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An economy wide circularity assessment in Flanders

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An economy wide circularity assessment in Flanders

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Executive summary

Following the study on the material flow analysis for Flanders in the period 2002-2018, which is published by the Circular Economy Policy Research Centre in June 2020, this study introduces the link between the material flows in and out of the Flemish economy and the material flows within the Flemish economy. The scope of this report is the understanding of physical flows of materials in Flanders, the assessment of the current circularity, the monitoring thereof and how they can be made more circular.

In the previous report the economy-wide material flow analysis (EW-MFA) methodology developed by Eurostat is applied to Flanders to estimate and explain the indicators: direct material input (DMI), domestic material consumption (DMC), raw material input (RMI) and raw material consumption (RMC). Next to applying the EW-MFA methodology, the material footprint of Flanders is estimated via input-output (IO) calculations. This study addresses the material flows within the economy of Flanders. The accounting of these flows and mapping efforts form the basis for the measuring step which includes the derivation of macro-economic indicators. One of these indicators, the circularity index, is elaborated in detail. The data requirements, policy relevance and improvements to this indicator are discussed. The conceptual modelling of circular economy (CE) scenarios supports the further understanding of the circularity index indicator.

In this report the reader finds the background to the material flow framework developed for Flanders (2018) and the circular material use rated indicator (CMUR) (2014-2016-2018). Both the framework and the CMUR are summarised in the indicator fact sheet which will become part of the CE Monitor for Flanders.

Samenvatting

Na de materiaalstroomanalyse van Vlaanderen in de periode 2002-2018 gepubliceerd in 2020, introduceert deze studie het verband tussen de materiaalstromen in en uit de Vlaamse economie en binnenin de economie. Dit rapport omvat het begrijpen van fysieke materiaalstromen in Vlaanderen, het beoordelen van de huidige circulariteit, het monitoren ervan evenals hoe de materiaalstromen meer circulair gemaakt kunnen worden.

In het voorgaande rapport werd de methodologie voor economiebrede materiaalstroomanalyse (EW-MFA), zoals ontwikkeld door Eurostat, toegepast op Vlaanderen om de volgende indicatoren te berekenen en uit te leggen: direct material input (DMI), domestic material consumption (DMC), raw material input (RMI) en raw material consumption (RMC). Naast het toepassen van de EW-MFA methodologie werd de materialenvoetafdruk berekend via input-output (IO) berekeningen. De huidige studie behandelt de materiaalstromen binnen de Vlaamse economie. Het begroten en in kaart brengen van deze stromen vormen de basis van het meten, met inbegrip van het afleiden van macro-economische indicatoren. Eén ervan, de circulariteitsindex, wordt in detail uitgewerkt. De datavereisten, beleidsrelevantie en verbeteringen van deze indicator worden besproken. Het conceptueel modelleren van circulaire economie scenario's ondersteunt het verdere begrijpen van de circulariteitsindex.

Dit rapport dient als achtergrond bij de materialenmonitor (voor het jaar 2018) en de CMU indicator (2014-2016-2018) ontwikkeld voor Vlaanderen. Beiden zijn ook samengevat in een indicatorfiche die deel zal uitmaken van de CE monitor voor Vlaanderen.

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Chapter 1

Introducing the economy-wide assessment of circularity

The **economy-wide circularity assessment** is acknowledged to be an effective tool to provide a high-level overview and understanding of the socio-economic metabolism of our economic system. In this report we make use of the framework and accompanying methodology developed by Mayer et al. (2019), which is presented in Figure 1. The framework builds upon existing scale indicators for material flow accounting and for statistics on waste flows and emissions, and it is extended with additional indicators that require specific modelling and can't be derived directly from macro-economic statistics. This framework by Mayer et al. (2019) builds upon several preceding publications including similar frameworks (e.g. Haas et al., 2015). Similar frameworks exist, for example the one developed by Aguilar-Hernandez et al. (2019) (see Figure 2), which is for example used in the Circularity Gap Reports of The Netherlands. Both frameworks show the relationships of the domestic economy with other economies (import and export) and the environment (domestic extraction and domestic processed output).

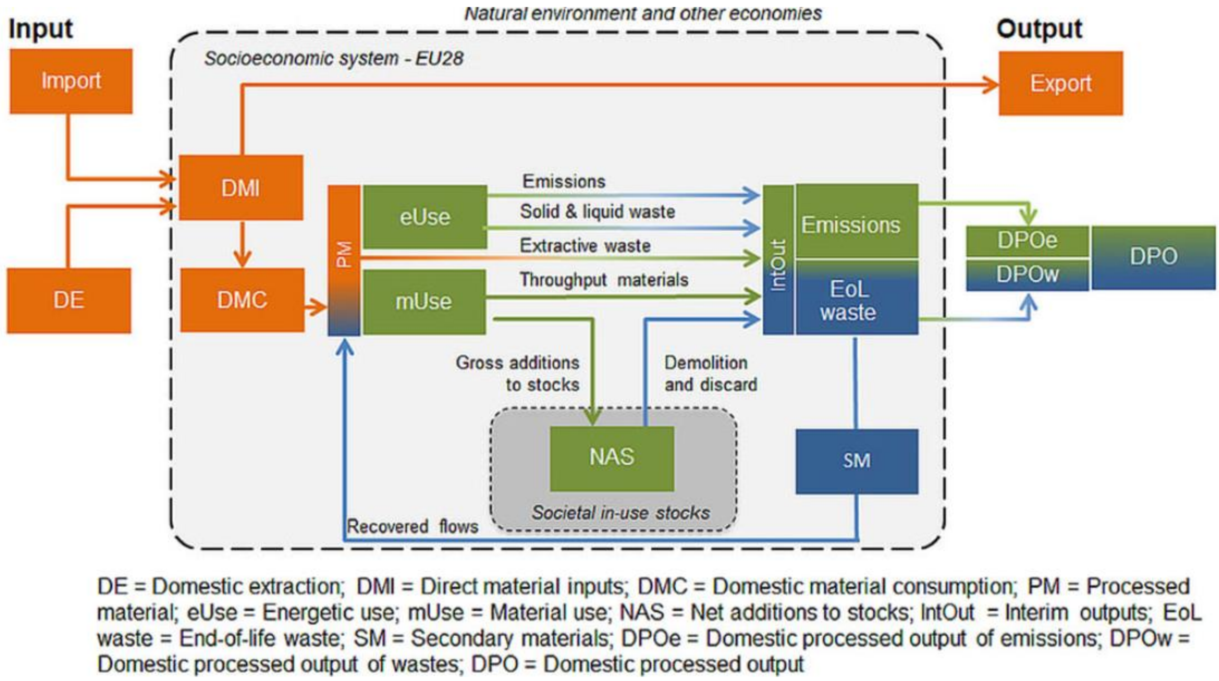


Figure 1: Example of a framework and derived scale indicators for an economy-wide CE assessment. Source: Mayer et al. (2019)

The actual material flows are domestic extraction used (DE), import, export, emissions, throughput materials (including dispersed and dissipated materials), stock additions, stock depletions (i.e. demolition and discard), supplied or generated waste (EoL waste), secondary materials (SM) and lost waste (DPOw). Next to the actual materials flows, there are virtual material flows including the raw material equivalents of import and export flows. Physical stocks include natural stocks of resources (preceding DE), socioeconomic stocks of products (societal in-use stocks) and domestic processed output (DPO).

The colours in Figure 1 indicate data sources that could be used to compile the framework:
- Orange: based on data from the economy-wide material flow accounts;

- Blue: based on waste and emission data; and
- Green: mass-balanced modelling (i.e. no data source available).

A shift from green to blue colour indicates a combination of statistical data and modelling.

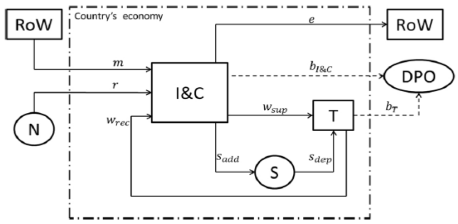


Fig. 1. System definition of the input-output material flows of a country. Solid blocks indicate economic activities of: I&C = Intermediate sectors and final demand; T = waste treatment activities; RoW = Rest of the world. Solid circles indicate resource stocks of: N = Natural resources; S = Material in-use stocks; DPO = Domestic processed output. Solid and dashed lines indicate flows of: m = imports; r = resource extraction domestically; w_{rec} = waste recovery; e = exports; s_{add} = stock additions; s_{dep} = stock depletion, w_{sup} = waste generation; $b_{I\&C}$ = dissipative emissions, others combustion and biomass residues from intermediate activities and final demand; and b_T = dissipative emissions and others combustion and biomass residues from waste treatment.

Figure 2: Example of a framework and derived throughput indicators for an economy-wide CE assessment.
Source: Aguilar-Hernandez et al. (2019)

The frameworks presented in Figure 1 and Figure 2 focus on domestic material flows at a macro-level. It is not the same as the representation of the material footprint (see Figure 3), which is, for example, presented in the Circularity Gap Reports (Circle Economy 2018, 2019 and 2020). The difference with the material footprint is the estimation of trade flows. In a framework presenting actual material flows, the import and exported are measured at their weight at the moment of crossing the borders of the domestic economy. In contrast, using the material footprint perspective, trade flows are converted in their raw material equivalent. This conversion includes all upstream resources used to produce and distribute the traded product.

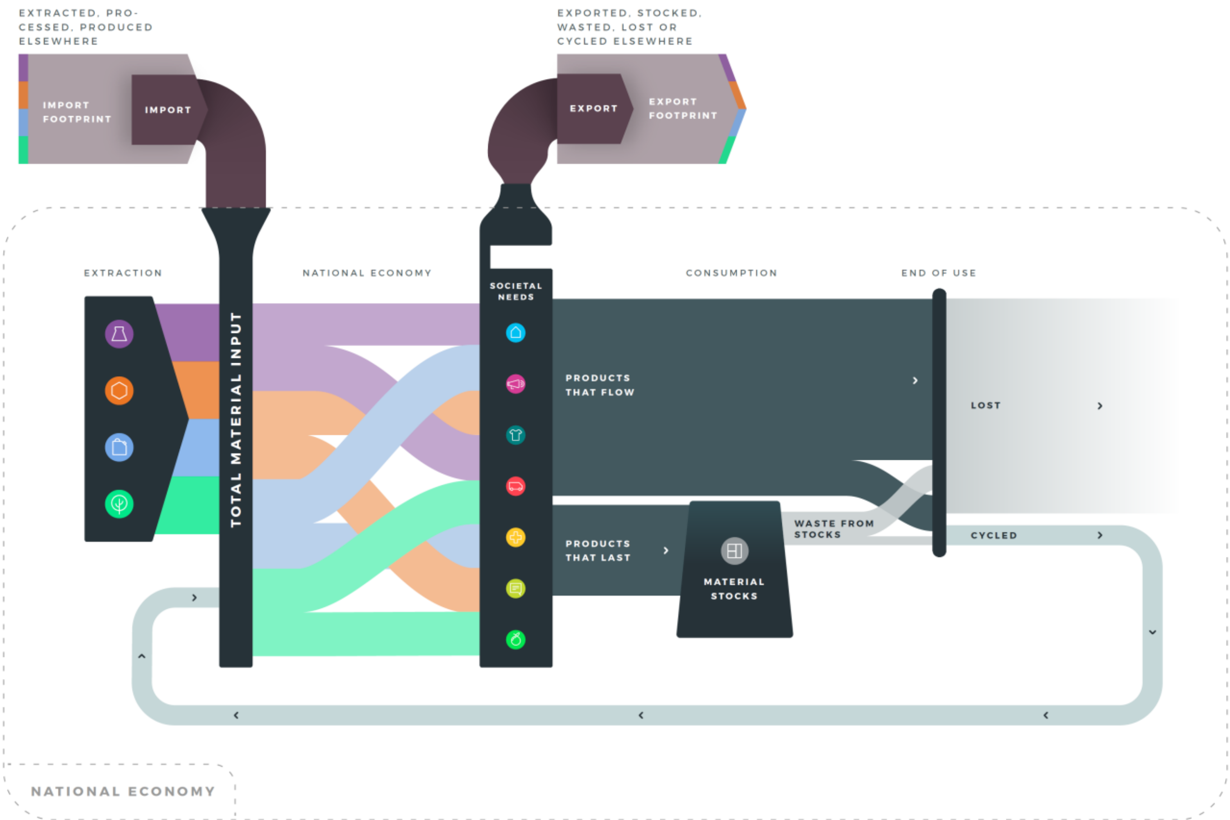


Figure 3: Schematic presentation of the material footprint for a nation. Flows of minerals in purple, ores in orange, fossil fuels in blue and biomass in green.
Source: Circle Economy (2020).

The material flows in the economy wide circularity framework as presented in Figure 1 are estimated for Flanders for the year 2018. The compilation, including the data sources and estimation assumptions, are provided in Annex 1. The results and interpretation are given in Chapter 2. Also, several examples of indicators that can be derived from the framework are explained including an estimation of the values for Flanders. Chapter 3 takes a closer look to different options for the calculation methodology and scope of the circularity rate indicator as defined for Flanders in chapter 2. Based on insights in these methods, a reflection is given on the methodology and scope of this indicator. This analysis finally leads to conclusions and recommendations for refining and improving the methodology and scope for calculating the circularity rate indicator for Flanders, keeping in mind comparability with other countries and updatability of the indicator in the future. Based on these recommendations, a refined economy-wide circularity framework for Flanders in 2018 is presented and discussed in Chapter 4. Also Eurostat's Circular Material Use Rate is discussed and calculated for Flanders. In addition, the role of the circularity rate in a wider set of indicator is discussed in this chapter. The future outlook is discussed in Chapter 5.

This report is considered as a background report to a much more condescended indicator fact sheet on the macroeconomic material flows in Flanders in combination with the CMUR. The fiche is added in Chapter 5. The report must therefore be seen as inseparable from this fact sheet.

Chapter 2

The economy-wide circularity applied to Flanders

2.1 The economy-wide circularity framework for Flanders

Applying the monitor framework to Flanders results in the economy-wide material flow overview estimated for the year 2018[1] and presented in Figure 4. This Sankey diagrams presenting material flows is based on the law of conservation of mass. It means that flows for which there are no reported data available, are modelled based on recent scientific publications to compensate differences in reported input and output flows. Consequently, for some material flows there are considerable uncertainties in the results presented. This and other uncertainties are discussed in Annex 1 and below. Nonetheless, like Mayer et al. (2019) we conclude that the data is sufficiently reliable to provide a **rough but comprehensive assessment of the circularity of the Flemish economy**. However, it is not possible to derive any numeric indicator from the framework as presented in Figure 4. Once an indicator is selected, it requires further research to understand and compile the indicators for Flanders. This iterative process is illustrated with the circularity indicator presented in Chapter 3.

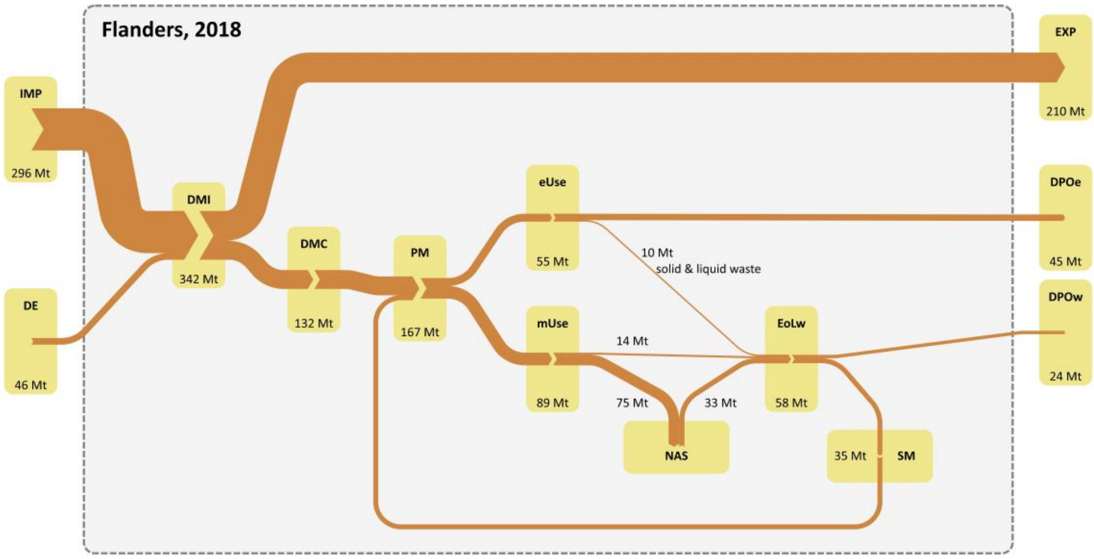


Figure 4: Material flows through the Flemish economy in 2018. [Improved framework presented in Figure 11!] In the Sankey diagram the width of the arrows is proportional to the size of material flows. The numbers show the size of the material flows in million tons per year. Note that the numbers may not always sum up to total due to rounding. Mt = million tons. IMP: import; DE: domestic extraction used; DMI: direct material input; DMC: domestic material consumption; PM: processed materials; eUse: energy use; mUse: material use; NAS: net additions to stock; EoLw: end of life waste; SM: secondary materials; EXP: export; DPOe: emissions in domestic processed output; DPOw: waste in domestic processed output.

Before starting the discussion on the overview, a few simple example cases are given and visualised to support the understanding of the framework. The examples are listed in Table 1. Although these examples are fictive and incomplete (no full production process with all inputs are shown), they illustrate how some typical material flows are represented in the framework. The examples start from the overview for Flanders, with all arrows in light grey. The flows included in the example are highlighted in

[1] See Annex 1. Some data was not available for the year 2018. In this case 2017 data is used instead.

colour as a part of the original flow. The quantities have no meaning. Some non-intuitive flows are discussed below the table.

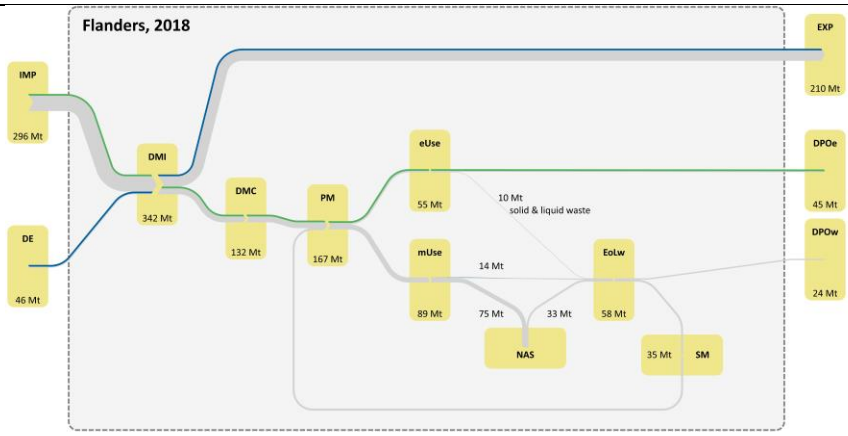
Table 1: Examples to support the understanding of the framework.

Example 1

A Flemish company produces clay bricks from domestically extracted resources. The output is exported. It uses natural gas as an input to its production process.

The material resources flow (blue) from DE to DMI to EXP. As the product is exported, the flow is not part of DMC nor PM.

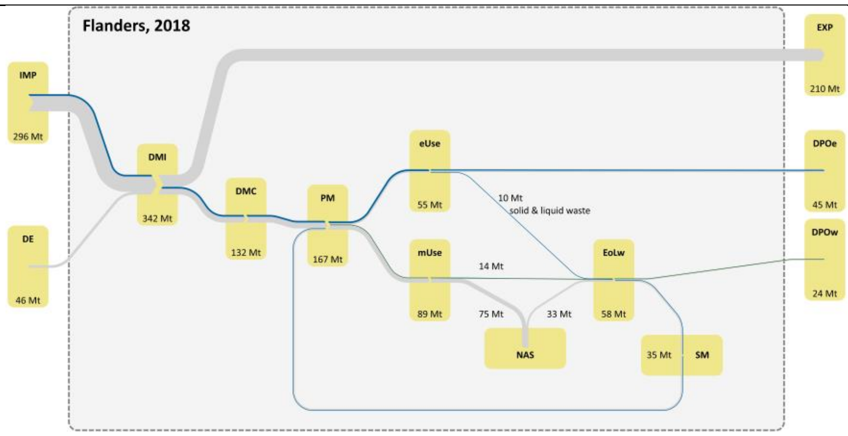
The use of natural gas as an energy source (green) flows from IMP to DMI to DMC to PM to eUse to DPOe, as it is transformed into emissions.



Example 2

A Flemish company produces food products from biomass cultivated abroad. All the output is sold to domestic households.

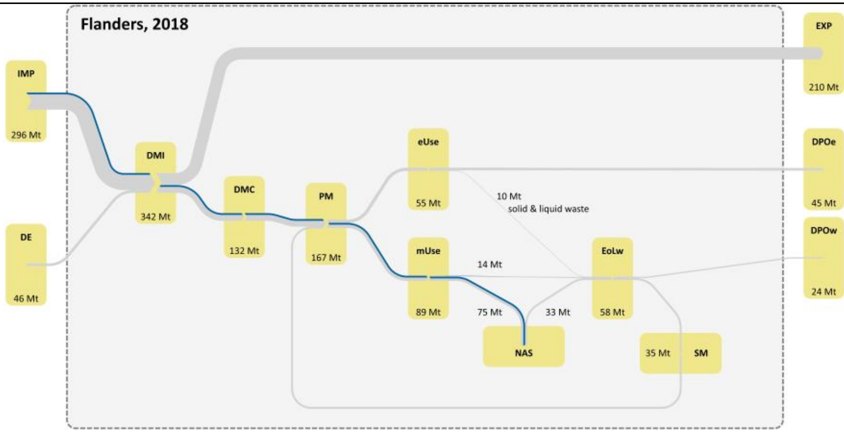
The imported biomass flows from IMP to DMI. As the output is sold to domestic households, the flow continues to DMC, to PM and to eUse. Part of the eUse is transformed into emission (flows to DPOe) and part is transformed into manure and food waste (flows to solid and liquid waste). The manure and food wastes are reused as a fertilizer (flow from EoLw to SM to PM to mUse to EoLw to DPOw).



Example 3

A Flemish household invests in building their own house. All construction materials originate (directly and indirectly) from abroad.

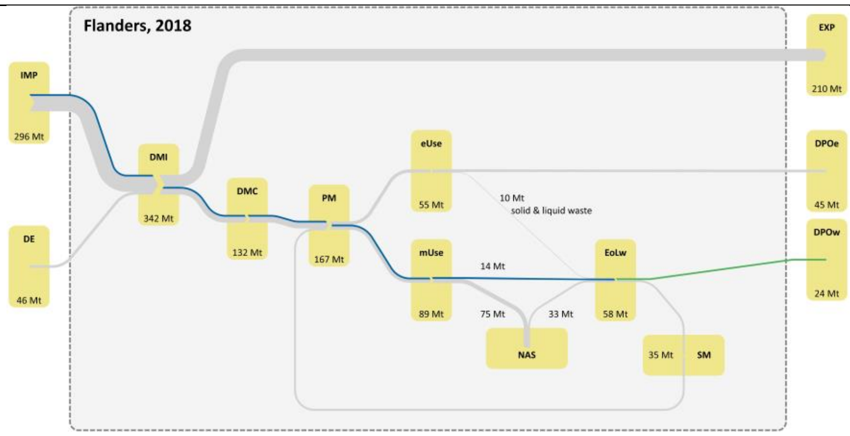
The imported construction materials flow from DMI, to DMC, to PM and to mUse. As the building is a long-live product, the flow of construction materials continues to NAS.



Example 4

A Flemish household buys plastic bags, which after use are discarded and incinerated.

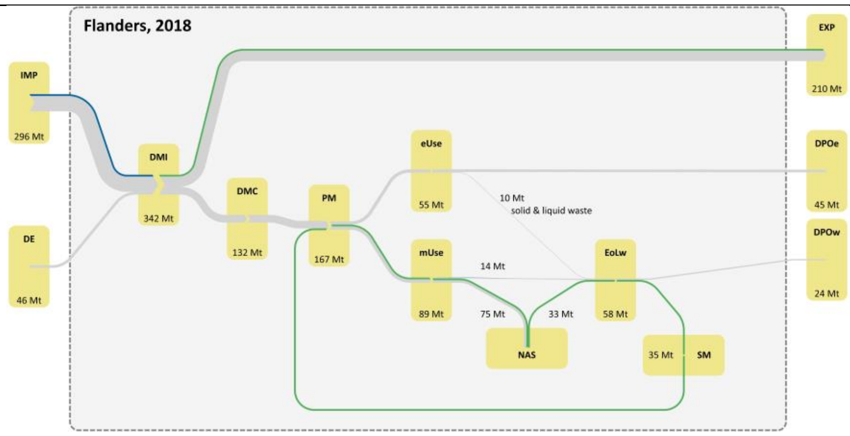
The imported resources (blue; all fossil energy carriers are at least indirectly imported) flow from IMP, to DMI, to DMC, to PM and to mUse. These bags are considered as short-live products, so the flow continuous to EoLw. After use (green), the material is incinerated. This is represented by a flow from EoLw to DPOw.



Example 5

A Flemish window producing company generates glass waste (cutting residues). The resources originate from abroad. The residues (glass cullet) are exported.

The flows only represent the amount of glass cullet, not the produced windows. The material is imported (represented by a flow from IMP to DMI). As a side production output, the glass cullet is exported (represented by a flow from DMI to EXP). However, in the Flemish waste statistics this generation of glass cullet is part of the secondary materials. This is represented by the green flows from EoLw to SM to

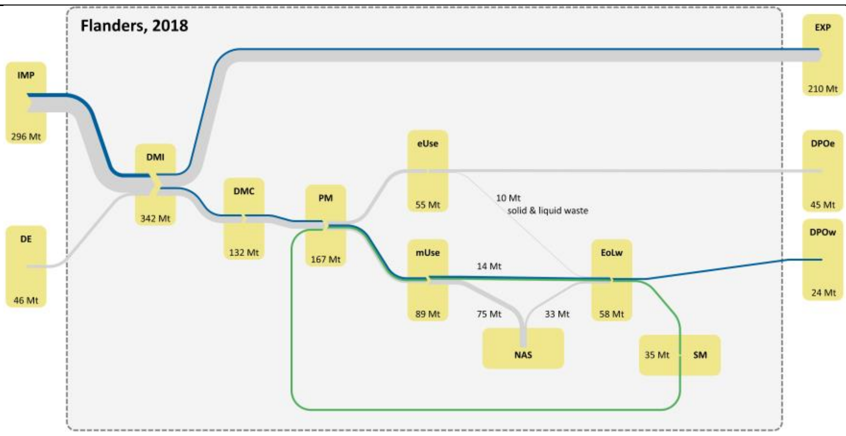


PM to mUse to NAS and to EoLw.

Example 6

A Flemish company imports waste from abroad, to recycle in Flanders. The recycled material is exported again. A part of the input remains waste which is landfilled here.

The import of waste is represented by a flow from IMP to DMI. Part of this waste is, after recycling in Flanders, exported again as secondary material (represented by a flow from DMI to EXP). As the recycling takes place in Flanders, the generation of recycled material is part of the waste statistics. This process is visualized by the green loop from EoLw to SM to PM to mUse to EoLw again. Here, we assume the recycled material is representing a short-living product. During the recycling process, waste is generated which is being landfilled. This is represented by the blue flows from DMI to DMC to PM to mUse to EoLw to DPOw.

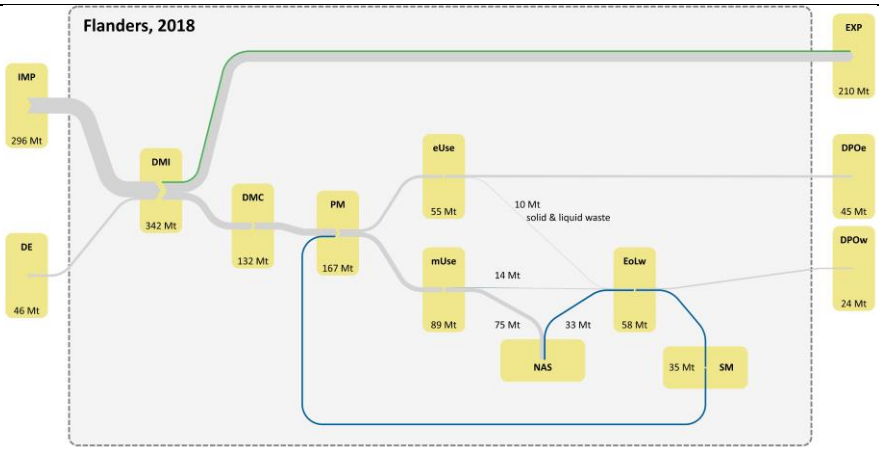


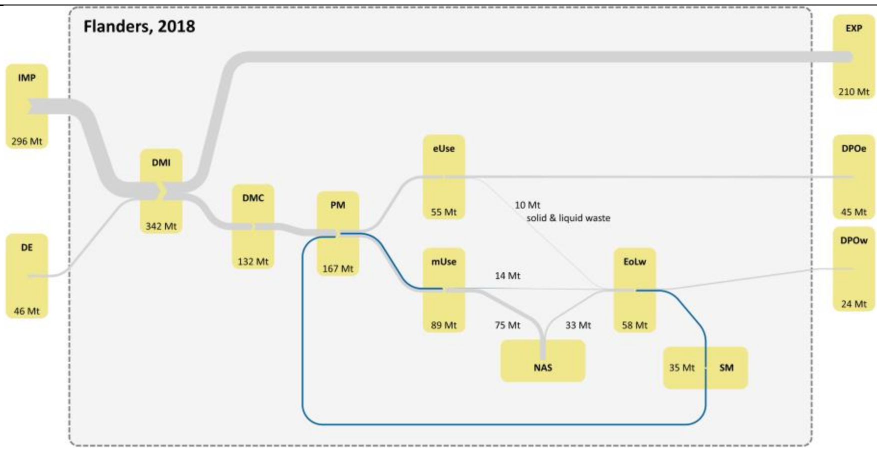
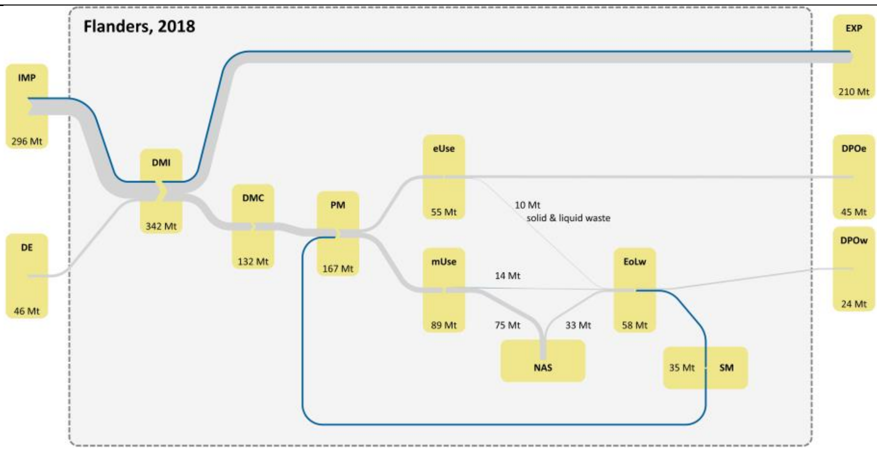
Example 7

A Flemish household wants to discard their own car and considers two options. First, to send the car for recycling at a Flemish authorised recycling centre or to sell the car.

During its use the car is part of the socio-economic stock (possibly for several years).

First option (blue flows): At the moment the car is send to a recycling centre, it gets out of this stock and becomes EoLw. About 95% of the materials are recycled (flow to SM) and



the rest is part of the flow to DPOw. Second option: If the car is sold to another Flemish household, it remains part of the Flemish socio-economic stock. Nothing changes in the framework. If the car is sold to a Flemish company that is exporting the car, this is only visible via the flow to export (green flows; there is no decline in stocks monitored). In case the car is sold abroad (private sell), this is not visible in the framework.	
Example 8_1 *A Flemish company is recycling waste turning it into secondary resources. In this example the waste originates from domestic sources and the secondary materials are used by another Flemish company.* Waste is sent to recycling and the secondary materials re-enter PM and, for example, are used as materials within the socio-economic system.	
Example 8_2 *A Flemish company is recycling waste turning it into secondary resources. In this example the waste originates from abroad (import) and the secondary materials are sold abroad (export).* Imported waste is sent to recycling, represented by a flow from EoLw to SM to PM and the secondary materials are exported.	

From the examples presented in Table 1 we derived some non-intuitive representations:

- In Example 1 the flows of an export-oriented company are visualised. The use of input materials is represented by a flow from outside the Flemish system (from DE or IMP) to DMI, being part of the Flemish socio-economic system. If all the input materials are, after processing, part of the production output being exported, none of these materials is reflected in DMC or PM although they are processed in Flanders. Only if this production process uses energy (Example 1) or generates waste (Example 5 and Example 6) part of the input continues to flow from DMI to DMC, PM and so on.

- Only if the production output is consumed inside Flanders (e.g. by households, investments) or turned into waste (meaning, it is not exported) the flows on the input side continue to flow to DMC and PM (see Example 2, Example 3 and Example 4).
- Example 4 shows a potential problem in the division of eUse and mUse. In the example, the plastic bag is used by a household (mUse). After the bag is discarded (flow to EoLw) it is incinerated (flow to DPOw). However, the incineration generates emissions (and electricity), so, the emissions are counted already in DPOe. This is one of the reasons why some frameworks only show DPO (without the distinction between DPOe and DPOw).
- Example 5 visualises the generation of waste (as part of a production process within Flanders), that is exported (in this example the export of glass cullet). The resources are imported and flow via DMI directly to EXP. Disconnected from this flow, is the recycling loop. In theory, all blocks within the socio-economic system are balanced. The generation of secondary resources is represented by a flow from EoLw to SM to PM. To balance the system, the loop is completed via a flow from PM to EoLw (in this case via NAS). The recycling activity is clearly visible within the socio-economic system, but it is not part of the DMC.
- Example 5 is equal to Example 6, except for the waste generated during the recycling process. The recycling process generates waste, which is represented by an amount flowing from IMP to DMI to DMC to PM to mUse to EoLw to DPOw. In contrast to Example 5, the landfilled share of the flow being recycled in Example 6 is part of the DMC, due to local recycling.
- Example 7 is on the products remaining part of the socio-economic stock for a long period. After use, there are several options available with a different representation in the framework. Some of these options do not even appear in the framework. Febelauto estimates a yearly flow of 35,000 to 65,000 cars[2] per year in Belgium with no EoL trackability. In the framework, they incorrectly remain part of the socio-economic stock.
- Example 8_1 and 8_2 show a drawback of the framework and the calculation methodology which is behind the framework. Example 8_1 perfectly shows the flow of waste to recycling to the re-entering on the input side of the economy. However, once waste originates from abroad or the secondary materials are exported (example 8_2), the framework shows disconnections. Also, the mass balancing which is needed to compile the framework is distorted, especially if these trade flows are considerable.

The examples above give the reader a better understanding of how the framework should be interpreted. The next paragraphs discuss the results for Flanders, presented in Figure 4, and derive a few more general insights. First, the overview shows the openness of the economy in Flanders. The domestic flows of materials are accompanied by huge flows of import and export. The domestic economy requires huge flows of import compared to a relatively small flow of DE. Meaning, the Flemish socio-economic system is dependent on resources from abroad. Not only the import dependency is high, also on the dependency on export is high. In 2016, on average 71% of the mass output of Flemish companies was directly or indirectly linked to export.

Next, the overview shows the relatively small loop of resources within the socio-economic system. The feedback loop of resources (estimated at 35 million ton) is small compared to the input of materials (except export this is 132 million ton). This feedback loop is elaborated in Chapter 4. The framework does not allow to estimate the stock of materials in Flanders. It does estimate the NAS, which is 41 million tons. It shows the large volume of resources being accumulated within the Flemish socio-economic system. This NAS creates a substantial time gap between the input and output of materials. Materials in mUse will eventually flow to EoLw, but a time gap between both should be considered.

Also, the overview shows the importance of materials for energy use. The flow of these materials is of similar size (55 million ton) compared to the use of resources for material related purposes (89 million

[2] https://www.febelauto.be/public/Febelauto-memorandum-traceerbaarheid-NL.pdf

ton). An estimated 50% of the eUse is biomass for use in food and feed products, meaning a goal of achieving all materials in DMC (or PM) to feedback loops (on short term) seems impossible.

Finally, during the construction process of the overview figure we encountered several discrepancies between data sources. Although in theory each block within the socio-economic system has an input that equals the output, this is in some cases a result of mass balancing meaning the input or output flow is calculated and not derived from a data source. In these cases, a potential discrepancy or uncertainty is hidden. For PM, both the input and output side are derived from data sources, resulting in a considerable gap between input and output. While the input is estimated at 167 million tons, the output is estimated at 144 million tons. The difference of 23 million tons is due to a difference in the estimation of the use of energy related products. Another imbalance is present in the NAS-block. Because there is no mass balance required in this block, there is no check possible on the estimations for the input and output. Using the mass balancing approach for estimating (some) flows potentially masks these uncertainties. These uncertainties are present in each block.

In the next section, several indicators are derived from the material flow overview figures to further facilitate the interpretation.

2.2 Indicators derived from the economy-wide circularity framework

A first set of economy-wide indicators is based on Mayer et al. (2019). All the indicators they describe in this set are derived from the framework presented in Figure 1. These authors distinguish between:

- **scale indicators**: which provide measures for the overall size of the socioeconomic metabolism;
- **circularity rates**: which measure socioeconomic and ecological cycling relative to input and output flows. Providing independent measures for flows on both the input and output sides is necessary because of the delaying effect that in-use stocks of materials have on output flows.

	Dimension	*Input-side indicator*	*Output-side indicator*
Scale indicators (t)	In- and output flows	*Domestic material consumption* **DMC**	*Domestic processed outputs* **DPO**
	Consumption based perspective	*Raw material consumption* **RMC**	n.a.
	Interim flows	*Processed materials* **PM** = DMC + secondary materials	*Interim outputs* **IntOut** = EoL waste + DPO emissions
Circularity rates (%)	*Socioeconomic cycling* SC	*Input socioeconomic cycling rate* **ISCr** = Share of secondary materials in PM	*Output socioeconomic cycling rate* **OSCr** = Share of secondary materials in IntOut
	Ecological cycling potential EC	*Input ecological cycling rate* potential ***IECrp*** = Share of DMC of primary biomass in PM	*Output ecological cycling rate* potential ***OECrp*** = Share of DPO biomass in IntOut
	Non-circularity NC	*Input non-circularity rate* **INCr** = Share of eUse of fossil energy carriers in PM	*Output non-circularity rate* **ONCr** = Share of eUse of fossil energy carriers in IntOut

Note: n.a. = not applicable.

Figure 5: Mass-based circular economy indicators where scale indicators measure the absolute size of input and output flows in tons and circularity rates measures socioeconomic and ecologic cycling relative to input and output flows in percentage. Source: Mayer et al. (2019).

The **scale indicators** are directly available from the material flows monitor. However, the framework only shows values for one year hampering a relevant interpretation thereof. Therefore, we recommend showing the trend of these indicators if the source data is available. The estimations presented in Figure

6 show the trend of the scale indicators DMC, DPO, RMC, PM and IntOut, expressed in absolute values (million tons). As seen in Figure 5, the indicators are allocated to input-side and output-side indicators. Providing independent indicators for flows on both the input (DMC, RMC, PM) and output sides (IntOut, DPO) is necessary because of the delaying effect that in-use stocks of materials have on output flows (Mayer et al., 2019). As described above, the presence of a stock in the socio-economic system creates this delaying effect.

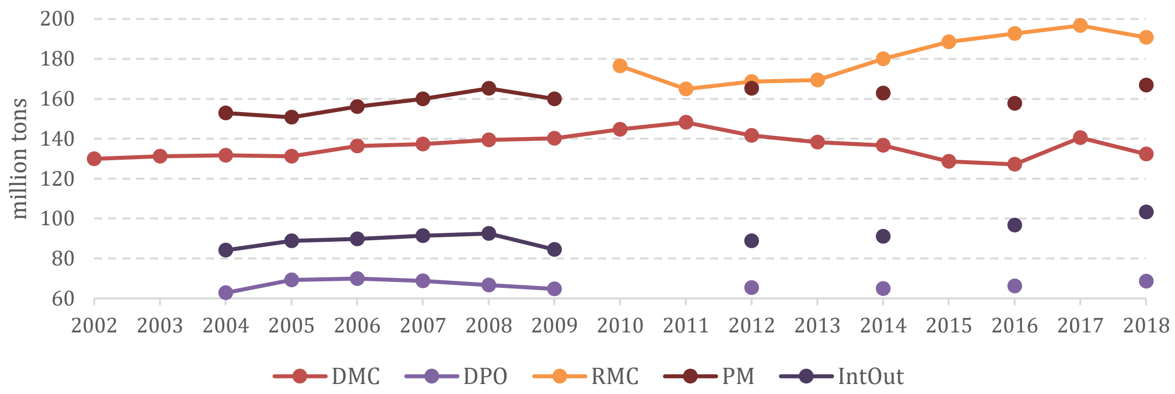


Figure 6: The trend in the scale indicators DMC (domestic material consumption), DPO (domestic processed output), RMC (raw material consumption), PM (processed materials) and IntOut (interim output), 2002-2018, Flanders.

The **DMC** in Flanders varies between 130 and the 148 million tons in the period 2002-2018. The estimation shows an increasing material use between 2002 till 2011 from 130 to 148 million tons. After 2011 the domestic material uses decreased to 127 million tons in 2016, followed by a temporary increase in 2017, and again a decrease to 132 million tons in 2018.

DPO is estimated annually for the period 2004-2009 and biannually from 2012 onwards. The DPO, as total output flow, varies between 63 and 70 million tons. The DPO shows a variable trend with first an increase till 2006, then a decrease till 2014 and again an increase till 2018. The input of materials, measured by DMC, is higher compared to the output of materials, measured by DPO. The reasons for this difference are an increasing stock of materials (in NAS) and the presence of a feedback loop of materials (via SM) within the socio-economic system. An increasing stock means that more long-living products are consumed (invested in) compared to the amount of these products that is discarded.

The **RMC** indicator trend is expressed using the moving average approach. This method calculates the average of the estimation for the current year and the estimation of the previous two 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. The RMC estimation is between 165 and 197 million tons in the 2010-2018 period. The RMC shows an increasing trend, with a decrease in 2011 and 2018.

The interim flows, PM on the input side and IntOut on the output side, are estimated annually for the period 2004-2009 and biannually starting in 2012. **PM** is the sum of DMC and SM. The estimation of PM for Flanders shows a variable, slightly increasing trend. The DMC shows a decreasing trend from 2012 onwards, however, together with the increasing trend in SM this results in a rather stable to slightly increasing amount of materials on the input side of the economy between 161 and 167 million tons. The interim flow for measuring outputs, **IntOut**, equals the sum of DPOe and EoLw. The indicator is like DPO, except also includes the SM flow. Therefore, the estimation is higher compared to the estimation for PM. As from 2008 onwards the SM shows an increasing trend, the gap between PM and IntOut increases. The interim input of materials, measured by PM, is higher compared to the interim output of materials, measured by IntOut. The reason for this difference is an increasing stock of materials (in NAS). The difference between PM and IntOut is equal to the difference between DMC and DPO. Only SM is still part of the interim flows, while this is not the case for DMC and DPO.

The **circularity rates** can't be derived directly, but need to be calculated from the framework. Again, the framework only shows values for one year hampering a relevant interpretation thereof. Therefore, it is preferred to look at the trend of the rates estimates if the source data is available. Three types of circularity rates are defined by Mayer et al. (2019): socioeconomic cycling (SC), ecological cycling potential (EC) and non-circularity (NC).

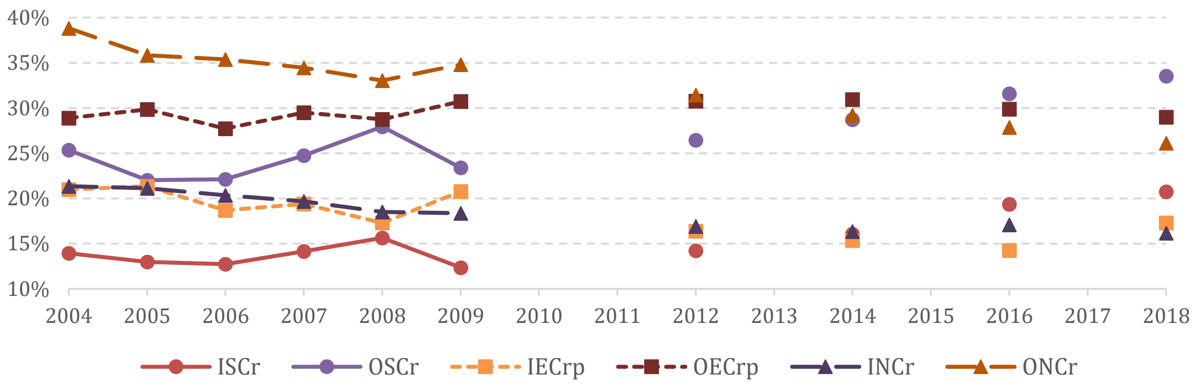


Figure 7: The trend in the circularity rates ISCr (input socioeconomic cycling), OSCr (output socioeconomic cycling), IECrp (ecological cycling rate potential), OECrp (output ecological cycling rate potential), INCr (input non-circularity rate) and ONCr (output non-circularity rate), 2004-2018, Flanders.

The input socioeconomic cycling rate (**ISCr**) and the output socioeconomic cycling rate (**OSCr**) are estimated via the share of secondary materials in PM and in IntOut, respectively. The socioeconomic cycling rates measure the contribution of secondary materials to PM and the share of IntOut that is diverted to be used as secondary materials. On the input side, the cycling rate is steadily increasing from 14% to 21% in the 2004-2018 period, with a minimum in 2009 of 12%. On the output side, the cycling rate is fluctuating in the period 2002-2009 between 22 and 28% and increasing from 2012 onwards to 34% in 2018. As the numerator for both rates is the same, the difference is in the denominator. While the denominator for the input side is measured by PM including the DMC and SM, the denominator for the output side is measured by IntOut including DPOe and EoLw. The difference between both denominators is the NAS. In an economy which increased its stock, like the economy in Flanders, the rates are higher on the output side compared to these on the input side. Both the socioeconomic cycling rates show an increasing trend (from 2012 onwards), meaning the economy in Flanders is relatively increasing the use of SM on the input side and is increasingly sending secondary materials in feedback loops.

The input ecological cycling rate potential (**IECrp**) and the output ecological cycling rate potential (**OECrp**) are estimated via the share of domestic material consumption (DMC) of primary biomass in PM and the share of domestic processed output of primary biomass in IntOut, respectively. On the input side, the cycling rate potential has a fluctuating and decreasing trend from 21% in 2004 to 17% in 2018, with the lowest rate of 14% in 2016. On the output side, the cycling rate potential shows a steady potential ranging between 28 and 31%, with a share of 29% in 2018.

The input non-circularity rate (**INCr**) and the output non-circularity rate (**ONCr**) are estimated via the share of eUse of fossil energy carriers in PM and in IntOut, respectively. These rates are quantifying the share of material flows that do not qualify neither for socioeconomic and ecological loop closing. Both the input and output rate show a decreasing trend. However, the trend on the input side in the period

2012-2018 is more stable. The rates on the input side decrease from 21% in 2004 to 16% in 2018. The rates on the output side decrease from 39% to 26% in the 2004-2018 period.

Putting together the input and output circularity rates, one can derive the remaining non-renewable primary resources on the input side and the remaining interim outputs on the output side (see Figure 8). On the input, the use of secondary materials (socioeconomic cycle) and the use of primary biomass (ecological cycling potential) sum up to 38% of the total PM. Also, 16% of PM consists out of fossil energy carriers assigned to energy use. The remainder, 46% or 76 million tons, are non-renewable primary resources required for the domestic economy in Flanders. Although this high percentage shows the huge amounts of resources the domestic economy needs to fulfil its needs, this might not be all primary resources. The reasoning for this is the following. Only a small part of the input of materials to the Flemish economy are domestically extracted or cultivated. Most material input, 87%[3] in 2018, are imported materials. Only the import of products assigned to the material category of biomass and fossil energy carriers in energy use are reported separately. Other imported products might also be or consist out of biomass or secondary materials. This issue is discussed in Chapter 3.

On the output side, the output of secondary materials (socioeconomic cycle) and the output of biomass in DPO (ecological cycling potential) sum up to 63% of the total IntOut. Also, 26% of the output in IntOut are (emissions from) fossil energy carriers used in energy consumption. This leaves, 11% or 12 million tons, as remaining interim outputs which can be interpreted as the current loss of resources. Based on this overview, the **two major obstacles hampering a substantial increase in socioeconomic cycling are the ongoing expansion of in-use stocks and the high share of non-circular fossil energy carriers in PM**. The same conclusion from Mayer et al. (2019) equally applies: *"While it is important to further improve the recycling and downcycling of EoL waste, these results emphasize that achieving a CE goes far beyond increasing reuse and recycling. Major obstacles for substantially increasing socioeconomic cycling are the ongoing expansion of in-use stocks and the high share of non-circular fossil energy carriers in PM (INCr). Increasing the lifetime and a more intensive use of material stocks, as envisaged via increasing value and utility of products, are important measures towards a CE and need to be developed in this direction. Additionally, improved recycling technology and changes in product design to enhance recyclability are important challenges. Clearly, also a reduction of fossil fuel consumption is urgently required to mitigate climate change, which would also increase socioeconomic circularity. For renewable biomass resources, CE strategies should focus on less wasteful, more efficient, and cascadic uses as well as a production system that fosters and sustains ecological cycles, rather than simply increasing biomass inputs to substitute other materials".*

[3] Excluding secondary materials (SM).

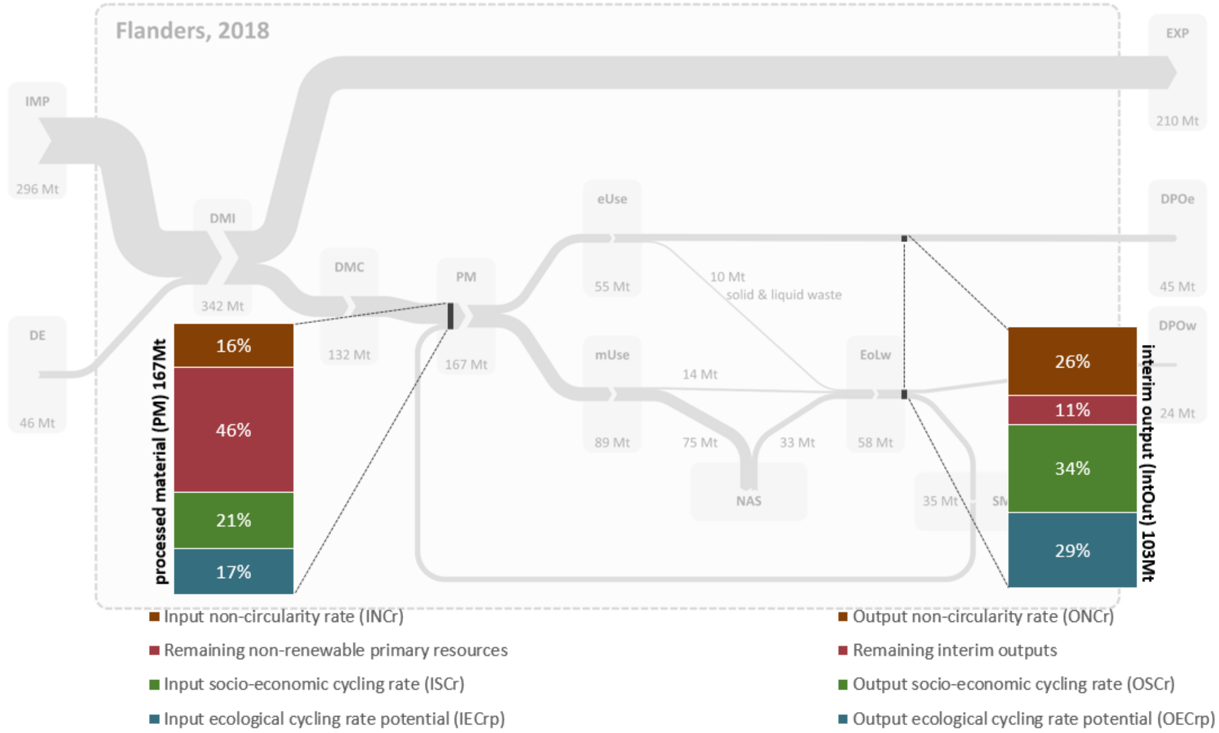


Figure 8: Input- and output-side CE-indicators. The left bar depicts the processed materials (PM), and the right bar depicts interim outputs (IntOut). The percentages denote the share in relation to the PM (left bar) and the IntOut (right bar). Based on Mayer et al. (2019).

An alternative indicator is the *circularity gap* presented by Aguilar-Hernandez et al. (2019). The indicator is defined as the generated waste *plus* old materials removed from stocks and durable products disposed *minus* recovered waste. The circularity gap (CG) can be interpreted as the measure of waste materials that are theoretically available for material circularity. From the framework presented in Figure 1, the stock depletion, waste generation and waste recovery are represented by -Stock, EoLw and SM, respectively. Also, in this framework the CG is represented by DPOw. From 2005 onwards, the estimated CG for Flanders fluctuates around 22 million tons, with an estimation of 24 million tons in 2018. The estimation shows that 58 million tons of materials are (theoretically) available for material circularity, but (only) 35 million tons are effectively part of a feedback loop. The remainder, 24 million tons, is part of DPO and can be interpreted as lost resources.

Next to the CG, Aguilar-Hernandez et al. (2019) present two other indicators: the *circularity index (CI)* and the *circularity gap index (CGI)*. The index CI equals waste recovery (equal to SM) divided by DMI. This index is like the socioeconomic cycle but with a difference in the denominator. While the CI index uses DMI as the denominator, the socioeconomic cycle used the PM as denominator. The relation between DMI and PM is illustrated by the following expression: $\mathrm{PM} = \mathrm{DMI} - \mathrm{EXP} + \mathrm{SM}$. The CGI is calculated as the CG divided by the sum of waste supply and stock depletion.

The CI for Flanders has increased in the 2004-2018 period from 7% to 10%, with an index of 10% in 2018. The CGI index decreased from 53% to 41% in the 2005-2018 period, with an index of 41% in 2018. The estimated CGI index of 2004 seemed to be an outlier at 41%, due to a remarkably lower estimation of the stock depletion in that year. Both the increase in CI and the decrease in CGI can be considered as positive trends.

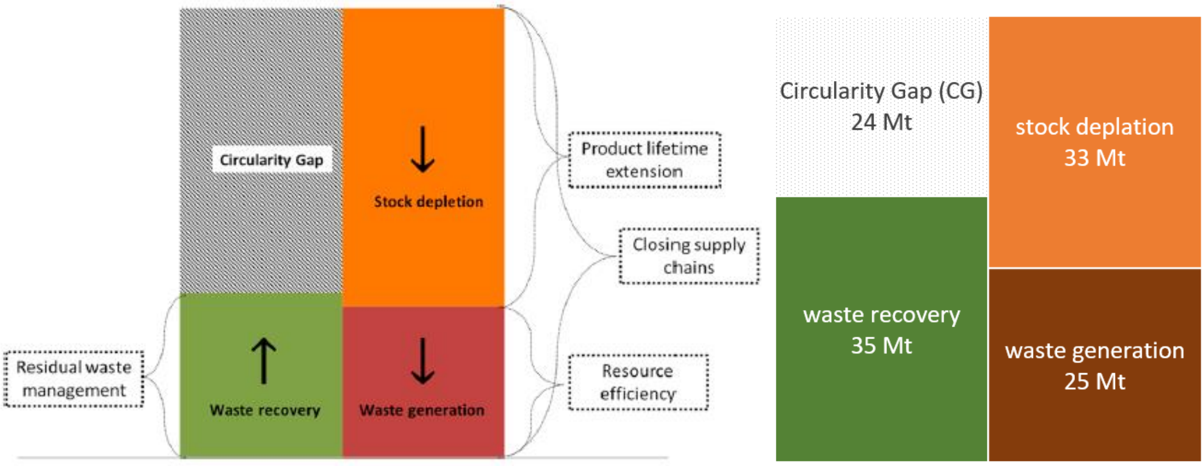


Figure 9: (left) A circularity gap reduction through four intervention types. Green, red and orange squares indicate material recover, waste generation, and stock depletion, respectively. The grey area depicts the circularity gap. Upward arrows indicate an increase of materials flows, and a downward arrow indicates a decrease or delay of the flow. (right) The estimated circularity gap for Flanders, 2018.
Source: Aguilar-Hernandez et al. (2019).

The CI index, estimated at 10% for Flanders in 2018, shows the fraction of waste recovery compared to the total material input in the domestic economy. The rest of the materials are either exported or part of the DPO. The CGI, estimated at 41%, shows the amount of material wastes passed through waste treatment sectors, that were not reintroduced into the economy as recovered materials.

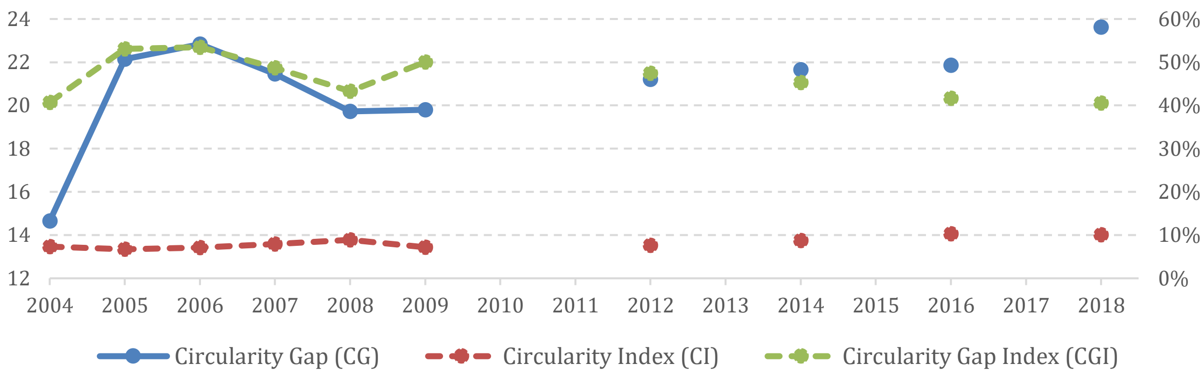


Figure 10: Estimations for the circularity gap (left axis) and the circularity index and circularity gap index (right axis) for Flanders, 2004-2018.

At first sight the frameworks presented in Figure 1 and Figure 2, show a simple and intuitive representation of macro-economic material flows crossing and within the socio-economic system. However, the compilation of an overview for Flanders and the interpretation was not straightforward. The compilation of the framework required the combination of different datasets, data from literature and gap filling based on mass-balancing. The combination of sources reveals mismatches in data. The gap filling based on mass-balancing potentially masks potential uncertainties.

The framework focusses on actual flows of materials within the socio-economic system and distinguishes two types of resources. First, it distinguishes between the energetic or material use of resources, which allows to see the difference in purpose in the total domestic material use. While in energetic use, the resources are consumed and no longer available for future use, the resources for material use purposes have the potential for longer use, reuse, recycling etc. A second distinction is within the material use. Here, the framework separately reports on resources in short-living and long-living products. In this last group, the time gap between input and output is important to consider.

The presented example cases showed the complexity of understanding and interpreting the framework. Especially the interpretation and visualization of trade and domestic recycling within the framework is non-intuitive. Adding more details will improve the understanding. For example, in Section 4.1 Adding **trade in waste** and **trade in secondary materials** to the framework the role of trade in waste, recyclables or secondary materials as pats of the framework are examined.

Chapter 3

Methodological assessment of circularity rate indicator

In this chapter a closer look is given to different options with regard to the methodology and scope for calculating the circularity rate defined as input socioeconomic cycling rate (*ISCr*), which is discussed and calculated for Flanders in the previous chapter. This circularity rate is defined as the ratio of secondary material (SM) and processed material (PM).

It is important to thoroughly assess the scope of the SM flow:

- Which waste flows (to which treatment) are included?
- Which perspective is defined: waste collected for recovery or use of secondary material recovered from waste?
- How is dealt with import and export of waste resp. secondary material?

First the calculation methods for this indicator applied by relevant European initiatives/frameworks are discussed and compared i.e.

- Circular Material Use (CMU) rate defined by Eurostat and one of the indicators included in the European CE Monitoring framework;
- National Circularity Index (NCI) defined by Circle Economy and reported for some European countries like Austria and the Netherlands.

Based on insights in these methods, a reflection is given on the methodology and scope of the circularity rate (ISCr) as calculated for Flanders in the previous chapter. In a next step the effect of different circularity strategies on the circularity rate indicator is discussed to identify potential limitations and points of attention.

This analysis finally leads to conclusions and recommendations for refining and improving the methodology and scope for calculating the circularity rate indicator for Flanders, keeping in mind comparability with other countries and updatability of the indicator in the future.

3.1 Calculation method for comparable circularity rate indicators

Although the same ratio (SM/PM) is used for the circularity rate of an economy, differences exist e.g. depending on what is included in the SM resp. PM flow. This paragraph discusses the calculation method for the CMU rate indicator (Eurostat) and the NCI indicator (Circle Economy), and compares these to the method used for the Flemish indicator as calculated and discussed in the previous chapter.

3.1.1 Circular Material Use (CMU) rate indicator (Eurostat)

The calculation method is described in a separate document[4]. It discusses the concept and the relation with the Sankey diagram of material flows based on Eurostat statistics of material flow accounts and waste statistics, which is also the basis for the Flemish indicator.

[4] https://ec.europa.eu/eurostat/web/products-eurostat-news/-/DDN-20200312-1#:~:text=The%20European%20Union%20(EU)%20circular,increase%20in%202016%20(11.4%25).

Eurostat confirms that a “reference value” is necessary. Only using the absolute value of secondary materials (SM) is not per se representative for the circularity of an economy e.g. when the amount of SM increases at the same pace as overall material use.

The CMU rate is the ratio of circular use of materials to overall material use. Eurostat confirms that the numerator and denominator can be measured by different indicators, in different ways. The Eurostat indicator focusses on a country’s effort to collect waste for recovery (and not on the capacity of a country to produce secondary raw materials). *‘This perspective credits the country’s effort to gather waste bound for recovery which indirectly contributes to the worldwide supply of secondary materials and hence avoidance of primary material extraction.’*

The denominator is defined by an indicator for overall material use. Eurostat prefers to use the Raw Material Consumption (RMC) for this. This indicator is however not yet available for all EU countries, which is an important condition for Eurostat. For that reason the Domestic Material Consumption is suggested as a proxy indicator. Arguments for using **DMC as a proxy** for RMC is the fact that its development over time resembles that of RMC, and data are collected annually, for all member states. An alternative denominator would be the Domestic Material Input (DMI), but this would lead to double-counting as materials extracted in one EU country and imported by another one are counted twice. As the CMU rate is defined as a ratio-indicator, it should have a maximum threshold of 1 (or 100%) and thus the denominator is defined as the sum of DMC+SM.

The numerator has to indicate the circular use of materials and is approximated by the amount of **waste recycled in domestic recovery plants.** Ideally this includes two components:

- Residual material legally declared as waste, which is recovered and after treatment fed back to the economy (so, going through legally demarcated waste management system). This part is approximated by waste statistics, representing the flow of materials that have become legally defined waste and after recovery are fed back into the economy thus avoiding the use of primary materials. Only the waste flows going to ‘Recovery-Recycling’ are taken into account, thus not energy recovery and not backfilling.
- Residual material outside legal waste coverage (outside waste management system (WMS)) e.g. a by-product of production processes which is either fed back into the own processes (intra) or sold and processed by others (economic transaction). This flow is not captured by official statistics[5] and thus not included.

The waste recycled in domestic recovery plants needs to be corrected by imports and exports of waste destined for treatment. As the CMU rate indicator focusses on the country’s effort to collect waste for recovery, the waste collected abroad and imported has to be excluded, and vice versa the waste that is collected domestically but exported for treatment needs to be included. Eurostat refers to the CN-codes in Eurostat’s trade in good statistics for import and export of waste. So, the numerator can be summarized as: **amount of waste recycled in domestic recovery plants – import of waste for recovery/recycling + export of waste for recovery/recycling**

Using waste statistics for measuring the circular use of materials has some consequences for the interpretation of the indicator. One effect is that only the contribution of WMS to CE is included, the circular use of residual material which goes outside the WMS is not (‘non-waste part’). This is important, as it is this flow which is expected to increase in the future because of increasing value. Another consequence is that the indicator focusses on the input of waste into recovery plants and not on the quantity and quality of secondary materials that come out which is the ideal option. Although it is analysed by Eurostat that input of recovery plants is an acceptable proxy for their output.

[5] PRODCOM data for production of secondary raw materials (CPA 38.32.2 and .3) are not provided, intra flows are not recorded anywhere.

Eurostat uses the perspective of a country's effort to collect waste for recovery in the standard CMU rate indicator. The other perspective, which emphasizes the domestic use of secondary material recovered from former waste (= contribution to saving of primary raw material extraction on global scale), is also possible and is called the **alternative CMU-rate**. In this perspective the country which uses the secondary material gets the credit. Like the CMU rate, the alternative CMU rate distinguishes different components:

- Secondary material produced in domestic recovery plants: As these data are typically not available the amount of waste recycled in domestic recovery plants is used as a proxy.
- Plus imports of secondary materials recovered from former waste
- Minus exports of secondary materials recovered from former waste

This perspective is closer to the national accounts logic (in which most re-attributions are directed towards final use).

Data required for the calculation of the CMU rate as currently defined by Eurostat are readily available on country basis:

- Waste statistics (Regulation (EC) No 2150/2002)
- EW-MFA accounts (Regulation (EC) 691/2011)
- International trade in goods stats (COMEXT database)

3.1.2 National Circularity Index (Circle Economy)

The National Circularity Index (NCI) follows from the Global Circularity Metric defined by Circle Economy and published annually in the Circularity Gap reports since 2018[6]. While the Global Circularity Metric takes a global perspective, the NCI is developed for monitoring on a national and regional scale.

Looking at circularity from a global perspective is more straightforward i.e. there is less risk for double-counting or missing flows). The Global Circularity Metric is defined as the share of cycled materials as part of total material inputs into the global economy every year. Total material inputs includes:

- Cycled materials = materials classified as waste which are cycled (=to water treatment, to land application, to biogasification, to recycling and to composting)
- Extracted resources = all resources extracted globally (except water)

Like the CMU rate indicator, the Global Circularity Metric does not explicitly include the effect of strategies that are core to building a CE such as asset sharing, life time extension or remanufacturing. These strategies extend the functional life of products, thus waste creation is prevented and material requirements for new products are reduced as well. Nor does the indicator consider quality loss of cycled materials, but only measures how much materials are cycled.

More interesting in the context of our study is the National Circularity Index (NCI), which is derived from the Global Circularity Metric methodology but calculated and reported on a country-level for e.g. Austria, the Netherlands and more recently for Norway[7]. The methodology is discussed in different documents[8]. The NCI also starts from a Sankey diagram which is based on MFA. Some important differences can be seen in the Sankey diagram compared to the traditional Sankey as presented by Eurostat (and in chapter 2 of this report):

[6] The Circularity Gap reports: An analysis of the circular state of the global economy (2018), Closing the circularity gap in a 9% world (2019), When circularity goes from bad to worse – the power of countries to change the game (2020); https://www.circularity-gap.world/global

[7] https://www.circularity-gap.world/countries

[8] https://assets.website-files.com/5e185aa4d27bcf348400ed82/5e247840992bfa79a82cfec0_Website_short%20GCM%20for%20nations.pdf

- The flows are not only visualizing the direct material inputs, but are expressed in tons of Raw Material Equivalents (RME) and thus include the indirect use of raw materials (i.e. the rucksack of materials required in the production of the product. The RME-coefficients are estimated by combining national and Eurostat data.
- The Sankey shows explicit flows of imported resp. exported cycled materials.

The ratio of the NCI is the same as for Eurostat i.e. it is defined as the share of cycled materials as part of the total national material consumption. An important difference is the perspective used for the cycled materials. The NCI applies the perspective of a country that recycles the secondary materials putting emphasis to the recycling process within the national economy, thus not a country's efforts to collect waste for recycling (as is used in Eurostat's CMU rate). The indicator distinguishes 4 key resource groups i.e. biomass, metals, non-metallic minerals and fossils. The type of material flows accounted for is different to the Eurostat CMU rate indicator i.e. backfilling material is included, as well as material send to energy recovery if it has a Combined Heat and Power (CHP) efficiency of more than 65%.

The NCI is defined by the following formula:

$$\mathrm{NCI} = \frac{\mathrm{smc} + \mathrm{wu}}{\mathrm{RMC} + \mathrm{smc} + \mathrm{wu}}$$

The numerator distinguishes two flows:

- The **waste reused domestically without preprocessing (wu)**: It is assumed that short-lived, low-value and bulky recyclable waste (e.g. non-metallic mineral waste such as aggregates, rubble and composting material) is only consumed within the national economy and thus not imported nor exported. This flow is known from the waste statistics.
- The **secondary materials consumed domestically (smc)**: This includes the secondary materials domestically cycled plus imported, minus the secondary materials exported. These flows are not captured by statistics and need to be calculated using proxies and assumptions.
  - *Secondary materials imported (smi)*: Approximated by applying the Global Circularity Metric per resource group to the net direct imports (aggregated by resource group using shares of RME per resource group).

    $\mathrm{smi} = \mathrm{sm} + (\mathrm{imp} * \mathrm{GCI})$ (1)

    sm = secondary materials deployed domestically → known from statistics
    imp = net direct imports of physical products → known from statistics
    GCI = global circularity index = calculated and published in Global Circularity reports
  - *Secondary materials consumed domestically rather than being exported*: Assumed that the share of secondary materials in the total consumption of raw materials equals the share of imported and domestically cycled secondary materials in total input of raw materials.
    $\frac{\mathrm{smc}}{\mathrm{RMC}} = \frac{\mathrm{smi}}{\mathrm{RMI}} \rightarrow \mathrm{smc} = \frac{\mathrm{RMC}}{\mathrm{RMI}} * \mathrm{smi}$ (2)

    RMC and RMI → known from MFA
    smi = calculated with formula (1)

The denominator uses the **Raw Material Consumption (RMC)** as a measure for the total national material consumption. The RMC is not available for all European countries (in Eurostat statistics), but is calculated by combining MFA data with RME-coefficients from Eurostat and national Input-Output modelling data. As the maximum threshold should be 1 (or 100%), the denominator is defined as the sum of RMC+smc+wu.

3.1.3 Reflections on method and scope of indicators

In general is the circularity indicator defined by the same ratio i.e. ratio of secondary materials versus total (primary + secondary) materials. The indicator is typically based on the mass of material flows, which implies that other aspects, like preservation of value and security of supply, are not directly captured by this indicator. Although the general formula is the same, we can observe some differences between the calculation methods of the indicator. The most important differences relate to the following issues:

- ***Which flows of materials are included?***
  All methods include the four main material categories for primary and secondary materials: biomass, metals, non-metallic minerals and fossils. There are however some differences in secondary materials which are included. For example, backfilling material is not considered as a secondary material in the CMU rate indicator of Eurostat, while it is included in the NCI of Circle Economy. Materials which are incinerated with energy recovery are out of scope for the CMU rate indicator, but are included in the NCI in case the CHP efficiency is more than 65%.
  The NCI adds a complementary indicator which excludes flows of biomass and fossil fuels for energetic use. This has a significant effect on the circularity indicator, because a large part of these flows are not available for reuse as secondary materials. A circularity indicator including biomass and fossil fuels for energetic use will most likely never reach a score of 100%, although a high score is possible and can be achieved by replacing fossil fuels by renewable energy sources.
  It has added value to calculate the circularity indicator per material category (which is done for CMU-rate and NCI), to show differences between the categories and to have better insight in the material categories with a smaller share (based on mass) in the total e.g. metals and fossil fuels. It is important to acknowledge though that the degree of circularity also depends on the type of materials, e.g. between biomass for food and minerals or metals, and it is not relevant to compare the materials with each other. Also, CE-strategies might imply substitutions between material categories. For example, product-service systems might require more robust products, increasing the demand for metals.
  In this report: *The Flemish indicator as calculated in chapter 2 includes all material flow (biomass, fossils, metals and non-metallic minerals) for PM and SM. For SM (primary and secondary) waste destined for secondary resource, composting, reuse and recycling is taken into account. Waste flows going to energy recovery and backfilling are excluded from the SM flow. To understand exactly what is included in the SM flow (backfilling, waste from material processing and manufacturing, dredged material, …) the waste statistics are further explored in Chapter 4.*

- ***Which perspective is used to look to secondary materials?***
  Two perspectives are possible to look at secondary materials, either the perspective of a country's efforts to collect waste for recycling (which is used for Eurostat's CMU rate) or the perspective of a country's efforts to use secondary material recovered from former waste (which is used for Circle Economy's NCI).
  The first perspective gives credits to the country that collects the waste, in the second the country which uses the secondary material gets the credit. The latter perspective is closer to the national accounts logic, but is less usable for international comparison. The first perspective gives a fair indication of the circularity of a country but doesn't measure the use of secondary materials in that country and has the risk of 'not considering' the export of waste to countries where recycling is less qualitative.
  In this report: *The Flemish indicator is based on waste statistics for the SM flow, as such the perspective that is followed for the circularity indicator depends on the scope of the waste statistics: do these only consider waste collected in Flanders are do they include waste imported, and are any secondary materials included? A detailed analysis of what is included resp. excluded from the waste*

statistics is necessary to thoroughly assess if the Flemish circularity rate indicator follows the CMU rate perspective or not. This is elaborated in Chapter 4, together with the estimation of trade in waste and secondary materials.

- ***Is a footprint perspective applied or is only direct material use included?***
  Ideally the direct and indirect (footprint) use of materials is considered when calculating the circularity indicator. Direct material use is defined by indicators like DMC, for including also the indirect material use DMC is converted to RMC using RME-conversion factors. Indicators like RMC also include materials that were required for producing imported products, but not physically entered the country.
  The CMU rate indicator (Eurostat) bases the circularity indicator on the direct material use only (DMC). Reasons for this are that i) the RMC is not available for all Member Countries, ii) policy focusses on direct material flows and iii) no data nor reliable method exist to express the secondary material flows in indirect material use. The NCI of Circle Economy does include the indirect material flows in the assessment. This is done by combining MFA data with input-output (IO) analyses. An RME is calculated for imported and exported products, based on RME-coefficients of Eurostat validated by other data and models. Also, for domestic extraction the indirect material flow is accounted for. But for secondary materials no material footprints are available nor could be approximated with models and thus only direct material use is considered for the secondary material use in the circularity indicator.
  <u>In this report:</u> *The Flemish indicator as calculated in chapter 2 follows the logic and approach of Eurostat's CMU rate, i.e. only includes the direct material use for SM and PM. This indicator gives a good indication of the level of circularity of material use in economic processes in Flanders and has the advantage to be based solely on available data. Flemish policy decision-making corresponds to this scope as well. The disadvantage is the limited scope as indirect material use in the (international) value chains is not included, which is an important issue for an open economy like Flanders. It is worthwhile considering to complement the circularity indicator with an additional indicator that follows a footprint approach (although this will require modelling data i.e. from input-output databases), however the footprint approach is not covered by this study.*

- ***Are secondary materials in imported products included?***
  Ideally, to measure circularity, the secondary materials included in the footprint of imported products should be accounted for. However, no (or only rough and/or incomplete) data are available about secondary materials used in the value chain and processed in imported products. For that reason Eurostat's CMU rate doesn't include the secondary materials used in imported products. The NCI of Circle Economy does consider this flow, by approximating this based on the GCI results.
  Not accounting for the secondary materials in imported products underestimates the circularity of a country and has the consequence that reaching a 100% circularity is not possible. However, accounting for this flow like is done in the NCI introduces a significant uncertainty in the circularity indicator.
  <u>In this report</u>*: The circularity indicator for Flanders (Chapter 2) follows the Eurostat approach and doesn't include secondary materials in imported products. It could be done though, if found valuable, by using the same approach of the NCI (possibly refined with bottom-up modelling data). However, this approach has significant impact on the results, particularly for an open economy as Flanders. By using the global circularity rate of material types as a proxy for the circularity in the imports of a specific country, changes in this global indicator have a large impact on the indicator of the country. The more a country imports, the more impact it has and the higher the uncertainty is. In the longer term, it is a better option to invest in further data collection for this specific secondary materials flow instead of using the proxy method of NCI. For this reason, the secondary materials in imported product are not considered in this report.*

The method used to calculate the Flemish indicator as discussed in chapter 2 resembles the Eurostat methodology applied for the CMU rate[9], although the scope of the waste statistics needs further investigation. The country-specific CMU rate indicators differ from NSI indicators due to differences in methodology and scope, source data, secondary materials selection.

3.2 Conclusions

The circularity rate indicator SM/PM as calculated for Flanders in chapter 2 is a good basis to assess and monitor the level of circularity in Flanders. But it is essential that the scope and data behind the indicator are clear and transparently described to understand the evolution and to benchmark with other countries if that would be desired. It is clear that the scope of the SM flow has consequences for the circularity indicator, as such a published indicator should clearly report what is included and what not.

Based on the assessment of other comparable indicators, there are different options to further **improve, refine and elaborate the SM/PM indicator for Flanders**. The following list summarizes potential options.

- ***Flows of materials that are included***
  The Flemish indicator already includes all material types and can be considered complete in this respect. Some refinements are possible, e.g. a breakdown of the indicator by type of material is recommended. This conveys the relative significance of various materials and their potential for reuse, recovery and recycling. A point of attention is that data with the same classification breakdown are needed for all components of the indicator, which is not a problem for DMC, but can be a challenge for the SM flow[10]. One should be aware of a spill-over effect between the material categories if flows are reported separately.
  It can be discussed whether it is useful to add an additional indicator (cfr. NCI) excluding biomass and fossil fuels for energetic purposes. However, we don't recommend this because it creates methodological difficulties and might give a distorted image as increasing renewable energy will require more non-fossil materials (e.g. metals) which would not be reflected in this indicator.
  It is important to take a close look to the Flemish waste statistics currently used for the calculation of the indicator, to clarify which flows are included and which are not.
  A breakdown with separated material categories like plastics and wood is of interest, once the methodology and data are available.
- ***Perspective used to look to secondary materials***
  This relates to the aspect of the scope of the SM flow in the indicator: from the collection of waste perspective or from the use of secondary materials perspective. First, it is important to clarify what is included in the Flemish waste statistics currently used for the calculation of the indicator, and what is not (waste collected for recovery and recycling or secondary materials as output of recycling facilities, risk of double-counting because primary and secondary waste is included). This should allow to identify the perspective which is applicable for the current Flemish indicator. Secondly, it is worthwhile calculating the SM/PM indicator according to the other perspective to check the differences and to assess its feasibility for Flanders.
- ***Apply a footprint approach and not only direct material use***
  It is worthwhile considering to complement the circularity indicator with an additional indicator that follows a footprint approach (although this will require modelling data i.e. from IO-analyses).
- ***Include secondary materials in imported products***

[9] The CMU rate calculated by Eurostat for Belgium is 12.5% in 2010 and 20.5% in 2016. The Flemish circularity rate as calculated in chapter 2 is 12% in 2009 (2010 not available) and 19% in 2016.

[10] The correspondence of waste codes to the four material flows MF1 to MF4 is provided by Eurostat (Annex to circular material use rate methodology), to allow an allocation of the total amount to the four main material categories.

The circularity indicator for Flanders (chapter 2) follows the Eurostat approach and doesn't include secondary materials in imported products. It could be done though, if found valuable, by using the same approach of the NCI (possibly refined with bottom-up modelling data).

- ***Refine the Sankey diagram to ensure consistency with the different scopes of the SM/PM indicator and to visualize the import and export of waste and secondary materials***
  The SM/PM indicator represents the size of the closing loop relative to the overall amount of materials entering the economy (Sankey diagram). However, attention is required as full consistency between the Sankey diagram and the circularity rate indicator is not straightforward. Classifications of waste, import and export flows of waste resp. secondary materials need to be clearly agreed upon and visualized separately on the Sankey in order to improve consistency. More and better data on the production and trade of secondary raw materials is therefor required, as well as a good insight in the waste statistics.
- ***Calculate the circularity indicator for specific consumption domains***
  The circularity rate indicator is a macro-economic indicator which has the entire economy in scope. The same type of indicator can be defined on a meso-level, for different consumption domains. Some points of attention are important here though: The availability of data on the level of consumption domains is probably less and other indicators might exist that are better suited to monitor circularity on a meso-level as the Sankey diagram (which is the basis of the circularity rate indicator) is specifically targeting entire economies and not individual consumption domains.
- ***Enrich the macro-economic perspective with microlevel pointers***
  The micro-level pointers are examples of sector or product level statistics that indicate potential progress in the growing importance of circular strategies. The advantage of these statistics is to enable the monitoring of small scale progress in support of the more slowly moving macro-economic trends via for example the circularity rate. In addition, one should be inspired by the fast moving micro-level trends that pop up within businesses, while these trends might still not be invisible from the macro-economic perspective.

Besides further refining and improving the Flemish SM/PM indicator from the perspective of methodology, scope and data, it is worthwhile to also aim to understand the effect that circular strategies might have on the indicator. Or vice versa to check how much a circular strategy needs to be implemented to significantly affect the SM/PM indicator. This could be done by defining cases to serve as hypothetical examples e.g. related to mobility.

When deciding where to focus the efforts for refining the SM/PM indicator for Flanders, it is important to decide about the scope and to what we want to do with the indicator. Is it the only objective to monitor the status in Flanders over time, or will the indicator serve to benchmark the situation in Flanders with other countries? The Eurostat CMU rate could differ from the NSI indicator, due to differences in methodology, source data, selection of materials. For countries that have more detailed data available, this can improve the indicator. It is very likely that Flanders has data available to refine the SM/PM indicator, which would give additional insights in the circularity rate of the region. However, as not all countries have the data available to do so, the refined indicator can't be used to benchmark with other countries. Comparability is an issue in any case, because of the many different options for defining the scope of the SM component of the indicator.
The choice for the scope of the indicator largely determines where the responsibility of improving circularity is given: in this case the indicator takes a consumption perspective and as such focusses on the material use for which Flanders is responsible by its final consumption. By focusing on the direct material use the materials that physically enter Flanders are looked at, these are the flows that Flemish policy measures can influence. Furthermore, it needs to be decided whether Flanders wants to focus on the contribution of a region to the global availability of secondary materials (and thus reducing primary material use globally) or on the amount of secondary materials used in the Flemish economy.

Interpretation of the indicator requires also looking at individual components of the indicators. Factors that influence the indicator might be: structural differences of national economy, e.g. low DMC, and installed recovery capacity in a country. It is also important to look at the complete set of indicators (e.g. also DMC individually, DMI, etc.) as they give complementary insight in the progress of circularity. Another option might be to express the circularity rate indicator not only as a ratio (in %), but to show the absolute values of the numerator and denominator (SM and PM). This will allow better monitoring (over time) of specific evolutions. As previously discussed, it may not only be the objective to increase the circularity rate, an important objective should be to use less material (primary and secondary together) for meeting our consumption needs.

One could discuss whether to define the indicator as a "Circularity gap" indicator, which is calculated as 1 – circularity indicator (SM/PM). This term seems confusing, as it is more straightforward to define an indicator which evolves in the right direction when increasing, such as the circularity indicator does. A higher score means a better circularity.

In the remainder of this report we will put our focus on:

- Flows of materials that are included;
- Perspective used to look to secondary materials;
- Refine the Sankey diagram to ensure consistency with the different scopes of the SM/PM indicator and to visualize the import and export of waste and secondary materials; and
- Enrich the macro-economic perspective with microlevel pointers.

Chapter 4

Refining the economy-wide circularity framework

The examples presented in Table 1 and further discussed below the table revealed several non-intuitive flows or disconnected flows. One of the major issues is the recording of trade in waste and secondary materials. In the framework presented in Figure 4 the import and export flows are recorded as an aggregate: both the trade in products, waste and secondary materials are combined in one single flow. This leads to a disconnection between the waste management system and the trade flows of waste and secondary materials.

The goal of the development of a refined framework is to overcome this issue by explicitly adding trade in waste and secondary materials to the framework. To avoid double counting, this trade should be excluded from the trade flows already present in the framework.

A second change to the framework is to discuss the mass-balancing inconsistency in the framework presented in Figure 4. The input to PM does not equal the output of PM (167 million tons vs. 144 million tons, respectively). In the extended framework we developed an alternative route to remove the inconsistency. This route starts from the use of energy related materials (both for energetic and non-energetic purposes) based on the dataset 'Energiebalans Vlaanderen'. Using mass-based balancing, this route resulted in a discrepancy between these results and the estimation from EW-MFA for Flanders, because the import of fossil energy carriers is overwritten in the alternative route (see Annex 2). This change results in a framework which is completed using two routes resulting in different estimations for PM, DMC, DMI, IMP and EXP:

- **Route 1**: the indicators are based on the estimations resulting from the EW-MFA methodology from Eurostat. This route aligns with the common European methodology allowing an international comparison of the resulting values.
- **Route 2**: the indicators are estimated using the values for use of energy related materials (both for energetic and non-energetic purposes) based on the dataset 'Energiebalans Vlaanderen'. This route closer aligns with the available Flemish statistics.

4.1 Adding **trade in waste** and **trade in secondary materials** to the framework

Extending the existing framework with trade, both import and export, of waste and secondary materials will further improve the understanding of the framework and will increase the possibilities for reading/deriving indicators directly from the framework. In this chapter, the trade of waste and secondary materials are made visible in the Sankey diagram, starting from the framework presented in Figure 1 and completed for Flanders in Figure 4. It is recommended, for reasons of interpretability and transparency, to refine the Sankey diagram with regard to the trade of waste and secondary materials, including as much as possible the disaggregated flows for the different material categories. Other disaggregations are also possible, for example, to separately monitor (bulk) materials which are used for backfilling purposes.

The SM/PM indicator represents the size of the closing loop relative to the overall amount of materials entering the economy. However, attention is required as full consistency between the framework and the circularity rate indicator is not straightforward. Classifications of waste, trade flows of waste and secondary materials need to be clearly agreed upon and visualized separately on the Sankey in order to improve consistency. Improved data on the production and trade of secondary raw materials is therefore required, as well as a good insight in the waste statistics. The goal of this chapter is to end up with an extended framework which will improve the interpretation of the SM/PM indicator by visualizing the individual components of the indicators. This will allow better understanding of potential evolutions.

The extended version of the economy wide material flow framework should include, in addition to Figure 1, the trade in waste and secondary raw materials. Both flows should explicitly be visible. Imported waste is added to the domestic EoL waste. However, in order keep domestic EoL waste visible the imported waste is only added to a ‘new step’ which we call the waste management system (WMS). The WMS processes both the domestic waste and imported waste. Part of this volume might be exported (with or without processing in Flanders). Adding imported secondary raw materials and subtracting exported secondary raw materials results together with the domestic provision of secondary materials in the volume of secondary raw materials being feedback into the domestic economy. The import and export are still present, but (in theory) no longer include the trade in waste and secondary materials. In practice, the trade in products containing secondary materials are still included. The trade in secondary materials is based on a list of CN-codes (see Annex 4) developed by Eurostat and extended for use in this study. Secondary materials outside these CN-codes or products outside these CN-codes containing secondary materials are still included in the original trade flows of import and export.

The estimation of Flemish trade in waste and secondary materials is based on:

- The **import of waste** relies on the dataset import of waste for processing in Flanders, provided by OVAM. This dataset shows the several characteristics of imported waste by Flanders: year, classification following the European Waste Catalogue, a common name, weight, volume and origin of the waste stream. The dataset allows sufficient detail to disaggregate total import of waste into the four material categories using the correspondence of waste codes to the four material flows MF1 to MF4 which is provided by Eurostat (Annex to circular material use rate methodology), to allow an allocation of the total amount of the import of waste to the four main material categories
- The **trade in secondary materials** relies on the methodology provided by Eurostat on ‘trade in recyclable raw materials’. The indicator measures the quantities of selected waste categories and by-products that are shipped between the EU Members States (intra-EU) and across the EU borders (extra-EU). Five classes have been selected: plastic, paper and cardboard, precious metal, iron and steel, and copper, aluminium and nickel. The scope of the 'recyclable raw materials' is measured in terms of relevant product codes from the Combined Nomenclature used in International Trade in Goods Statistics. Although the data source shows in essence trade in waste, they only contain recyclable raw materials and are therefore a good approximation for the estimation of trade in secondary materials. However, an overestimation should be taken in to account.
- The **export of waste** is estimated via mass-based balancing of the extended framework.

There is an overlap in the estimations between the trade in waste and the trade in secondary materials. A full discussion on the data gathering is presented in Annex 3.

4.2 Improved framework

The material flow diagram presented in Figure 11 shows the improved framework of material flows through the Flemish economy in the year 2018. This figure shows a Sankey diagram the width of the arrows is proportional to the size of material flows. The numbers show the size of the material flows in million tons per year. The green flows are trade flows of either products, waste or secondary materials. The trade in waste and secondary materials are excluded from the 'traditional' import and export flow. The flows between the Flemish domestic economy and the environment are presented by blue arrows. On the input side it shows domestic extraction; on the output side it shows domestic processed output of emissions and waste. Remind that controlled landfills are considered as part of the domestic economy (stock). The domestic flows are visualised by orange flows.

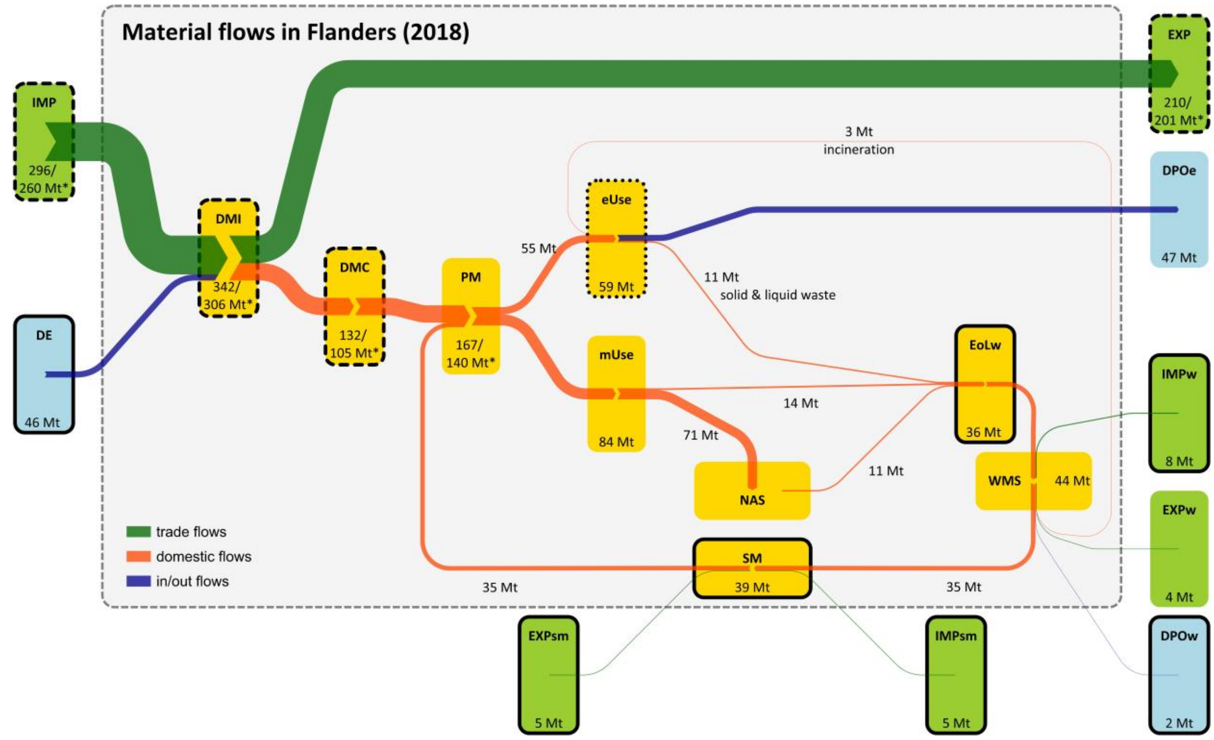


Figure 11: Material flows through the Flemish economy in 2018.
**Numbers according to the EW-MFA/numbers according to Energiebalans Vlaanderen.*

Reading guide*: In the Sankey diagram the width of the arrows is proportional to the size of material flows. The numbers show the size of the material flows in million tons per year. Note that the numbers may not always sum up to total due to rounding.*

Green flows represent trade flows; blue flows represent flows between the domestic socio-economic system and the environment; orange flows represent domestic flows.

Boxed processes are directly covered by statistics: IMPw, EoLw, DPOw, SM and incineration volumes are directly covered by OVAM waste statistics. The fossil energy carriers part of eUse is covered by the statistics on the energy balance of Flanders. DE, IMP, DMI, DMC and EXP are covered by the EW-MFA statistics, although the fossil energy carriers part is overwritten due to the mass balancing exercise.

Mt = million tons. IMP: import; DE: domestic extraction used; DMI: direct material input; DMC: domestic material consumption; PM: processed materials; eUse: energy use; mUse: material use; NAS: net additions to stock; EoLw: end of life waste; SM: secondary materials; EXP: export; DPOe: emissions in domestic processed output; DPOw: waste in domestic processed output; IMPw: import of waste materials; EXPw: export of waste materials; IMPsm: import of secondary materials; EXPsm: export of secondary materials.

Interpretation guide*: The diagram visualises the macro-economic material flows in Flanders in 2018. The input of materials originate from abroad (IMP, IMPw and IMPsm) or from the environment via extraction and agriculture (DE). The total input of materials (excluding import of waste and secondary materials) sums up to the domestic material input (DMI). Exported materials (EXP, excluding the export of waste and secondary materials) are subtracted from the DMI-indicator resulting in the domestic material consumption (DMC).*

The total volume of domestically processed materials (PM) is the sum of DMC and the feedback loop of secondary materials (SM). These materials are either used for energetic (eUse) or material-related (mUse) purposes. Energetic use is completed by a feedback loop of incineration from the waste management system (WMS). The energetic use encompasses food, feed and use of energy products. After use they either are transformed into emissions (DPOe) or solid and liquid waste. The material-related use is divided into short-lived products and stock accumulation. Together with removals from stock they form the net additions *to stock (NAS). The removals from stock, the solid and liquid waste and the short-lived throughput materials sum up to the domestic end-of-life waste (EoLw) category.*

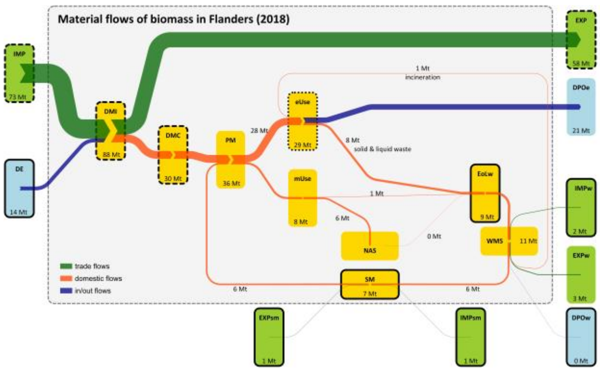
The domestic end-of-life waste (EoLw) enters the domestic waste management system (WMS) together with all imported waste (IMPw). This total volume is, potentially after processing, send to incineration (flow to eUse), to waste landfill (DPOw), abroad (EXPw) or becomes secondary materials (SM). The total volume of secondary materials (SM) in the feedback loop of the Flemish domestic economy is corrected with trade in secondary materials (IMPsm and EXPsm).

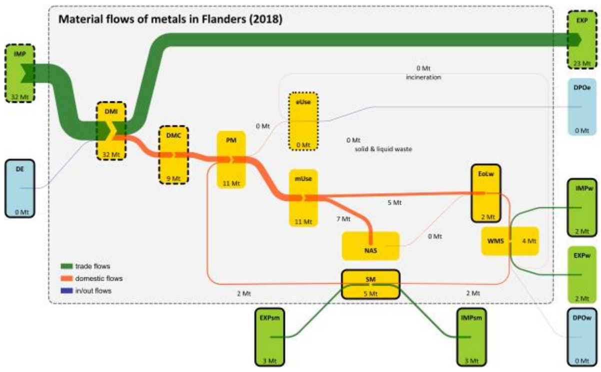
The advantages of the improved framework can be explained by the shortcomings of the original framework that are no longer present in the improved framework. In the examples discussed in Table 1 the issue of disconnected flows popped up. The addition of trade in waste en secondary material in the improved framework this issue is partly ruled out. Only the disconnection of export flows still might be the case. The fewer disconnected flows enhances the intuitive interpretation of the framework. For example, the connection of the WMS with eUse (incineration of waste) is a direct flow present in the framework. Also the processing of imported waste to generate secondary materials which are either used domestically or exported can be traced as a connected series of flows.

The improved framework is closely aligned with the waste statistics provided by OVAM. The framework is directly related to several waste statistics produced by the OVAM. EoLw, IMPw, DPOw, SM and incineration volumes are directly covered by these statistics.

A remaining issue is that the values according to the EW-MFA methodology and energiebalans Vlaanderen do not align. We made the choice to start from the use of energy related materials (both for energetic and non-energetic purposes) based on the dataset 'Energiebalans Vlaanderen'. Using mass-based balancing, this resulted in a discrepancy between these results and the estimation from EW-MFA. Therefore, two estimations for the recording of import of fossil energy carriers are available. This results in two estimations for IMP, EXP, DMI and DMC: one based on the EW-MFA methodology and one based on starting from the dataset from energiebalans Vlaanderen. Both values are included in Figure 11.

Figure 12 presents the material flows for Flanders in the year 2018. The flows are disaggregated in the four main material groups: biomass, metal ores, non-metallic minerals and fossil energy carriers. To improve de readability, the material groups other products and waste for final treatment and disposal are equally spread across the four main material groups as these two material groups are too small (i.e. invisible) to be presented separately. Although the disaggregation in material categories is present in all flows, the quality of the data in each flow varies. Also, the numbers are only available according to the route starting from the dataset from the Energiebalans Vlaanderen (route 2). Although route 1 could also be possible, we opt not to incorporate this route in the report.





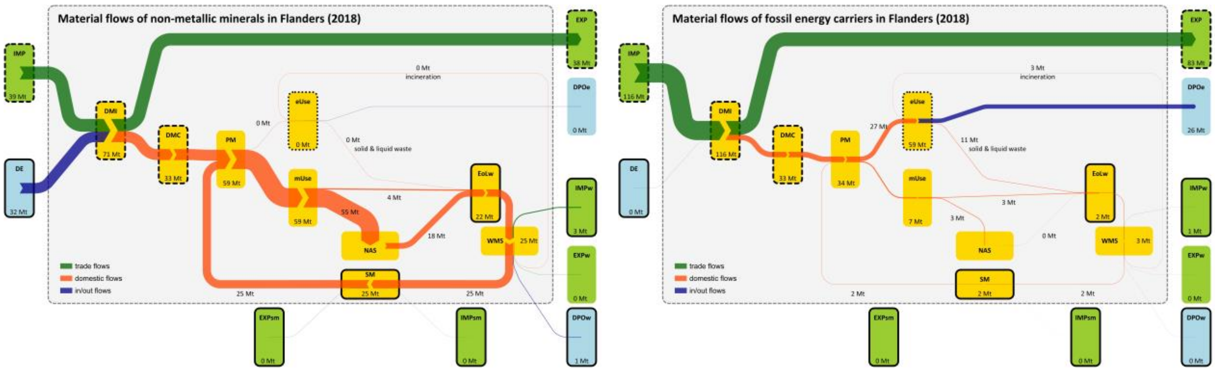


Figure 12: Material flows through the Flemish economy in 2018, per material category. The numbers show the size of the material flows in million tons per year. Legend and explanation: see the caption of Figure 11.

Looking at these four material categories immediately reveals some huge differences between them. One of them is the huge stock build-up for non-metallic minerals and metals that put a potentially large time gap between the ‘inflow’ and the ‘outflow’ of the materials. The inflow to stock is much larger than the outflow out of stock. A large inflow is preceded by a high material use (high DMC) and a relatively small outflow negatively impacts the current potential for a large feedback loop. Secondly, the large quantities of biomass materials and fossil energy carriers going to energy use, leading to emissions with limited potential for feedback loops. A third difference is the Flemish dependency of each material category. Only the non-metallic minerals and biomass materials show an input of materials from domestic extraction. For biomass this share is small (ca. 16%); for non-metallic minerals this share is ca. 45%.

4.3 Eurostat’s circular material use rate (CMUR)

As described in Section 3.1.1 the circularity indicator developed by Eurostat, the circular material use rate (CMUR), is defined as:

$$\text{circular material use rate (CMUR)} = \frac{\text{circular use of materials}}{\text{overall use of materials}} = \frac{\mathrm{U}}{\mathrm{M}}$$

with

$$\mathrm{M} = \mathrm{DMC} + \mathrm{U}$$

and

$$\mathrm{U} = \mathrm{RCV\_R} - \mathrm{IMP_W} + \mathrm{EXP_W}$$

So,

$$\mathrm{CMUR} = \frac{\mathrm{RCV\_R} - \mathrm{IMP_W} + \mathrm{EXP_W}}{\mathrm{DE} + \mathrm{IMP} - \mathrm{EXP} + \mathrm{RCV\_R} - \mathrm{IMP_W} + \mathrm{EXP_W}}$$

In order to keep the comparability with Eurostat’s national figures, we stick as close as possible to Eurostat’s methodology. Therefore, the numbers differ at some points from the values given in Section 4.2. For example, the estimation for DMC (= DE +IMP -EXP) is derived from the EW-MFA framework (i.e. route 1), which differs for the material flow of trade in products catalogued in the material category fossil energy carriers.

The circular use of materials (U) is defined as the amount of waste recycled in domestic recovery plants minus the import of waste for recovery/recycling and plus the export of waste for recovery/recycling. Recovery as energy recovery and backfilling are excluded from these figures. RCV_R is the waste recycled in domestic recovery plants and it comprises the recovery operations R2 to R11 – as defined in the Waste Framework Directive 75/442/EEC.

The focus of U is to represent a country's effort to collect waste for recovery, including waste collected in the country and later exported for treatment abroad. This perspective credits the country's effort to gather waste bound for recovery which indirectly contributes to the worldwide supply of secondary materials and hence avoidance of primary material extractions. Eurostat point at the database ‘trade in recyclable waste’ for estimating the trade in waste for recover. In Section 4.2 the methodology behind this database is used to estimate the trade in secondary materials, with the list of CN-codes was being extended.

Table 2 presents the building blocks of the CMUR and the CMUR for Flanders. All data is available for 2014, 2016 and 2018. Eurostat’s includes an interpolation methodology to estimate in between years, but the interpolation is not applied in this study. In this period the CMUR increased from 15.9% in 2014, to 19.0% in 2016 and to 20.7% in 2018. The increase is attributed to the substantial increase in waste recycled in domestic recovery plants.

Table 2: The estimation of the Flemish circular material use rate (CMUR), 2004-2018 if available, in million tons, CMUR in %. Source: DMC is estimated based on EW-MFA; RCV_R equals the SM (see section 4.2); IMPW and EXPW are estimated using the ‘trade in recyclable waste’-methodology.

year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
DMC	131.6	131.1	136.3	137.3	139.4	140.2	144.6	148.2	141.7	138.3	136.7	128.6	127.2	140.5	132.3
RCV_R	*21.3*	*19.6*	*19.9*	*22.6*	*25.8*	*19.8*			*23.5*		*26.2*		*30.6*		*34.6*
IMP_W											4.3	4.0	4.2	4.0	4.2
EXP_W											4.0	3.3	3.4	3.9	4.1
U											25.9		29.8		34.5
M											162.6		157.0		166.8
CMUR											15.9		19.0		20.7

The comparison the Flemish CMUR with the CMUR of neighbouring countries and the EU27_2020 is visualized in Figure 13. In 2018, the Flemish CMUR is close to the CMUR of Belgium and France. The CMUR of Germany, Luxembourg and the EU27_2020 are substantially lower, while the CMUR of the Netherlands is substantially higher.

To better understand these differences, it necessary to look separately at U and DMC. The strong influence of structural differences of national economies e.g. low DMC and high recovery capacities The comparison of CMU rates across countries becomes only meaningful when the economic structure is considered. A mere ranking of countries according to the achieved rates is not very telling unless it is recognised that their economies have different structures and starting points.

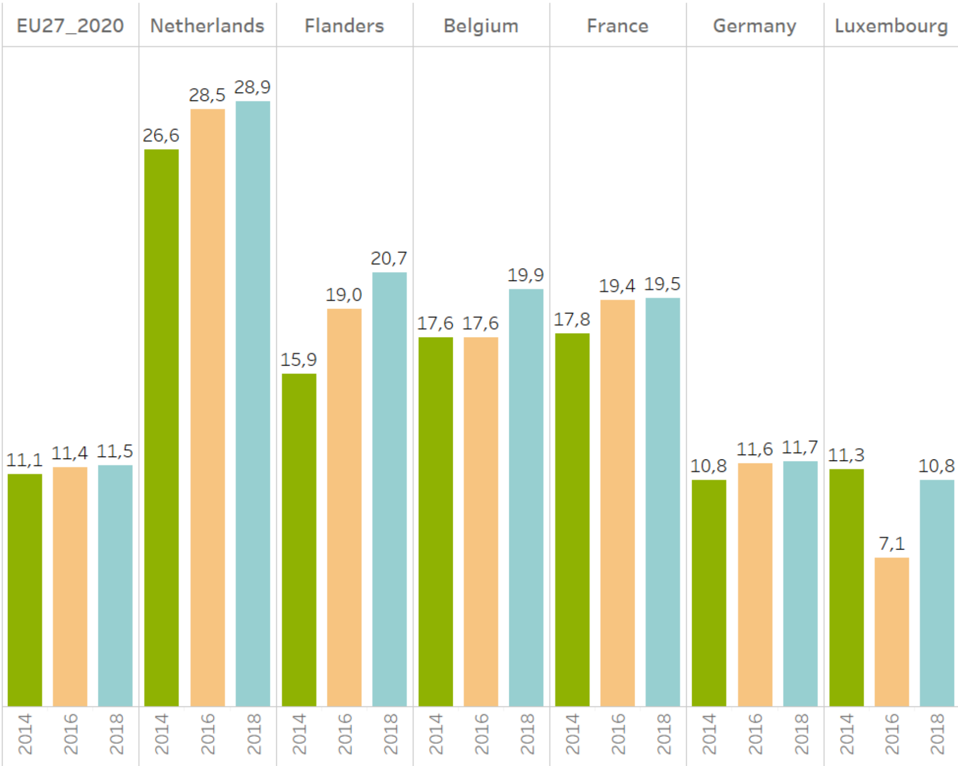


Figure 13: The comparison of the Flemish CMUR with the CMUR of neighbouring countries and the EU27_2020 average, 2014-2016-2018, in percentages.
Source: Eurostat [CEI_SRM030]

In addition to the 'official' Eurostat calculation of the CMUR, the CMUR can also be calculated based on the route 2 (i.e. starting from the dataset 'Energiebalans Vlaanderen) of which the values are also presented in Figure 11. The estimated DMC is lower (105.1 instead of 132.2 million tons) and the trade in waste has a slightly enlarged scope. Mainly the down-estimated value for the DMC results in an increased rate to 25.8% in 2018. Both circularity rates have their advantage: this percentage is closely aligned with available statistics at Flemish level, while the 20.7% is better suited in comparing the rate with other countries.

Based on the data gathering exercise behind Figure 11 and Figure 12, the CMUR can also be estimated at the level of material categories. The results are presented in Table 3. The CMUR is highest for non-metallic minerals (43.2%), followed by biomass (17.3%), metals (10.5%) and fossil energy carriers (5.2%). The huge stock build-up for non-metallic minerals and metals (see Figure 12) has a negative impact on the CMUR. The inflow to stock is much larger than the outflow out of stock. A large inflow is preceded by a high material use (high DMC) which increases the denominator. A relatively small outflow negatively impacts the current potential for a large feedback loop which negatively impacts the numerator. Still the outflow from non-metallic minerals is considerable leading to a higher CMUR. The reason for a low CMUR for biomass and fossil energy carriers is found in the large quantities going to energy use which meanly lead to emissions leaving no potential for feedback loops.

Table 3: The estimation of the Flemish circular material use rate (CMUR) per material category, 2018, in million tons, CMUR in %.

material category	DMC	RCV_R	IMPw	EXPw	CMUR
biomass	29.7	6.1	0.8	0.9	17.3%
metal ores	9.4	1.6	3.4	2.9	10.5%
non-metallic minerals	33.5	25.3	0.2	0.4	43.2%
fossil energy carriers	32.5	1.7	0.2	0.3	5.2%

Although the CMUR developed and calculated by Eurostat is part of the EU monitoring framework for a CE, caution is required interpreting this ratio. In general, a higher CMU rate value means that more secondary materials substitute for primary raw materials thus reducing the environmental impacts of extracting primary material. However, a higher CMUR is not per definition a desired evolution, neither is a declining CMUR per definition an undesired evolution. Of equal importance are the movements of the underlying indicators, i.e. DMC and U. The long term goal is to evolve to an economy using less materials. Therefore, an increasing CMUR with underlying an increasing DMC is not an evolution that has our preference.

A higher CMUR can be achieved in more ways than only increasing the recycling rates (increasing the numerator). Deeper transformation within our societies can also improve the circularity rate:

- replacing fossil fuels by renewable energy (lowering the denominator) strongly reduces single use materials like natural gas and crude petroleum, while (temporarily) increasing the demand for construction materials and metals;
- using more efficient production technologies (lowering the denominator) lowers the demand for input materials while keeping the output at a constant level; or
- extending the lifespan of products (lowering the denominator), e.g. by product-service systems, lowers the demand for new product while keeping consumer needs satisfied.

However, a decreasing CMUR does not per definition reflect an undesired trend. The CMUR and the material flow diagram (see Figure 11) both describe (economy-wide) flows of materials. As such there is a clear link with circular economy, where the purpose is to reduce the extraction of materials from nature and the release of waste and emissions. The CMUR as such measures whether we go in the right direction, but at the macro-economic level. R-strategies like reuse, remanufacturing, recycling, which focus on maintaining the value of the stock of materials, can be considered as means/ways to reduce material extraction and waste flows. However, different strategies have an effect on different components of the CMUR. For example, the inner circle strategies mostly relate to the material accumulation flow from Figure 3, e.g. remanufacturing promotes an increased lifetime of existing stock with minimal additional material inputs (e.g. spare parts and updates). A transition to a more circular economy, keeping demand constant, is able to downsize the material flow diagram (lowering the denominator). In turn, this could also affect the numerator as potentially less waste is available for recycling which puts a downward pressure on the volume of the numerator. Depending on the relative magnitude of decrease in both the denominator and numerator, the CMUR can even decrease.

It is thus important for countries to not simply aim to increase the CMUR indicator blindly, but to also keep in mind the longer term concept of keeping materials in the loop, first as products, then as parts, then as materials (recycling) and only then as waste for backfilling, incineration, landfilling. The butterfly diagram as developed by the Ellen Mac Arthur Foundation (Figure 2) illustrates how material recycling should be considered as the 'last resort' before landfilling/incineration, and that the long term strategy should aim towards the higher R-strategies (like reuse, repair, remanufacture) bearing in mind the footprint. It is this trade-off that is lost if one simply aims to increase the CMUR blindly. Focusing on the higher R-strategies positively influences the CMUR indicator, but due to the economy-wide nature of the indicator the effects of individual actions of governments, businesses citizens are not directly visible. Therefore, the CMUR should be accompanied by micro-level pointers (i.e. micro and meso level indicators focusing at specific consumer needs) to help us understand and monitor the smaller changes within our economy.

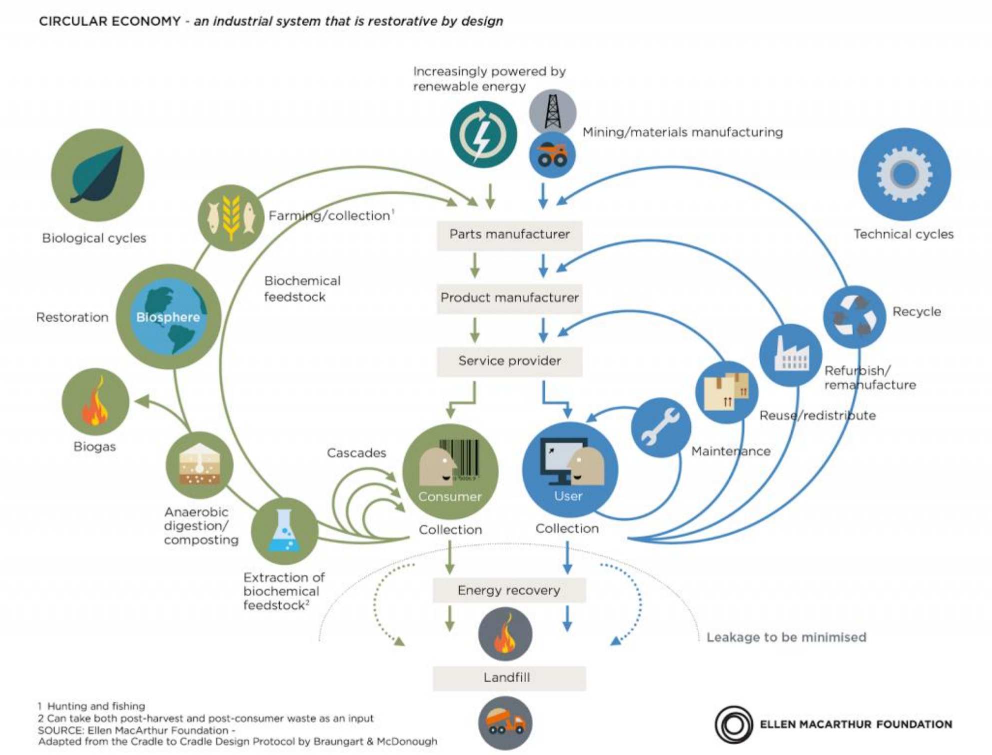


Figure 14: The Butterfly Diagram (Ellen Mac Arthur Foundation)

4.4 Effect of circular strategies on the indicator

In this paragraph we aim to investigate the effect of circular strategies on the circularity rate indicator as currently calculated for Flanders, to better interpret what is captured by this indicator and what not.

As explained previously, the circularity rate is defined as:

$$\frac{SM}{PM} = \frac{SM}{DMC + SM} = \frac{SM}{DEU + IMP - EXP + SM}$$

Recycle - Recover

The Flemish circularity rate indicator, like the CMUR and the NCI, takes a consumption perspective, not a 'production' perspective. This is reflected by the use of the indicator DMC for the denominator, only the materials used for consumption in Flanders are included so the exported products are not considered in this indicator[11]. If the circularity indicator follows the perspective of collection of waste (instead of use of secondary materials) the materials, also secondary materials, which are extracted/recovered or processed in products in Flanders but exported, are not included. A consequence of this perspective is that the use of secondary material by Flemish companies in products which are exported is not awarded. The use of secondary materials by Flemish companies is only awarded for the share of products that are consumed in Flanders. In this case the circularity rate doesn't credit the complete use of secondary materials in Flemish industry. If the perspective of use of secondary materials from waste is applied for the circularity indicator, the secondary materials used in Flanders are included in the SM flow regardless of the fact that they are used for products consumed in Flanders or exported. An option is to define a complementary indicator which starts from the production perspective of a country and uses e.g. the DMI as a measure for total material use. However, this leads to double-counting of some import and export flows for different countries. The choice between an indicator from

[11] If this would be required, the DMI as alternative indicator could be used. But this also has its disadvantages.

a consumption or production perspective is also related to the choice where to put the responsibility of improving circularity of a country: to the country as a producer or as a consumer?

In a case where additional fossil fuels are required (e.g. for transportation, sorting) to increase the collection of waste for recovery/recycling (SM), the trade-off between on the one hand the increase in DMC due to extra fossil fuel use and on the other hand the increase in SM determines whether the circularity rate SM/PM improves. If too much fossil fuels are needed for too little additional waste collected for recovery/recycling, the indicator will decrease. It is good that the indicator captures this effect. Distinguishing the circularity indicator for the different material types helps even more to have insight in the different elements of this scenario.

Take as an illustrative example the effect of developing Flanders as a recycling hub. This would lead to more waste being imported for recycling in Flanders and to export secondary materials for use abroad, which is reflected in an increased volume from the WMS to SM. The effect on the DMC depends on the scope of the trade flows. If trade in waste and secondary materials are excludes from the trade determining the DMC (e.g. see Figure 11), this example has no effect on the DMC. Only the SM increases benefitting the circularity rate. Recycling wastes are reflected by an increased export of waste or increased DPOw. If trade in waste and secondary material are included in the trade that determine the DMC (e.g. see Figure 4), than the DMC also increases due to recycling wastes. Recycling wastes increase to gap between import and export leading to an increased DMC. The numerator increases relatively more than the denominator thus the circularity rate increases. Except when the imported waste for recycling is of such a bad quality that the share to be recycled is much less than the share to be landfilled. Than the risk exists that the denominator increases more (DMC part) than the numerator.

Reduce – Rethink - Refuse

The example 4 from Table 1, related to the use of plastic bags, can be used to illustrate the effect of reducing the amount of plastic bags used by consumers. This reduces the DMC, but has no effect on the SM as in Flanders the waste for energy recovery is not included in the SM. The circularity rate indicator would thus increase.

A similar reasoning can be followed for drinking water bottled in plastic PET-bottles. If Flemish households would increase the use of tap water at the expense of PET bottled water, the DMC would decrease (less PET-bottles), the waste going to recycling would decrease with a similar absolute amount (assuming that close to 100% of PET-bottles are collected for recycling) but the relative decrease of the numerator is higher than the denominator. This would lead to a lower circularity rate, which is opposite to what you would expect. This illustrates the importance of not only using the circularity rate as the one single indicator for monitoring circularity. It is important to put this next to other indicators, for example at micro or meso-level. In this example the DMC would decrease, which is also what you want to achieve with circular economy. It may not only be the objective to increase the circularity rate, an important objective should be to use less material (primary and secondary together) for meeting our consumption needs.

With regard to biomass, e.g. for food, some circular strategies are reflected in the circularity rate indicator but other are not. For example, additional valorisation of food waste causes the circularity rate indicator to increase because the SM increases. Switching to a more high-quality valorisation is not reflected in the indicator if the total amount of SM remains equal. A shift from animal to vegetal food products is only accounted for in the circularity rate indicator if the value chain is located in Flanders. If these products are imported, they represent an equal amount (tonne) of imported products thus the DMC doesn’t change, although less biomass is required to produce the vegetal products.

Reuse – Repair - Remanufacture

Reuse, repair and remanufacture are CE strategies that aim at reducing the useful life of products. Referring to the Sankey diagram (see Figure 11) the Net Addition to Stock (NAS) part creates a time gap between the input and output of materials. Materials in mUse will eventually flow to EoLw, but there is a time gap between both. Reuse, for example, will extend the time a 'material' remains mUse until it becomes EoLw. The issue with the Sankey and the related indicators is that the stock is not presented, only the flows going in and out of the stock are. Increased reuse will lead to a smaller flow going out of the NAS, but also a smaller inflow, while the (unknown) stock remains the same.

These examples only serve to illustrate some of the aspects that the circularity rate indicator does and does not capture. The indicator is based on waste flows and residuals and captures less the effect of 'inner circle' strategies like reuse, repair and remanufacturing. These strategies have an effect on the stock. The same stock can be preserved with less input (materials) and less output (waste) is created. But this is not directly captured in the circularity rate indicator as defined here. This is important to realize when the indicator is intended to support the setting of policy priorities.

4.5 Widen the scope with other indicators

In order to present a coherent set of macro-economic indicators to monitor the circular economy, it is imperative to include generic indicators on the economic impact of the circular economy into the indicator set. This set collects data on the added value of recycling industry and employment.

Former reports and studies from the support center can present a foundation for this part. This also includes clear communication on the limitation of these indicators, such as the incompatibility of the data to grasp all recycling or circular activities, and estimates of gray areas within the circular economy that are not adequately covered by the available indicators.

An economy wide circularity assessment cannot rely just on one macro-economic indicator. The effect of value retention strategies on economy wide material use and waste flow indicators will not be visible in a short term. To support the understanding and monitoring of the growing importance of circular economy strategies in Europe's economy a number of micro-level pointers can be presented. The micro-level pointers are examples of sector or product level statistics that indicate potential progress in the growing importance of value retention strategies. The advantage of these statistics is that they enable the monitoring of small scale progress in support of the more slowly moving macro-economic trends via for example the circularity rate or the economy-wide material flow analysis indicators. In addition, one should be inspired by the fast moving micro-level trends that pop up within businesses, while these trends might only on the long run be visible from the macro-economic perspective.

Table 4 presents a matrix with three dimensions: the product groups, the value retention strategies and the demand and supply perspective. It shows a possible classification of such micro-level pointers. The selection of product groups can be based on, for example, consumer needs (e.g. clothing, transport, food, housing) or materials (e.g. plastics, plastic packaging). Ideally, this selection should be diverse but not too extensive. The classification of circular economy strategies make use of follows the 9R-framework from Potting et al. (2017) and adopted in the Bellagio Principles. The third dimension is present in each cross section as both the demand (consumer perspective: households, institutional demand, business in B2B-markets) and the supply side (producer perspective: both business and households can be the supplier) can be highlighted. At each cross section potentially relevant micro-level pointers can be selected.

Table 4: Matrix of product groups and value retention strategies.

	electric and electronic equipment		textiles		...	
	demand	**supply**	**demand**	**supply**	**demand**	**supply**
R0 refuse						
R1 rethink eco-design						
R2 Reduce						
R3 reuse redistribute						
R4 repair maintain/prolong						
R5 refurbish						
R6 remanufacture						
R7 repurpose						
R8 recycle						
R9 recover						

Chapter 5

Conclusion and future outlook

5.1 Indicator fact sheet

What do we see?

The CMUR in Flanders increased from 15.9% in 2014, to 19.0% in 2016 and to 20.7% in 2018. Table 2 presents the building blocks of the CMUR together with the CMUR for Flanders. All data to compile the CMUR is available for the years 2014, 2016 and 2018. The increase in CMUR can mainly be attributed to the substantial increase in waste recycled in domestic recovery plants.

Table 5: The estimation of the Flemish circular material use rate (CMUR), 2004-2018 if available, in million tons, CMUR in %. Source: DMC is estimated based on EW-MFA; RCV_R equals the SM (see section 4.2); IMPW and EXPW are estimated using the 'trade in recyclable waste'-methodology.

year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
DMC	131.6	131.1	136.3	137.3	139.4	140.2	144.6	148.2	141.7	138.3	136.7	128.6	127.2	140.5	132.3
RCV_R	*21.3*	*19.6*	*19.9*	*22.6*	*25.8*	*19.8*			*23.5*		*26.2*		*30.6*		*34.6*
IMP_W											4.3	4.0	4.2	4.0	4.2
EXP_W											4.0	3.3	3.4	3.9	4.1
U											25.9		29.8		34.5
M											162.6		157.0		166.8
CMUR											**15.9**		**19.0**		**20.7**

Although the CMUR developed and calculated by Eurostat is part of the EU monitoring framework for a CE, caution is required interpreting this ratio. In general, a higher CMU rate value means that more secondary materials substitute for primary raw materials thus reducing the environmental impacts of extracting primary material. However, a higher CMUR is not per definition a desired evolution, neither is a declining CMUR per definition an undesired evolution. Of equal importance are the movements of the underlying indicators, i.e. DMC and U. The long term goal is to evolve to an economy using less materials. Therefore, an increasing CMUR with underlying an increasing DMC is not an evolution that has our preference.

The comparison the Flemish CMUR with the CMUR of neighbouring countries and the EU27_2020 is visualized in Figure 13. In 2018, the Flemish CMUR is close to the CMUR of Belgium and France. The CMUR of Germany, Luxembourg and the EU27_2020 are substantially lower, while the CMUR of the Netherlands is substantially higher.

To better understand these differences, it necessary to look separately at U and DMC. The strong influence of structural differences of national economies e.g. low DMC and high recovery capacities The comparison of CMURs across countries becomes only meaningful when the economic structure is considered. A mere ranking of countries according to the achieved rates is not very telling unless it is recognised that their economies have different structures and starting points.

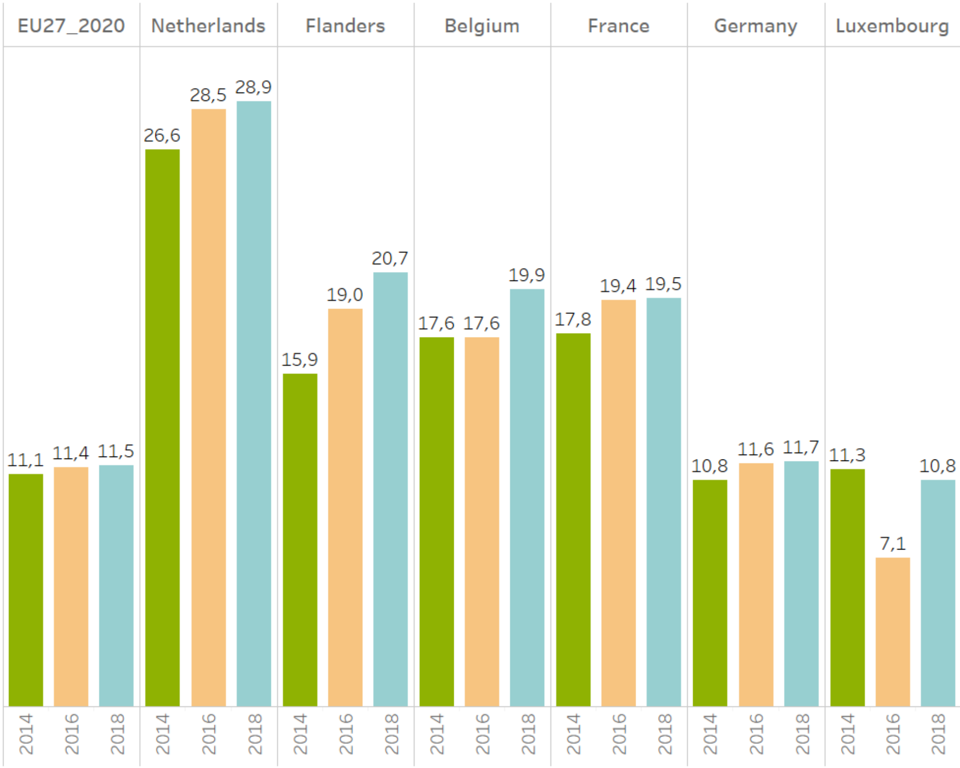


Figure 15: The comparison of the Flemish CMUR with the CMUR of neighbouring countries and the EU27_2020 average, 2014-2016-2018, in percentages.
Source: Eurostat [CEI_SRM030]

Where to go?
A higher CMUR can be achieved in more ways than only increasing the recycling rates (*increasing the numerator*). Deeper transformation within our societies can also improve the circularity rate:

- replacing fossil fuels by renewable energy (*lowering the denominator*) strongly reduces single use materials like natural gas and crude petroleum, while (temporarily) increasing the demand for construction materials and metals;
- using more efficient production technologies (*lowering the denominator*) lowers the demand for input materials while keeping the output at a constant level; or
- extending the lifespan of products (*lowering the denominator*), e.g. by product-service systems, lowers the demand for new product while keeping consumer needs satisfied.

However, a decreasing CMUR does not per definition reflect an undesired trend. The CMUR and the material flow diagram (see Figure 17) both describe (economy-wide) flows of materials. As such there is a clear link with circular economy, where the purpose[12] is to reduce the extraction of materials from nature and the release of waste and emissions. The CMUR as such measures whether we go in the right direction, but at the macro-economic level. R-strategies like reuse, remanufacturing, recycling, which focus on maintaining the value of the stock of materials, can be considered as means/ways to reduce material extraction and waste flows. However, different strategies have an effect on different components of the CMUR. For example, the inner circle strategies mostly relate to the material accumulation flow from Figure 17, e.g. remanufacturing promotes an increased lifetime of existing stock with minimal additional material inputs (e.g. spare parts and updates). A transition to a more circular

[12] The purpose of a circular economy is to maintain the value of products, materials and resources for as long as possible by returning them into the product cycle after they have reached the end of their lifecycle, while minimising the generation of waste.

economy, keeping demand constant, is able to downsize the material flow diagram (*lowering the denominator*). In turn, this could also affect the numerator as potentially less waste is available for recycling which puts a downward pressure on the volume of the numerator. Depending on the relative magnitude of decrease in both the denominator and numerator, the CMUR can even decrease.

It is thus important for countries to not simply aim to increase the CMUR indicator blindly, but to also keep in mind the longer term concept of keeping materials in the loop, first as products, then as parts, then as materials (recycling) and only then as waste for backfilling, incineration, landfilling. The butterfly diagram as developed by the Ellen Mac Arthur Foundation (Figure 16) illustrates how material recycling should be considered as the 'last resort' before landfilling/incineration, and that the long term strategy should aim towards the higher R-strategies (like reuse, repair, remanufacture) bearing in mind the footprint. It is this trade-off that is lost if one simply aims to increase the CMUR blindly. Focusing on the higher R-strategies positively influences the CMUR indicator, but due to the economy-wide nature of the indicator the effects of individual actions of governments, businesses citizens are not directly visible. Therefore, the CMUR should be accompanied by micro-level pointers (i.e. micro and meso level indicators focusing at specific consumer needs) to help us understand and monitor the smaller changes within our economy.

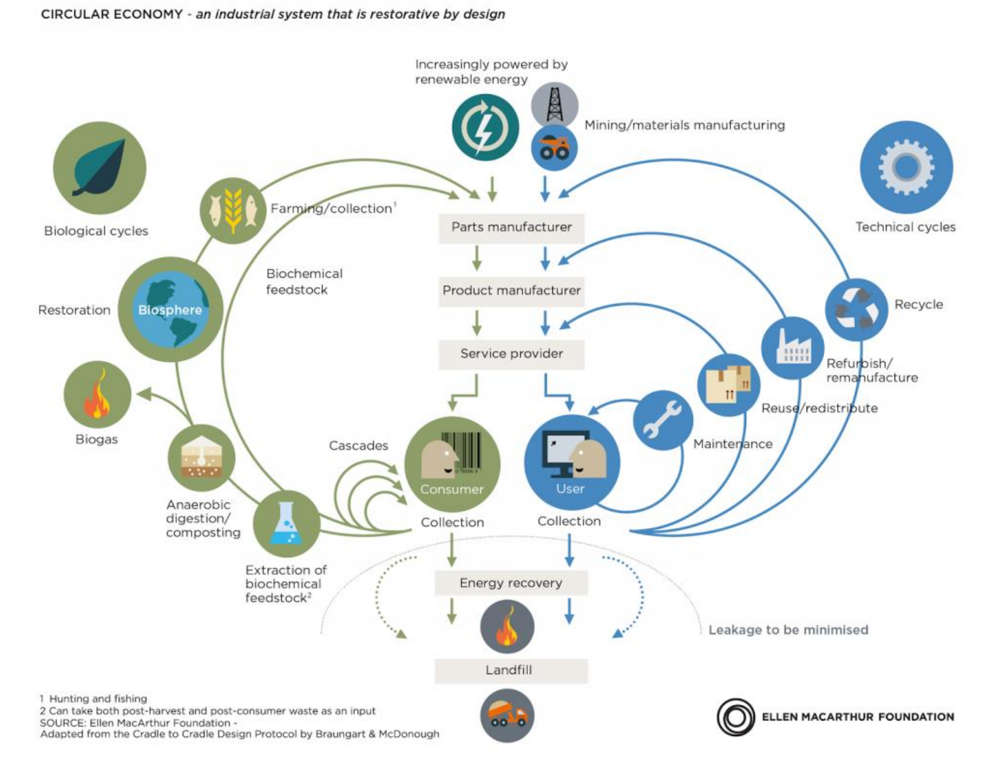


Figure 16: The Butterfly Diagram (Ellen Mac Arthur Foundation[13])

What does the indicator measure?

The CMUR is the ratio of circular use of materials to overall material use. Both the circular use and the overall material use can be measured by different indicators, in different ways. Eurostat has chosen to focus the CMUR indicator on a country's effort to collect waste for recovery (and not on the capacity of a country to produce secondary raw materials). 'This perspective credits the country's effort to gather waste bound for recovery which indirectly contributes to the worldwide supply of secondary materials and hence avoidance of primary material extraction.'

[13] Towards a CE: Business Rationale for an accelerated transition (2015)

The economy wide material flow diagram which is shown in Figure 17 visualizes the material flows relevant for the CMUR indicator. A Sankey diagram presents the (annual) flows of: (1) resources extracted to make products or be used as a source of energy; (2) materials and products flowing in and out of our society (imports and exports); and (3) materials and products discarded into the environment as residuals (e.g. landfilled waste or air emissions) or recovered and fed back into the economy. This latter part closes the loop in the circular economy. Products with a longer life span and infrastructure such as buildings, roads, and machinery are used over a long period during which they mount up in our societies, until they are eventually dismantled or taken out of use.

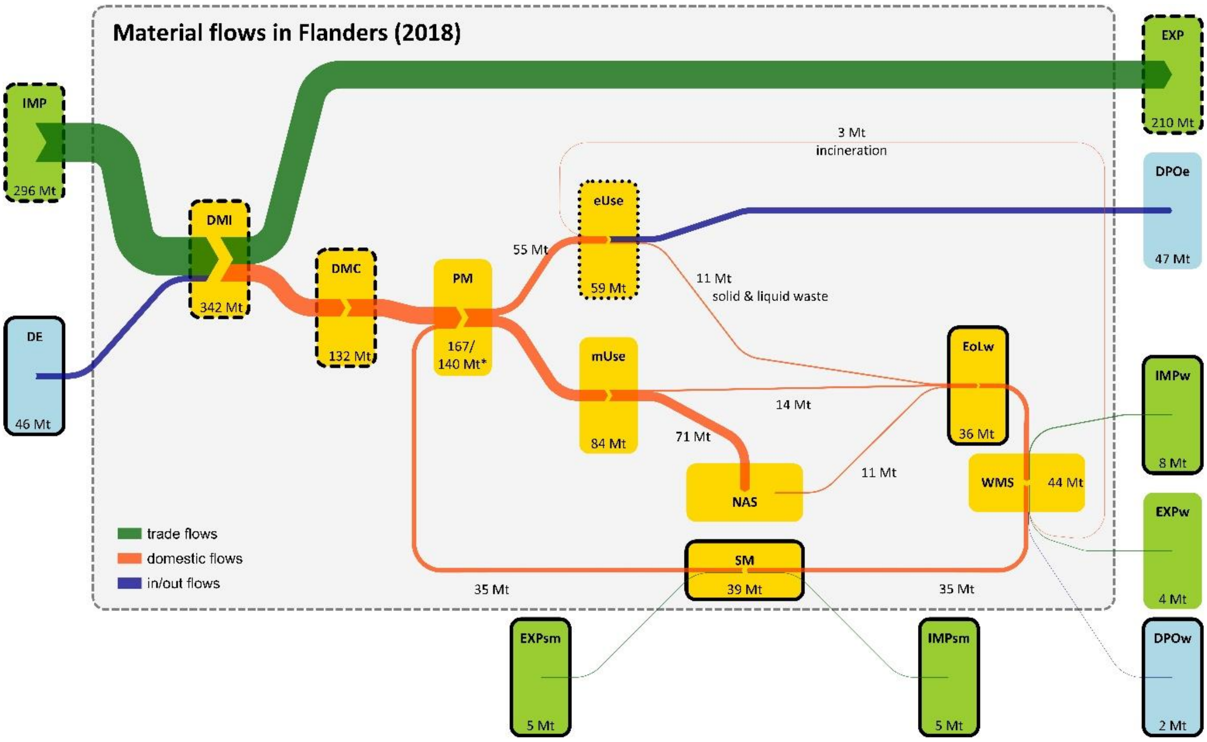


Figure 17: The material flow diagram of Flanders, 2018, in million tons. (*) Inflow and outflow statistics on PM do not match.

Reading guide: In the Sankey diagram the width of the arrows is proportional to the size of material flows. The numbers show the size of the material flows in million tons per year. Note that the numbers may not always sum up to total due to rounding.

Green flows represent trade flows; blue flows represent flows between the domestic socio-economic system and the environment; orange flows represent domestic flows.

Boxed processes are directly covered by statistics: IMPw, EoLw, DPOw, SM and incineration volumes are directly covered by OVAM waste statistics. The fossil energy carriers part of eUse is covered by the statistics on the energy balance of Flanders. DE, IMP, DMI, DMC and EXP are covered by the EW-MFA statistics, although the fossil energy carriers part is overwritten due to the mass balancing exercise.

Mt = million tons. IMP: import; DE: domestic extraction used; DMI: direct material input; DMC: domestic material consumption; PM: processed materials; eUse: energy use; mUse: material use; NAS: net additions to stock; EoLw: end of life waste; SM: secondary materials; EXP: export; DPOe: emissions in domestic processed output; DPOw: waste in domestic processed output; IMPw: import of waste materials; EXPw: export of waste materials; IMPsm: import of secondary materials; EXPsm: export of secondary materials.

Interpretation guide: The diagram visualises the macro-economic material flows in Flanders in 2018. The input of materials originate from abroad (IMP, IMPw and IMPsm) or from the environment via extraction and agriculture (DE). The total input of materials (excluding import of waste and secondary materials) sums up to the domestic material input (DMI). Exported materials (EXP, excluding the export of waste and secondary materials) are subtracted from the DMI-indicator resulting in the domestic material consumption (DMC).

The total volume of domestically processed materials (PM) is the sum of DMC and the feedback loop of secondary materials (SM). These materials are either used for energetic (eUse) or material-related (mUse) purposes. Energetic use is completed by a feedback loop of incineration from the waste management system (WMS). The energetic use encompasses food, feed and use of energy products. After use they either are transformed into emissions (DPOe) or solid and liquid waste. The material-related use is divided into short-lived products and stock accumulation. Together with removals from stock they form the net additions to stock (NAS). The removals from stock, the solid and liquid waste and the short-lived throughput materials sum up to the domestic end-of-life waste (EoLw) category.

The domestic end-of-life waste (EoLw) enters the domestic waste management system (WMS) together with all imported waste (IMPw). This total volume is, potentially after processing, send to incineration (flow to eUse), to waste landfill (DPOw), abroad (EXPw) or becomes secondary materials (SM). The total volume of secondary materials (SM) in the feedback loop of the Flemish domestic economy is corrected with trade in secondary materials (IMPsm and EXPsm).

In the diagram, the values for the inflow and outflow of PM do not match. The use of energy related materials (both for energetic and non-energetic purposes) based on the dataset 'Energiebalans Vlaanderen' does not match the estimation for the same flow using the economy-wide material flow analysis methodology. Here, we choose to use the values of DMC from the EW-MFA methodology.

The *numerator* has to indicate the circular use of materials. The circular use of materials is approximated by the amount of waste recycled in domestic recovery plants minus imported waste destined for recovery plus exported waste destined for recovery abroad. Waste recycled in domestic recovery plants comprises the recovery operations R2 to R11 - as defined in the Waste Framework Directive 75/442/EEC. Preferably, the approximated amount of <u>waste recycled in domestic recovery plants</u> includes two components:

- Residual material legally declared as waste, which is recovered and after treatment fed back to the economy (so, going through legally demarcated waste management system). This part is approximated by waste statistics, representing the flow of materials that have become legally defined waste and after recovery are fed back into the economy thus avoiding the use of primary materials. Only the waste flows going to 'Recovery-Recycling' are taken into account, thus not energy recovery and not backfilling.
- Residual material outside legal waste coverage (outside waste management system (WMS)) e.g. a by-product of production processes which is either fed back into the own processes or sold and processed by others (economic transaction). However, in practice this flow is not captured by official statistics and thus not included.

The waste recycled in domestic recovery plants needs to be <u>corrected by imports and exports of waste</u> destined for treatment. As the CMUR indicator focusses on the country's effort to collect waste for recovery, the waste collected abroad and imported has to be excluded, and vice versa the waste that is collected domestically but exported for treatment needs to be included. Eurostat refers to the CN-codes in Eurostat's trade in good statistics for import and export of waste. So, the numerator can be summarized as:

= amount of waste recycled in domestic recovery plants
- import of waste for recovery/recycling
+ export of waste for recovery/recycling

The *denominator* is defined by an indicator for overall material use. Eurostat prefers to use the Raw Material Consumption (RMC) for this. This indicator is however not yet available for all EU countries, which is an important condition for Eurostat. For that reason the Domestic Material Consumption is suggested as a proxy indicator. Arguments for using <u>DMC as a proxy for RMC</u> is the fact that its development over time resembles that of RMC, and data are collected annually, for all member states. DMC is defined in economy-wide material flow accounts. An alternative denominator would be the Domestic Material Input (DMI), but this would lead to double-counting as materials extracted in one EU country and imported by another one are counted twice. As the CMUR is defined as a ratio-indicator, it should have a maximum threshold of 1 (or 100%) and thus the denominator is defined as the sum of DMC + cycled materials (as defined in numerator).

$$\text{CMU} = \frac{\text{recycling}}{\text{processed materials}}$$

Using waste statistics for measuring the circular use of materials has some consequences for the interpretation of the indicator. One effect is that only the contribution of WMS to CE is included, the circular use of residual material which goes outside the WMS is not ('non-waste part'). This is important, as it is this flow which is expected to increase in the future because of increasing value. Another consequence is that the indicator focusses on the input of waste into recovery plants and not on the quantity and quality of secondary materials that come out which is the ideal option. Although it is analysed by Eurostat that input of recovery plants is an acceptable proxy for their output.

Learn more?

The CMUR is part of the report (forthcoming) on the economy-wide circular economy assessment by VITO in commission of the CE-center of Flanders. Next to the CMUR, alternative indicators are developed which are more tailored to local poly and local data availability. Also, the CMUR is not a stand-alone indicator: it measures the macro-economic trends towards a more circular economy. To understand and highlight short term and small scale progression, a richer dashboard of indicators is indispensable.

5.2 Discussion

The CMUR in Flanders increased from 15.9% in 2014, to 19.0% in 2016 and to 20.7% in 2018. The increase in CMUR can mainly be attributed to the substantial increase in waste recycled in domestic recovery plants. Looking at the Flemish waste statistics, the share of recycling, composting, reuse or use as secondary resources remained fairly stable in the last decade, 74% in 2007 to 79% in 2018. Also the volume of primary waste[14] remains fairly stable, around 18 to 23 million tons per year. However, the amount of secondary waste increased substantially from 15 million tons in 2007 to 35 million tons in 2018. For more details and insights on this topic, we refer to the reporting on waste statistics by OVAM.

It is a common critique on macro-economic indicators: the short term influence of policy action on the macro-economic indicator is only limitedly visible. The macro-economic indicator is influenced by numerous factors that overwhelm the effect of a single measure on this macroeconomic indicator. For this reason, it is of less interest to put a target on the CMUR for Flanders. Also, the theoretic maximum of 100% is impossible, because of food, feed and energetic needs. Renewable energy could support the progression towards a higher CMUR, but 100% is impossible. The estimation of a 'reachable' theoretic maximum is a difficult exercise. For example, the transition towards a full renewable energy system will reduce the needs for fossil energy carriers for energetic purposes, however, this transition will inseparable be connected with huge material-intensive investments in and maintenance of infrastructure (e.g. solar panels, wind turbines and water turbines). It should be of interest to regularly update the material framework and the indicator to understand our material metabolism.

In this discussion section, we would like to come back on the denominator of the CMUR. The denominator of the CMUR is defined by an indicator for overall material use. Eurostat prefers to use the

[14] With regard to industrial waste, we can make a distinction between primary and secondary industrial waste. Primary industrial waste is industrial waste that arises from the original waste producer. Secondary industrial waste is waste that is generated by companies that processing waste (the waste processors). Because the processing of waste consists out of a number of (linked) processes (sorting, further purification, recycling, ...) the same primary waste can return to secondary waste multiple times. This causes double counting, but the info can be very useful in estimating the necessary processing capacities.

RMC for this. This indicator is however not yet available for all EU countries, which is an important condition for Eurostat. For that reason the DMC is suggested as a proxy indicator. Arguments for using DMC as a proxy for RMC is the fact that its development over time resembles that of RMC, and data are collected annually, for all member states. An alternative denominator would be the Domestic Material Input (DMI), but this would lead to double-counting as materials extracted in one EU country and imported by another one are counted twice. As the CMU rate is defined as a ratio-indicator, it should have a maximum threshold of 1 (or 100%) and thus the denominator is defined as the sum of DMC + SM. In Flanders, estimations of both the DMC and RMC are available. However, the calculation of the DMC is much more mature, stable and less uncertain it currently is the most preferred one.

Despite this, we used two routes to estimate the overall use of materials (i.e. PM). A first route makes use of the official Flemish EW-MFA statistics which encompasses the DMC indicator. A second route started from the estimations using the values for use of energy related materials (both for energetic and non-energetic purposes) based on the dataset ‘Energiebalans Vlaanderen’. Both routes are available in this report, but the first route (based on EW-MFA) is used to calculate the CMUR for Flanders (see Section 5.1). We recommend to review the EW-MFA methodology applied to Flanders in the next update of the DMC/RMC indicators.

The CMUR measures the macro-economic contribution of recycled materials towards the overall use of materials. It measures the volume of recycled and comprises the recovery operations R2 to R11 – as defined in the Waste Framework Directive 75/442/EEC. The interpretation of this macro-economic indicator is not straightforward as indicated above. Also, it cannot be seen as a stand-alone indicator. In the monitoring of material flows at macro-economic level, it is of equal importance to monitor (reductions in) the DMC (and RMC) for Flanders. Also, the understanding of the huge trade flows of the open economy in Flanders (composition, recycled content, etc.) is important. Likewise, the interlinkages with greenhouse gas emissions, biodiversity, etc. are as well of equal importance.

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Annex 1

Compilation of an economy wide circularity model for Flanders

2018-data for Flanders on **import, export and domestic extraction used (DE)** are directly copied from the EW-MFA assessment report. Import and DEU are input flows to the framework. Both these flows are disaggregated in the four main material categories: biomass, metal ores, non-metallic minerals and fossil energy carriers. The economy-wide material flow assessment shows six material groups, but to simplify the overview the smaller fifth and sixth (other products and waste for final treatment and disposal, respectively) material groups *are equally spread across the other material groups*.

In Flanders, import is 6.4 times bigger compared to the DE. As DE only consists out of biomass and non-metallic minerals, the import dependency is 100% for metal ores and fossil energy carriers. The import dependency of biomass is 84%, and of non-metallic minerals is 57%. The import of fossil energy carriers is the largest input flow. This flow is determined by more than 800 imported product groups. However, the top-5 product groups represent already 55% of the total import volume and the top 10 product groups accumulate to a share of 64% (see Table 6). In this top-10 product groups, two flows are provided in TJ instead of kilograms. These are converted into kilograms via a conversion factor. Also, Table 7 shows the exported volume of these CN-codes. It shows that within the same product category, Flanders both has import and export (e.g. a result of trade activities by domestic companies). The data on trade follows the national concept. The national concept includes only import and export of products that involve domestic companies. In contrast, the community concept includes all import and export transactions occurring in the domestic area, even those which do not involve a domestic company. Within this exercise, the national concept is preferred. The top-10 product groups represent 49% of the total export volume (see Table 7). Note, the top-10 is not fully equal to the top-10 of imported flows within the product group of fossil energy carriers.

Although import and export consist out of numerous different product flows, the total trade flow, expressed in weight, is largely determined by only a limited number of flows. This is shown here for illustrative purposes and to give the reader an idea of what is behind these totals. In additions, this is important to keep in mind in the interpretation of the results. For example, the increase or decrease in stocks of energy products (e.g. as a reaction to oil price changes), might have a substantial effect on these yearly flow totals. A detailed study of all trade flows might reveal other influences on the totals. However, this was not part of this study. More insights are explained in the preceding report.

*Table 6: Top-10 of the **imported** product groups of fossil energy carriers, 2018, interregional and international import by Flanders, in tons.*

CN-code	Import	Export
2709 00 90 crude petroleum oils	32,186,631	687,481
2711 21 00 natural gas (gaseous state) *	26,916,683	6,316,546
2710 19 43 petroleum oils (other than crude; gas oils; sulphur content below 0,001%)	8,742,272	5,869,729
2710 12 90 petroleum oils (other than crude; light oils; motor spirit)	4,522,098	2,286,877
2710 12 11 petroleum oils (other than crude; light oils and preparations for undergoing a specific process)	4,161,567	310,847
2711 11 00 liquefied natural gas*	3,164,676	612,739

2710 19 68 petroleum oils (other than crude; fuel oils; sulphur content exceeding 1%)	2,715,467	6,539,244
2710 19 64 petroleum oils (other than crude; fuel oils; sulphur content between 0,1 and 1%)	2,268,805	3,306,185
2710 19 47 petroleum oils (other than crude; gas oils; sulphur content between 0,002 and 0,1%)	2,143,208	2,669,742
2710 12 25 petroleum oils (other than crude; light oils; special spirits)	2,134,717	1,134,332

** Natural gas (gaseous state) and liquefied natural gas are provided in TJ units. This is converted to kilograms with conversion factors 19,300 TJ/kg and 19,170 TJ/kg, respectively.*

*Table 7:Top-10 of the **exported** product groups of fossil energy carriers, 2018, interregional and international export by Flanders.*

CN-code	Import	Export
2710 19 68 petroleum oils (other than crude; fuel oils; sulphur content exceeding 1%)	2,715,467	6,539,244
2711 21 00 natural gas (gaseous state) *	26,916,683	6,316,546
2710 19 43 petroleum oils (other than crude; gas oils; sulphur content below 0,001%)	8,742,272	5,869,729
2710 12 41 petroleum oils (other than crude; light oils and preparations; motor spirit; with lead content not exceeding 0,013 g per litre; with an octane number of less than 95)	1,580,201	5,516,199
2710 19 62 petroleum oils (other than crude; fuel oils; sulphur content not exceeding 0.1%)	176,221	3,386,381
2710 19 64 petroleum oils (other than crude; fuel oils; sulphur content between 0,1 and 1%))	2,268,805	3,306,185
2707 99 99 mineral fuels**	1,084,342	3,278,382
2710 19 47 petroleum oils (other than crude; gas oils; sulphur content between 0,002 and 0,1%)	2,143,208	2,669,742
2710 12 90 petroleum oils (other than crude; light oils; motor spirit)	4,522,098	2,286,877
2710 19 21 jet fuel, kerosene	1,280,310	2,147,164

** Natural gas (gaseous state) is provided in TJ units. This is converted to kilograms with conversion factor 19,300 TJ/kg.*
*** Oils and other products of the distillation of high temperature coal tars and similar products in which the weight of the aromatic constituents exceeds that of the non-aromatic constituents, not elsewhere classified.*

The input side of the domestic economy has two entrances: import and DEU. Together they sum up to the indicator DMI. The DMI for Flanders in 2018 is 342 million tons. By subtracting the export from DMI, the DMC is calculated. The DMC for Flanders in 2018 is 132 million tons.

$$\mathbf{DMI} = \mathrm{DE} + \mathrm{IMP} = 46\ \mathrm{Mton} + 296\ \mathrm{Mton} = 342\ \mathrm{Mton}$$
$$\mathbf{DMC} = \mathrm{DMI} - \mathrm{EXP} = 342\ \mathrm{Mton} - 210\ \mathrm{Mton} = 132\ \mathrm{Mton}$$

Next to the two input flows from outside the domestic economy, a third input flow is described that originates from inside the domestic economy. This flow contains **secondary materials (SM)** that are domestic recovered flows from end-of-life waste. Here, we use waste statistics data from OVAM[15] to estimate the SM-flow. Secondary resources from abroad are part of import. The SM flow contains secondary resources (i.e. reusable resource without further processing), composted materials and

[15] OVAM (2019). Bedrijfsafval en secundaire grondstoffen productiejaar 2004-2018 (uitgave 2019) [in Dutch].

recycled and reused materials. Materials requiring further treatment, for incineration or landfill are excluded from this feedback loop.

Re- and downcycling comprises flows reported as recycling or backfilling in waste statistics. Recycling is defined as ‘any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes’. Backfilling is defined as a recovery operation where waste is used in excavated areas (such as underground mines, gravel pits) and where the waste is substituting other non-waste materials which would have had to be used for the purpose. We refer to re- and downcycling also as secondary materials. Secondary materials refer to materials recovered through all forms of recycling, reuse, and remanufacturing but also downcycling (e.g., backfilling) or cascadic use.

The data for SM is derived directly from OVAM-statistics. Both SM from industries and from waste treatment activities are included. The statistics provide some level of detail on the composition. These data are completed with shares from Mayer et al. (2019) (shares from Table S4), to allow an allocation of the total amount of SM to the four main material categories. The SM of Flanders in 2018 is estimated at 35 million tons.

The **processed materials (PM)** is the total input of materials of the domestic economy, excluding exports. The PM of Flanders in 2018 is estimated at 167 million tons.

$$\mathrm{PM} = \mathrm{DMC} + \mathrm{SM} = 132\ \mathrm{Mton} + 35\ \mathrm{Mton} = 167\ \mathrm{Mton}$$

Each product in the total flow of PM is allocated to either **energetic use (eUse)** or **material use (mUse)**. eUse not only comprises materials used to provide technical energy (fossil fuels, fuel wood and biofuels) but also feed and food, the primary energy sources for livestock and humans. The division between eUse and mUse is based on Mayer et al. (2019) and Haas et al. (2015), together with the allocation these sources provide[16]:

- 50% of the ‘other crops’ (e.g. flowers and ornamental plants, seeds and seedings, tobacco, aromatic, medicinal and culinary plants and energy crops) is allocated to mUse;
- Also, timber and other biomass products are allocated to mUse;
- Crops (except the other crops category), fodder crops, wood fuel, fish and live animals are allocated to eUse;
- Metal ores are allocated to mUse, except for uranium and thorium ores which are allocated to eUse;
- Non-metallic minerals are fully allocated to mUse; and
- Based on the non-energetic use of fossil fuels reported in the Flemish energy balance, a total of 6,589 kilotons is allocated to mUse (see Table 8).

Table 8: The non-energetic use per fuel type in Flanders, data year 2017.

Fuel type for non-energetic use	Use in PJ	Use in kilotons
Coal tar	10,639	363
LPG	56,158	1,124
Gas and diesel oil	21	0
Heavy fuels	622	15
Naphtha	167,134	3,853
Petroleum cokes	987	28

[16] It is not within the scope of this study to review and adopt the allocation factor to the specific context of Flanders. The focus of this report is to provide a first overview on material flows in Flanders, mainly to show the possibilities with the framework and to feed further discussions. In a later phase, one can decide to improve the allocation factors.

Other petroleum products	19,948	476
Natural gas	36,466	730
Total	**291,975**	**6,589**

Source: Energiebalans Vlaanderen 1990-2017.

After the allocation of all products with PM to eUse and mUse, the mUse is further disaggregated into either **throughput materials (TM)** or **gross additions to stock (+Stock)**. +Stock are material used to build up in-use stock of materials (life span > 1 year). TM are short-lived products (live span < 1 year) and processing and manufacturing waste; wastage and deliberative dissipative uses. Based on Mayer et al. (2019) – Table S2, Wang et al. (2007) – Fig. 2, Cullen et al. (2016) – Fig. 2 and Allwood et al (2010) – Table 4 the following allocation factors16 are derived:

- 10% of the fodder crops and 90% of the roundwood is allocated to +Stock;
- Salt and 5% of the other non-metallic minerals are allocated to TM;
- 50% of the fossil energy carriers to +Stock; and
- 47% of iron, 75% of aluminium and 64% of other metal products allocated to +Stock.

Next to the flows on the input side of the economy are the flows on the output side of the domestic economy discussed. **Extractive waste** refers to waste material that occurs during early stages of the processing of domestically extracted ores and directly goes from PM to interim output (IntOut). In Flanders, extractive waste is assumed to be zero as this flow is mainly related to the extraction of metal ores.

The flow **solid and liquid waste** combines all waste flows from the combustion of fuels and the excrements of humans and livestock. These flows should be measured at the same water content of that of biomass intake. It excludes the water uptake by humans and livestock. The flow is estimated via ratios from Mayer at al. (2019) – Table S6:

- 7.75% of eUse for fossil energy carriers; and
- 28.96% of eUse for biomass.

The **emissions (DPOe)** comprise all gaseous emissions (e.g. carbon dioxide [CO_2], sulphur dioxide [SO_2], methane [CH_4]) including water vapor from combustion and human and animal respiration. The oxygen input from air is excluded.

$$\mathbf{DPOe} = \text{eUse} - \text{ solid \& liquid waste}$$

Three methods can be used to estimate the emissions related to the use of fossil energy carriers:

1. First, the import minus export of fossil energy carriers resulting from the EW-MFA calculations.
2. Second, using statistics from VMM on the greenhouse gas emissions in Flanders. Considering an average vapor, including vapor from combustion, and an excess H_2 of 24% (from Mayer et al. (2019) - Table S5) the emission excluding oxygen from air can be estimated.
3. Third, based on the energy balance of Flanders from VEA. All three methods are discussed below, and the results thereof are compared.

Following the first method, the import of fossil energy carriers is estimated at 136,384 kilotons and the export is estimated at 80,204 kilotons. Import minus export of fossil energy carriers results in a DMC of 56,180 kilotons. Added a small amount of SM of 346 kilotons results in an estimation for fossil energy carriers in PM of 56,526 kilotons. This amount minus 6,589 kilotons of mUse results in an eUse of fossil energy carriers of 49,937 kilotons. Subtraction of the solid and liquid waste (7.75% of eUse from fossil energy carriers) results in DPOe of 46,067 kilotons fossil energy carriers. This method relies on the following formula for estimating DPOe for fossil energy carriers:

$\mathbf{DPOe} = \text{eUse} - \text{solid \& liquid waste} = 49{,}937\ \text{kton} - 3{,}870\ \text{kton} = 46{,}067\ \text{kton}$

The second method starts from total greenhouse gas emissions in Flanders, which amount to 77.7 million tons CO_2-eq (data year 2018). The method requires converting these emissions into the chemical elements contained in the fuel at the point of extraction. Thus, CO_2 is converted to C and SO_2 to S. CH_4 and N_2O are emissions stemming from elements already included in fossil fuels. Adding 24% of average vapor and excess H_2 results in an estimation for fossil energy carriers in DPOe of 22,579 kilotons.

The third method starts from the gross consumption of energy (excl. international bunkers) from fossil energy carriers, which is estimated at 1,126 PJ in 2017 (Energiebalans Vlaanderen 1990-2017). Converted to kilograms this is ca. 34,024 kilotons. Subtracting the non-energetic use of fossil energy carriers (6.589 kilotons) results in an estimation for fossil energy carriers in DPOe of 27,436 kilotons. Subtraction of the solid and liquid waste (7.75% of eUse from fossil energy carriers) results in DPOe of 25,310 kilotons fossil energy carriers.

There is a considerable variation in the results depending of the applied calculation method. Especially the estimation via the import minus export of fossil energy carriers results in a significantly higher result compared to the other two approaches. The second and third estimation are based on emission and energy use data, respectively. Therefore, the average of both results is used for the estimation of DPOe, which is 23,905 kilotons.

The **end-of-life waste (EoLw)** comprises all solid waste from eUse and mUse including throughput materials, solid and liquid waste and demolition and discard. The data for EoLw is derived from OVAM-statistics[17]. Both waste and secondary materials from industries and from waste treatment activities are included. Note that some double counting is included in the data, as waste treatment can have multiple sorting and processing steps. The statistics provide detailed data on the composition. These data are supplemented with shares from Mayer et al. (2019) (shares from Table S4), to allow an allocation of the total amount to the four main material categories. The total EoLw for Flanders is estimated at 58.2 million tons.

Demolition and discard (-Stock) is solid waste from discarded in-use stocks. It comprises construction and demolition waste but also other discarded long living products. The -Stock flow is estimated via the difference between EoLw and TM plus solid and liquid waste.

$-\text{Stock} = \text{EoLw} - \text{TM} - \text{solid \& liquid waste} = 58\text{Mton} - 14\ \text{Mton} - 10\ \text{Mton} = 33\ \text{Mton}$

By calculating +Stock and -Stock, the NAS (net additions to stock) can be derived as the difference between both. +Stock is estimated at 75 million ton and -Stock at 33 million ton. The NAS for Flanders in 2018 is 41 million ton (due to rounding thus subtraction does not match).
Interim outputs (IntOut) comprises all waste and emissions after the use phase. It is calculated via the sum of TM, -Stock, eUse (sum of DPOe and solid and liquid waste):

$\text{IntOut} = \text{TM} + -\text{Stock} + \text{eUse} = 14\ \text{Mton} + 33\ \text{Mton} + 55\ \text{Mton} = 103\ \text{Mton}$

Domestic processed output (waste; DPOw) is all EoLw excluding materials recovered for re- and downcycling. All liquid and solid outputs including moisture content as included in extracted material but excluding extra added water. DPOw is calculated as EoLw minus SM:

$\text{DPOw} = \text{EoLw} - \text{SM} = 58\ \text{Mton} - 35\ \text{Mton} = 24\ \text{Mton}$

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[17] OVAM-statistcs 'bedrijfsafval en secundaire grondstoffen (2004-2018)'.

Domestic processed output (DPO) is the total domestic processed output to the environment (waste and emissions). DPO is the sum of DPOe and DPOw:

$$\mathrm{DPO} = \mathrm{DPOw} + \mathrm{DPOe} = 24\ \mathrm{Mton} + 45\ \mathrm{Mton} = 69\ \mathrm{Mton}$$

Annex 2

Improvements in the compilation of an extended economy wide circularity model for Flanders (in addition to Annex 1)

Based on the insides from Chapter 2 and 3 several improvements to both the framework presented in Figure 1 and the first estimation of material flows presented in Figure 4 are introduced and elaborated in Chapter 4 onwards and the executive summary. More details on these changes are provided in Chapter 4. Here, the deviations are summarized.

In the scope of this report, two deviation from the numbers on import and export in the EW-MFA are present:

- First, the trade flows exclude the trade in waste and secondary raw materials. These trade flows are recorded separately in the framework; and
- Second, the import of fossil energy carriers is estimated as the difference between DMC and export. We made the choice to include two routes. A first routes makes use of the EW-MFA results and includes a discrepancy between the inflow and outflow of PM. In a second route the use of energy related materials (both for energetic and non-energetic purposes) is based on the dataset 'Energiebalans Vlaanderen'. Using mass-based balancing, this also resulted in a discrepancy between these results and the estimation from EW-MFA. Therefore, the import of fossil energy carriers is overwritten to remove the discrepancy.

Figure 4: Estimation based on EW-MFA, with incomplete mass-based balancing.
⇕
Figure 11: Extended framework, improved estimations and full mass-based balancing.

Due to the mass-based balancing exercise (second route), these two changes have an impact throughout almost the whole framework. The use of fossil energy carriers is estimated to be lower, resulting in a lower DMI for Flanders in 2018 (306 million tons compared to 342 million tons in the EW-MFA study); a lower DMC estimated at 105 million tons (compared to 132 million tons in the EW-MFA study), and a lower PM estimated at 140 million tons (compared to 167 million tons in the EW-MFA study).

In the extended framework we use the correspondence of waste codes to the four material flows MF1 to MF4 which is provided by Eurostat (Annex to circular material use rate methodology), to allow an allocation of the total amount of SM to the four main material categories.

In addition to the previous version of the framework, the flow of SM is corrected for trade flows: import of secondary materials are added to PM, while the export of secondary materials is subtracted from it. Both the import and export flow are estimated at 4.5 million tons (see Annex 3).

$$\mathrm{PM} = \mathrm{DMC} + \mathrm{SM} + \mathrm{IMP_{SM}} - \mathrm{EXP_{SM}} = 105\ \mathrm{Mton} + 35\ \mathrm{Mton} + 5\ \mathrm{Mton} - 5\ \mathrm{MTon} = 140\ \mathrm{Mton}$$

Three methods can be used to estimate the emissions related to the use of fossil energy carriers:

- First, the import minus export of fossil energy carriers resulting from the EW-MFA calculations (resulting in an estimation of 46.1 million tons);

- Second, using statistics from VMM on the greenhouse gas emissions in Flanders. Considering an average vapor, including vapor from combustion, and an excess H_2 of 24% (from Mayer et al. (2019) - Table S5) the emission excluding oxygen from air can be estimated (resulting in an estimation of 22.6 million tons); and
- Third, based on the energy balance of Flanders from VEA (resulting in an estimation of 25.3 million tons).

There is a considerable variation in the results depending of the applied calculation method. Especially the estimation via the import minus export of fossil energy carriers results in a significantly higher result compared to the other two approaches. In the extended framework, we choose to make use of the third estimation based on energy use data, because it is a direct estimate of the use of fossil energy carriers in Flanders. Due to the mass-balancing exercise within the framework, this triggers a change in the estimation of the import of fossil energy carriers compared to the EW-MFA results.

DPOw is estimated via the waste statistics provided by OVAM: it is assumed to equal the statistics on backfilling to 2.3 million tons. The incineration (2.8 million tons) is considered as a feedback loop to eUse. The inclusion of this feedback loop and the choice of sticking with the energy use data has its effect on the distribution between eUse and mUse.

The methodology and formulas for the other building blocks of the framework are equal to the ones described in Annex 1.

Annex 3

Adding trade in waste and trade in secondary materials to the framework

In order to complete the framework with statistics on the trade in waste and secondary materials, we first look at statistics available at the European level extracting data for Belgium for illustrative purposes. Afterwards, we dive into the Flemish statistics to enable the completion of the framework for Flanders.

To our knowledge, at the European level two macro-economic data sources are available for determining the role of waste and secondary raw materials in the total trade of products:

- The regulatory framework of transboundary shipments of waste (regulation 1013/2006); and
- Trade in recyclable raw materials.

First, according to the **regulatory framework of transboundary shipments of waste** (commonly referred to as the Waste Shipment Regulation or WShipR), all wastes for disposal operations and for recovery operations, all hazardous waste as well as some problematic waste streams and other wastes defined by the WShipR, must be notified to the authorities before it is allowed to transboundary ship them. The shipments of waste data are broken down by type of waste, hazardous characteristics, treatment type, dispatch and destination country. The amounts are reported in tons. Eurostat reports the statistics gathered from this regulation at the level of the member states. The reporting of transboundary shipments in Flanders is controlled by OVAM.

Second, the **trade in recyclable raw materials** is a methodology to derive waste statistics from the trade database. In a circular economy, residual materials are recycled and re-injected into the economy as new raw materials - then called 'secondary raw material'. This may have several benefits, both reducing net wastes and increasing the security of raw materials supply. An accurate picture must include the movements of raw materials originating from waste, i.e. secondary raw materials, crossing Flemish boundaries both as imports and exports, even if the recycling operation itself did not yet occur. Many non-hazardous waste streams are regarded as valuable resources because they are potentially an important source of raw materials. Overall, cross-border movements of recyclable waste have significantly increased over the last decade (Eurostat, 2020).

Table 9 and Table 10 show an extract of Belgian data retrieved from the Eurostat website.

Table 9: Transboundary shipments of notified waste, Belgium, in tons, 2018. Source: Eurostat [env_wasship].

		Import	Export
Total	**Total**	**1.774.153**	**3.951.779**
Disposal	Hazardous	144.664	55.793
Disposal	Other	110.953	58.773
Recovery	Hazardous	489.232	610.489
Recovery	Other	1.029.304	3.226.724

Table 10: Trade in recyclable raw materials by waste, Belgium, in tons, 2018. Source: Eurostat [env_wastrd].

	Import	Export
Total waste	**6.620.895**	**6.713.523**
Plastics	260.653	670.220

Paper and cardboard	1.039.552	1.586.454
Iron and steel	4.536.862	4.034.556
Precious metals	191.867	3.315
Copper, aluminium and nickel	591.960	418.977

Trade in recyclable raw materials shows the amount (in mass unit) and the monetary value (in Euro) of selected waste flows that are shipped across borders. The scope of the "recyclable raw material" is defined and approximated in terms of relevant product codes selected from the list of Combined Nomenclature (CN) codes used in International Trade in Goods Statistics. They are grouped according to a Joint Research Centre (JRC) classification, which provides a breakdown for the following material classes:

- Plastic;
- Paper and cardboard;
- Precious metal;
- Iron and steel; and
- Copper, aluminium and nickel.

The full list of all CN-codes is given in Table 11. Based on this selection of CN-codes the indicator provides an estimation of waste trade flows. Eurostat reports these statistics at the level of the member states. Also, this methodology can be applied to the Flemish trade database, in which the trade of products is also provided in CN-classification.

The estimation of Flemish trade in waste and secondary materials is based on:

- The import of waste relies on the dataset import of waste for processing in Flanders, provided by OVAM;
- The trade in secondary materials relies on the methodology provided by Eurostat on 'trade in recyclable raw materials'; and
- The export of waste is estimated via mass-based balancing of the extended framework.

The import of waste by Flanders is estimated at 8.0 million tons. Mainly with the intention to recycling (28%) or sorting (19%), although 41% is categorised in the 'other'[18] category. 3.1 million tons are linked to the material category of non-metallic minerals, 2.3 million tons to metal ores, 2.1 million tons to biomass and 0.5 million tons to fossil energy carriers.

The trade in secondary materials is estimated via Eurostat's methodology on estimating the trade in recyclable raw materials. However, in this study we choose to extend the list of Eurostat. A search in the list of CN-codes on the words "waste" and "secondary resource" resulted in a list of additional CN-codes that are relevant to include (see Table 12). Waste from (the processing of) food and feed products is excluded from this list.

We used the Flemish international trade statistics, which cover trade by Flanders with the rest of the world. Trade with Brussels Capital Region and the Walloon region is not included in this database. In 2018, the total trade volume of Flanders based on the CN-codes from Table 11 and Table 12 is estimated at 4.5 million tons of import and an equal amount of 4.5 million tons of export. We cannot exclude a potential overlap between these figures and the above estimated figure for the import of waste.

On the import side, the determining flows are waste from iron and steel[19] (31%) and waste from stainless steel[20] (19%). The combined flows of paper (CN-codes 4707) sum up to a share of 17%. The CN-codes

[18] Other then composting, reuse, recycling, sorting, landfill or incineration.

[19] CN-codes 7204 49 10, 7204 49 30 and 7204 49 90.

[20] CN-codes 7204 21 10, 7204 21 90 and 7204 29 00.

from Table 11 already make up 93% of the total on the import side. Looking at the import of the extra CN-codes from Table 12, only the import of glass cullet (CN-code 7001 00 10) is substantial, with a share of 5% of the estimated total. Remind that this trade data source only shows information on the trade flows itself, not the user or generator of the waste flow.

On the export side, a smaller number of trade flows determine the estimated total export volume of waste. The determining flows are waste from iron and steel[19] (52%), the combined flows of paper (CN-codes 4707) that sum up to a share of 20% and the export of glass cullet (9%).

Comparing these volumes (8.0 million 4.5 million tons on the import and export side) with the total volume of trade (an import trade flow estimated at 260 million tons on and an export trade flow estimated at 201 million tons), shows that the estimated waste flows are insignificant in the total trade flows of Flanders. However, the above estimation of flows of waste and recyclable materials is an underestimation. Traded products containing recycled materials or direct trade in secondary materials not covered by the selected CN-codes are examples of trade flows not included in the estimation.

Although the estimated trade flows of waste and recyclable materials are rather small compared to the total volume of trade, the numbers are substantial compared to the estimated SM-flow (35 Mt). While the SM-flow shows the feedback loop within the socio-economic system in Flanders of EoLw to the input side, the estimated trade flows of waste and recyclable materials show the (minimum) amount of materials that (potentially) have a feedback flow outside Flanders.

Based on the available Flemish statistics, we were able to established a clear and comprehensive overview of waste flows for 2018. All statistics provided sufficient detail to disaggregate each flow into the four main material categories. Only the export of waste was not available from the statistics, and therefore is estimated by mass-based balancing.

The description of waste flows in Flanders starts with an estimation on the total volume of generated waste of 35.9 million tons (Generation of waste in Flanders, 2018, OVAM). This amount includes household wastes, but excludes the waste generated by waste treatment activities, in order to avoid double counting. Three routes exist for this in Flanders generated waste:

- 6.8 million tons of this generated waste is directly used as secondary material and 3.1 million tons is reused, recycled or composted;
- 1.2 million tons are send to incineration or landfill; and
- The remainder, 24.8 million tons, is send to a waste treatment system.

Including trade of waste, adding 8.0 million tons import and subtracting an estimated 4.1 million tons export, sums up to 28.7 million tons. After (multiple loops in) the waste treatment system this volume is transformed into:

- 22.0 million tons of secondary materials;
- 2.8 million tons of materials for reuse, recycled materials or composted materials; and
- 4.0 million tons are send to incineration or landfill.

The total volume of secondary materials (including reuse, recycling and composting) is 34.6 million tons. Including the trade of secondary materials, adding 4.5 million tons of import and subtracting 4.6 million tons of export, still sums up to 34.6 million tons. This is the amount of secondary materials feed back into the domestic economy.

Annex 4

CN-codes used for the estimation of trade in recyclable raw materials

Table 11: List of CN-codes used for the estimation of trade in recyclable raw materials.
Source: Eurostat (2020).

CN-code	Description of CN-code	Materials class
39151000	Waste, parings and scrap, of polymers of ethylene	plastics
39152000	Waste, parings and scrap, of polymers of styrene	plastics
39153000	Waste, parings and scrap, of polymers of vinyl chloride	plastics
39159011	Waste, parings and scrap, of polymers of propylene	plastics
39159018	Waste, parings and scrap, of addition polymerization products (excl. that of polymers of ethylene, styrene and vinyl chloride and propylene)	plastics
39159080	Waste, parings and scrap, of plastics (excl. that of polymers of ethylene, styrene, vinyl chloride and propylene)	plastics
39159090	Waste, parings and scrap, of plastics (excl. that of addition polymerization products)	plastics
40040000	Waste, parings and scrap of soft rubber and powders and granules obtained therefrom	plastics
40122000	Used pneumatic tyres of rubber	plastics
40122010	Used pneumatic tyres of rubber, for civil aircraft	plastics
40122090	Used pneumatic tyres of rubber (excl. Those for civil aircraft of subheading 40 4012.20.10)	plastics
47071000	Recovered "waste and scrap" paper or paperboard of unbleached kraft paper, corrugated paper or corrugated paperboard	paper
47072000	Recovered "waste and scrap" paper or paperboard made mainly of bleached chemical pulp, not coloured in the mass	paper
47073010	Old and unsold newspapers and magazines, telephone directories, brochures and printed advertising material	paper
47073090	Waste and scrap of paper or paperboard made mainly of mechanical pulp (excl. old and unsold newspapers and magazines, telephone directories, brochures and printed advertising material)	paper
47079010	Unsorted, recovered "waste and scrap" paper or paperboard (excl. paper wool)	paper
47079090	Sorted, recovered "waste and scrap" paper or paperboard (excl. waste and scrap of unbleached kraft paper or kraft paperboard, or of corrugated paper or corrugated paperboard, that of paper or paperboard made mainly of bleached chemical pulp not coloured in the mass, that of paper or paperboard made mainly of mechanical pulp, and paper wool)	paper
71123000	Ash containing precious metal or precious-metal compounds	precious metal scraps
71129100	Waste and scrap of gold, incl. metal clad with gold, and other waste and scrap containing gold or gold compounds, of a kind used principally for the recovery of precious metal (excl. ash containing gold or gold compounds, waste and scrap of gold melted down into unworked blocks, ingots, or similar forms, and sweepings and ash containing precious metals)	precious metal scraps
71129200	Waste and scrap of platinum, incl. metal clad with platinum, and other waste and scrap containing platinum or platinum compounds, of a kind used principally for the recovery of precious metal (excl. ash containing platinum or platinum compounds, waste and scrap of platinum melted down into unworked blocks, ingots, or similar forms, and sweepings and ash containing precious metals)	precious metal scraps
71129900	Waste and scrap of silver, incl. metal clad with silver, and other waste and scrap containing silver or silver compounds, of a kind used principally for the recovery of precious metal (excl. ash, and waste and scrap of precious metals melted down into unworked blocks, ingots or similar forms)	precious metal scraps

72041000	Waste and scrap, of cast iron (excl. radioactive)	ferrous metal
72042110	Waste and scrap of stainless steel, containing by weight >= 8% nickel (excl. radioactive, and waste and scrap from batteries and electric accumulators)	ferrous metal
72042190	Waste and scrap of stainless steel (not containing >= 8% nickel, radioactive, or waste and scrap from batteries and electric accumulators)	ferrous metal
72042900	Waste and scrap of alloy steel (excl. stainless steel, and waste and scrap, radioactive, or waste and scrap from batteries and electric accumulators)	ferrous metal
72043000	Waste and scrap of tinned iron or steel (excl. radioactive, and waste and scrap of batteries and electric accumulators)	ferrous metal
72044110	Turnings, shavings, chips, milling waste, sawdust and filings, of iron or steel, whether or not in bundles (excl. such items of cast iron, alloy steel or tinned iron or steel)	ferrous metal
72044191	Trimmings and stampings, of iron or steel, in bundles (excl. such items of cast iron, alloy steel or tinned iron or steel)	ferrous metal
72044199	Trimmings and stampings, of iron or steel, not in bundles (excl. such items of cast iron, alloy steel or tinned iron or steel)	ferrous metal
72044910	Waste and scrap of iron or steel, fragmentised "shredded" (excl. slag, scale and other waste of the production of iron and steel; radioactive waste and scrap; fragments of pigs, blocks or other primary forms of pig iron or spiegeleisen; waste and scrap of cast iron, alloy steel or tinned iron or steel; turnings, shavings, chips, milling waste, sawdust, filings, trimmings and stampings; waste and scrap of primary cells, primary batteries and electric accumulators)	ferrous metal
72044930	Waste and scrap of iron or steel, not fragmentised "shredded", in bundles (excl. slag, scale and other waste of the production of iron and steel; radioactive waste and scrap; fragments of pigs, blocks or other primary forms of pig iron or spiegeleisen; waste and scrap of cast iron, alloy steel or tinned iron or steel; turnings, shavings, chips, milling waste, sawdust, filings, trimmings and stampings; waste and scrap of primary cells, primary batteries and electric accumulators)	ferrous metal
72044990	Waste and scrap of iron or steel, not fragmentised "shredded", not in bundles (excl. slag, scale and other waste of the production of iron and steel; radioactive waste and scrap; fragments of pigs, blocks or other primary forms of pig iron or spiegeleisen; waste and scrap of cast iron, alloy steel or tinned iron or steel; turnings, shavings, chips, milling waste, sawdust, filings, trimmings ands tampings; waste and scrap of primary cells, primary batteries and electric accumulators)	ferrous metal
72045000	Remelting scrap ingots of iron or steel (excl. Products whose chemical composition conform//or ferro-alloys)	ferrous metal
74040010	'Waste and scrap, of refined copper (excl. ingots or other similar unwrought shapes, of remelted refined copper waste and scrap, ashes and residues containing refined copper, and waste and scrap of primary cells, primary batteries and electric accumulators)	copper, aluminium and nickel scraps
74040091	Waste and scrap, of copper-zinc base alloys "brass" (excl. ingots or other similar unwrought shapes, of remelted waste and scrap of copper-zinc alloys, ashes and residues containing copper-zinc alloys and waste and scrap of primary cells, primary batteries and electric accumulators)	copper, aluminium and nickel scraps
74040099	Waste and scrap, of copper alloys (excl. of copper-zinc alloys, ingots or other similar unwrought shapes, of remelted waste and scrap of copper alloys, ashes and residues containing copper alloys, and waste and scrap of primary cells, primary batteries and electric accumulators)	copper, aluminium and nickel scraps
75030010	Waste and scrap, of non-alloy nickel (excl. ingots or other similar unwrought shapes, of remelted non-alloy nickel waste and scrap, ashes and residues containing non-alloy nickel, waste and scrap of primary cells, primary batteries and electric accumulators)	copper, aluminium and nickel scraps
75030090	Waste and scrap, of nickel alloys (excl. ingots or other similar unwrought shapes, of remelted nickel alloys waste and scrap, ashes and residues containing nickel alloys)	copper, aluminium and nickel scraps
76020011	Turnings, shavings, chips, milling waste, sawdust and filings, of aluminium; waste of coloured, coated or bonded sheets and foil, of a thickness "excl. any backing" of <= 0,2 mm, of aluminium	copper, aluminium and nickel scraps
76020019	Waste of aluminium, incl. faulty workpieces and workpieces which have become unusable in the course of production or processing (excl. slag, scale	copper, aluminium and nickel scraps

	and other waste from the production of iron or steel, containing recyclable aluminium in the form of silicates, ingots and other primary forms, of smelted waste or scrap, of aluminium, ash or the residues of the production of aluminium, and waste in heading 7602.00.11)	
76020090	Scrap of aluminium (excl. slags, scale and the like from iron and steel production, containing recoverable aluminium in the form of silicates, ingots or other similar unwrought shapes, of remelted waste and scrap, of aluminium, and ashes and residues from aluminium production)	copper, aluminium and nickel scraps

Table 12: List of extra CN-codes used for the estimation of trade in recyclable raw materials. [Description of CN-codes in Dutch]

CN-code	Description of CN-code	Materials class
70010010	glasscherven en ander glasafval (m.u.v. glas in de vorm van poeder, van korreltjes, van schilfers of van vlokken)	minerals
70010091	optisch glas	minerals
70010099	glasmassa (m.u.v. optisch glas)	minerals
80020000	resten en afval, van tin (m.u.v. assen en residuen van de tinproductie bedoeld bij post 2620; ingots e.d. primaire vormen, van gesmolten resten en afval, van tin, bedoeld bij post 8001)	non-ferrous metal
81019700	resten en afval van wolfraam (m.u.v. assen en residuen die wolfraam bevatten)	non-ferrous metal
81029700	resten en afval van molybdeen (m.u.v. assen en residuen die molybdeen bevatten)	non-ferrous metal
81033000	resten en afval, van tantaal (m.u.v. assen en residuen die tantaal bevatten)	non-ferrous metal
81042000	resten en afval, van magnesium (m.u.v. assen en residuen die magnesium bevatten; draaisel en korrels, van magnesium, gecalibreerd)	non-ferrous metal
81053000	resten en afval, van kobalt (m.u.v. assen en residuen die kobalt bevatten)	non-ferrous metal
81073000	resten en afval van cadmium (m.u.v. schuim bevattende cadmium)	non-ferrous metal
81083000	resten en afval, van titaan (m.u.v. assen en residuen die titaan bevatten)	non-ferrous metal
81093000	resten en afval van zirkonium, n.e.g.	non-ferrous metal
81102000	resten en afval, van antimoon (m.u.v. assen en residuen die antimoon bevatten)	non-ferrous metal
81110019	resten en afval, van mangaan (m.u.v. assen en residuen die mangaan bevatten)	non-ferrous metal
81122200	resten en afval, van chroom (m.u.v. assen en residuen die chroom bevatten; chroomlegeringen met een nikkelgehalte van > 10 gewichtspercenten)	non-ferrous metal
81125200	resten en afval van thallium (m.u.v. schuim dat thallium bevat)	non-ferrous metal
81130040	resten en afval van cermets (m.u.v. schuim bevattende cermets)	non-ferrous metal
27109100	afvalolie, bevattende polychloorbifenylen "PCB's", polychloorterfenylen "PCT's" of polybroombifenylen "PBB's"	fossil energy carriers
27109900	afvalolie die hoofdzakelijk aardolie en olie uit bitumineuze mineralen bevat (m.u.v. die welke polychloorbifenylen "PCB's", polychloorterfenylen "PCT's" of polybroombifenylen "PBB's" bevatten)	fossil energy carriers
30069200	farmaceutische afvallen	mixed waste
38251000	stedelijk afval	mixed waste
38252000	slib van afvalwater	mixed waste
38253000	klinisch afval	mixed waste
38254100	afvallen van organische oplosmiddelen, gehalogeneerd	mixed waste
38254900	afvallen van organische oplosmiddelen, tenzij gehalogeneerd	mixed waste
38255000	afvallen van beitsvloeimiddelen voor metalen, van hydraulische vloeistoffen, van remvloeistoffen en van antivriesvloeistoffen	mixed waste
38256100	afvallen van de chemische of van aanverwante industrieën, hoofdzakelijk organische oplosmiddelen bevattend (m.u.v. antivriesvloeistoffen)	mixed waste
38256900	afvallen van de chemische of van aanverwante industrieën (m.u.v. afvallen van beitsvloeimiddelen voor metalen, van hydraulische vloeistoffen, van remvloeistoffen en van antivriesvloeistoffen en die welke hoofdzakelijk organische oplosmiddelen bevatten)	mixed waste
85481010	gebruikte elektrische elementen en gebruikte elektrische batterijen	mixed metal waste
85481021	elektrische loodaccumulatoren, gebruikt	mixed metal waste
85481029	elektrische accumulatoren, gebruikt (m.u.v. loodaccumulatoren)	mixed metal waste
85481091	resten en afval, van elektrische elementen, van elektrische batterijen en van elektrische accumulatoren, lood bevattend	mixed metal waste

85481099	resten en afval, van elektrische elementen, van elektrische batterijen en van elektrische accumulatoren (m.u.v. lood bevattende resten en afval)	mixed metal waste

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