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Biomass Flows in the Flemish Economy

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Biomass Flows in the Flemish Economy

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Summary

This short-term assignment attempts to improve our understanding on the data availability of biomass flows within the Flemish economy and develops a methodology to approximate the flow of biomass between different industries. While there are already a myriad of measurements using bottom-up approaches to estimate the flow of biomass in the Flemish economy, said measurements often start from different data, can apply different assumptions and are therefore difficult to reconcile with one another to obtain an aggregate overview of biomass flows within the Flemish economy. The novelty and contribution of this study rests on the application of a top-down approach using existing macro-scale data on biomass flows in the Flemish economy from several official sources. These are combined with data on the 2010 supply and use tables of the Flemish economy that show how each Flemish industry/industrial sector uses and supplies different products, and reports the accompanying monetary flows. Based on these datasets, the biomass flow between industries is estimated from source to final consumption. In a next step, the top-down results of the biomass flows are cross-checked with the results of bottom-up analyses of the wood flows in the paper and pulp industry and an extensive analysis of wood waste flows to assess the validity of the top-down approach.

While the top-down approach is suited as a tool to complement bottom-up analyses with insights into the most important economic downstream users and upstream suppliers, large discrepancies are found between the top-down and the bottom-up analyses. These result from the stringent assumption in the top-down analysis that applies a fixed conversion factor from money to mass for each industry. In the case of biomass, where certain flows can have a large mass but lower monetary value, these conversion factors cause estimation errors that cascade further down the supply chain. For a true overview of the biomass flows in an economy it is still first-best to attempt to reconcile all mass flows with a bottom-up approach. The macro-economic flows reported in the supply and use tables can be used to obtain insights into the relevant goods/services providers to industries in order to obtain an idea of the relevant economic players that need to be considered during the bottom-up approach as potential linkages.

While there is a clear need to understand the biomass flows in the Flemish economy in order to maximize their potential and reduce unnecessary waste flows, our results indicate that combining currently available data sources is ineffective to garner insights into the macro-level biomass flows. The construction of a physical counterpart to the monetary input output tables, while challenging, can possibly offer the necessary reprieve.

Samenvatting

Deze korte termijn opdracht tracht ons begrip omtrent de databeschikbaarheid van biomassa stromen in de Vlaamse economie te verbeteren en ontwikkelt een methodologie die de biomassa stromen tussen de verschillende industrieën schat. Hoewel er reeds verschillende metingen hebben plaatsgevonden door gebruik te maken van bottom-up data, worden er vaak verschillende assumpties en databronnen gebruikt. Dit bemoeilijkt de reconciliatie van de bottom-up studies om zo een geïntegreerd overzicht van de totale biomassa stroom in de Vlaamse economie te bekomen. Deze studie benadert de biomassa stromen van een top-down benadering waarbij reeds een een macro-beeld van de biomassa stromen uit officiële databronnen wordt gebruikt. Deze data wordt gecombineerd met de 2010 Vlaamse aanbods- en gebruikstabellen die tonen hoe elke Vlaamse industrie/industriële sector verschillende producten gebruikt en aanbiedt en de geassocieerde monetaire stromen in kaart brengt. Op basis van deze data wordt de biomassa stroom van ontginning tot finale bestemming getraceerd. In een daaropvolgende stap wordt de correctheid van de geschatte stromen nagegaan door een bottom-up analyse uit te voeren voor de biomassa stromen in de de papier- en pulpindustrie en eveneens door een uitgebreide analyse te maken van de houtafvalstromen in Vlaanderen.

Hoewel de top-down benadering geschikt is om de belangrijkste economische leveranciers en afnemers in kaart te brengen in monetaire termen, toont de analyse aan dat de top-down benadering aanzienlijke verschillen vertoonde ten opzichte van de bottom-up analyse. Dit is het gevolg van de assumptie in de top-down analyse alwaar geldstromen naar biomassa stromen worden geconverteerd volgens factor die per industrie vaststaat. Aangezien bij biomassa stromen een stroom een aanzienlijke massa kan hebben, maar een lage monetaire waarde veroorzaken deze conversiefactoren schattingsfouten die verder propageren in de waardeketen. De beste benadering om tot inzichten te komen omtrent biomassa stromen in een economie betreft nog steeds de reconciliatie van de massastromen via een bottom-up benadering. De macroeconomische stromen van de gebruiks- en aanbodstabellen kan gebruikt worden om een beter inzicht te krijgen in de industrieën die goederen/diensten leveren of afnemen van de industrie om zo een indicatie te bekomen van de relevante economische spelers.

Hoewel er een duidelijke nood is om de biomassastromen in de Vlaamse economie te kennen om zo diens potentieel te maximaliseren en onnodige afvalstromen te verminderen, geven de resultaten van dit onderzoek aan dat de combinatie van huidige databronnen niet succesvol is om inzichten te verwerven in de biomassastromen die op macro-niveau plaats vinden. De ontwikkeling van een fysieke input-output tabel kan mogelijk de nodige inzichten wel verschaffen, maar is tevens een veeleisende oefening.

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Chapter 1: Introduction

This short-term assignment attempts to improve our understanding of data availability on biomass flows within the Flemish economy and develops a methodology to approximate these flows. While there are already a myriad of measurements using bottom-up approaches to estimate the flow of biomass in the Flemish economy, said measurements often start from different data, can apply different assumptions and are therefore difficult to reconcile with one another to obtain an aggregate overview of biomass flows within the Flemish economy.

The novelty and contribution of this study rests in the methodology we apply to tackle the measurement problem. We initially apply a top-down approach using existing macro-scale data on biomass flows in the Flemish economy from several official sources and combine these with data on the 2010 supply and use tables of the Flemish economy. These tables show how each Flemish industry/industrial sector uses and supplies different products, and reports the accompanying monetary flows. The new dataset allows us to quantify the use of the different biomass flows of each industry as well as their origin. Additionally, we then trace the same biomass flows as they move through industries and are eventually consumed, used in investment goods or exported to the Brussels and Walloon regions or exported abroad.

While the explicit advantage of this approach is that it consistently uses the same top-down approach, its caveats are particularly of interest as these make for interesting avenues for future research that can then attempt to merge the top-down and bottom-up approaches. Our approach is thus complementary to most existing studies that exclusively apply bottom-up approaches. In this study we attempt two such reconciliations for the biomass flow of wood where we take a deeper look at the paper and pulp industry and the wood waste industry. The comparison of these bottom-up and top-down approaches conveys several findings. While the top-down approach delivers a clear overview of the important economic players, the use of a money-to-mass conversion factor to the output of each industry adversely affects the representativeness of the obtained flows. As waste biomass flows can be of considerable mass for the concerned sectors, they are generally of limited monetary relevance. Therefore, our top-down approach can only be considered a complementary tool to bottom-up analysis, rather than a method that is able to solve the divergence in bottom-up methods.

Our approach has no intent on being the final word on the exact measurement of biomass flows in the Flemish economy, but rather to merge existing methods and to stimulate better understanding and measurements of the relevant flows. The exploration of new methodologies, such as the one explored here, are thus necessary exercises to improve our knowledge of biomass flows within the economy.

In the next chapter we describe the methodology that we have applied throughout our analysis. In the chapter 3 we present our top-down measurement results. Here, we report wood flows separately from the other raw biomass flows within the Flemish economy. We then present more in-depth analyses on the application of wood in the Flemish wood industry and the paper industry. Finally, we include a small word on the policy implications of our work.

Chapter 2: Methodology

In this chapter we describe the methodology that we have applied to obtain our macro-scale estimates. While we have used the monetary flows of the supply and use tables to construct the intra-economy flows of biomass, several outside sources on biomass production and trade were used to ensure maximum correspondence between the in- and outflows of the Flemish economy and the officially reported biomass flows. Each of these factors is discussed here in turn.

2.1. Flemish Supply and Use tables

We use the most recent 2010 version of the Supply and Use tables which have been regionalized by the Federal Planning Bureau so as to have a specific view of the monetary flows within the Flemish economy. In total the tables are made up of 124 industries and 127 products that encompass the total economic activity of the Flemish economy[1].

For each industry in the Flemish economy, the supply table expresses in monetary terms how much an industry produced of each product. On the basis of the supply table we are thus able to observe the composition of the total monetary output of each industry. As a result of the aggregate definition of the products, most of the monetary output of a specific product can generally be linked to one individual industry. However, there is no 1-to-1 match between product and industry. We are also able to observe the imported monetary amount for each product.
While the supply table offers a view of the origin of the different products within the Flemish economy, the application of said products is reported in the use table. Through the use table we see how much each industry uses of each product as an intermediary input into its production process. Additionally, we also observe how much of the product in monetary terms ends up in consumption, as an investment good or in flows to the other Belgian regions or abroad through exports.

Although all reported data are expressed in monetary terms, the macro-economic nature of the tables makes these an ideal candidate to trace flows within the Flemish economy from a top-down point of view. Before explaining how we have proceeded to estimate all the relevant flows, we first discuss in greater detail the different data sources that we have used to obtain representative physical weight estimates of the production and import of biomass in the Flemish economy. These are necessary as we attempt to estimate mass flows of biomass in the Flemish economy rather than monetary flows.

[1] Although we combine these 2010 tables with more recent 2015 data on biomass flows, implicitly we are assuming that the structure of the Flemish economy has remained unaltered when comparing 2015 to 2010. Realistically this will of course not be the case and especially with regard to some more recent applications of biomass within the Flemish economy, our approach may fall short in properly identifying the flows of biomass that occur towards certain industries. There could thus be value in periodically repeating the exercise performed here whenever new supply and use tables become available.

2.2. Biomass production and trade in the Flemish economy

The supply and use tables report six different products that can be directly linked back to raw biomass[2]:

- Cereals, sugarcane, legumes and high oil-content seeds, fibre plants
- Potatoes, edible carrots and other tubers with high degrees of inulin or starch
- Sugarbeets
- Vegetables, melons, other annuals, plant material, living plants, perennials (fruit and nuts), tubers, mushroom brood.
- Wild game hunting and wild fisheries
- Wood products

We will analyze wood-based products separately from the other five categories.

2.2.1. Wood products

To approximate the wood based production in Flanders we started from the material flow accounts prepared by the Belgian federal planning bureau. These report mass statistics of the amount of harvested wood on a Belgian level and indicate that 2449 ktons of wood biomass was domestically extracted in 2015. While domestic extraction does not exclusively occur on the basis of forestry activities (as Figure 1 below will demonstrate), we nevertheless use statistics on forest coverage to divide total wood biomass between the different Belgian regions. We assume that forests in Flanders are harvested at a similar rate per hectare as those in the other Belgian regions. Since Flemish forests account for about 21 percent of total Belgian forests, we assume that Flemish wood production represents an equal fraction of total Belgian wood production. In the end, the estimate for Flemish wood production that we obtain is situated within the interval of different estimates on Flemish wood production that circulate in the literature.

Aside from the Flemish production, Flanders also imports wood from other Belgian regions and from abroad. Flemish imports of wood from abroad are obtained from the National Bank of

[2] We refer to raw biomass in order to distinguish it from other forms of biomass. This is relevant as certain types of raw biomass are used within the economy to obtain a different form of biomass. By only accounting for raw biomass that has thus far not been transformed in a different type of biomass, we avoid issues of double counting biomass. For instance, wild game that was hunted is considered as biomass, but cows (or products derived thereof) that were obtained through industrial cattle-breeding and for which industrially grown maize fodder was used, are not considered as raw biomass. However, the maize fodder used to feed the cows is considered as raw biomass. Similarly, fish that were obtained from wild fisheries are considered as biomass but farm-raised fish are not as they were fed certain agricultural crops and thus result from the transformation of one type of biomass to another one. When we refer to biomass in this study, we mean raw biomass.

Belgium[3]. When quantity estimates are not immediately reported for a certain flow, we apply a conversion factor that converts the monetary flow into a mass flow. These conversion factors were provided by the National Bank of Belgium. To estimate the Flemish imports from the other Belgian regions the calculation is more demanding. We first subtract the amount of wood approximately harvested in Flanders from the total mass of wood mentioned in the mass energy accounts. Next, we apply the average weight/monetary value conversion factors from the National Bank of Belgium to convert mass into production value. From the supply and use tables we are able to derive the total monetary value that is exported from non-Flemish Belgian regions to Flanders. We use this to calculate the fraction of wood that is exported to Flanders and then apply this to the total amount of wood that was approximately harvested in non-Flemish regions.

2.2.2. Non-wood biomass products

Quantitative data on the biomass production in the Flemish economy are generally available for all the biomass categories pertaining to crop production (first four bullet points reported above) via Eurostat[4]. As the above mentioned products are rather aggregated, Eurostat data on the crop production are generally reported at a more disaggregated level. We thus attempt to reconstruct the aggregate products from the supply and use tables based on the general description of the products in the Eurostat tables. We use 2015 data for the Flemish production of biomass. However, for some products we only observe the total Belgian production of biomass. In this instance, we use one of two methods to distribute the relevant production across regions. Generally we use the regional distribution of production from the nearest other year as a proxy of regional production. However, when this is not available we fall back on the estimated arable surface area that was used in agricultural production in 2016 across the different regions. These data were collected by the Belgian Statistical Office BelStat.

For the data on game hunting and wild fishery biomass we use hunting statistics from the Flemish agency for nature and forest. We also assume that wild fishery is generally limited to the Flemish region as it is the only Belgian region to have access to the sea. We therefore use the aggregate Belgian quantity estimate of the amount of harvested fish.

We reconcile these data with the material flow accounts of the Federal Planning Bureau for the year 2015. Since the supply and use tables and the material flow accounts are both constructed by the same organization, this appears to us to be the best way to ensure maximum correspondence between data sources. However, the material flow accounts are only available at the Federal Belgian level and not at the regional level. We thus use these data to rescale the Eurostat data if total Belgian production in the Eurostat data differs from that reported in the material flow accounts.

As in the case of wood imported from abroad, we again rely on Flemish trade statistics from the National Bank of Belgium. For the non-wood biomass imported from other Belgian regions the

[3] Communication with the Federal Planning Bureau has revealed that their import statistics also contain products made of wood and are therefore much more inflated than our import statistics which only consider raw wood products.

[4] Data on crop production in national humidity by NUTS2 regions: apro_cpnhr

calculation again is more involved. We use the aforementioned sources to determine the production of non-wood biomass in the Walloon and Brussels region in 2010. Based on the Flemish production data, we are also able to determine conversion factors that convert the non-wood biomass production in the other Belgian regions to 2010 monetary values. From the supply and use tables we are able to derive to export flow in 2010 to Flanders from the other Belgian regions and we are thus able to estimate the fraction of total non-Flemish production that is exported to Flanders. We apply this fraction to the total produced weight of biomass in the Walloon and Brussels region to obtain the estimate of the weight exported to Flanders.

2.3. Calculating the biomass flows in the Flemish economy

Having collected all the data, we now combine our mass statistics with the flows represented in the supply and use tables. To do so requires one main assumption which is important to state overtly to understand the benefits and the caveats of our current approach. Specifically, we assume that the monetary flows in the supply and use tables are each associated with the same intensity of associated biomass. This assumption is critical in understanding how we are able to obtain an overview of the mass flows between industries as well as highlighting a clear caveat of this top-down approach.
To understand it more clearly, we present the following example. Suppose that 1 ton of wood enters the wood industry. From the supply and use tables we can then subsequently obtain an idea of how the output of the wood industry is used by different other industries as intermediary inputs or how it ends up in final demand (consumption, investment, or exports). In the end, the entire one tonne of input material is subsequently assigned to all the output flows from the wood industry. However, the information on the size of the different output flows is only available in monetary terms and we have no idea how the value of one ton of output from the wood industry to the furniture industry differs from one ton of output from the wood industry to the paper or the construction industries. Our assumption essentially imposes that all these flows originating from a single industry have the same mass per euro of flow so that the mass flows are divided in accordance to the relative size of the monetary flows. If the biomass intensity, i.e. the weight of biomass per euro of monetary flow, of a certain monetary flow diverges strongly depending on the industry to which the material flows, a bias thus occurs in the estimations.

The strength of this assumption is clear. It allows us to tie together all the biomass data that we collected and link them with the monetary flows of the supply and use tables. First, the supply tables allow us to retrace the likely origins of the different biomass sources and are thus initially of interest. Flemish wood does not only originate from forestry but also from other activities. The Supply table allows us to retrace these origins.

Next, the Flemish supply and use tables show how domestically extracted biomass, imported biomass from the other Belgian regions and imported biomass from abroad is used by the different industries. Since qualitative differences between the domestically extracted biomass and the imported biomass are more than likely, the composition of the initial use of these raw

biomass sources differs depending on the origin. There are three different use tables available that allow the researcher to correctly identify where which type of biomass source will be initially used.

To determine the subsequent flows in the Flemish economy, we make one additional assumption from this point onwards. We assume that a given industry produces only one given product. While this is generally not the case, we observe for the manufacturing industries in the supply tables that most products are almost uniquely produced by one specific industry so that this assumption has no substantial consequences for our calculations. Through this assumption it is possible to tie the input of wood that flows to one industry to the use of the output of that same industry by other industries. For instance, if wood flows to the wood industry, this assumption allows us to then trace how the output of the wood industry is subsequently used by other industries such as the paper industry, construction, etc.

Of course, the economy consists of a multitude of intersectoral links. Part of the output of one industry can flow back to that very same industry and be used as an intermediary input. Additionally, the wood industry might use some of the output of the paper industry as an intermediate input. It is important to recompute each time how the intermediate inputs of one step are re-used in the next step. Eventually, all input flows will end up at one of the final demand flows to ensure that the system is balanced and the mass inputs are equal to the mass outputs that are embodied in the final demand[5].

2.4. Bottom-up approach

The applications of each type of biomass are many and the heterogenous end products that are obtained through the processing of biomass require different types and qualities of biomass materials. There is thus a possibility that applying a top-down approach which effectively imposes the same monetary value to each quantity of biomass circulating in the economy only offers a blurred picture of the true biomass flows. One of the main objectives of this analysis is to uncover to what extent the top-down analysis is helpful in gaining a bird's-eye view of the biomass flow in the economy. Therefore, we take a detailed look at specific industries) in order to understand better what the complementary value is of the top-down approach and whether the assumptions used in our top-down approach are too troublesome.

In this regard we analyze the total (bio)mass flows passing through the Flemish paper and waste wood industry. For the paper industry, we gather this information through a bottom-up approach where we make extensive use of data provided by the Belgian paper federation (COBELPA), available information from Flemish paper producers (Sappi, VPK, Sofidel, St-Leonard and Stora Enso), Flemish trade data on pulp and paper collected from the National Bank of Belgium and data on paper waste collection from OVAM. While these varied sources offer some pieces of the puzzle, substantial uncertainty remains. Therefore we applied two methods to attempt to reconcile the mass flows in the paper industry:

[5] In reality we end up with slight imbalances between input and output. These result from rounding errors and from the fact that insufficient iterations of the calculations were carried out to obtain total mass balance. However, as these differences do not exceed 0.5% of the total input flows, the imbalance is minimal.

1. We employed a completely bottom-up approach and tried to retrace the amounts of wood and pulp that are necessary to produce the total amount of Flemish paper. To do so, we looked at the Best Available Techniques references documents (BREF)[6] of the paper industry to obtain the amount of pulp required per kg of paper produced and from COBELPA we obtained numbers on the conversion of wood into pulp. We then complemented this data with data already available on Flemish wood flowing to the paper industry and the recycling of wood fibres in old paper;
2. We applied a hybrid method, where the gaps in the paper industry were filled in through the use of the Flemish Supply- and Use tables.

Additionally, we also have a picture of the paper industry from our top-down approach. We are thus able to compare the results from the different reconciliations and observe to what extent these estimates diverge.

By examing the paper industry it immediately becomes apparent that the heterogeneity in the types of paper and cardboard applications greatly inhibits the ability to apply a common money-to-mass conversion factor and obtain realistic results. This makes the paper industry an ideal industry to analyze whether the use of a common conversion factor to convert money to biomass is too far-fetched. Additionally, it has not been possible to trace a woodflow entirely through the production chain of the paper industry. Rather, we have chosen to represent the mass flows of the wood-containing product (hence Flemish and imported wood as an input alongside old paper; pulp as an intermediate product; and paper as the final product) in the Sankey diagrams.

With regard to the waste wood industry in Flanders, we collect data mainly from the industry declarations and OVAM inventory. For the information on the supply of waste wood, we obtained data from two main industries: the wood processing industry (sawmill, furniture industry etc.) and the waste management companies (Suex, Renewi etc.). The data on pre-consumer waste, that is the waste generated in manufacturing processes, is obtained from the wood processing companies; whereas the data on post-consumer waste is obtained from waste management companies. The data from the wood waste of the households comes from the annual OVAM inventory of household waste. With respect to the use of waste wood, we use the data from the two industries that are the main consumers of waste wood: energy (A&S energie, E&ON & Stora Enso) and wood-panel production (Unilin). The data on trade of waste wood is collected from the National Bank of Belgium.

The material flow analysis for waste wood was developed for the year 2014. In order to validate the representativeness of these values, they were compared to the data from preceding and following years. The comparison showed that the values differed considerably in different years. One reason for this discrepancy is the continuous improvement in the methodology for developing the inventory. But the more prominent reason is the sensitive nature of the waste-wood market in Flanders. The waste-wood supply and demand in Flanders are rapidly affected by the economic/financial situation of the market, policy changes and international trade. Changes in neighbouring countries – policy changes and development or discontinuation of

[6] Suhr, M., Klein, G., Kourti, I., Rodrigo Gonzalo, M., Giner Santonja, G., Roudier, S. and Delgado Sancho, L. (2015) Best Available Techniques (BAT) reference document for the production of pulp, paper and board.

operations – affect the price and supply of waste wood. Hence developing a waste wood analysis for a year that is most representative is a challenge.

An additional challenge in developing waste wood flow analysis is the heterogeneous nature of the wood waste stream and lack of clear characterisation of waste-wood stream. Every data source assumes a different definition while deriving numbers. Hence, aggregating data received from different sources is subject to these limitations which impede the analysis.

Chapter 3: Top-down measurement of biomass flows in the Flemish economy

In this chapter we present the results of our top-down analysis. First we delve into the flow of wood biomass in the Flemish economy before addressing the other biomass flows.
3.1. Wood flowsFigure 1 presents the total flow of wood biomass in the Flemish economy. We simultaneously present the Flemish wood biomass (green lines), the imported wood biomass from Wallonia and Brussels (red lines) and, finally, the wood biomass imported from abroad (blue lines).

Flemish wood biomass mostly originates from forestry. However, it is also generated as a side product in several other industries. This immediately reveals a difficulty in our methodology where we are unable to clearly distinguish the primary from the secondary flow given the apparent relevance of wood side flows that originate from some industries. For now it is necessary to impose the assumption that these are nevertheless virgin wood flows in some way. As can be seen on the flow diagram, the materials recovery industry contributes around 11 percent of the total biomass of Flemish wood products. This industry contains dismantling activities and the recovery of sorted materials and thus recovers wood from older applications. However, despite the size of the wood biomass coming from Flanders itself, most of the raw wood biomass that circulates within the Flemish economy originates from outside its own territory. In total, our estimations indicate that around 2,251kt entered the Flemish economy in 2015. The openness of the Flemish economy means that a considerable fraction of this wood is immediately exported to other countries or to other Belgian regions. These exports make up around 679 kt or 30 percent of the total wood biomass that entered the Flemish economy.

Aside from Flanders' role as a trade hub for wood, there are other clear conclusions that can be drawn from Figure 1. First and foremost, the wood industry plays a crucial role in understanding how wood is processed in the Flemish economy. Regrettably, the supply and use tables do not permit us to have a closer look at the exact activities that occur within the supply and use tables. However, to get a better understanding of what flows enter and leave the Flemish wood industry, Figure 2 presents a detailed overview of all the wood biomass flows that we estimate by using the supply and use tables. While the quantity of wood that flows from the wood industry to exports (where it might still be used as an intermediary input in foreign industrial operations) is large (374 kt to foreign countries and 125 kt to the other Belgians regions), only a small fracton ends up in domestic final expenditures such as Flemish consumption and Flemish investment. The wood from the raw wood biomass that is either imported or domestically extracted only ends up with domestic agents after having undergone additional

transformations in other industries. In this regard the construction industry stands out as a large user of wood processed by the Flemish wood industry[7].

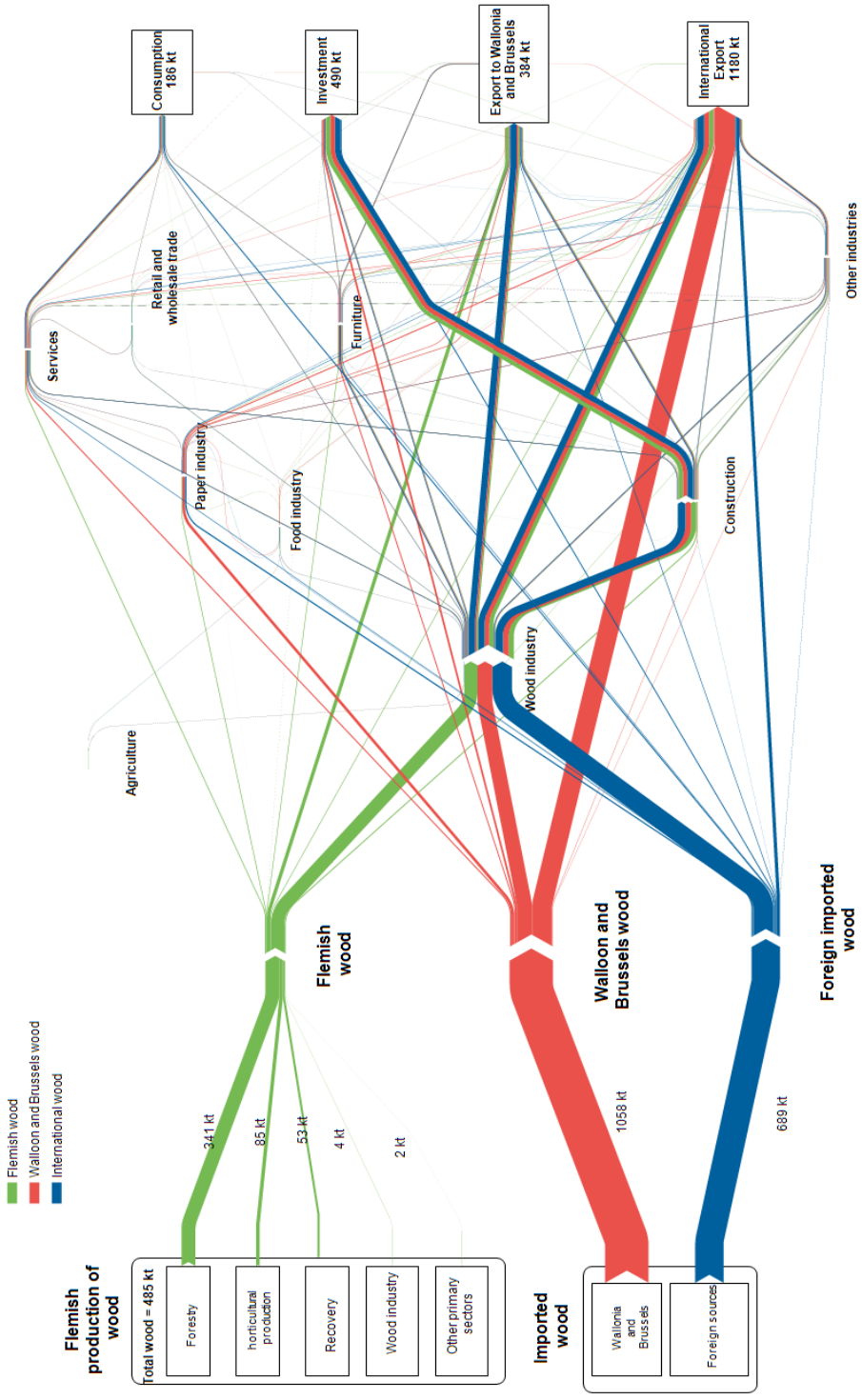

Figure 1: Aggregate overview of top-down estimates of wood biomass flows in the Flemish economy in 2015

[7] While it may counterintuitive that wood is also flowing to the less material intensive services sector, it is necessary to note that the service industry here encompasses an amalgam of different industries, both public and private, and is therefore in terms of pure economic activity a significant player in the Flemish economy. The limited wood flows to this industry are thus not an aberration.

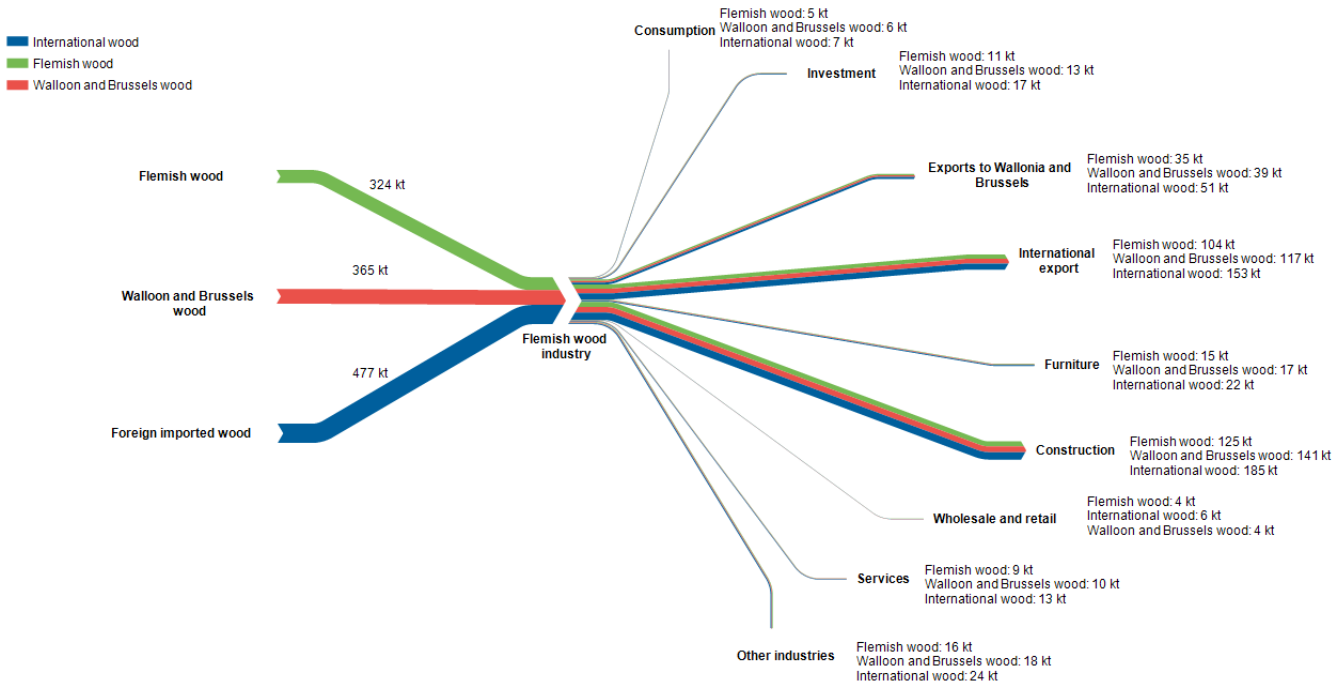

Figure 2: Top-down estimates of the in- and outflows of wood in the Flemish wood industry in 2015

In Figure 4 we take a closer look at this construction industry as the previous figure revealed that it received a large fraction of its wood-based intermediary inputs from the wood industry. It is clear from our estimations that a large fraction of the output of the construction industry eventually ends up in investment goods. This implies that a large fraction of the wood that was processed by the Flemish wood industry has a long-term application in an investment good and that the associated carbon that is stored in the wood is only slowly released back to the environment.

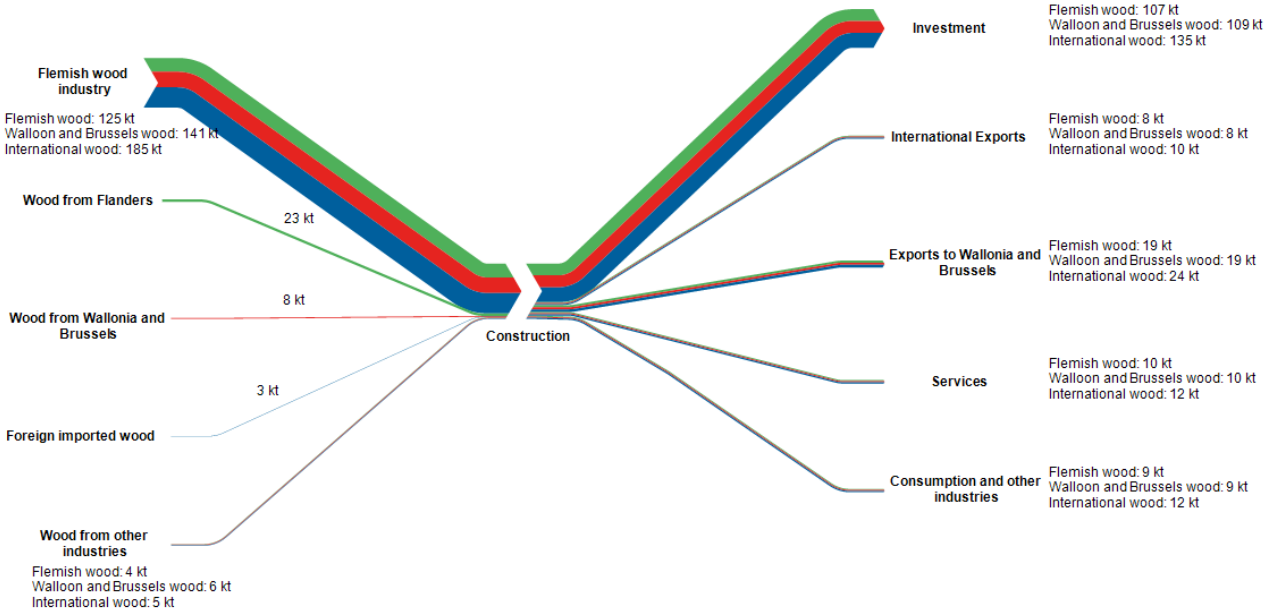

Figure 3: Top-down estimates of the in- and outflows of wood in the Flemish construction industry in 2015

While less significant than the construction and the wood industry, our analysis shows that the paper industry (Figure 4) also plays a significant role as a prime wood processing industry. In total, our estimations show that 117kt of wood is used in the paper industry. The food industry is the largest single industry user of the output of the paper industry. Most of the output, however, is exported abroad and to the other Belgian regions. There is thus a general recurring picture that wood that enters the Flemish economy is mostly exported abroad, either directly or processed in some way. If one truly wishes to understand the final applications of the different products that use wood as an intermediary input, it is thus necessary to look at the exported products.

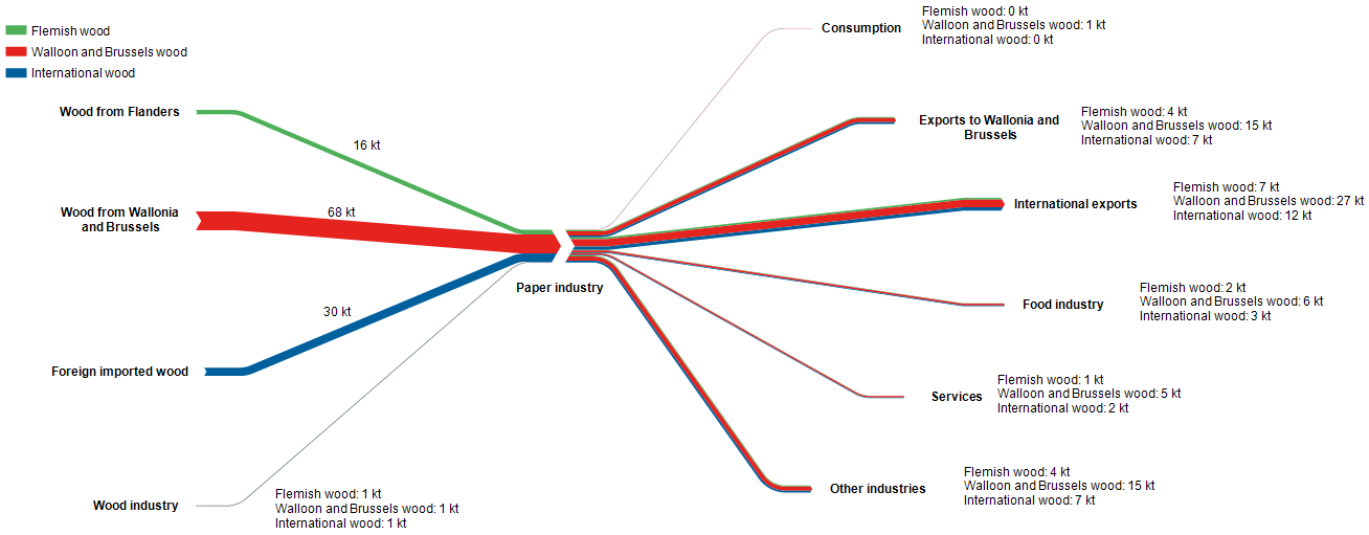

Figure 4: Top-down estimates of the in- and outflows of wood in the Flemish paper industry in 2015

We look at these export flows in Figure 5 and Figure 6. Aside from the industries that we already discussed, the furniture industry also stands out as an important processor of wood biomass. However, in the export markets the flows of wood biomass coming from the furniture industry and subsequently exported are dwarfed by the flows of raw wood that are immediately exported without further processing as well as the wood flowing out of the wood industry. With an estimated total outflow of wood of 1564kt, our analysis suggests that around 69 percent of the total inflow of wood into the Flemish economy leaves it through the exports.

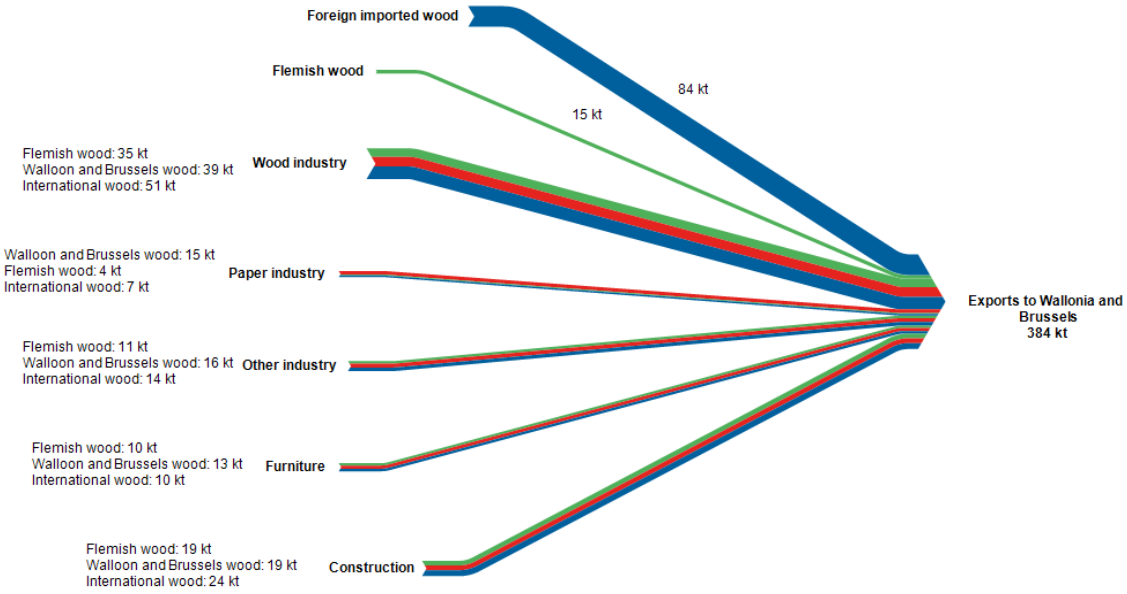

Figure 5: Top-down estimates of wood biomass in export flows from Flanders to Brussels and Wallonia in 2015

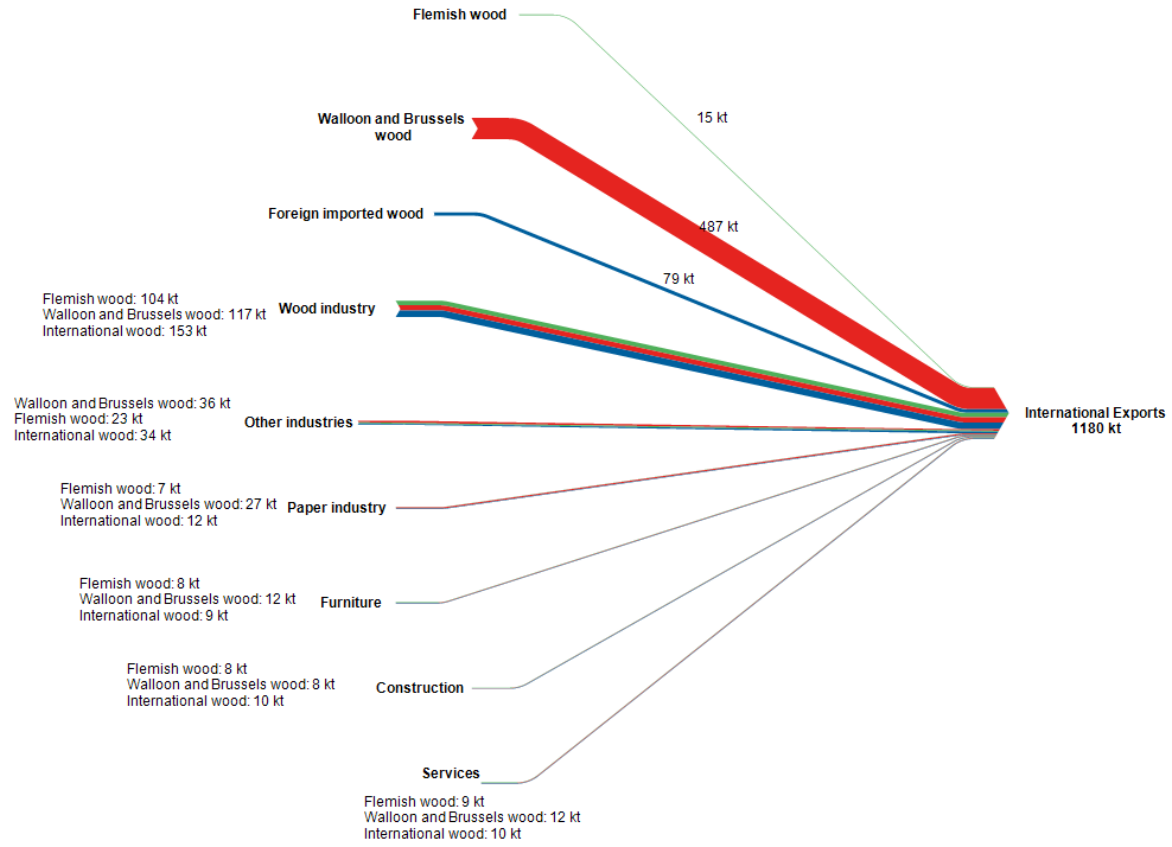

Figure 6: Top-down estimates of wood biomass in export flows from Flanders to foreign countries in 2015

The remaining 31 percent are flows to domestic final demand categories such as investment (Figure 7) and private consumption (Figure 8). While the wood flows to investment in Flanders are dominated by the construction industry, wood biomass that is flowing to the consumption industry is earmarked by a more diverse range of supplying industries and raw wood flows. However, wood flows to consumption are generally a rather small fraction of overall wood flows to final demand, making up according to our analysis only 186 kt of a total flow of 2240 kt.

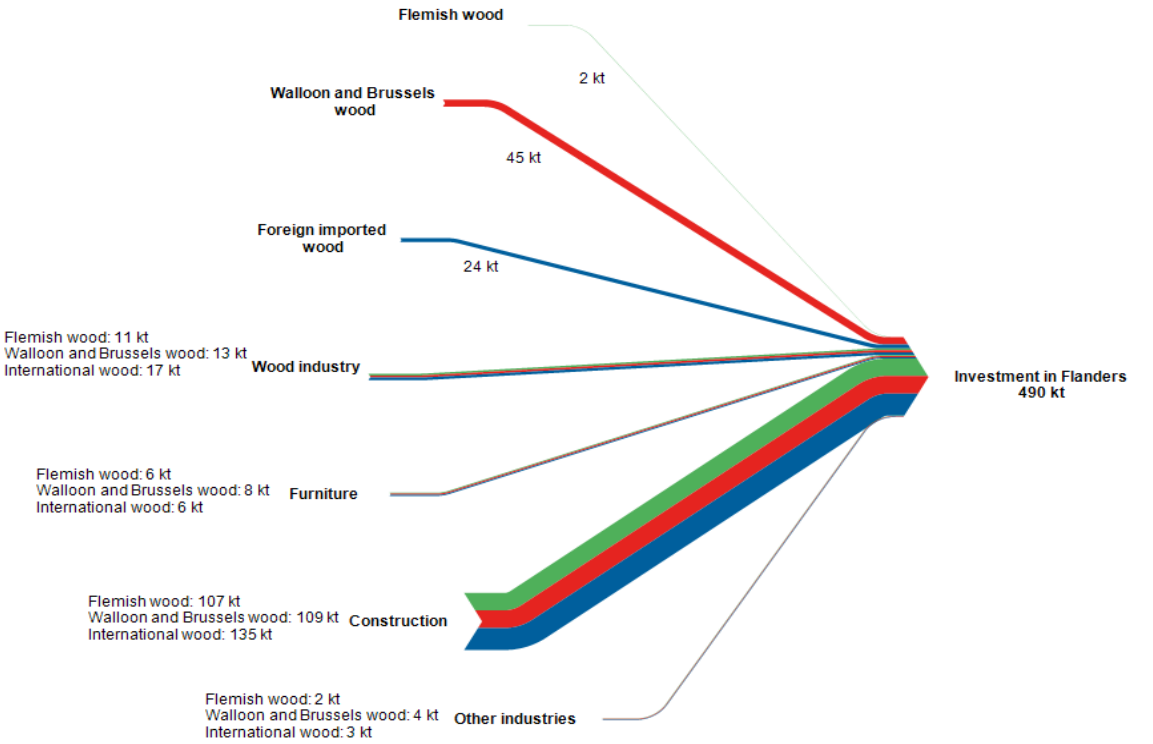

Figure 7: Top-down estimates of wood biomass flows to Investment in Flanders in 2015

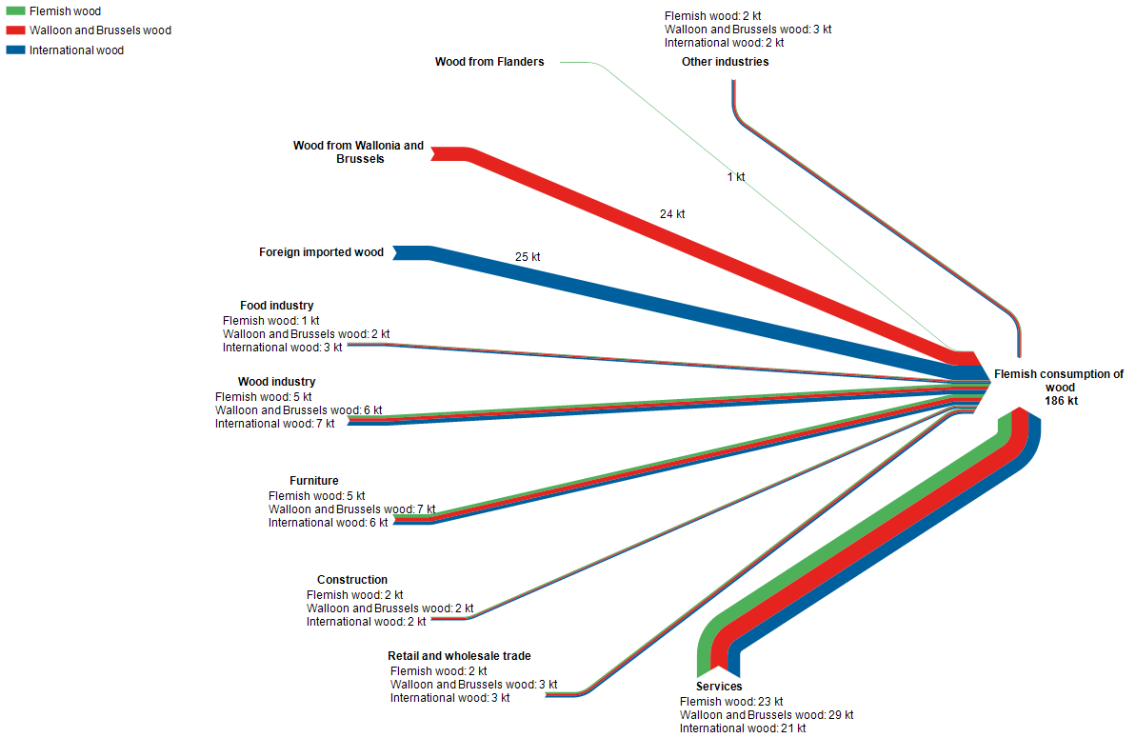

Figure 8: Top-down estimates of wood biomass flows to private consumption in Flanders in 2015

3.2. Other non-wood biomass flows

In total we identified six different aggregate categories of raw biomass flows that circulate in the Flemish economy. While we have addressed wood separately, we will now deal with the remaining five biomass categories. Though possible, the separate analyses of each of these biomass flows would overburden this study with figures and numbers. Therefore we have opted to aggregate the different biomass flows into one general non-wood biomass flow in Figure 9. When we refer to biomass flows in this section, we distinctly mean non-wood biomass flows unless specified otherwise. Again, biomass flows that were domestically extracted (green arrows) and biomass flows that were imported from the other Belgian regions (red arrows) and from abroad (blue arrows) are taken into account. Based on the trade statistics and on the material flow accounts constructed by the Federal Planning Bureau we estimate that just under 36 million tons of biomass enter the Flemish economy. In contrast to the wood flows where we showed that Flanders extracted only a fraction of the overall wood that entered the Flemish economy, a substantial fraction of the other biomass flows are obtained from Flanders itself: 46 percent of the biomass that circulates in the Flemish economy originates from its own territory.

In Figure 10, Figure 11 and Figure 12 we give a detailed overview of the destination of the biomass flows that enter the Flemish economy. It is clear from these figures that biomass is mostly destined for the Flemish food or agriculture industry as well as for export.

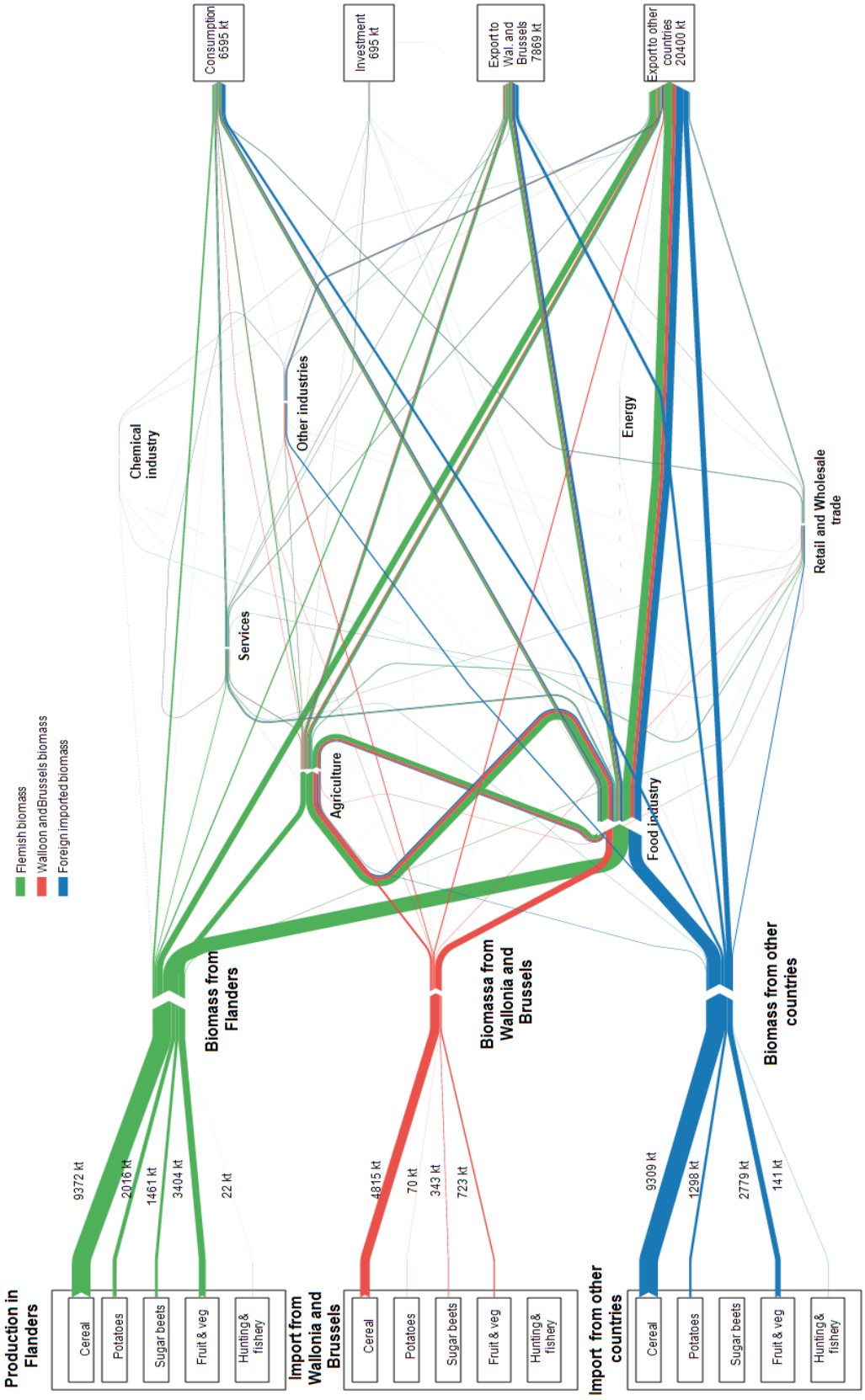

Figure 9: Aggregate overview of top-down estimates of wood biomass flows in the Flemish economy in 2015

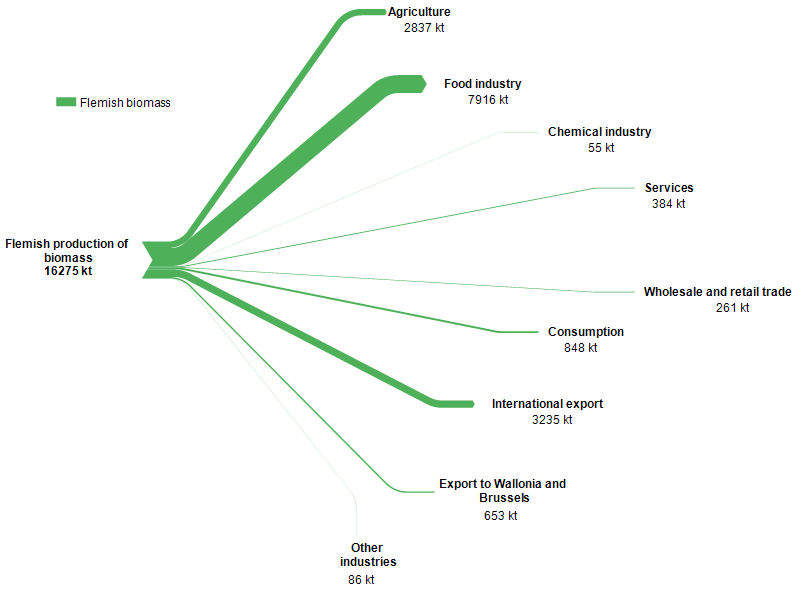

Figure 10: Top-down estimates of the use of Flemish biomass in 2015

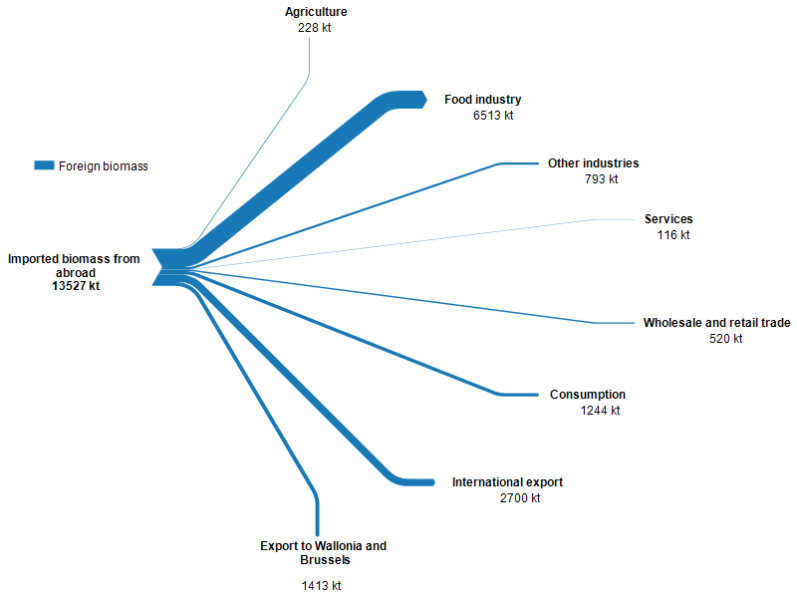

Figure 11: Top-down estimates of the use of biomass that was imported from abroad in 2015

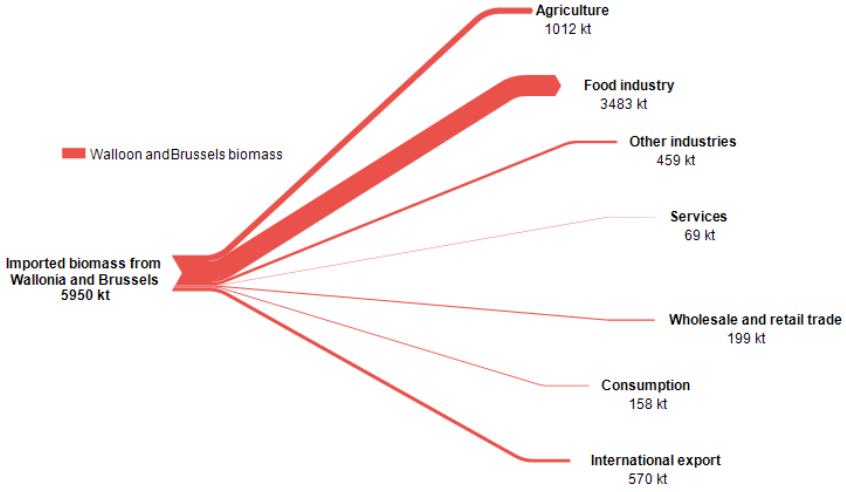

Figure 12: Top-down estimates of the use of imported biomass from other Belgian regions in 2015

It has thusfar become evident that the agricultural and the food industry stand out as central nodes within the biomass network. Not only do they use a substantial amount of raw biomass, they are also intricately interlinked and account for most of the processing of biomass that occurs within the Flemish economy. For instance, agriculture provides 4192kt of biomass to the food industry and the reverse flow from the food industry to the agriculture industry shows that the food industry is of major importance as a biomass provider to the agriculture industry. To shed more light on this link we exploit the full power of the use table. While we include only one general food industry in our figures, the use tables consist of a total of eight different sub-industries in the food industry which permit us to obtain a larger degree of clarity with respect to which type of food is flowing to the agriculture industry. We observe that 8,153kt of the cereal entering the Flemish economy either as a result of production on its own territory or because it is imported, flows to the food industry that produces livestock feed. Around 6 million tons of this cereal is subsequently supplied to agriculture. Hence, the biomass flowing from the food industry to the agricultural industry is entirely driven by the provision of feed for livestock.

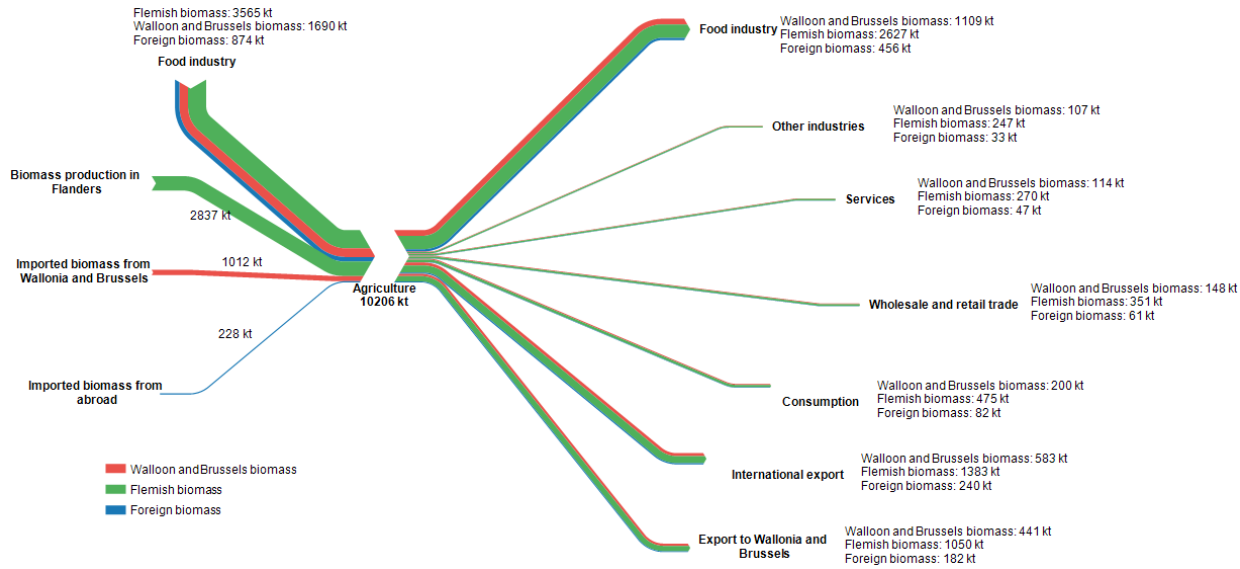

Figure 13: Top-down estimates of the in- and outflows of biomass in Flemish agriculture in 2015

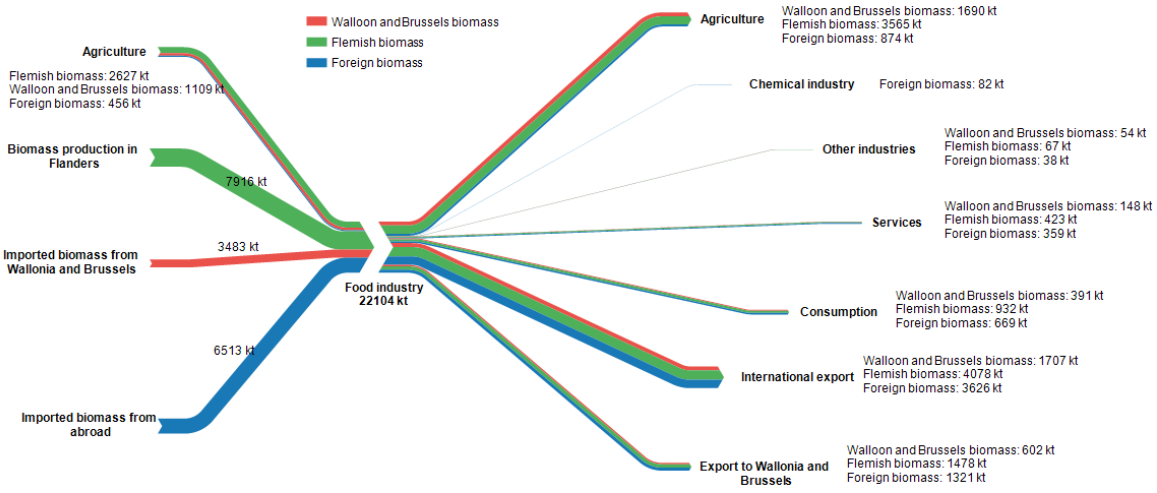

Figure 14: Top-down estimates of the in- and outflows of biomass in Flemish food industry in 2015

Aside from being suppliers to one another, the output of the agricultural and food industries mostly flows to different final demand categories. Figure 13 and Figure 14 show that while most of the output is exported abroad, a considerable fraction is also consumed domestically.

In contrast to the wood biomass flows, only a limited fraction of the total non-wood biomass eventually ends up in investment. Figure 15, Figure 16 and Figure 17 again highlight the central role of the food and agricultural industries.

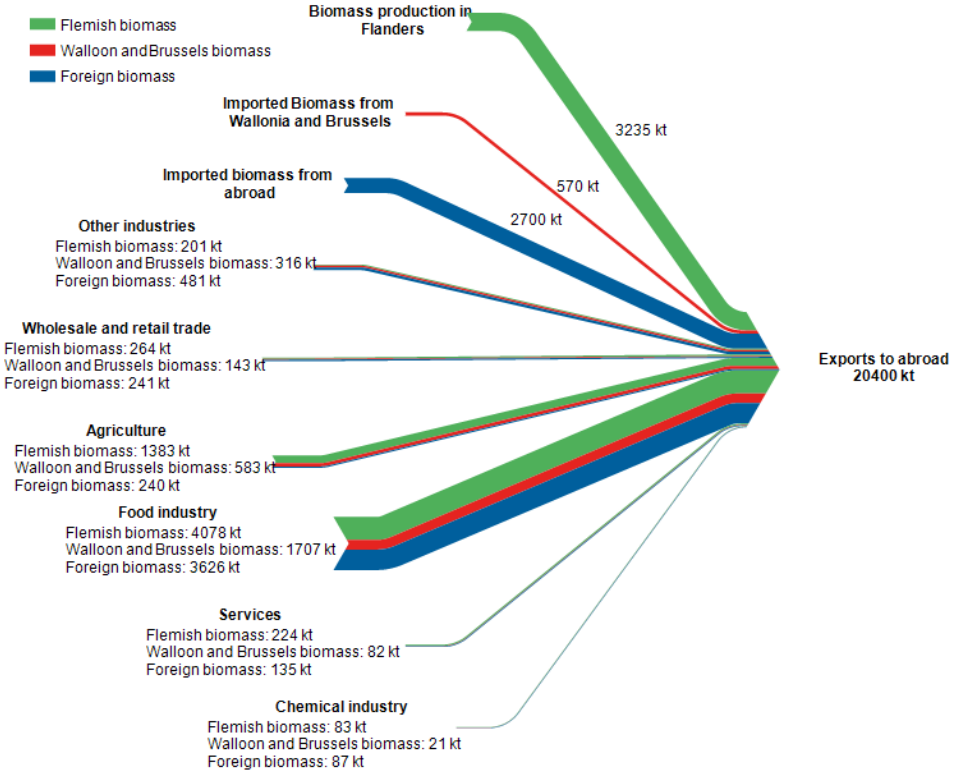

Figure 15: Top-down estimates of biomass flows internationally exported from Flanders in 2015

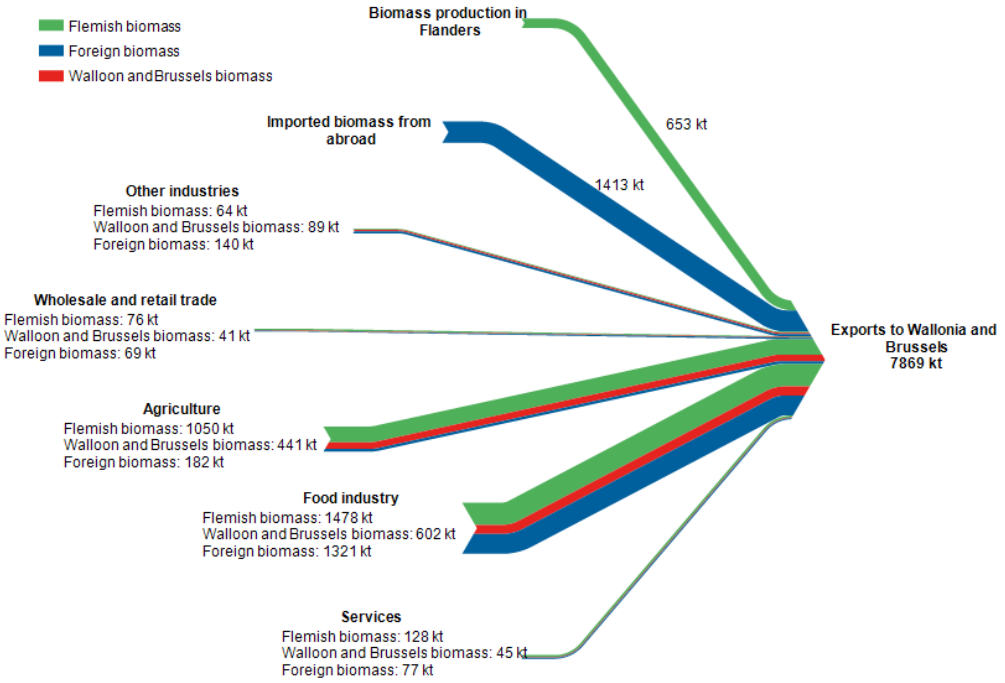

Figure 16: Top-down estimates of biomass flows exported to the other Belgian regions from Flanders in 2015

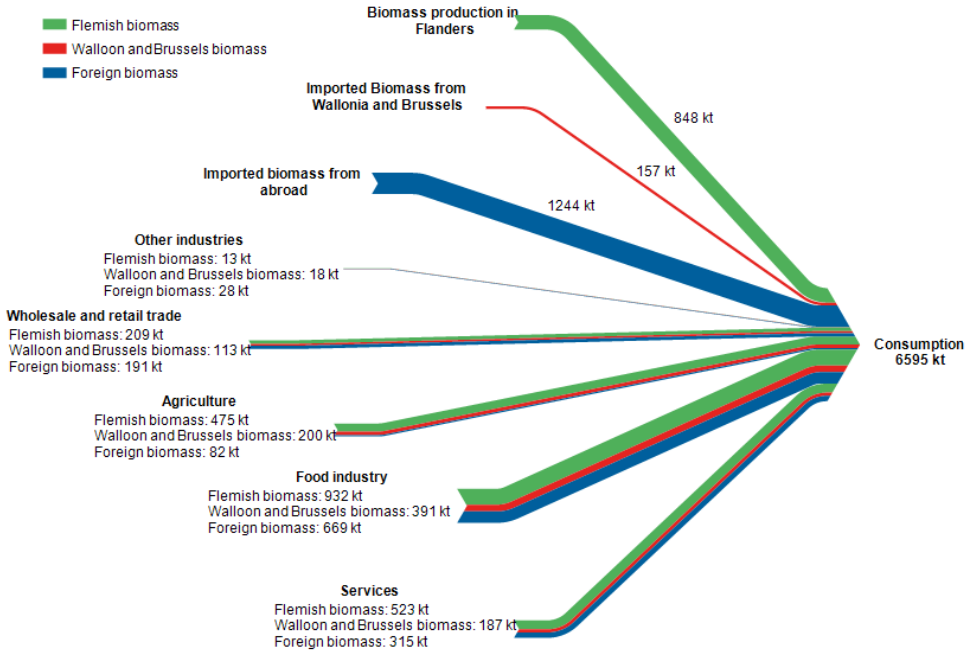

Figure 17: Top-down estimates of biomass flows to private consumption in Flanders in 2015

3.3. Preliminary conclusions

The application of our method provides a general measurement of the flows of biomass within the Flemish economy. In both the case of the wood biomass and the non-wood biomass flows the methodology allowed us to clearly identify the major players within the Flemish economy. As we have argued, the implementation of our current methodology requires some stringent

assumptions which realistically imply that the further along the supply chain we go, the greater the uncertainty of our estimates. Nevertheless, bottom-up analyses that aim to map the biomass flows in an economy will mostly focus on the industries that directly use the biomass sources rather than the entire supply chain that subsequently follows. Therefore, our top-down approach also has a clear strength as it serves as a tool to complement bottom-up analyses with the knowledge of downstream users and upstream suppliers. We were able to uncover a deeply entangled relationship between the food and agricultural industry and to observe where the biomass eventually ended up. Additionally, we observed that the construction industry serves as a large user of processed wood from the Flemish wood industry.

In the next chapter we will test the validity of our results obtained thusfar on the basis of a bottom-up case study of the paper and pulp industry. This comparison can reveal to what extent the assumptions in our top-down approach render the outcomes of the approach representative of the true situation.

Chapter 4: In-depth analysis of the paper and waste wood industry

In this chapter we look at the results of our bottom-up approach to estimate the (bio)mass flows in two specific industriesand test the validity of our results in the top-down approach. First, the results for the paper and pulp industry will be presented. Then, we will show the flows in the waste wood industry.

4.1. Paper and pulp industry

The bottom-up analysis for the paper and pulp industry was performed based on numbers for the year 2016. The results are shown in Figure 18. In order to obtain better mass estimates, we separated the paper and pulp industry, which were aggregated in the top-down approach. In this way, it is possible to account for the conversion of mass that occurs in the pulp industry. This industry uses both old wood fibers through the recycling of paper, as well as new wood fibers. The conversion of the new wood fibers into pulp depends on the type of pulping technique. For instance, Sappi applies an energy-intensive mechanical CTMP pulping process which is highly efficient in converting wood fibre into pulp (95 percent). VPK and St-Leonard recycle old paper to obtain paper pulp. Waste from the pulp industry was calculated by comparing the total amount of paper pulp that is required based on the production of paper and the effective amount of pulp that is obtained from paper recycling and from producing pulp from virgin wood sources.

The heterogeneity of the different paper products that are produced[8] imply that different pulp input quantities are necessary for the production of the different products. Additionally, other input requirements aside from pulp also diverge depending on the type of the end product. This results in an imbalance in the paper industry where 1554 kt of paper products were produced in Flanders and 1218 kt of pulp enters the industry. By adding further knowledge on the exact production processes the mass flows may become balanced, yet this information is currently not at our disposal.

While little is known about the exact types of wood that are used to produce pulp, it is clear that even within the paper industry, the combination of producing different types of paper products and the different input requirement needs imply that a top-down approach that assumes the same monetary-to-mass conversion rate is likely to oversimplify the computations leading to unrealistic estimates. This becomes more apparent upon comparing Figure 18 with Figure 4, where we obtained estimates for the Flemish paper industry through the use of Supply

[8] graphic paper by Stora Enso and Sappi, hygienic paper by Sofidel and packaging and carboard by VPK and St-Leonard.

and Use Tables. First, the figure shows that the amount of virgin wood used in the paper industry is underestimated. However, as it was impossible to account for old wood fibres encompassed in recycled paper products, the top-down approach does not reveal the total amount of wood fibres that are used in the end products of the paper and pulp industry. These two shortcomings of the top-down approach eventually lead to a gross underestimation of the amount of wood fibre that flows out of the paper industry. Additionally, the top-down approach was not able to account for waste biomass flows, which are nevertheless of great relevance in for instance the paper industry. This is a consequence of the fact that using money flows as a starting point for waste flows is problematic as the latter flows can have small monetary value but can represent large quantities.

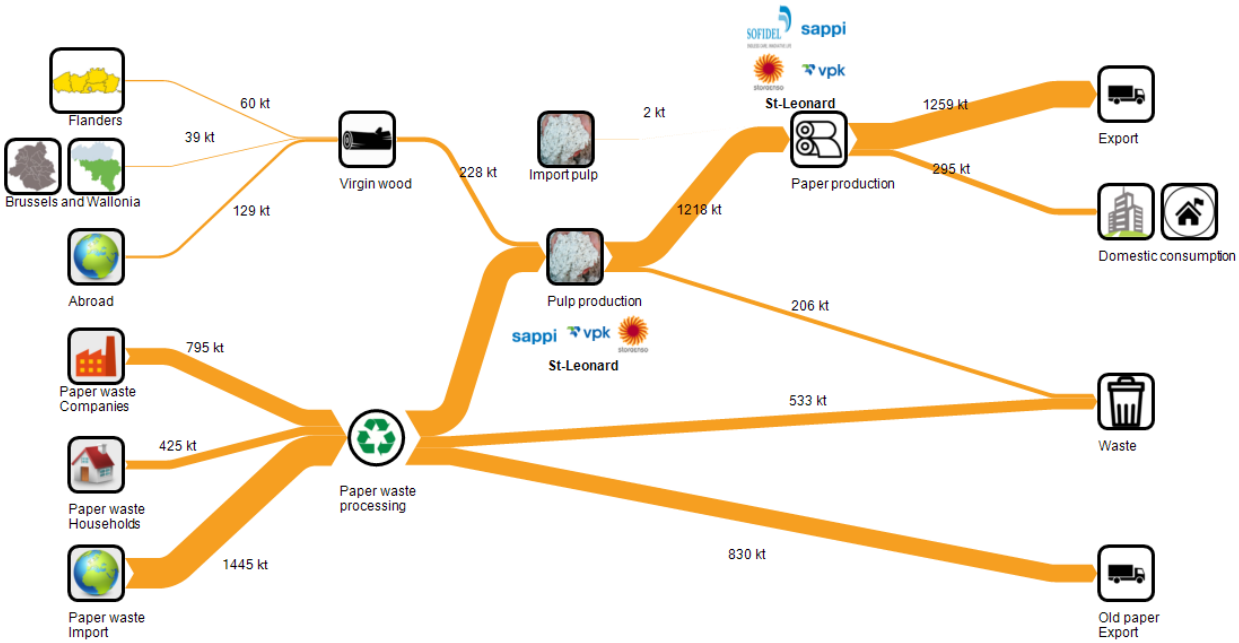

Figure 18: Overview of mass flows in paper and pulp industry

While the waste flows leaving the paper waste processing step are quite large, these are based on the COBELPA's estimate that around one fifth of all old paper cannot be recycled and thus ends up as waste.

We currently take the bottom-up approach as our best estimate of the true situation in the paper industry. However, one other possibility is to use the supply-and-use tables to complete the remaining data gaps. This hybrid method thus combines the bottom-up approach with a softer top-down approach. Ideally, the mass flows obtained from a bottom-up and a hybrid approach should not be too far apart and thus provide a confidence interval for the mass flow numbers. In Figure 19 we show our results using the bottom-up approach and the hybrid approach. The bottom-up approach derived the virgin wood requirements of the paper and pulp industry by looking at the wood requirements of companies that produce paper without recycling old paper. For this, we used the total amount of paper and pulp produced according to our bottom-up estimates. We then used process efficiences from the Best Available Techniques reports to compute the wood inputs that would be necessary to produce the reported quantity of paper and pulp.

The top-down SUT approach applied the virgin wood use numbers from the Belgian paper federation COBELPA. Based on the Belgian and the Flemish SUT, a money-to-mass conversion

factor was computed and the monetary flows in the Flemish SUT could then be converted to mass flows.

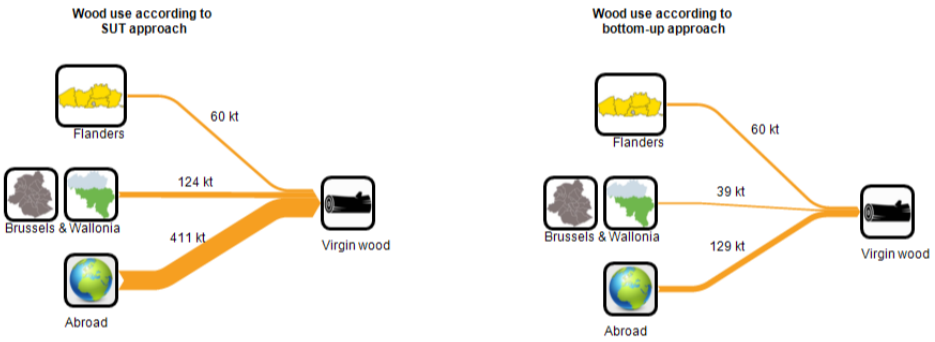

Figure 19: Comparison of results of hybrid SUT method and bottom-up method to estimate amount of wood used in the paper industry

The results show that the hybrid approach delivers results that diverge strongly from those of the first-best bottom-up approach. We especially observe that the estimated quantities of wood are considerably higher when looking at the imports from abroad. One can only hypothesize as to the exact reason for this outcome. One possibility is that there is some difference in terms of the unit value (the monetary value per unit of wood imported) between the wood imports in Flanders and the imports in the rest of Belgium, thereby biasing our estimates.

An additional problem that one encounters in the bottom-up approach is that the (intermediary and final) use of the product is not always clearly identifiable. The bottom-up approach used data on the quantity (mass) of paper exported by the Flemish paper industry relative to the total Belgian exports of paper mass to translate the export numbers from COBELPA to mass exports of paper for Flanders. By subtracting these exports from the total quantity of paper produced, we obtain an estimate from the domestic consumption of Flemish produced paper. For the hybrid method that uses SUT data we again use the total quantity of paper produced in Flanders, but now assign it to export or domestic consumption according to the monetary flows in the SUT. Again, there is a substantial difference between the two estimation techniques. This is likely the result of differences in terms of the money-to-mass conversion factor (potentially as a result of quality differences) between the types of paper or cardboard used domestically and those exported abroad. This can be interpreted quite broadly, it could even indicate that very different types of paper products (with substantially different values) are used domestically and also exported abroad. As we lack information on the types of products used domestically, it is nevertheless impossible to analyze this hypothesis.

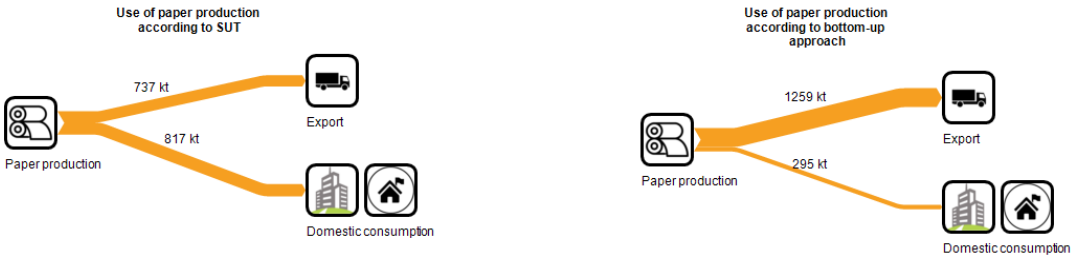

Figure 20: Comparison of results of hybrid SUT method and bottom-up method to estimate final destiny of paper use

The bottom-up analysis that we carried out thus reveals that even within a single industry, the heterogeneity of products that are used and produced make monetary flows an inadequate proxy for mass flows. The numerous applications of biomass and the diverging quality of biomass as input or as output (e.g. waste stream) imply that any analysis based solely on monetary flows will not deliver a sufficiently representative overview. The top-down method can identify industries that are the most relevant economic players in the use of different (virgin) biomass. In said way, it offers a starting point from whence to further analyze industries. However, money-to-mass conversion factors are unuseful as low-valued waste flows are completely lacking in the top-down approach.

4.2. Waste wood flow

Figure 21 presents the total flow of waste wood in the Flemish economy in the year 2014. The waste wood import, from neighbouring countries (blue lines) and from Wallonia and Brussels (red lines), and export to neighbouring countries (blue line) is also accounted for in order to get a complete picture of waste wood utilisation in Flanders.
The waste wood in Flanders originates in industries and households. The industrial wood waste is characterised as pre-consumer waste (also known as primary waste) and post-consumer waste (also known as secondary waste). The sources of pre-consumer waste, the waste generated during manufacturing, are the sawmill, furniture and wood products manufacturing companies. This constitutes mainly wood chips, shaving and sawdust. The post-consumer industrial waste, on the other hand, is the waste generated by the end consumer of material and is generated by a vast range of industries. The post-consumer industrial waste and household waste are very heterogeneous streams and are thus managed by the waste processing companies, who collect, sort and pre-process the waste before redirecting it to the downstream industries consuming the waste wood. As can be seen in the flow diagram (Figure 21), Flanders annually produces around 1 million tons of wood waste, out of which 820 kton is industrial waste (430 kton is pre-consumer wood waste and 390 kton is post-consumer wood waste) and 160 kton is household waste.

The two main industrial consumers of waste wood in Flanders are green-energy and wood-panel (mainly particleboard) producers. The other industries that consume waste wood in Flanders are paper and pulp industry, wood pallet and wood pellet production. However, the amount consumed by these industries is marginal in comparison to the amount consumed by the energy and wood panel industries. We can see in the flow diagram (Figure 21) that around 300 kton waste wood collected by waste processing companies is directed towards the production of green energy/electricity every year. An additional, 130 kton is imported for this purpose. However, the information through the bottom-up approach, wherein we make use of data provided by the energy providers (A&S Energie, E&ON Generation & Stora Enso), reveals that about 510 kton of waste wood (mainly post-consumer non-recyclable waste) is used by the companies to generate electricity annually. This immediately exhibits the discrepancy in the data, for which there are a multitude of reasons. It could be the result of underlying assumptions or due to the unreliability of the data on the waste wood being redirected to the wood panel industry. The wood panel industry in Flanders has seen massive fluctuations in their operations in the last decade. It has been severly affected by the economic situation of the

market, technical challenges, and fluctuations in the supply of waste wood in the international market. In some cases the fluctuations are tackled by increasing operations, whereas in other case waste wood is stored in container parks or at production sites. Stocking waste wood is often done when the company faces technical challenges in the production line or when the supply of waste wood exceeds the demand. Hence, using the top-down approach, which is using the monetary-to-mass conversion rate to estimate amount of wood panels produced by the company using the company revenues, does not give an accurate idea of the amount of waste wood being supplied to the company. This could be one of the reasons for the discrepancy in the data seen in this wood flow diagram.

Similarly, one can observe a gap in the amount of waste wood arriving at the waste processing companies and the amount of waste wood directed to the industries further along the supply chain. One possible explaination for that too could be the dynamic nature of the amount of waste wood stored in the container parks.

The waste wood diagram (Figure 21) gives the best estimates based on the available data. Additionally, it highlights the data gaps and also the industries that play a central role in supply and consumption of waste wood supply. It offers a starting point from which all industries involved can be further analyzed in order to improve the flow diagram.

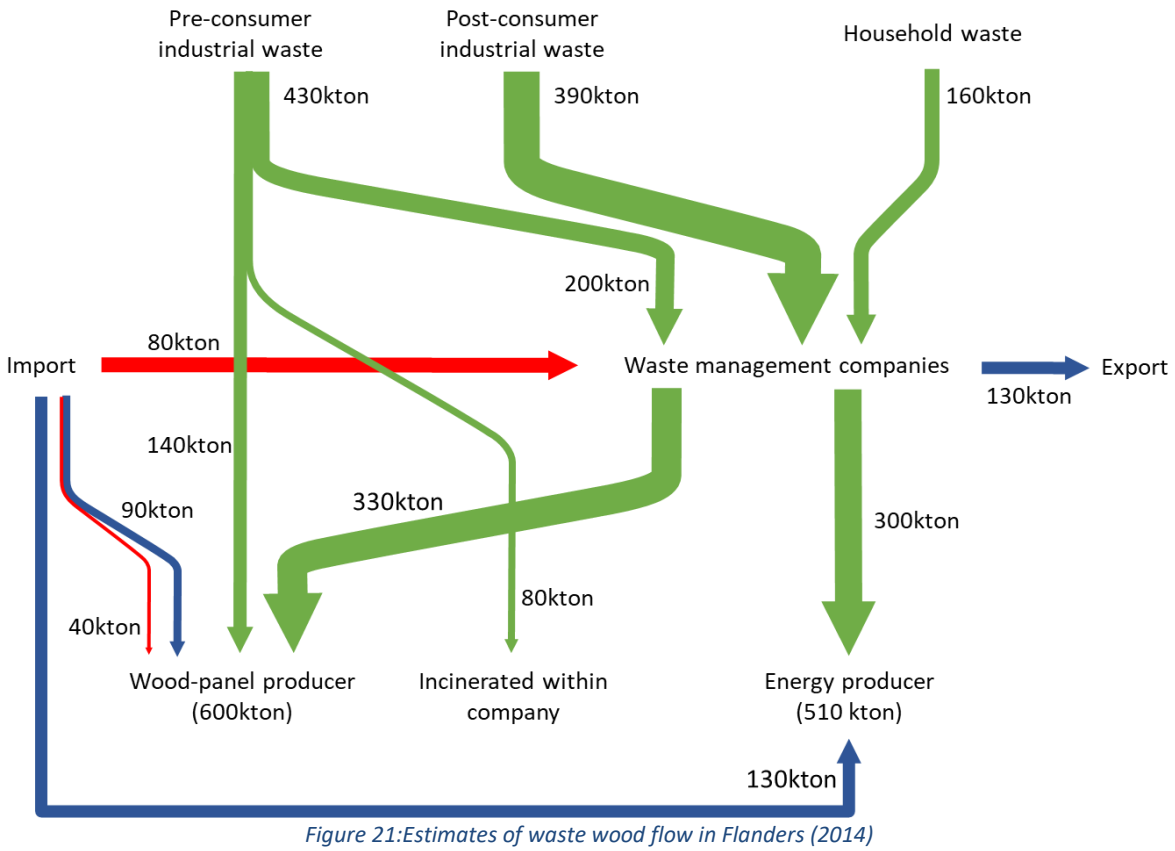

Figure 21:Estimates of waste wood flow in Flanders (2014)

Chapter 5: Policy implications

The analysis in this report reveals that we still lack a clear oversight of how biomass flows within the Flemish economy and a straightforward methodology to make such an unambiguous overview. The methodology set forth here was adequate to obtain insights in the economic interlinkage that currently exists between industries, but it was ineffective in obtaining a representative overview of the biomass flows. The assumptions that were necessary were too stringent and estimation errors cascaded further through the production chain and raised doubt on the usefulness of the obtained aggregate numbers. While the report focused on biomass in particular, the challenges that emerged here are likely to persist independent of the type of material (e.g. metals) that is analyzed, especially if a secondary waste stream with qualitative differences to the virgin material stream exists. Moreover, our bottom-up case study of the paper industry revealed that one needs to account for the multitude of products, all with different material compositions, that are likely to be produced by industries. In this respect, bottom-up studies offer more accurate views of individual industries. Yet, they are a time-consuming exercise that is still sensitive to some of the researcher's assumptions.

Meanwhile, the need to understand biomass flows remains of great relevance for policy makers. From a circular economic perspective, knowing how efficiently materials such as biomass are applied in the economy, requires good measurement of the inherent biomass flows. Knowing how biomass flows within the economy is therefore relevant to be able to assess and set-up policy measures and interventions to promote efficient and effective use of biomass. Additionally, it is also relevant to allow the identification of the highest value addingapplication of the specific material. When possible novel applications emerge for biomass sources, having insights into how the biomass flow is currently applied within the economy is a relevant step to be able to quantify the potential of the specific application. The case of waste wood flows has illustrated that developing clearly defined specifications for waste wood, albeit difficult, is necessary to be able to reconcile data obtained from different sources. This information will also be insightful to allocate the waste wood to the highest value product downstream along the supply chain.

Any approach to obtain a macro-economic oversight will thus have to be sufficiently top-down in order to maintain the general oversight of biomass flows in the Flemish economy while avoiding assumptions that hinder the accuracy of the approach. Since this will apply to different materials and aggregation error is quickly to occur, some necessary trade-offs between accuracy and feasibility of the work are necessary. The approach will thus require a well coordinated effort to construct a physical counterpart to the monetary input output tables as our analysis has shown that the latter can not be applied as a reference point. While the initial effort to construct such physical tables is likely to be considerable, after the first development of the tables one will have the necessary knowledge to improve future data collection and make the process more efficient. The treasure trove of information that such tables would hold can be a good starting point for bottom-up analysis to obtain really detailed insights into some industries in case this is necessary for policy questions relating to specific industries and for policy makers to trace the potential of some flows.

Chapter 6: Conclusions

In our analysis we have attempted to map biomass flows in the Flemish economy through the use of supply and use tables. We separated the wood flows from the other biomass flows as different industries were of key importance in the supply chain of both sets of biomass. The exercise revealed that the supply and use tables can be flexibily applied in order to obtain insights on the economic importance of different industries in the supply chain of a certain biomass. However, several quite stringent assumptions need to be imposed in order to succesfully carry out the exercise.

Given that even within the different categories of biomass there is still large variation in terms of the quality of the type of biomass, a check was done as to the extent to which the top-down estimate of (bio)mass flows corresponds to a bottom-up approach where one single industry is the focal point. We chose the paper and pulp industry for this analysis. This industry uses several types of inputs (e.g. both different types of wood as well as old wood-fibers recycled from paper) and produces heterogeneous end products ranging from paper and carboard boxes to tissues. This heterogeneity is generally lost in supply and use tables that apply more aggregated definitions of an industry. Therefore, the paper industry is a suitable industry to test the representativeness of the estimates obtained through the more aggregated top-down approach. It is found that there were considerable differences between the mass flow estimates obtained through the bottom-up and the top-down approach. This raises questions on the general assumption that a fixed conversion of a monetary unit to a biomass equivalent can be applied for each industry. For instance, waste flows of biomass are generally of low monetary value but can be substantial in terms of their mass.

We conclude that the top-down approach can be mostly applied to obtain a first overview of the economic relevance of the different players in the supply chain of a certain biomass. However, for a true overview of the biomass flows in an economy it is still first-best to attempt to reconcile all mass flows with a bottom-up approach. To ensure that future bottom-up analyses can be easily retraced, compared and improved, the impetus of the research thus needs to lie on the clarity of reporting on the use of data sources and the reconciliation of different bottom-up approaches.

Appendix A: Conversion factors

Money-to-mass conversion factors were applied during our analysis. These conversion factors were not used from external sources but were determined endogenously based on the SUT model. Specifically, we were able to use the SUT to know how much wood or other biomass sources were generated (supplied) in monetary terms. We combined this with the estimated quantitative biomass flow and obtained the money-to-mass conversion factors for the supplied quantity. These conversion factors are reported in Table 1.

As a result of the first step it was possible to compute how much virgin biomass was used by each industry. Hence, as we knew how much money an industry spent on a specific product, and we knew how much in terms of quantity flowed to that industry, we were subsequently able to determine how much of a certain biomass flow was contained in each euro of output of the industry. Hence, we obtained new conversion factors but this time for the use of the biomass in the Flemish economy. Since the Flemish domestic flows, the flows from the rest of Belgium to Flanders and the flows from international sources to Flanders were reported in separate use tables in the SUT and different amounts of the supplied biomass were computed for each of the wood flows from different origins, different conversion factors were obtained for biomass flows coming from these three different sources. These conversion factors are reported in
Table 2 and Table 3.

	Other biomass flows from Flanders	Other biomass flows from the rest of Belgium	Other biomass flows from international sources
Agriculture	0,982204	1,364132	0,047203
Food industry	0,503263	1,567082	0,801177
Energy	0,003425	0,003395	0,006456
Chemical industry	0,003871	0,008774	0,005412
Pharmaceutical industry	0,003309	0,001938	0,002539
Waste collection	0,001537	0,005018	0,000983
Other industry	0,004081	0,032755	0,010217
Trade	0,012621	0,866701	0,327751
Services	0,004737	0,012208	0,021825

Cereal	25,91
Potatoes	6,53
Sugar beets	9,85
Fruit & vegetables	1,78
Wild game and fishery	0,07
Wood	5,50

Table 1: Derived conversion factors of all Flemish virgin biomass supply flows considered in this study. Conversion factors are expressed in kt/Million euro.

	Wood from Flanders	Wood from Belgium	Wood from international sources
Agriculture	0,000475	0,002137	0,000197
Forestry	0,000124	9,84E-05	0,000134
Food industry	0,000289	0,003346	0,001381
Wood industry	0,169547	1,002739	0,391901
Paper	0,006622	0,084205	0,013474
Furniture	0,017584	0,369967	0,026116
Other industry	0,000271	0,001645	0,000392
Construction	0,005424	0,124072	0,223761
Trade	0,000151	0,024625	0,005837
Services	0,000255	0,002191	0,001863

Table 2: Implicit money-to-mass conversion factors (expressed in kg/euro) of wood for each industry product considered in the analysis

	Other biomass flows from Flanders	Other biomass flows from the rest of Belgium	Other biomass flows from international sources
Agriculture	0,982204	1,364132	0,047203
Food industry	0,503263	1,567082	0,801177
Energy	0,003425	0,003395	0,006456
Chemical industry	0,003871	0,008774	0,005412
Pharmaceutical industry	0,003309	0,001938	0,002539
Waste collection	0,001537	0,005018	0,000983
Other industry	0,004081	0,032755	0,010217
Trade	0,012621	0,866701	0,327751
Services	0,004737	0,012208	0,021825

Table 3: Implicit money-to-mass conversion factors (expressed in kg/euro) of other biomass flows for each industry product considered in the analysis

Appendix B: Sources used in the analysis

Description Source	Source name	Source reference
2010 Flemish Supply-Use tables	Federal planning bureau	Not publically available at level of detail used in this analysis
Belgian Economy wide Material Flow accounts	Federal planning bureau	https://www.plan.be/databases/data-44-en-economy+wide+material+flow+accounts+2008+2016+
Crop production in national humidity by NUTS2 region	Eurostat	https://ec.europa.eu/eurostat/data/database (table apro_cpnhr)
External trade statistics NBB.stat	National Bank of Belgium	http://stat.nbb.be/?lang=nl
Estimate forested area	Royal Society of Belgian forestry	http://www.srfb.be/nl/de_belgische_bossen
Annual Accounts paper and pulp industry COBELPA	COBELPA	http://www.cobelpa.be/nl/brochures.html
Information on paper producing procedure	COBELPA	http://www.cobelpa.be/nl/brochures.html
Annual accounts of Paper and pulp producing firms	BELFIRST	Private access
Statistics on company waste generation in Flanders	Public waste agency of Flanders (OVAM)	https://www.ovam.be/bedrijfsafvalstoffen

Statistics on household waste generation	Public waste agency of Flanders (OVAM)	https://www.ovam.be/afval-materialen/huishoudelijk-afval-en-lokale-besturen/inventarisatie-huishoudelijke-afvalstoffen
Information on operations Sappi	Sappi	https://www.sappi.com/lanaken-mill
Information on operations VPK packaging	VPK packaging	https://www.vpkgroup.com/en
Information on operations Stora Enso	Stora Enso	https://www.storaenso.com/en
BREF paper and pulp industry	Joint Research Center (European Commission)	http://eippcb.jrc.ec.europa.eu/reference/pp.html
Capacity information used to divide Belgian information from Cobelpa into Flanders and rest of Belgium	Burgo Ardennes	https://www.burgo.com/en/group/paper-mills/burgo-ardennes
Information on the amount of wood waste burned for (green-) electricity	A&S Energie	http://www.a-s-energie.be/watdoenwe.html
Supply and destination for biomass (residual) flows for the circular economy in Flanders	OVAM	https://www.ovam.be/afval-materialen/specifieke-afvalstromen-materiaalkringlopen/biomassa/verwerking-reststromen-biomassa
Information on the amount landfilled and incinerated	OVAM	https://ovam.be/tarieven-en-capaciteiten-voor-storten-en-verbranden

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