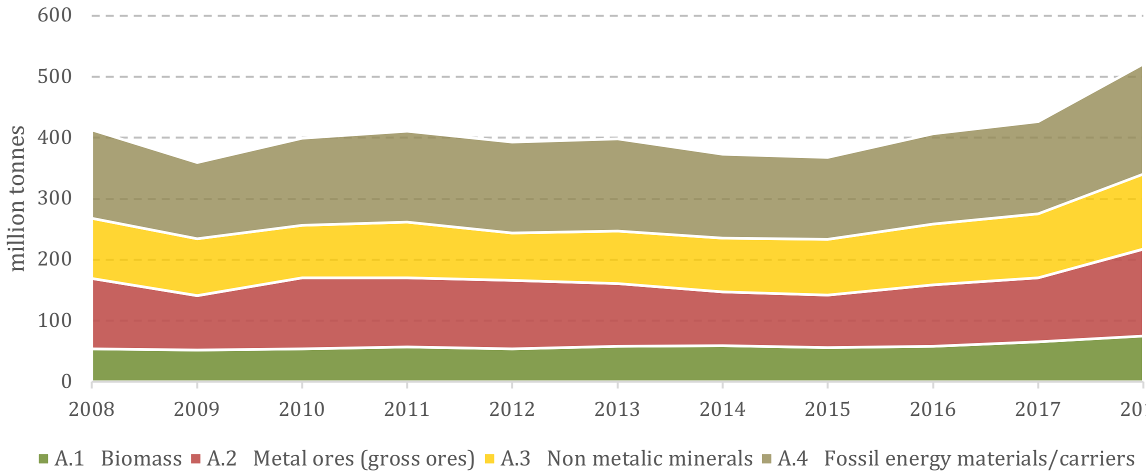

Figure 23: Export in raw material equivalents in Flanders per material category, 2008-2018.

The ratio of export in RME to export for the period 2008-2018 is on average 1.5 for biomass, 5.3 for metal ores, 3.8 for non-metallic minerals and 2.2 for fossil energy carriers. Overall this ratio is 2.4. This shows that the average imported product by Flanders (average ratio 2.1) has a lower RME-requirement than the average exported product by Flanders (average ratio 2.4) in the period 2008-2018. In other words, the production chain of imported products in Flanders is less material intensive than the production chain of exported products. A conclusion which is supported by the discussion on the stage of manufacturing (see section 2.3.3 Stage of manufacturing).

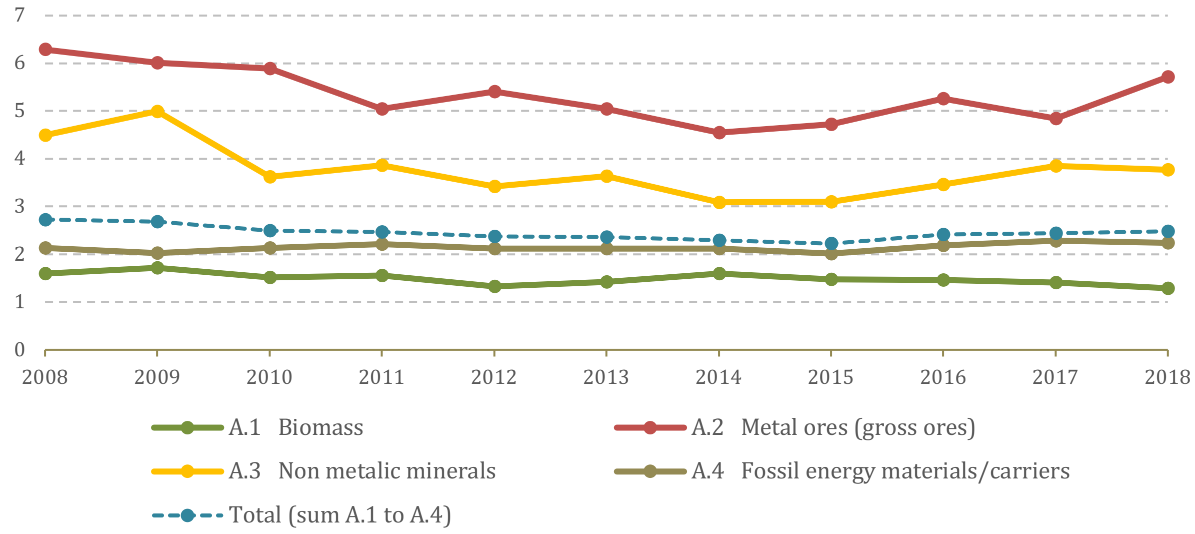

Figure 24: Ratio between export expressed in raw material equivalents and physical export, per material category, Flanders, 2008-2018.

2.6 Raw Material Input and Raw Material Consumption

The RMI and RMC are calculated by summing the DEU and import expressed in RME. For calculating the RMC the export expressed in RME is subtracted. To calculate the RMI, a large number of trade flows is aggregated to 182 aggregated product groups for which RME-coefficients are available. The necessary aggregation step introduces over- and underestimation to the results, decreasing the reliability of the estimation. Therefore, the RMI (and RMC) indicator trends are expressed using the moving average approach. The results after applying the moving average approach are visualised in Figure 25. The RMI for Flanders sums up between 555 and 642 million tons, or 88 to 98 tons per capita. The GDP per RMI, in which GDP is expressed in chain linked volumes, shows a stable trend between 0.36 and 0.40 euro per kilogram.

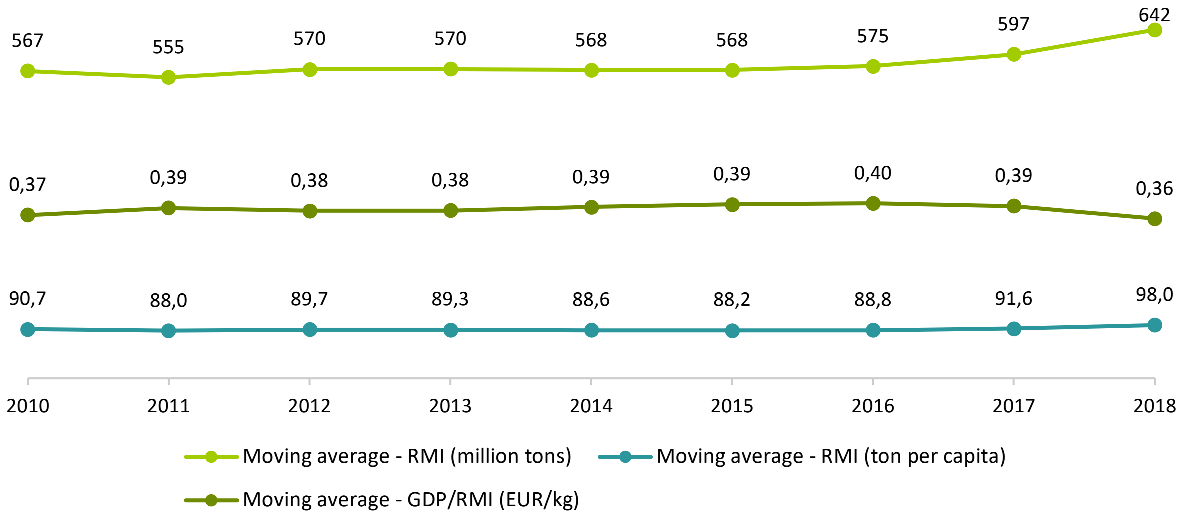

Figure 25: The moving average (N=3) of RMI, RMI per capita and GDP/RMI, Flanders, 2010-2018. GDP in chain linked volumes.

The import and export both expressed in RMEs follow the same path, with import consistently being around 20 ton per capita higher. The RMC in Flanders fluctuates between 160 and 215 million tons in the period 2014-2018. This corresponds to 25 and 33 tons per capita.

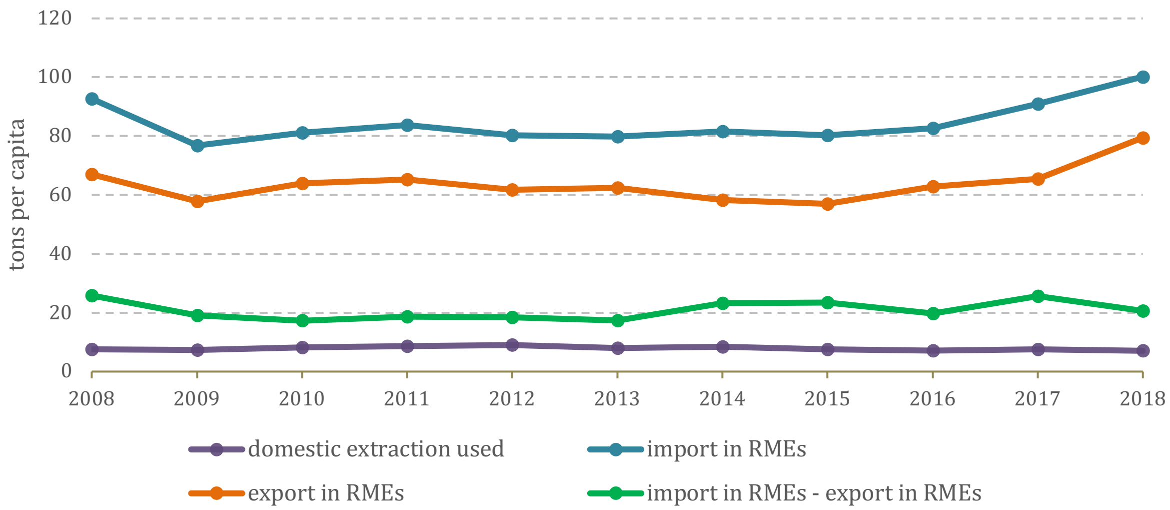

Figure 26: The building blocks of the raw material consumption indicator, Flanders, 2002-2018.

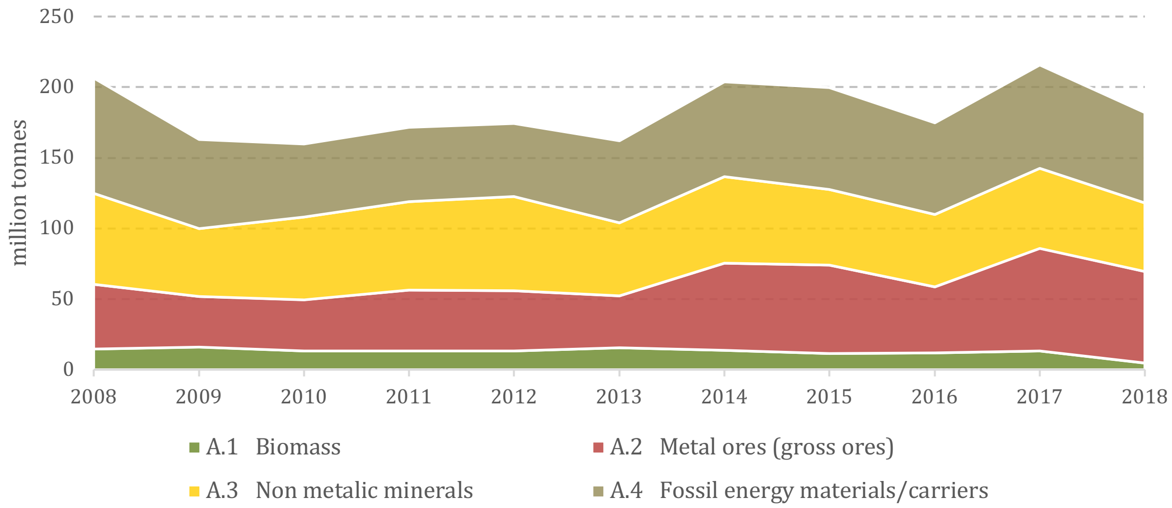

Figure 27: Raw material consumption in Flanders per material category, 2008-2018 [This figure is not for reproduction, only use the RMI and RMC estimation including the weighting average results].

The RMC-indicator, both in absolute values and in tons per capita, fluctuates more compared to the DMC-indicator. One of the explanations is the aggregation required in the estimation of the RMC-indicator (i.e. the thousands of trade flows being aggregated into 182 RME-conversion factors). The decrease in DEU is partly offset by a (smaller) increase in net physical trade, resulting in a slightly decreasing trend in the DMC-indicator in the period 2008-2018. However, this decrease is not consistent as it increased in the periods 2009-2011 and 2016-2017. There is an absolute decoupling from GDP in domestic material use in Flanders. In contrast, the decrease in DEU is fully offset by a much larger increase in net trade expressed in RMEs, resulting in an increasing trend in the RMC-indicator from 2009 onwards. Again, the trend is not consistent with decreases in the periods 2008-2009, 2015-2016 and 2017-2018. The increase, from 2009 onwards, in RMC per capita is volatile, especially from 2013 onwards. Compared to the GDP-evolution in the period 2010-2018, one can only (partly) speak of a relative decoupling from GDP of the RMC-indicator, except for the 2015-2017 period. Due to the volatility of the results, the focus should be on the trend. Therefore, the results of the RMC are visualised using the moving average method (see Figure 27).

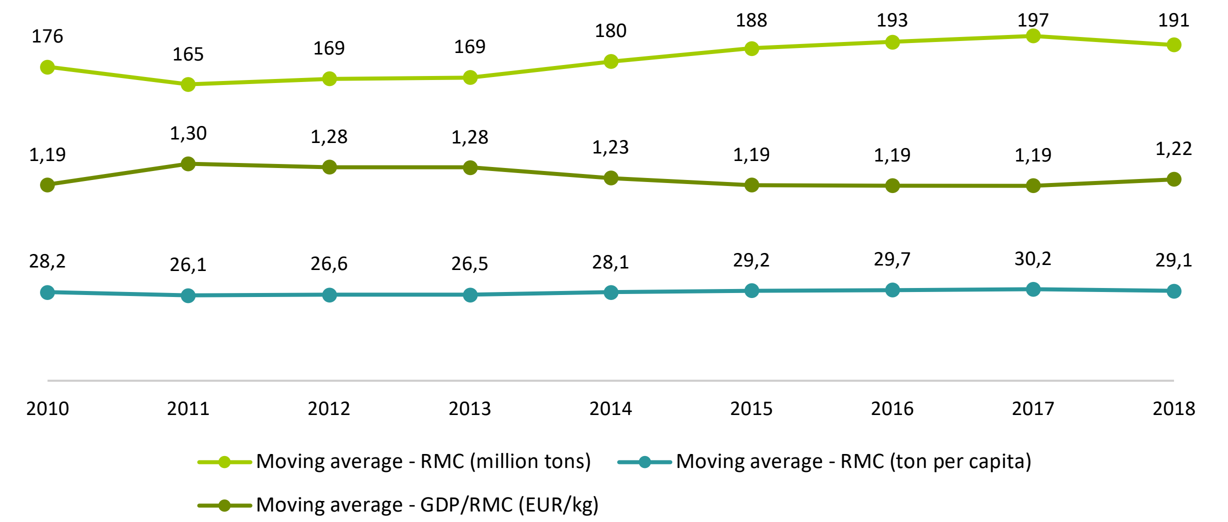

Figure 28: The moving average (N=3) of RMC, RMC per capita and GDP/RMC, Flanders, 2010-2018. GDP in chain linked volumes.

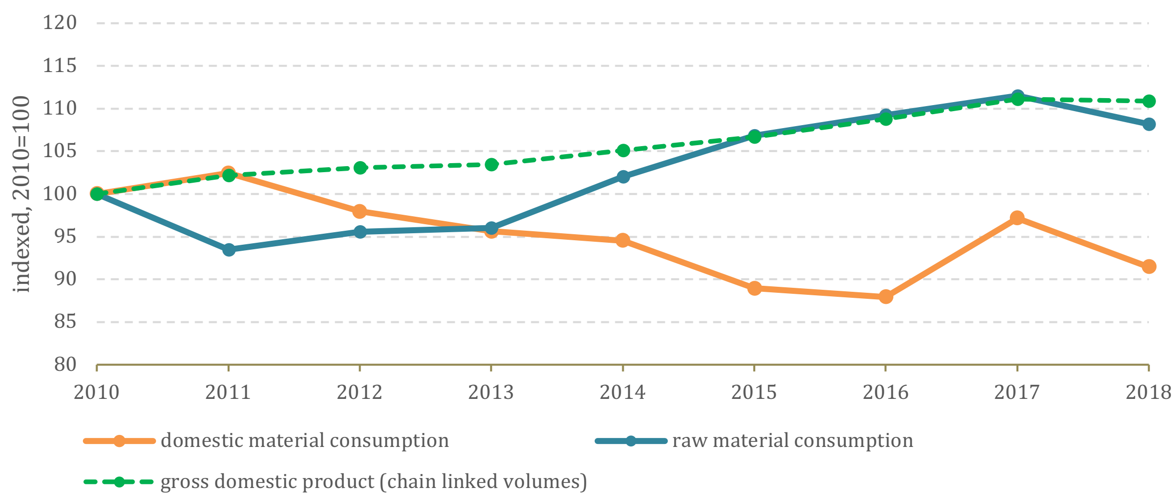

Figure 29: Domestic material consumption, raw material consumption (incl. the weighting average method) and gross domestic product (in chain linked volumes) of Flanders, indexed values (2010 = 100), 2010-2018.

A possible explanation of the increased gap between the DMC and RMC is the outsourcing of material intensive steps. Outsourcing causes a decrease (or a decrease in the growth) of the DMC, but not in the RMC.

Another observation is that the DMC is below the RMC in the period 2008-2018. This is only possible if the net physical trade is lower than the net trade expressed in RMEs. It implies that:

$$\frac{physical\ import}{physical\ export} > \frac{(1 - \frac{export\ in\ RME}{phyical\ export})}{(1 - \frac{import\ in\ RME}{physical\ import})}$$

The formula shows that the ratio of physical import and physical export is larger than the ratio of the average rucksack of exported products and the average rucksack of imported products. This last one includes only the weight of the rucksack and not the weight of the actual trade product (therefore the formula uses 1 -).

2.7 Actualisation of Domestic Material Consumption and Raw Material Consumption

In this section, the results from the 2016-project funded by the Flemish department LNE (2016)[19] are compared to the updated values presented in this study (sections 2.1 to 2.6). The main differences are explained.

The 2016-result comprise an estimation of DMC and RMC for the 2002-2015 period. This study estimated the DMC for the period 2002-2018 and the RMC for the period 2008-2018. The results, expressed in absolute values, are visualised in Figure 30. The updated DMC values are higher, but the gap with the previous estimation is continuously decreasing. Also, the updated RMC values are higher (ca. 50-80 million tons), but follow the same path compared to the previous estimation.

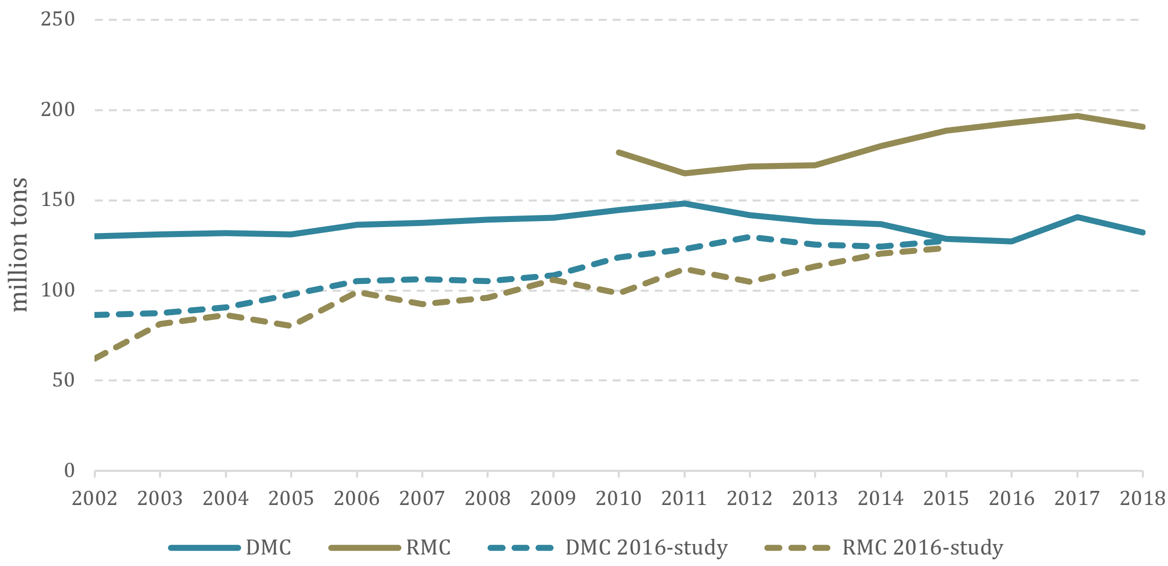

Figure 30: Comparision of previous and actualised estimation results of DMC and RMC in Flanders, 2002-2018.

The difference in DMC is caused by updated values on domestic extraction used, import and export:

- The value on **DEU** of non-metallic minerals is updated following an improved interpretation of MDO-data. This resulted in an increase of 2.6 to 5.4 ton per capita of non-metallic minerals in the 2002-2015 period.
- Changes in the trade data and improved weight conversion factors result in an update in the **import** of mainly biomass and fossil energy carriers in the 2002-2015 period. Changes in biomass relate to a correction on 2012-2015 import estimations varying between -3.0 and -4.7 tons per capita. The changes in fossil energy carriers relate to the 2002-2009 period with correction varying between +2.7 and +5.0 tons per capita.

[19] Project resulted in a report: 'Indicatoren voor een groene economie. Update van datafiche en Exceltabellen DMC en RMC' (Christis, et al., 2016). The results and conclusions are used in a publication by the Flemish Government 'Hoe groen is de Vlaamse economie?' (departement LNE, 2016).

- Changes in the trade data and improved weight conversion factors result in an update in the **export**. This update resulted in smaller correction for all material categories. They sum up to correction between -1.4 and 0.8 tons per capita in the 2002-2015 period.

DMC is calculated as the sum of domestic extraction used and import minus export. So, a negative change in export values results in an increase in the DMC estimation.

The use of new conversion factors RMEs (**183** RME conversion factors, 2008-2016) instead of the previous values (**166** RME conversion factors, 2002-2013) resulted in large changes for import and export expressed in RMEs:

- Import expressed in RMEs:
  - Biomass: stable negative difference (-1.3 to -2.5 t/cap)
  - Metal ores: mainly negative difference (-3.4 to +1.3 t/cap)
  - Non-metallic minerals: large positive difference (+3.3 to +5.4 t/cap)
  - Fossil energy carriers: large positive difference (+1.4 to +4.7 t/cap)
- Export expressed in RMEs:
  - Biomass: small difference (-1.7 to +0.1 t/cap)
  - Metal ores: large negative difference (-3.2 to -9.8 t/cap)
  - Non-metallic minerals: large positive difference (+3.4 to +5.5 t/cap)
  - Fossil energy carriers: large negative difference (-3.7 to +0.6 t/cap)

The updated RME conversion factors have a huge effect on converting trade flows in RMEs, resulting in a ‘double’ increase (increasing import and decreasing export) of the RMC estimation.

Chapter 3: Input-output analysis [top-down]

3.1 Method and data

In the following paragraphs we define and explain the concept of the material footprint, the input-output methodology applied to calculate it and the expenditures of households.

The material footprint measures the global primary material use in value chains linked to products consumed by domestic final demand in one year. This footprint includes indirect or embodied flows across production networks including imports and excludes exports and associated indirect flows of exports. Following the typology of Lebel et al. (2007), these footprints include direct material uses and deemed material uses (i.e. embodied material uses of imported products), but exclude responsible and logistic material uses (i.e. embodied material uses of exported products). The exclusion of exports (i.e. responsible and logistic material use) puts the focus on the consumption perspective: local material uses related to exported products are not considered, while deemed material uses are included.

The computation of the material footprint is based on input-output analysis (IOA). This analysis approximates the *primary* material uses resulting from final demand expenditures along its entire preceding network of value chains. The general formula that we apply in this paper to compute material footprints, MF, is based on the Leontief inverse and can be represented as (Matthews, Scott, Weber, & Hendrickson, 2008):

$$MF = \mathbf{g}(\mathbf{E}_{\text{coef}}\mathbf{L}\mathbf{f})$$

where

- $\mathbf{g}$ is a row vector of weighting and conversion values;
- $\mathbf{E}_{\text{coef}}$ is a matrix with material coefficients, rows indicating the different material types and columns indicating the sectors;
- $\mathbf{L}$ is the Leontief-inverse, $\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1}$, where $\mathbf{A}$ is the matrix product of a matrix $\mathbf{Z}$ containing the interindustry deliveries and the inverse of the diagonalized output vector $\mathbf{q}$, $\mathbf{A} = \mathbf{Z}\,\widehat{\mathbf{q}}^{-\mathbf{1}}$, and $\mathbf{I}$ is an identity matrix; and
- $\mathbf{f}$ is the final demand column vector including household consumption expenditures, governmental consumption and investments.

The final demand $(\mathbf{f})$ from the IO-database includes household consumption, consumption by non-profit institutions, governmental consumption, investments and changes in inventories and valuables. The household consumption is further specified by consumption domains (COICOP-classification[20]).

To calculate the footprint of households in Flanders, we apply an IOA (Eurostat, 2008). Specifically, we use a regional input-output table for Flanders and link this via the import to a globally covered multi-regional input-output table: if Flanders imports a product, the production chain of this product is traced back in the multi-regional input-output table. In this way, we can link the final demand in Flanders to the entire production network preceding it.

[20] Classification of individual consumption by purpose

The method applied for the integration of the regional Flemish database in a world input-output model is described in Christis, Geerken, Vercalsteren, and Vrancken (2017). Both the regional model for Flanders and the multi-regional model are used in their full detail without modification. Only the import and export of Flanders are linked to the producing or consuming actor in the multi-regional model. The method is closely related to the multi-scale multi-regional input-output model by Bachmann et al. (2015). The difference is that the methodology of Christis et al. adds a sub-region to an existing MRIO, while Bachmann et al. replace a nation with its sub-regions. However, both methodologies are similar as they both account for different sectoral representations. The combination of a local input-output model and a multi-regional input-output model allows for an analysis based on available local data, adapted to the local economic characteristics and including global sectoral data. This is particularly relevant for determining the footprints of non-autarchic economy material footprints which are determined both by local and global specific characteristics. The main shortcomings of the IOA for this type of application is the level of sector aggregation. Aggregated sectors present the 'average' production structure which can differ substantially from the production structure of a specific product, resulting in under- or overestimations of the material footprints. Therefore, the results are restricted to estimation for the macro-economic products (product groups) and provide no details on microlevel products.

For the methodology described above we use the Flemish EE-RIO table (2010 data) which is part of the interregional input-output database of Belgium. It contains 124 sectors, nine final demand categories, interregional and international trade, and six value added categories. Environmental data in the extension tables comprise the primary material use data necessary to calculate the material footprint. In the input-output model of Flanders, consumption is defined according to the residential (national) concept i.e. household expenditure of all residents in Flanders and abroad. The input-output tables follow the ESA95 rules[21].

We then link this Flemish IO table via the trade link to EXIOBASE3 (2010 data; product-by-product tables). EXIOBASE3 is a global EE-MRIO database produced in the context of the project 'Compiling and Refining of Economic and Environmental Accounts' (CREEA). The database covers 200 products and 163 industries for 43 countries and 5 rest-of-world regions. The extension tables include 15 land use types, employment broken down into three skill levels, 48 types of raw materials and 172 types of water use. Flanders is indirectly included in the EXIOBASE3 database via Belgium (Stadler et al., 2018).

To calculate the material footprint a final demand matrix is constructed for households in Flanders detailing the consumption domains. This matrix describes the expenditures of households at a detailed level based on the COICOP-classification. These matrices are compiled from the original final demand vector available in the input-output model but reconstructed using the household budget survey. The datasets and procedure are explained below.

The basis for the expansion of the final demand vector of Flemish households is the household final consumption expenditure account, which is part of the national accounts and covers expenditures incurred by households to acquire consumption goods and services. It excludes expenditures devoted by households to the acquisition of dwellings, which constitute an

[21] The European System of Accounts is the system of national accounting used within the European Union. It has now been succeeded by the ESA2010 framework.

investment in fixed assets, and those devoted to the acquisition of valuables[22] (Eurostat, 2008). The accounts use the COICOP-classification: a classification of individual consumption expenditures incurred by households according to their purpose. The household consumption expenditures are classified in 12 domains (level 1), which can be further disaggregated into more detailed COICOP levels 2 and 3.

3.2 Material footprint of Flanders

The material footprint of Flanders in 2010 is 111.1 million tons or 17.8 tons per capita. It is the total mass of primary materials used to produce all products for Flemish final demand in 2010. 11% of these materials are extracted or cultivated in Flanders. Flanders extracts or cultivates more primary materials (33 million tons in 2010), but only 38% of these materials are used in production for Flemish final demand. The rest is used in production directly or indirectly linked to exported products.

Table 14: Flemish material footprint per final demand category, 2010.

Final demand	**111,136 kton**
household expenditures	57,160 kton
household investments in housing	10,731 kton
non-profit institutions serving households	432 kton
governmental spending	9,165 kton
investments (other than household investments in housing)	30,802 kton
changes in inventories	2,846 kton

Table 15: Flemish material footprint of household expenditures per consumption domain, 2010.

Household expenditures	**56,025** kton
Household expenditures (+ household investments in housing)	**66,756** kton
food and non-alcoholic beverages	17,700 kton
alcoholic beverages, tobacco and narcotics	1,402 kton
clothing and footwear	2,915 kton
housing, water, electricity, gas and other fuels	10,589 kton
furnishings, household equipment and routine household maintenance	3,391 kton
health	2,099 kton
transport	6,729 kton
communications	398 kton
recreation and culture	4,281 kton
education	74 kton

[22] Valuables are stores of value that cannot be used for production or consumption, such as works of art, precious stones and metals, jewels.

restaurants and hotels	3,532 kton
miscellaneous goods and services	2,915 kton
household investments in housing	10,731 kton

An example of a disaggregated consumption domain is provided in Figure 31. The figure gives an overview of the material footprint of the ten product groups underlying the consumption domain of food and non-alcoholic beverages.

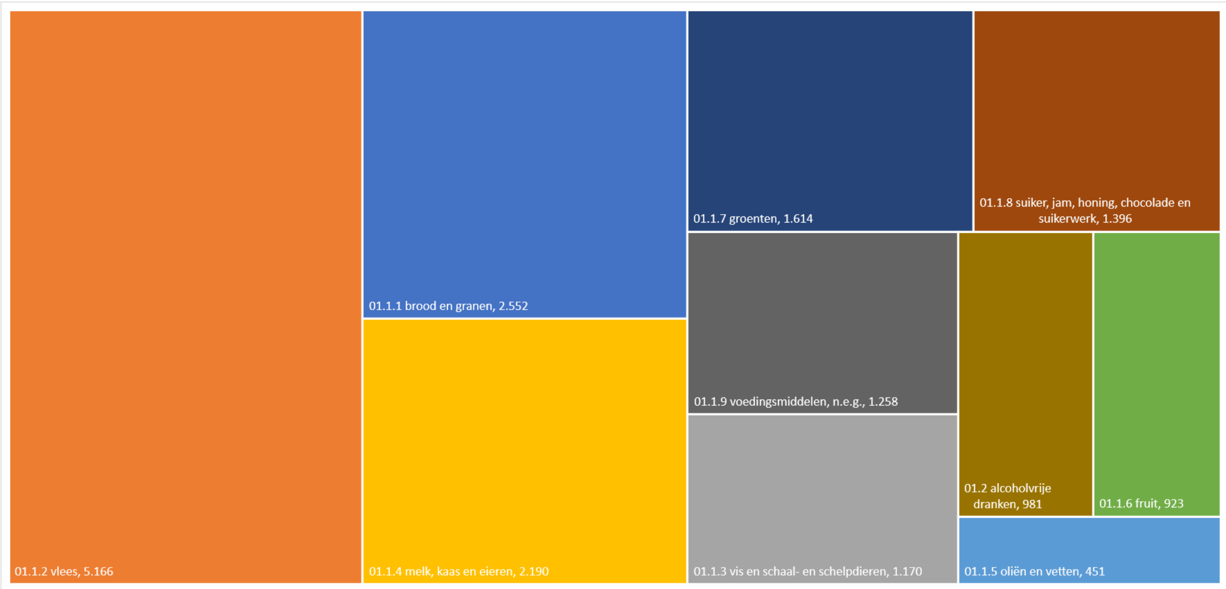

Figure 31: Example of a disaggregated material footprint of the consumption domain of food and non-alcoholic beverages, in tons, Flanders, 2010 [in Dutch].

Chapter 4: Flemish macro-economic material flow indicators

4.1 Conceptual differences between the indicators

The indicators discussed in this study, i.e. DMI, DMC, RMI, RMC and MF, have to be considered as complementary indicators that together give supplementary information about material flows. On top of the methodological differences, they differ in scope, system boundaries and level of detail and as such the messages and insights following from these indicators have a different focus.

DMI and RMI have in common that they are so-called input indicators, while DMC, RMC and MF have in common that they are all so-called consumption indicators. They give information about the material consumption in an economy. They can be broken down by material categories and looked at in absolute terms, and they give additional insights when related to population (per capita), to a specific area or to GDP.

DMI, DMC, RMI and RMC rely on the same type of basic data published by Eurostat and are based on apparent physical consumption, but the indicators RMI and RMC extends the scope of import and export to the global value chain of products (including the embodied material) by using the RME-factors. Due to the difference in weighting between domestic extraction of raw materials (in terms of ores or harvests) and imports resp. exports (in terms of weight of goods), the DMI and DMC indicators are not robust against outsourcing. When domestic demand remains unchanged but is satisfied by more import instead of domestic extraction, the DMI and DMC will decrease.

The RMI and RMC indicators on the contrary are robust against outsourcing, as it converts the use of raw materials associated with import and export in RMEs, which is comparable to the way domestic extraction is measured (in terms of ores or harvests). Because the exports and related flows are allocated to the consumer country, RMC avoids double counting of raw materials in international statistics. One limitation of RMI and RMC compared to DMI and DMC is the lower reliability due to the limited number of RME-coefficients (at level of product groups and not products). Although DMI, DMC, RMI and RMC are based on data with a high level of product detail, both indicators should not be assessed to a level of detail higher than 2-digit due to methodological reasons (e.g. different allocation of products to material categories for import and export).

The MF indicator relates closely to the RMC indicator, as both capture global primary material use linked to domestic consumption. However, the MF does not record the actual physical movement of materials within and among countries but identifies the link between the beginning of a production chain and its end. The limitation of the MF is related to the underlying methodology (IOA) which is based on average production structures. Results provide as such no details on microlevel products but must be looked at from product groups perspective.

Given these conceptual differences, it is fair to state that the DMI and DMC indicators assess the absolute amount of use of materials with a clear focus on domestic consumption. The RMI and RMC indicators have added value when looking at its trend over time, which helps to understand the evolution of the consumption of raw materials. The MF indicator can't be estimated annually as currently no dataset is being updated frequently. The MF typically gives additional insights in the consumption domains and product groups which are responsible for the material use induced by final demand. However, none of these indicators give information about the scarcity or impact of materials they only give an indication of the mass of primary raw materials used by an economy.

The estimation of the indicators for Flanders shows a decreasing trend for the DMC-indicator between 2010-2018, while the RMC-indicator shows an increasing trend. It is assumed from the assessment that one reason for the increased gap between the DMC and RMC is the outsourcing of material intensive steps. Outsourcing causes a decrease (or a decrease in the growth) of the DMC, but not in the RMC. Another observation is that the DMC is lower than the RMC in the period 2008-2018. This is only possible if the net physical trade is lower than the net trade expressed in RMEs. However, both indicators don't allow to look in detail for other reasons for the observed trendline.

A MF assessment gives some additional information about the causes for the observed evolution of DMC and RMC as it allows to identify consumption domains and product groups that are important contributors to the material consumption. By further assessing the value chain of the relevant product groups, it can become clear where (sector and region) the materials use related to our consumption takes place. This is useful information for policy makers. However, to fully exploit the potential of the MF indicator the indicator should be available in a consistent time series, which is not the case at this moment. Currently, VITO is working on an updated input-output model[23] that allows to estimate the material footprint for the years 2010-2012-2014-2015 and 2016.

4.2 Indicators to support Flemish policies

Typically, policies that can benefit from this type of indicators include economic policies, trade policies, technology development policies and environmental policies. Economic policies can use the insights into how an economic system interacts with material flows; trade policies can learn from the dependency of countries on materials from abroad and by monitoring the implications of trade in terms of shifts of environmental pressure between countries; environmental policies can benefit from the identification of system-wide sources of pollution (Kovanda et al, 2013).

Comparing or extending DMI and DMC indicators with RMI, RMC and MF indicators shows the importance of the latter. DMI and DMC indicators have theoretical drawbacks comped to the other two, due to which they provide incorrect and incomplete information on the trend of overall pressure related to material flows, underestimate the importance of material category types and underestimate the overall pressure related to foreign trade. Policy only based on the DMC indicator would have the risk of not focussing on the most important issues. Measuring resource productivity based on DMI or DMC alone does not give complete information of resource dependence and burden shifting, and as such can limit decision making.

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[23] Model is developed in the project 'Koolstofvoetafdruk van de Vlaamse consumptie' commissioned by VMM-MIRA (2020) and in the annual program of VITO commissioned by OVAM (2019).

For example, growing specialization within regions will shift the burden of raw material extraction and thus the DMI and DMC indicator shifts with it. Exporting regions have increasing DMI and DMC values and importing (mostly developed) regions such as Flanders have decreasing values. Developed regions typically experience an increase in imports of semi-finished and finished products and a transition towards a service economy. This is reflected in a reduced DMI and DMC and makes these regions look more resource efficient, but they actually remain highly dependent on materials. The added value of the RMC and MF is that they reallocate the burden to the ultimate point of consumption, and as such both indicators are less affected by specialization trends (Wiedmann et al, 2015).

One drawback DMI, DMC, RMI, RMC and MF indicators have in common is their relationship with environmental impacts, given their focus on weight as the only relevant material characteristic. Although it is commonly accepted that RMC and MF indicators bring material flow indicators closer to the environmental impact. An example of a framework to link material flows to environmental impacts is visualised in Figure 32. This example also shows the potential of adding domestic details to the DMC indicator.

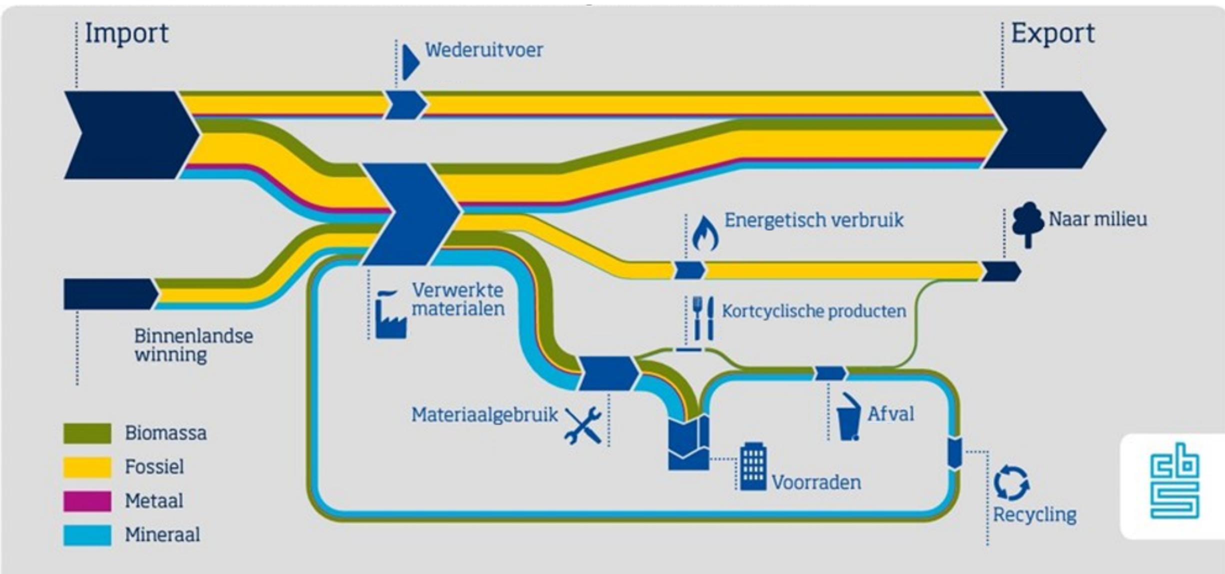

Figure 32: Example of a presentation of macro-economic flows [in Dutch].

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