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# Socio-economic effects of the circular economy

Modelling the recycling and waste  
sectors using CGE

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## Socio-economic effects for the circular economy

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# Summary

**An available macro-economic model for Belgium has been finetuned towards its use for assisting policy making dedicated to the circular economy. This possible use has been illustrated with three cases, suggesting that i) a mandatory increase in the share of waste and recycled materials as inputs may reduce manufacturing output, ii) facilitating high-quality recycling may increase economic activity, and iii) restricting waste exports may have a rather limited macro-economic effect.**

Upon transitioning to a circular economy, assessing economic effects is important as an input to develop policy measures that can adequately facilitate the transition. Using Computational General Equilibrium (CGE) modelling, this research has evaluated the directions of macro-economic changes on the Belgian economy upon introducing policies oriented on circular economy. CGE models take into account the interdependencies between different sectors, agents and markets in the economy and therefore they shed light on the wider economic impact of policies often revealing indirect and sometimes even unintended effects. The value of CGE modelling lies in assisting the policy making process rather than predicting or simulating effects.

A methodological approach for isolating the waste and recycling sector in the Belgian general equilibrium model has been developed and applied. Three validations have been carried out with respect to the companies covered within the waste and recycling sector statistics. Next, the macroeconomic effects of three policy measures derived from the Circular Economy Action Plan of the European Commission have been analysed thoroughly:

1. The model outcome shows that increasing the minimum share of waste and recycled input materials may reduce the output of the manufacturing industry, negatively impacting household utility, GDP and job creation. Additional measures for mitigating negative effects on e.g. manufacturing could be appropriate/recommended.
2. Facilitating high quality recycling is expected to increase economic activity, household consumption and GDP, though a rebound in increased production needs to be considered – absolute consumption of secondary materials is up but the share of secondary against primary input materials won't be affected too much. The costs of development to make this happen need to be further studied, e.g. the introduction of digital product passports.
3. Restricting export of waste to non-EU countries seems to have a rather limited macro-economic effect. The model suggests an increased domestic demand, and the remaining waste production will be incinerated.

These results hold even with increased energy prices. When recycled and conventional inputs are better substitutes, the intended policy effects are more pronounced.



# Samenvatting

Voor deze studie werd een bestaand macro-economisch model voor België verfijnd met het oog op het gebruik ervan ter ondersteuning van de beleidsvorming inzake de circulaire economie. De inzichten die het model biedt werden geïllustreerd door de doorrekening van drie maatregelen. Samengevat stellen we dat: i) een verplichte verhoging van het aandeel van secundaire materialen als inputmateriaal kan een vermindering van de productie van de maakindustrie tot gevolg hebben, ii) het faciliteren van hoogwaardige recyclage kan de economische activiteit doen toenemen, en iii) het begrenzen van de uitvoer van afval naar niet-EU landen zou een eerder beperkt macro-economisch effect hebben.

Bij de overgang naar een circulaire economie is de beoordeling van de economische effecten belangrijk als input voor de ontwikkeling van beleidsmaatregelen die de overgang adequaat kunnen vergemakkelijken. Met behulp van Computational General Equilibrium (CGE) modellering heeft dit onderzoek de richtingen van macro-economische veranderingen op de Belgische economie bij de invoering van beleid gericht op circulaire economie geëvalueerd. CGE-modellen houden rekening met de onderlinge afhankelijkheid tussen verschillende sectoren, agenten en markten in de economie en werpen daarom licht op de bredere economische impact van beleidsmaatregelen, waarbij vaak indirecte en soms zelfs onbedoelde effecten aan het licht komen. De waarde van CGE-modellering ligt eerder in het ondersteunen van het beleidsvormingsproces dan in het voorspellen of simuleren van effecten.

In deze studie werd vooreerst een methodologische aanpak ontwikkeld en toegepast om de afval- en recyclingsector in het Belgische algemene evenwichtsmodel af te zonderen. Om meer grip te krijgen op welke bedrijven precies onderdeel uitmaken van de sector, werden er drie validaties uitgevoerd. Vervolgens zijn de macro-economische effecten van drie beleidsmaatregelen uit het Actieplan Circulaire Economie van de Europese Commissie grondig geanalyseerd:

1. Uit het modelresultaat blijkt dat een verhoging van het minimumaandeel van afval en gerecycleerde materialen als input, de output van de maakindustrie kan verminderen, met negatieve gevolgen voor de welvaart van huishoudens, het BBP en de werkgelegenheid. Aanvullende maatregelen om de negatieve effecten op bijvoorbeeld de maakindustrie te verzachten kunnen overwogen worden.
2. Het faciliteren van hoogwaardige recyclage zal naar verwachting de economische activiteit, het huishoudelijk verbruik en het BBP doen toenemen. Het absolute verbruik van secundaire materialen neemt weliswaar toe als gevolg van de toegenomen productie. Maar het aandeel van secundaire ten opzichte van primaire inputmaterialen zal niet al te zeer worden beïnvloed. Daarnaast moeten de ontwikkelingskosten om dit mogelijk te maken bv. de invoering van digitale productpaspoorten verder worden bestudeerd want nu komt deze verandering in voege zonder dat er een kost of investering nodig was.
3. Het begrenzen van de uitvoer van afval naar niet-EU-landen lijkt een vrij beperkt macro-economisch effect te hebben. Het model suggereert een grotere binnenlandse vraag, en de resterende afvalproductie zal worden verbrand.

Met een sensitiviteitsanalyse werd de robuustheid van de resultaten getest. Daaruit bleek dat de resultaten ook opgaan bij hogere energieprijzen. Wanneer gerecycleerde en conventionele inputs beter substitueerbaar zouden zijn, worden de beoogde beleidseffecten meer uitgesproken.



# Afkortingen

CE	Circular Economy
CEAP	Circular Economy Action Plan
CET	Constant Elasticity of Transformation
CGE	Computable General Equilibrium Model
CPA	Categorisation of the Products by Activity
GDP	Gross Domestic Product
GTAP	Global Trade Analysis Project
KBO	KruispuntBank van Ondernemingen
NACE	Nomenclature statistique des Activités économiques dans la Communauté Européenne
RoW	Rest of the World
SAM	Social Accounting Matrix
SUT	Supply and Use Tables
W&R	Waste and Recycling

# 1 Introduction

The last decennia, management of waste and secondary materials has created economic value and jobs in Flanders. Furthermore, it is one of the building blocks of the circular economy (CE). In Flanders, 68% of primary industrial waste and secondary raw materials get a second life<sup>1</sup>, in 2018 (CE Center, 2023c). For household waste, 64%<sup>1</sup> of the materials is recuperated by recycling or composting in 2019 (CE Center, 2023d). The figure below shows the evolution of the production of primary industrial waste in Flanders. The years after the economic crisis (in 2008) show a decrease in total production, however, in recent years the production shows a slight increase again (CE Center, 2023b).

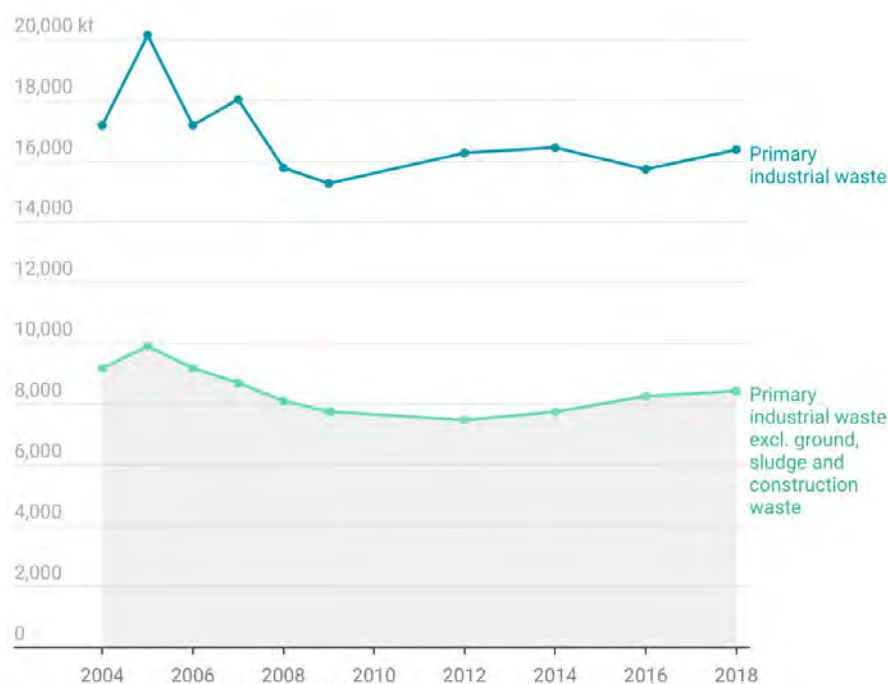


Figure 1: Production of primary industrial waste in Flanders (2004 – 2018). Source: CE Center (2023b)

In this study, we aim to quantify the macroeconomic effects of an increased uptake of the CE by modelling policy measures for the waste and recycling (W&R) sector in a Computable General Equilibrium model (CGE model). We formulate the research question as “Which macroeconomic effects will the adoption of policy measures targeted at the waste and recycling sector entail in order to facilitate a circular economy?”

CGE models optimize the behaviour of the economic agents present in the model (Lahcen et al., 2020). Important agents in the proposed model are producers (classified per sector), households, international trading partners, and the government. These agents make different decisions to optimize their own utility (e.g. how to produce, what to consume, in what to invest, which policy measure to implement...). The presence of the government as an agent in the model is essential, as this allows for the analysis and comparison of the impact of different

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<sup>1</sup> excl. the selectively collected construction and demolition waste

policies. The different policy measures can demonstrate different impacts on the transition to a CE, and how undesirable impacts on the labour market are provoked or can be avoided. A CGE model is the only type of model that can account for economic flows throughout the entire territorial economy in equilibrium with international export and import flows. As such, it can identify the interactions and spill-overs of a policy on sectors and agents other than the ones targeted by the policy. CGE models are appropriate to monitor macroeconomic parameters such as GDP, trade, price levels, employment, supply and demand, government revenue and spending, etc. Moreover, CGE models can define each of these parameters at sectoral level.

In the current literature, some authors have tried to capture waste management and material recovery activities in quantitative models such as McCarthy et al. (2018). However, these activities are still poorly represented, e.g. in several models waste related activities are included within aggregated service sectors which capture everything from insurance, health, education, and financial services (e.g. ICES and MEMO II models: Bosello et al. (2016)). This poor representation has hindered the modelling of a number of relevant enabling policies, including landfill taxes, disposal bans, and recycling quotas. Cambridge Econometrics (2018) modelled an econometric model, where they treat the waste collection and treatment sector as NACE 38-39.

When we look at CGE models only, the well-known model GEM-E3 does not identify a W&R sector (Capros et al., 2013). Other CGE models do introduce a specific waste management sector into the model, such as the Exiomod model and the ENGAGE model where the sectors are based on the Exiobase database<sup>2</sup>. They use the sector with the NACE Rev 1.1 code 37<sup>3</sup> as W&R sector (Bulavskaya et al., 2016; Winning et al., 2017). Furthermore, the GTAP model from Aguiar et al. (2019) is based on the GTAP database<sup>4</sup> which has a 'Water supply; sewerage, waste management and remediation activities' sector based on ISIC classification (36 - 39).

In this report, we will follow this approach and also introduce a W&R sector based on NACE codes as well as W&R goods & services as a secondary material based on CPA codes in the SAM. Consequently, the Belgian SAM is extended from 12 sectors and 12 products to 13 sectors and 13 products (see Table 1). This extension allows us to capture the impact of this sector and its inputs and outputs of measures to promote the circular economy (CE) with a focus on W&R. To get a grip on the representability, we introduce some checks based on financial account & activity code data from Bel-first, on a webscraping exercise provided by Inoopa, and on the member list from sector federation Denuo.

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<sup>2</sup> <https://www.exiobase.eu/>

<sup>3</sup> As compared to NACE Rev 2 classification, NACE Rev 1.1 does not have a separate section on waste & recycling. NACE Rev 1.1 code 37 includes all recycling activities. Hence, roughly what is defined in NACE Rev 2 as 37-39.

<sup>4</sup> The GTAP Data Base is a consistent representation of the world economy for a pre-determined reference year. Underlying the data base there are several data sources, including among others: national input-output (I-O) tables, trade, macroeconomic, energy and protection data. Source: <https://www.gtap.agecon.purdue.edu/>

	Sectors	Products / Services
Basic model	S1. Agriculture, fishing, forestry	G1. Agriculture, fishing, forestry products
	S2. Mining	G2. Mining products
	S3. Manufacturing	G3. Manufacturing products
	S4. Energy	G4. Energy
	S5. Construction	G5. Construction products & services
	S6. Retail	G6. Retail services
	S7. Land transport	G7. Land transport services
	S8. Water transport	G8. Water transport services
	S9. Air transport	G9. Air transport services
	S10. Logistics & mail	G10. Logistics & mail
	S11. Market services	G11. Market services
	S12. Non- market services	G12. Non- market services
Extension	S.13 Waste & recycling sector(s)	G.13 Waste & recycling products & services

*Table 1: Overview of the basic sectors and products and the extension for waste and recycling.*

Thereafter, we will model three measures for the uptake of CE by improved waste management according to the Circular Economy Action Plan (CEAP) of the European commission in Belgium's CGE model. This model was developed in the IECOMAT project funded by BELSPO (Eyckmans et al.). These measures are formulated as follows: (i) Increasing share of recycled content (e.g. minimum recycled content measures), (ii) Enabling high quality recycling, (iii) Addressing waste exports to third countries.

The added value of this research are the threefolded representativity checks of the sector, the simulation of measures from the CEAP, and the application to Belgian data. In what follows, we will first establish a methodology to disaggregate the W&R sector and product. Furthermore, we will describe in a detailed manner the representativeness checks which were compiled. Next, we will describe the methodology for the modelling of the policy measures. Finally, the results will be analysed and conclusions will be drawn.

## 2 Methodology

### Expanding the Social Accounting Matrix

The Belgian CGE model is calibrated for 2018 using a Social Accounting Matrix or SAM as input data. The SAM is constructed from the Belgian Supply and Use Tables (SUT). The supply table shows the supply of goods and services by product and by producing industry. It distinguishes supply amongst domestic industries and import. A use table shows the use of goods and services categorised by product and by type of use. This include: intermediate consumption by industry, final consumption expenditure by households, government and non-profit institutions serving households, gross capital formation and exports (Eurostat, 2013a).

The sectors in the SUT are based on NACE codes, which is the statistical classification of economic activities in the European Community and consists of 4 digits (Eurostat, 2016). The latest available classification is NACE Rev. 2 and was implemented in 2007. The categorisation of the products by activity is called CPA and each product is assigned to one single NACE activity (Eurostat, 2013b). CPA consists of 6 digits and the most recent classification is from 2008 and consists of 3142 goods and services. It is important to note that firms within a given NACE code can offer products and services outside this NACE code (Eurostat, 2013a). For example, a car manufacturer in the car manufacturing sector produces cars, but also supplies metals, waste, scrap material, services in the form of accounting services or advice for corporate management, etc. For the Belgian SUT, data is available on the level of 63 sectors and 63 products (Instituut voor de Nationale Rekeningen, 2015).

For the Belgian SAM, these 63 products and 63 sectors categories are aggregated to 12 sectors and 12 goods. In other CGE models as described in the introduction, we saw that the introduction of W&R sector is often based on the NACE codes 37-39. To fully align with the CE Center sector study of Willeghems and Bachus (2018) we also add 46.77 'Wholesale of waste & scrap' to the W&R sector. Table 2 provides an overview of the NACE codes and its description. The codes 37-39 and 46.77 are initially included in the Belgian SAM in the aggregated manufacturing sector.

NACE code	Description
37	Sewerage
38	Waste collection, treatment and disposal activities; materials recovery
39	Remediation activities and other waste management services
46.77	Wholesale of waste and scrap

*Table 2: Overview of the relevant NACE codes and their descriptions to split off in a 13<sup>th</sup> sector*

In order to model the policy measures, we split off these sectors and goods from the manufacturing sector and goods in a separate category to extend the SAM with a 13<sup>th</sup> sector and a 13<sup>th</sup> commodity. However, there are some points of attention to this approach:

- Internal reuse of materials, without external help of companies, for example for collecting or treating waste, is not visible in the model. The model only depicts monetary flows which are represented in existing data. No formal data means no representation. For example, when a company collects and treats waste itself, this is not included in the data as this does not represent a monetary transaction;
- The CGE model is monetary-based. As the values (in €/kg) strongly differ between the material flows, a translation to physical units is difficult.

In a next step, we aim to understand to what extent these NACE codes cover the actual Belgian W&R activities. Therefore, it is important to understand that the SUT (and by extension the SAM) represent these activities in two ways in the supply table:

- What goods & services do the companies active under a W&R NACE code (37-39) produce?
- Which companies produce W&R goods & services (37- 39)?

Note that the code 46.77 is not directly included here. This is because the SUT for NACE 46 (wholesale trade) and 47 (retail trade) only capture the trade margins (Eurostat, 2013a). The effective transaction of materials is captured in the relevant manufacturing sectors.

For the first question, we can look at Figure 2. In this figure we see the products produced by companies active under a W&R NACE code. We see that 96% of the W&R products are produced by companies in a W&R NACE code 37-39. Other products produced by this sector can be found in Table 3 and are, for example, architectural and engineering services and security and investigation services, facility support, and office administration.

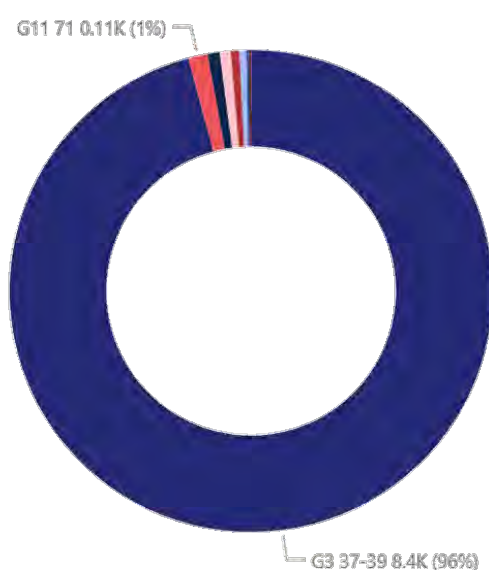


Figure 2: Goods offered by sector 37-39 based on 2018 SUT

CPA code	Description	Supply (€M)
37-39	Sewerage, Waste collection, treatment and disposal services; materials recovery services, remediation services	8,399
71	Architectural and engineering services	114
80-82	Security and investigation services, facility support, office admin	70
41-43	Civil and utility construction, buildings	65
35	Electricity, gas, steam and refrigerated air	50
72	Scientific research and development	41
49	Land transport and pipeline transport	14
62-63	Computer programming, consulting, and related services	11
77	Rental & lease	1

Table 3: Goods offered by sector 37-39 based on 2018 SUT

In Figure 3, we see that 77% of the W&R goods are produced by W&R activities, 12% by NACE code 36 which is water collection, treatment and supply, and 6% by NACE code 24 which is manufacture of basic metals. Other sectors can be found in Table 4.

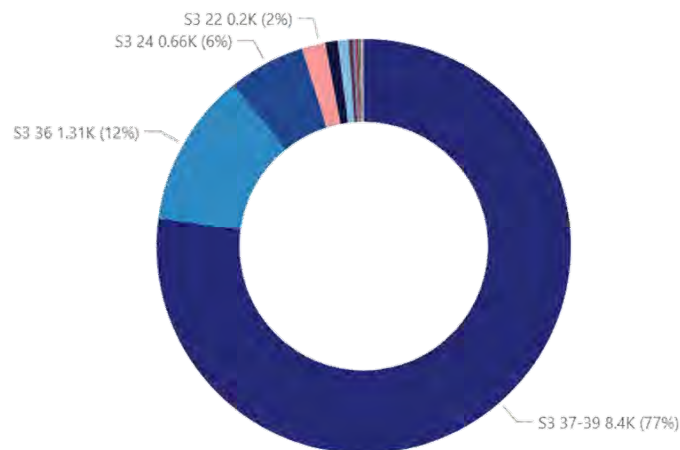


Figure 3: Activities that offer commodity 37-39 based on 2018 SUT



NACE code	Description
16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
17	Manufacture of paper and paper products
19	Manufacture of coke and refined petroleum products
20	Manufacture of chemicals and chemical products
22	Manufacture of rubber and plastic products
23	Manufacture of other non-metallic mineral products
24	Manufacture of basic metals
25	Manufacture of fabricated metal products, except machinery and equipment
29	Manufacture and assembling of motor vehicles, trailers and semi-trailers
30	Manufacture of other transport equipment
33	Repair and installation of machinery and equipment
35	Electricity, gas, steam and air conditioning supply
36	Water collection, treatment and supply
37	Sewerage
38	Waste collection, treatment and disposal activities; materials recovery
39	Remediation activities and other waste management services
41	Construction of buildings; development of building projects
42	Civil engineering
43	Specialised construction activities
46	Wholesale trade excluding repair of motor vehicles and motorcycles
69	Legal and accounting activities
70	Activities of head offices; management consultancy activities
78	Employment activities
80	Security and investigation activities
81	Services to buildings and landscape activities
82	Office administrative, office support and other business support activities
94	Activities of membership organisations

*Table 4: Activities that offer commodity 37-39 based on 2018 SUT*

Based on the previous analysis, we can conclude that the SUT (and hence the SAM) captures the Belgian waste & recycling sector in 2 different ways (also illustrated in Figure 4):

- Direct: the company has a direct W&R NACE code (37-39);
- Indirect: the company has no primary W&R NACE code but produces W&R goods and/or services.

To get a better understanding of which companies are captured (directly and indirectly) and if there are any significant gaps in the above approach, we will address three representativeness checks in the next section.

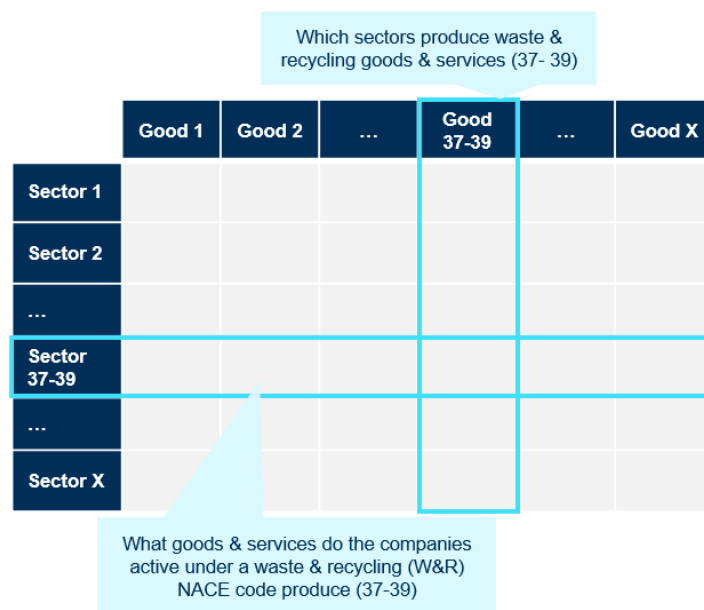


Figure 4: Cross sections for scoping the waste and recycling sector

## Representativeness checks

It is important to understand if NACE 37-39 and 46.77 sufficiently capture the W&R sector and whether there is a need for expansion of current definition. Therefore, we will check for Belgian W&R companies whether they fall under the (SUT) NACE codes that produce W&R goods (directly or indirectly). The Belgian W&R companies can be checked in 3 different ways:

- **Bel-first data:** extract of all Belgian companies reporting 37-39 or 46.77 as primary or secondary NACE code. The data is based on self-declaration;
- **Inoopa data:** all Belgian companies for which Inoopa predicts, based on webscraping, that the 'most suited' NACE code is 37-39 or 46.77. The data is webscraping-based;
- **Denuo member list:** the members of Denuo, the Belgian waste & recycling sector federation. The data is based on active federation members.

### Representativeness check 1: self-declaration in Bel-first

Bel-first is a database that contains extensive information on companies in Belgium (including NACE code, turnover, workforce, etc.) (Bel-first, 2022). All Belgian companies with a primary or secondary NACE code 37-39 or 46.77 were selected and extracted from this database. This should constitute a good representation of the companies that indicate themselves to have a main or secondary activity in waste & recycling. For those companies we then check whether they have a primary NACE code as reported in Bel-first of 37-39 or 46.77, or whether they produce the commodities 37-39 or 46.77.

The results can be found in Table 5. We note that data on the turnover is not always available and depending on the company, we used data from a different year. We see that 4,133 companies (accounting for 55% of turnover as reported by Bel-first) have a primary NACE code 37-39 or 46.77. These companies are directly captured in the SUT. 2,925 companies (accounting for 38% of turnover) have a secondary NACE code 37-39 (or 46.77) and a primary NACE code that produces commodities 37-39. These companies are therefore captured indirectly (via the

goods column) in the SUT. Finally, 1,962 companies (accounting for 7% of turnover) report having a secondary NACE code 37-39 or 46.77 but are not linked in the SUT to the production of commodities 37-39.

	# companies	Turnover (B€)
Directly captured	4,133 (46%)	7.66 (55%)
Indirectly captured	2,925 (32%)	5.28 (38%)
Not captured	1,962 (22%)	1.05 (7%)
<b>Total</b>	<b>9,020</b>	<b>13.99</b>

*Table 5: Results from the representativeness check based on the Bel-first database.*

We see that 93% of the W&R companies are captured either directly or indirectly in the SUT. Examples of companies that are directly captured are Aquafin (38), Galloo, Renewi, Veoli, Belgoprocess (38), Deme environmental, Envisan (39), Synergy tradeco, and ASB recycling (46.77). Examples of companies that are indirectly captured are Umicore (24), Watergroep (36), Fluvius (35), Fostplus, and Recupel (82). We thus conclude that the SUT capture most of the relevant Belgian companies and we argue that the companies captured in the SUT are a representative sample for the W&R activities.

Furthermore, we did two extra checks based on the Bel-first data. First, we checked the presence in the NACE codes of the intermunicipal companies responsible for waste collection in Belgium (for a list of all the intermunicipal companies, see: Recupel (s.d.)). On Bel-first we found that all intermunicipal companies have a NACE code in the category of 38, namely 38110, 38213 or 38219. One intermunicipality (IBW in Walloon Brabant) has the NACE code 37000. We can thus conclude that the intermunicipal companies responsible for waste collection in Belgium are all directly captured in the NACE codes 37-39.

Second, we checked whether the largest W&R companies were included in the Bel-first data which we extracted for the representativeness check. When we look at the turnover, of the top 10 largest companies doing W&R 40% are directly captured and 40% indirectly, of the top 20, this is respectively 45% and 45%, of the top 30, this is respectively 43% and 46%. We can thus conclude that of the 30 largest W&R companies in Belgium based on turnover, 89% are captured in the SUT.

### **Representativeness check 2: webscraping by Inoopa**

Inoopa defines company activities by using AI advanced technologies. They start from default company databases such as KBO<sup>5</sup> and combines this with information found on websites, Google, Facebook and Googlemybusiness. By applying AI, they predict the best matching NACE code for each Belgian company (Multani et al., 2022). The companies with a NACE code 37-39 or 46.77 as predicted by Inoopa are selected. These companies, according to webscraping, are mainly involved in waste & recycling activities. We therefore check whether these companies are included directly and/or indirectly by the SUT (and hence the SAM).

The results can be found in Table 6. We note that information on the number of employees was not always available in the dataset. We see that 1,838 companies (accounting for 92% of

<sup>5</sup> Kruispuntbank van Ondernemingen, offering data about BE companies

<https://economie.fgov.be/nl/themas/ondernemingen/kruispuntbank-van/kruispuntbank-van>

workers - where data available) categorized by Inoopa as W&R also effectively have a primary NACE code under 37-39 or 46.77. These companies are directly captured in the SUT. 134 companies (accounting for 5% of employees) categorized by Inoopa under an W&R NACE code, have a primary NACE code producing commodities 37-39. These companies are therefore captured indirectly (via the goods column) in the SUT. And finally, 1,134 companies (accounting for 3% of employees) categorized by Inoopa under a W&R NACE code exhibit no link in the SUT to production of commodities 37-39. 1,061 of these 1,134 (94% of this category) do not have a NACE code, which signifies that these are probably inactive companies (that consequently do not report on employees).

	# companies	# employees
Directly captured	1,838 (59%)	19,317 (92%)
Indirectly captured	134 (4%)	1,063 (5%)
NOT captured	73 + 1,061 (2% + 34%)	553 (3%)
<b>Total</b>	<b>3,102</b>	<b>20,933</b>

*Table 6: Results from the representativeness check based on Inoopa webscraping data.*

To conclude, we pose that 97% of the companies defined by Inoopa as performing W&R activities are directly or indirectly captured in the SUT. Examples of companies that are captured directly are Aquafin (37), Renewi (38), Asbest car (39), Galloo, ASB recycling, and Belgian scrap terminal (49.77). Examples of companies that are indirectly captured are Recypac (43), Recutex (46), Traflux (81) and Scrap metal services (24).

### **Representativeness check 3: Active federation members of Denuo**

For the last representativeness check, we looked at the list of members of Denuo, which is the Belgian federation for the W&R sector. We received the list on June 15<sup>th</sup> 2022 and note that since, Denuo has 17 new members which are not included in this representativeness check. For each Denuo member, we checked their primary NACE code and the results can be found in Table 7. We see that 137 members (77%) have a primary NACE code belonging to 37-39 or 46.77. These companies are directly captured in the SUT. Note that some companies showed an unrelated NACE but upon further investigation revealed that they are part of a group in which the parent/subsidiary does have a primary W&R NACE. 50 members (26%) have a NACE code that produces commodities 37-39 according to the SUT. These companies are captured indirectly (through the goods column) in the SUT. Finally, 7 members do not have a NACE code that is captured in the SUT, 2 (1%) of these members are Dutch companies.

	# companies
Directly captured	137 (71%)
Indirectly captured	50 (26%)
Not captured	5+2 (2% 1%)
<b>Total</b>	<b>194</b>

*Table 7: Results from the representativeness check based on active federation members from Denuo.*

Based on these results, we conclude that 97% of the members of Denuo are captured directly or indirectly in the SUT. Examples of companies that are directly captured are De Bree Solution (37), Galloo, Veko Recycling (38), Adensol (39), Recytex, and Stevens Recyclin (46.77). Examples of companies that are indirectly captured are De Kock Recycling, Crealis (46), Veolia, Traflux

(81), and Balchem (20). Therefore, we argue that the SUT sectors 37-39 and 46.77 are a relevant representation of the W&R sector.

## Conclusion

The three representativeness checks show that the SUT provides good coverage of the W&R sector. Based on the representativeness checks, we can conclude that the SUT adequately captures the W&R sector through NACE codes 37-39. As a result, we can expand the CGE model with a 13<sup>th</sup> sector and commodity. NACE code 37-39 is extracted from "S3. Manufacturing" and modelled as a separate sector "S13". CPA code 37-39 is extracted from "G3. Manufacturing products" and modelled as a separate commodity "G13" (see Table 1).

# Modelling approach and scenarios

The European Commission launched their new Circular Economy Action Plan (CEAP) in support of the European Green Deal on the 11th of March 2020 (European Commission, 2020). The updated CEAP provides a future-oriented agenda for achieving a cleaner and more competitive Europe in co-creation with economic actors, consumers, citizens and civil society organisations. It aims at accelerating the transformational change required by the European Green Deal, while building on circular economy actions implemented since 2015. One of the key chapters in the CEAP is the chapter on “less waste, more value”. This chapter describes the high-level (policy) measures to be taken in the waste field. These can be roughly summarized as follows:

- Increasing recycled content (e.g. minimum recycled content measures);
- Enabling high quality recycling;
- Addressing waste exports to third countries.

In this report the focus will be on simulating the above in the Belgian CGE model. Below we will explain in more detail how the three policies have been modelled. We note that the Belgian CGE model allows for trade with two trading partners, namely, the EU and the Rest of the World (RoW)

First, we would like to point to three important disclaimers:

- We note that the CGE model used is comparative static by nature and hence does not introduce time-dynamics or future developments.
- The model only allows us to impose measures on the Belgian economy. Consequently, measures discussed above are imposed as if they are Belgian measures only (while in reality these measures will be imposed on a European level). Furthermore, prices and volumes of commodities from and to foreign trading partners stays unchanged;
- The proposed circular economy scenarios are model-based projections that are used to explore the effects of different types of circular economy policies and/or modus operandi. The aim is to provide insights into how a certain circular economy policy and/or modus operandi could impact the Belgian economy and its key indicators. It is therefore important to realize that these scenarios do not represent a vision or prediction of the future (but rather make theoretical assumptions on cost-efficiency, technological progress and policy measures) and should always be interpreted in above context. These scenarios are set up to help guide thinking about possible circular economy pathways but always alongside the current economic landscape and taking into account the broader political and societal context.



To summarize, the Circular economy scenario shocks were progressively applied – ranging from a moderate to an ambitious scenario. The aim of the exercise was to understand the impact on the state of the economy of (rather extreme) circular economy shifts - **NOT to make statements on where Belgium will eventually land in this range.** Consequently, it is **important to focus on the direction of the effects and their relative comparison** – NOT on the precise numbers.

## Increased share of waste and recycled materials as inputs

For this first CEAP measure of increasing the recycled content, we note that it is not possible to model this as the CGE model is based on monetary flows. Therefore, we rename this CEAP measure to “increasing share of W&R inputs”. We thus model the increased uptake of W&R inputs by the manufacturing sector.

For representing the substitution between primary and secondary materials, three main approaches have been used in literature (McCarthy et al., 2018):

- 1) Explicit representation of available alternative technologies (e.g. primary iron ore vs. secondary scrap);
- 2) Exogenous changes to the production functions of selected material intensive sectors to increase substitutability between primary and secondary materials (technical coefficients);
- 3) Separation of one (or more) dedicated waste management or secondary material producing sector in the underlying SAM.

Given that the first method requires detailed (product-level) information, we will employ method 2 and 3 to represent the impact of increased recycled content. One important side note needs to be made regarding this approach: The production functions and the waste management sector are calibrated according to present-day data. In case of extreme shocks these might not hold anymore.

The function below presents the MCES production function:

$$\min p_1 x_1 + p_2 x_2 \text{ s.t. } x_0 = A \left[ \alpha_1^{\frac{1}{\sigma}} (\lambda_1 x_1)^{\frac{\sigma-1}{\sigma}} + \alpha_2^{\frac{1}{\sigma}} (\lambda_2 x_2)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

$x_0$  = output

$x_i$  = inputs

$p_i$  = price of inputs for producers

$\sigma$  = elasticity of substitution

$A, \lambda_i$  = technology shift parameters

$\alpha_i$  = distribution parameters

$$\sum_i \alpha_i = 1$$



For this CEAP measure, we change the production function of the manufacturing sector (S3) such that more input is needed from the W&R sector (simulating increased share in recycled content). The technical coefficient lambda, “ $\lambda$ ”, of the manufacturing sector for G13 (Waste & recycling goods) is ranged from 1 (standard value) to 0.05 with following recycled input percentages in Figure 5 as a result. The % recycled input is calculated as the input of secondary materials as a share of the total input level of intermediates of materials. The input of these materials is calculated as the total value of input in the Belgian SAM divided by the price. As a comparison, CE Center estimated the circular material use rate<sup>6</sup> of Belgium at 20.7% in 2018 (CE Center, 2023a).

	SC0 (BAU)	SC1	SC2	SC3	SC4	SC5	SC6	SC7	SC8	SC9
Lambda(S3, G13)	1	0.8	0.75	0.6	0.5	0.4	0.3	0.2	0.1	0.05
% recycled input	7.15%	8.35%	8.73%	10.16%	11.49%	13.32%	16.05%	20.36%	30.59%	42.82%
% primary input	92.85%	91.65%	91.27%	89.84%	88.51%	86.68%	83.95%	79.37%	69.41%	57.18%

Figure 5: an overview of the technical coefficient (lambda) of S3 for G13 in the different scenarios.

## Enabling high quality recycling

The EU aims to enable high quality recycling via effective separate collection of waste, extending the Eco-design Directive and creating Digital Product Passports (European Commission, 2020; European Parliament, 2021). These measures should allow for more efficient recycling activities. In the CGE model, this is implemented not by modelling the different European actions but the result, i.e. more efficient recycling activities. Hence, in the constant elasticity of transformation (CET) production function<sup>7</sup> for the Belgian waste & recycling sector, the efficiency parameter is adjusted. (More recycling activity output can now be achieved with the same inputs (see also Figure 6). As a result, the production cost for the W&R sector decreases (see Figure 7).

The function below presents the CET function for aggregate output:

$$\begin{aligned} & \text{Max } p_1 x_1 + p_2 x_2 \\ \text{s.t. } & V = A \left[ \sum_{i=1}^L g_i (\lambda_i x_i)^{\frac{\omega+1}{\omega}} \right]^{\frac{\omega}{\omega+1}} \end{aligned}$$

$\omega$  = transformation elasticity

$V$  = aggregate volume of output

$x_i$  = individual categories of goods and services

$p_i$  = corresponding individual price of goods and services

$g_i$  = constant

$p_v$  = aggregate price

$A, \lambda_i$  = Shifters to implement changes in technology or preferences

<sup>6</sup> The circular material use (CMU) rate measures the share of material recovered and fed back into the economy — thus saving extraction of primary raw materials — in overall material use. Source: Eurostat, Circular material use rate, calculation method, 2018.

<sup>7</sup> Firms in the model have the ability to produce more than one commodity type. If the prices of commodities change, firms are able to change their output mix to maximise profits. This is captured by the constant elasticity of transformation (CET) production function, with the elasticity of transformation determining the ease with which sectors can change their output mix in response to changes in relative commodity prices.

$$0 < \omega \leq \infty$$

	SC0 (BAU)	SC1	SC2	SC3	SC4	SC5	SC6	SC7	SC8	SC9
<u>Lambda CET(S13)</u>	100%	99%	97%	95%	92%	90%	87%	85%	80%	70%

Figure 6: An overview of the efficiency parameter for S13 in the different scenarios.

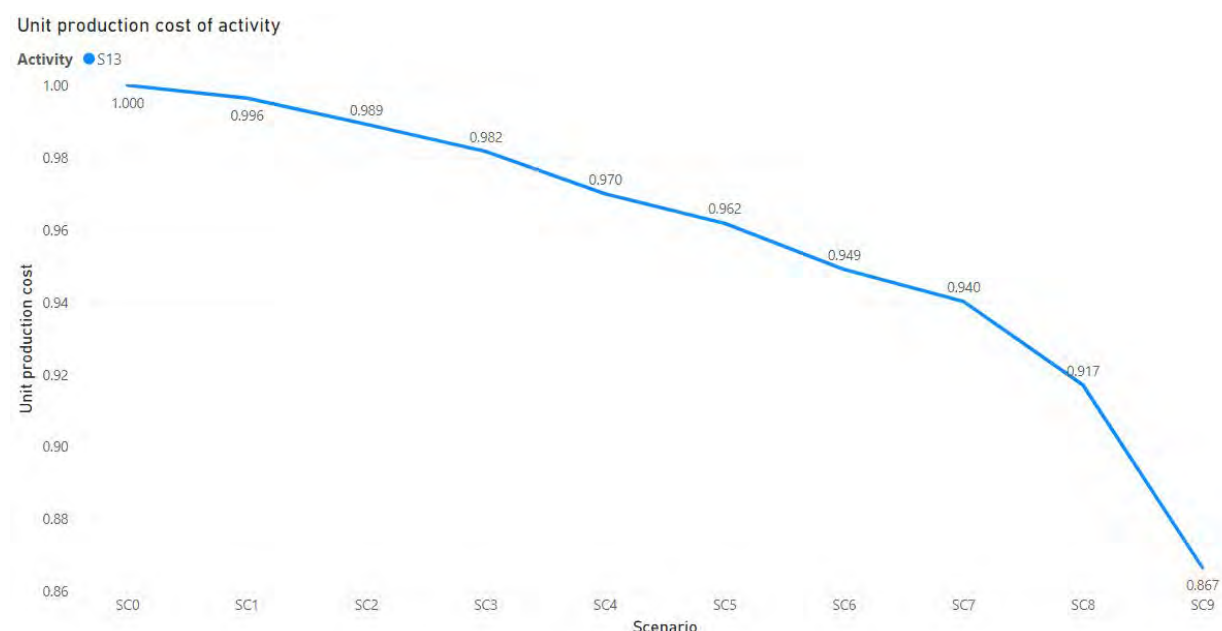


Figure 7: Evolution of the unit production cost of the W&R sector

For this measure, two important caveats should be made:

- The model allows us to make these adjustments for the Belgian production sector but not for the broader EU sector (whilst this is an EU measure). Consequently, this simulation will show an increase in export of Belgian W&R outputs towards the EU and RoW where the former might not hold in reality.
- In this scenario, we assume that these efficiency gains do not imply a cost. However, it could be that certain investments need to be done (e.g. in better design, in infrastructure to enable Digital Product Passports etc.) to enable the rise in efficiency. This scenario does not introduce an additional cost to analyse the efficiency gain effect in isolation.

## Addressing waste export to third world countries

The EU wants to ensure that its waste challenges are not exported to third countries and to make 'recycled in the EU' a benchmark for qualitative secondary materials (European Commission, 2020). To that end, it states in the CEAP that it will thoroughly review the EU rules on waste shipment with the aim to restrict exports of waste. These type of restrictions can be seen as non-tariff barriers (NTB) on the export of waste & recycling goods.

In CGE modelling, the most common way to measure such NTBs is through 'ad valorem equivalents' (AVEs), which increases the difference between world and domestic prices

(Fugazza & Maur, 2008). We thus model a decrease in the price that producers receive for their exports to RoW. Figure 8 shows the different scenarios that were modelled. For example, in the first scenario, producers receive only 95% of the price for their export compared to the baseline. Hence, in this context, NTBs can be thought to behave like a tax on export from Belgium to RoW.

	SC0 (BAU)	SC1	SC2	SC3	SC4	SC5	SC6	SC7	SC8	SC9
Tax rate applied	0%	5%	10%	15%	20%	25%	50%	75%	90%	100%

Figure 8: An overview of the tax parameter in the different scenarios

## Sensitivity analysis

### Increasing energy prices

In recent months, due to the Russian invasion in Ukraine, energy prices have been on the rise (see Figure 9 for the electricity prices). We want to check if the conclusions from the three policy measures still hold in the face of such shocks. Therefore, energy prices are raised by 80% in the model while all other parameters are kept the same as before. This analysis allows us to identify the key impacts and the direction of the change of such an energy price shock on our initial conclusions.

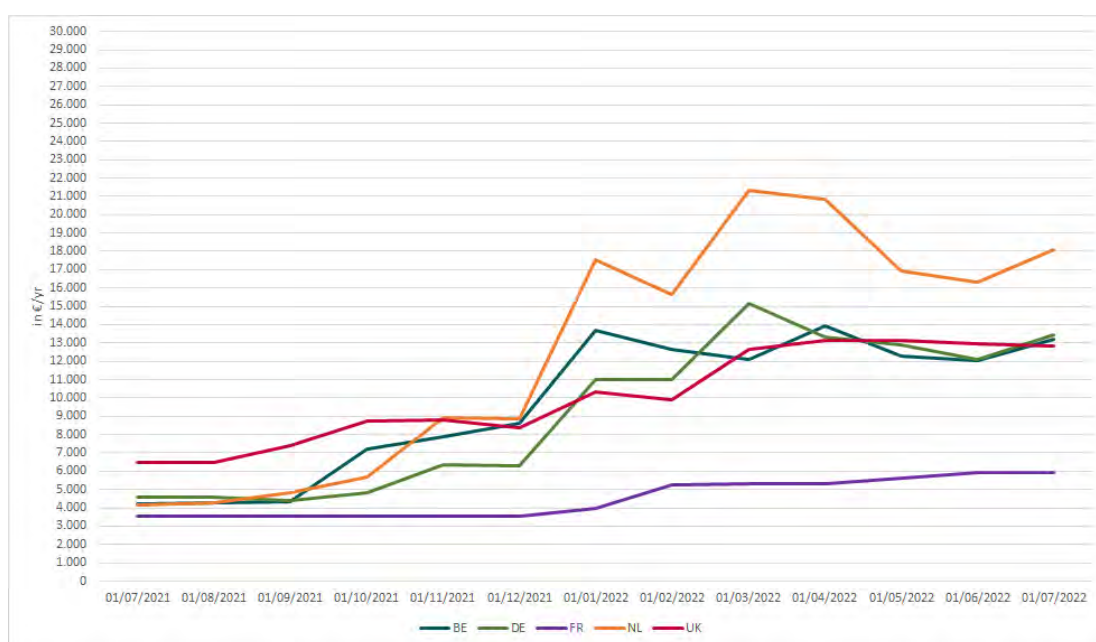


Figure 9: Evolution of electricity price for professional consumption (50 MWh). Source: CREG (s.d.)

### Increasing elasticity of substitution

An important parameter for the policy measures is the elasticity of substitution between primary and secondary materials (i.e. between virgin materials and W&R products), as this determines to what extent these inputs are interchangeable for production. While modelling the policy measures, the elasticity of substitution for the intermediate inputs in the production function is set at 0.25 (based on GEM-E3 elasticities). In the future, we can expect virgin and recycled input materials to be more substitutable thanks to CE measures being taken today. It

is hence important to understand how these measures impact if substitutability (and thus the elasticity of substitution) is increased.

In what follows we will test the sensitivity of our results against an increasing elasticity of substitution (when intermediate inputs are increasingly better substitutes) with all other parameters equal. Figure 10 shows an overview of the imposed elasticities. We note that the model only allows to change the elasticity of substitution at an industry level. As a result this elasticity holds for all intermediate inputs used in that industry, and not only for W&R goods.

	BAU	Run 1	Run 2	Run 3	Run 4
Elasticity of substitution	0.25	0.5	2	5	20

*Figure 10: An overview of the range of the elasticity of substitution*

# 3 Results and discussion

## Increased share of waste and recycled materials as input

This CEAP measure has been modelled by changing the production function of the manufacturing sector (S3) as such that more input is needed from the W&R sector to mimic an increase in the use of recycled materials. Therefore, we diminished the technical coefficient of the manufacturing sector for the W&R goods (G13).

In Figure 11 we see that the total output of W&R goods and services increases. This is due to the increased demand by the manufacturing sector. Figure 12 depicts the results for the manufacturing sector. We see that the output of this sector is reduced by the forced shift of replacing primary by secondary materials. This has a negative impact on total output produced.

We note that due to the nature of the model for both sectors, the structure of the production function remains unchanged. This implies that a similar production method is assumed for all sectors where in reality the manufacturing sector will adapt its method to the new regulation and the W&R sector to the additional required capacity (e.g. through innovation).

Waste & recycling goods & services produced (in M units)

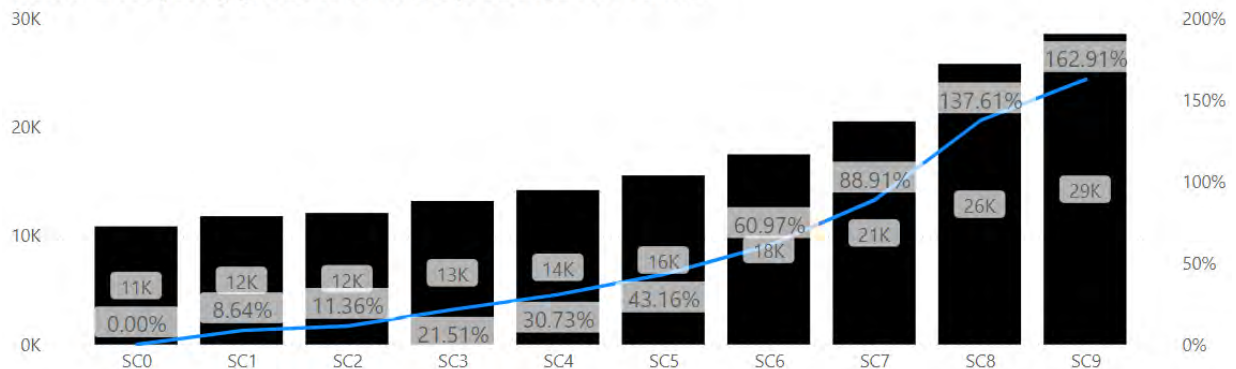


Figure 11: Results for the production of W&R commodity (in million units)

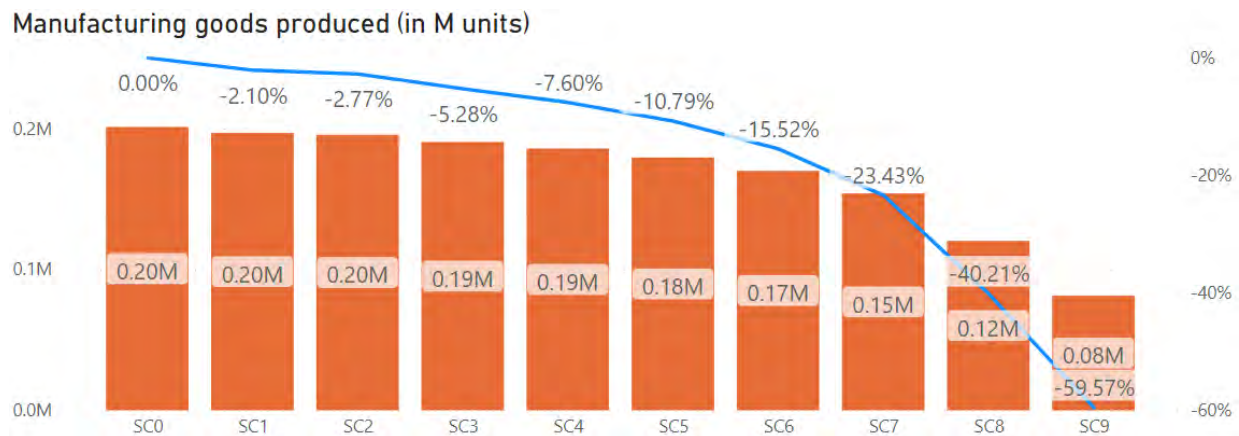


Figure 12: Results for the production of the manufacturing commodity (in million units)

The impact on the W&R and manufacturing products cause a chain reaction in the production of other sectors. Table 8 shows these changes for the most moderate and the most extreme scenario. In all cases, the direction of the changes stays the same and the size of the impacts are enlarged. We note that the previous graphs showed the results for the commodities produced, while the table shows the results for the sector (often producing more than 1 commodity).

Sector	% change production	
	SC1	SC9
Waste & recycling	11.86%	229.05%
Nonmarket services	0.04%	1.39%
Market services	0.50%	16.35%
Logistics & mail	0.20%	7.79%
Air transport	0.18%	7.43%
Water transport	-0.18%	-5.51%
Land transport	0.05%	2.55%
Retail	-0.30%	-9.61%
Construction	1.91%	58.81%
Energy	0.52%	29.76%
Manufacturing	-2.29%	-65.52%
Mining	3.35%	141.18%
Agriculture	-0.91%	-27.14%
Total	-0.07%	-1.37%

Table 8: Results for the change in the production of the sectors

The construction and market services are typically affected by the investment demand. In this scenario, the investment demand increases to stimulate the economy and boost its efficiency after a decreased GDP. The total economic output decreases in all scenarios and as a consequence more will be invested to increase productivity again. Typical investment goods are infrastructure, and design and consulting services. The logistics and transport sector have an increased activity (except water transportation as their key income is from transporting manufacturing goods) due to more activity in the W&R sector, which typically requires more

transport and logistics to transport the products at the end-of-life to separation facilities, to recycling facilities, and finally back to the producer.

The energy and mining sector are also positively impacted given import of these products is decreased and export increased – there is hence a shift towards more domestic production. Given the increased price of manufacturing goods, prices for other consumption goods incl. energy drop to compensate. As a result it becomes more beneficial to import less energy and export more. The mining sector is indirectly positively impacted through the increased activity in the energy sector. The mining sector is a marginal sector in Belgium (only making up 0.08% of economic activity) that focuses on extraction of stone and sand. Most mining inputs come from export and are used by the energy sector. As a result an increased activity in that sector increases activity in the mining sector as our model does not differentiate between different mining activities.

The decrease in agriculture is driven by the substitution of agricultural outputs by W&R outputs and by the overall decrease in manufacturing activity. The agriculture sector is relatively small in Belgium (only 1% of economic activity) with most output going to the manufacturing sector. A reduction in that sector has as a result that also agricultural activity decreases (e.g. less inputs such as wood, cotton etc. required).

The results for the labour market can be found in Figure 13 and Figure 14. Figure 13 depicts the input of labour or the total employment while Figure 14 shows the household labour supply. We see an increase in both the total employment and the labour supply. The total employment increases by more than 6% in the most extreme scenario driven by increased employment in sectors:

- Waste & recycling (+ 12 - 247%)
- Construction (+ 2 - 70%)
- Energy (+ 3 – 150%). This makes up only minor part of total employment in Belgium
- Market & non-market services (+ 0.5 – 20%)



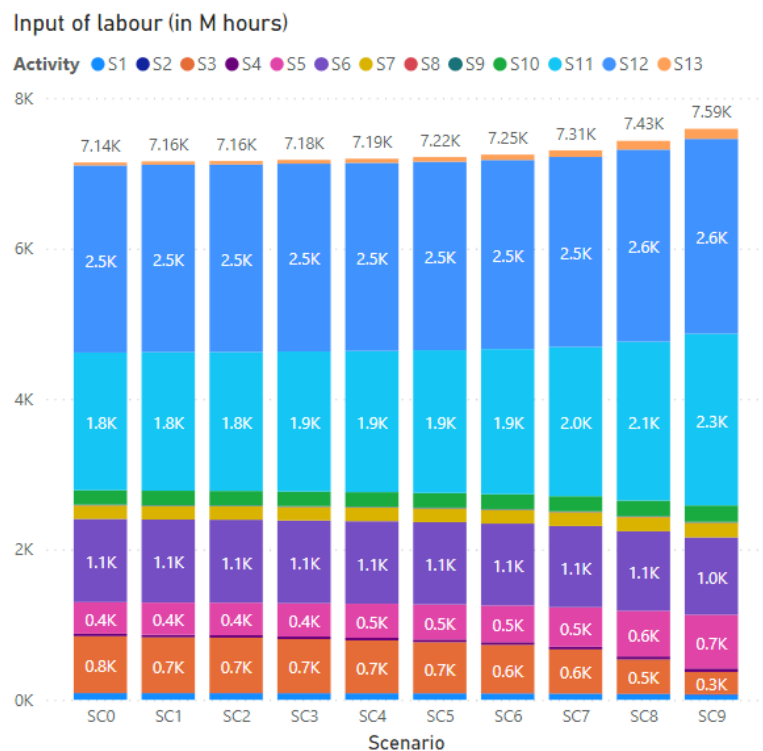


Figure 13: Total employment demand per sector (in million hours)

The domestic labour supply increases as well by 3%. Interestingly the total employment increases more than the increase in domestic labour supply. This means that part of the newly created jobs are filled up from abroad. At the same time, we observe stable to decreasing wages (of 0% in SC1 up until 13% in SC9). Domestic households are hence torn between working more to keep up current consumption levels and working less because of decreasing wages. At current wage, households are incentivized to work more but not sufficiently to support total industry demand for labour. Hence, the increased need for labour from abroad.

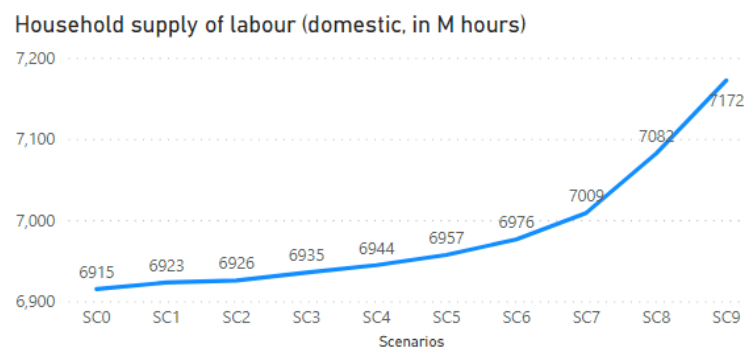


Figure 14: Domestic household labour supply (in million hours)

In Figure 15 we can see the total import (left) and export (right) and their respective percentage changes. The total import sees an increase (0.5 - 16%). This is driven by increased import of manufacturing goods and waste & recycling goods & services. Most other goods & services show a decrease in import. The total export on the other hand decreases (0.2 - 7%). This is driven by the decreased export of manufacturing and retail goods. All other goods and services are exported more than before. We note that in reality, imported products should also comply to the regulations from the CEAP which would slow down the increase in import.

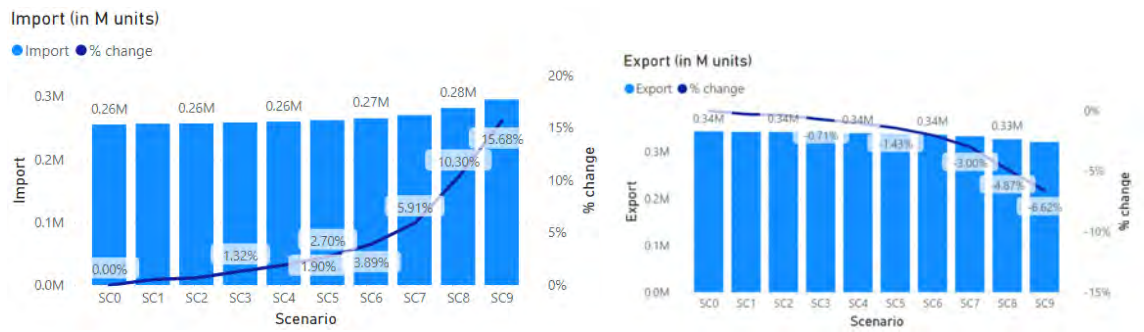


Figure 15: Import and export in million units and their respective percentage change

Further macroeconomic results concern the household utility and the GDP. Figure 16 depicts the indirect household utility on the left and GDP on the right. Due to the forced shift of the manufacturing sector and their large share in household budget, total household consumption and utility is reduced. Total GDP decreases due to decreased economic output and consumption.

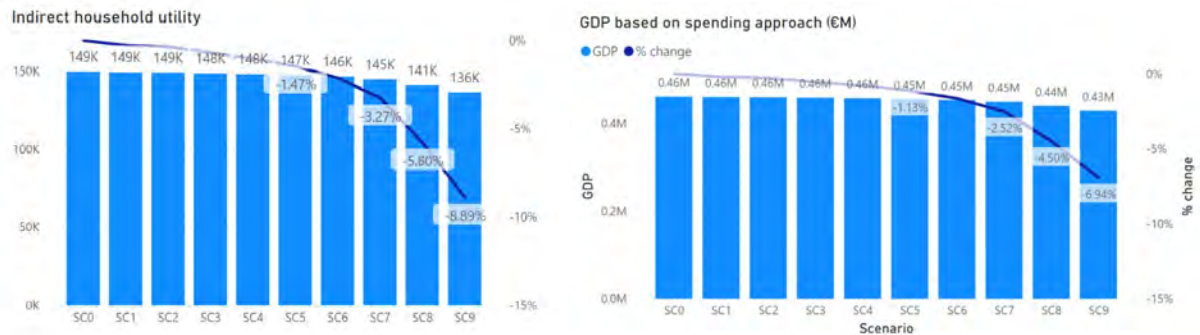


Figure 16: Indirect household utility (left) and GDP (right) and their respective percentage change.

## Conclusions

If the Belgian government would impose an increased share of waste and recycled materials as input for the manufacturing sector, the model results indicate that:

- The production of waste & recycling activities increases to meet increased demand;
- Manufacturing companies see a reduction in output due to the 'forced' shift to secondary materials;
- The investment demand increases which may boost productivity in the future. As a result there is a positive impact on investment sector construction and services;
- There is a higher demand for workers (job creation) which is partially being filled by non-Belgian workers, and
- Household utility is negatively impacted as well as GDP.

These results need to be interpreted whilst being mindful of disclaimers from pages 18 & 19.

## Enabling high quality recycling

This measure has been modelled by adjusting the efficiency parameter in the CET production function for the Belgian W&R sector. This reflects several actions such as effective separate collection of waste, extending the Ecodesign Directive, or creating Digital Product Passports. Note that this is modelled as a free gift. The efficiency gains are acquired without affecting (depreciation) costs.

In Figure 17 we see the output of the W&R sector. Due to the measures taken and their corresponding efficiency gains, the costs for these commodities will go down. This will increase the output of the sector. Next to the W&R sector, we see minor effects on other sectors (mostly negative) in Table 9, this can be explained by two effects. On the one hand, to the extent possible, W&R goods are being used (given lower prices) as input materials at the expense of other inputs. On the other hand, the investment demand decreased impacting mostly the construction & market services sectors.

### Waste & recycling sector output (in M units)

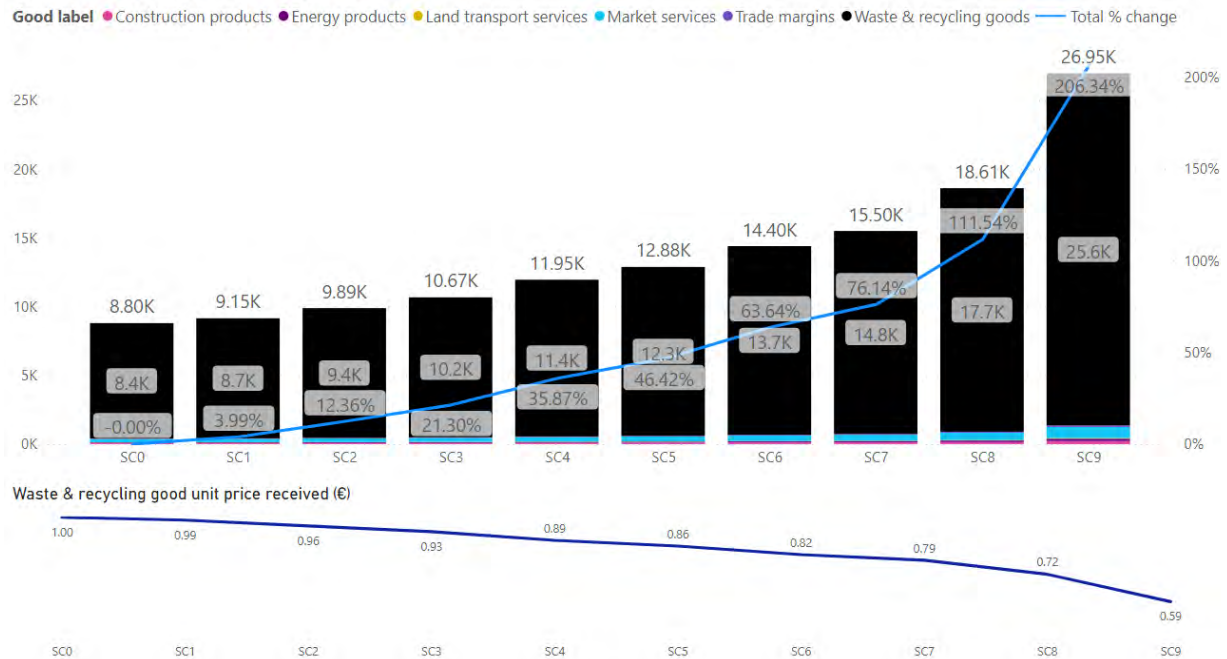


Figure 17: Output of the W&R sector (in million units) and their unit prices, standardised to 1 in the baseline scenario.

Sector	% change production	
	SC1	SC9
Waste & recycling	3.98%	206.22%
Nonmarket services	-0.01%	-0.28%
Market services	-0.03%	-1.42%
Logistics & mail	-0.02%	-0.69%
Air transport	-0.02%	-0.86%
Water transport	0.02%	0.93%
Land transport	0.01%	0.33%
Retail	-0.01%	-0.08%
Construction	-0.12%	-5.35%
Energy	-0.01%	-0.53%
Manufacturing	0.00%	0.60%
Mining	-0.02%	-1.67%
Agriculture	-0.01%	-0.22%
Total	0.02%	1.22%

Table 9: Results for the change in the production of the sectors

As this scenario aims at high quality recycling, we are also interested in the uptake of W&R inputs. Figure 18 gives an overview of the percentage recycled input for the manufacturing sector that use W&R goods as inputs. We see an increased uptake of these goods (and hence an increase in recycled content) till up to 10% more in SC9 for the majority of the sectors. However, this increase in recycled input is significantly lower than when a minimum recycled input is imposed (see previous scenario). The reason for this is what is called the rebound effect:

the reduction in price for secondary materials has a stronger impact on the production of manufacturing goods. Therefore, there is an increased total output as production can now happen more cheaply. This increase in total output reduces the positive effect of the substitution of primary by secondary materials.

	SC0 (BAU)	SC1	SC2	SC3	SC4	SC5	SC6	SC7	SC8	SC9
% recycled input	7.15%	7.16%	7.19%	7.22%	7.28%	7.31%	7.37%	7.41%	7.53%	7.82%
% primary input	92.85%	92.84%	92.81%	92.78%	92.72%	92.69%	92.63%	92.59%	92.47%	92.18%

Figure 18: Evolution of the share of recycled input used by the manufacturing industry.

Given the higher efficiency and resulting price decrease for W&R (Belgian) commodities, these become more competitive compared to products produced in other countries<sup>8</sup>, which results in decreasing imports and increasing exports (Figure 19). As indicated previously, this effect is somewhat magnified due to the inability to include efficiency gains for EU W&R commodities as well. In reality, we would expect to see a more moderate increase of export and decrease of import.

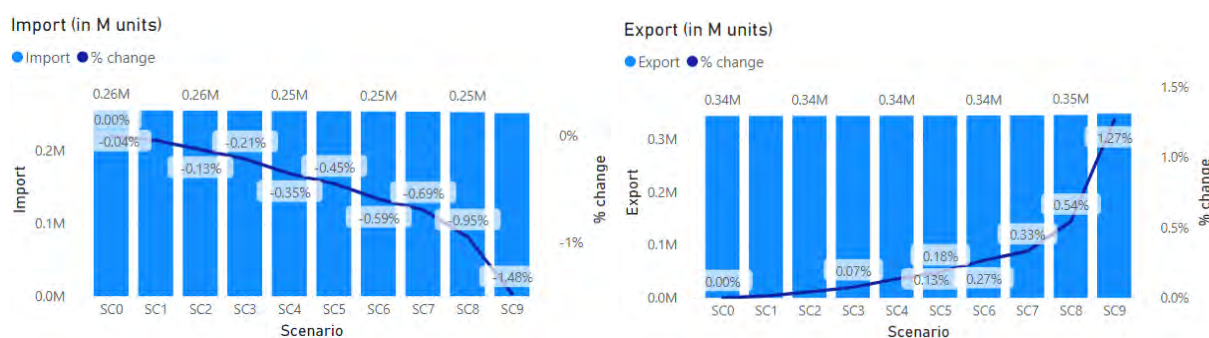


Figure 19: Import (left) and export (right) in million units and their respective percentage change

Several other macroeconomic effects can be found in Figure 20, Figure 21, and Figure 22 for respectively the GDP, the household utility, and the investment demand. We see that GDP is positively impacted in this scenario due to the increase in Belgian economic activity. Furthermore, wages are up resulting in increased household consumption and utility. The wage increase also incites an employment decrease of 0.01 – 0.59%. Finally, due to the shifting trade balance (less import, more export), investment demand has decreased. As the net trade balance increases as well as consumption, there will be less saved for future consumption. This implies an outflow of money resulting in a decreased demand for construction goods, manufacturing goods and market services.

<sup>8</sup> For product produced in countries abroad, the ceteris paribus assumption applies.



## GDP based on spending approach (€M)



Figure 20: Evolution of the GDP (in million euros)

## Indirect household utility (in M units)



Figure 21: Evolution of the indirect household utility

## Volume of investment demand (in M units)

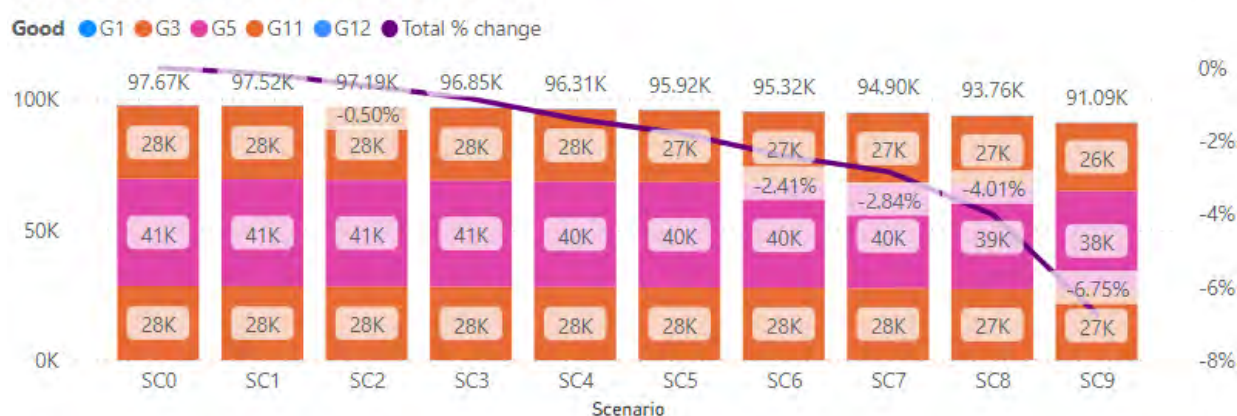


Figure 22: Evolution of the investment demand (in M units)

## Conclusions

If measures are taken to increase efficiency in the waste & recycling sector, model results indicate that:

- Thanks to price decreases, the waste & recycling goods and services see an increased uptake and hence an increased output for the sector;
- The economic activity increases and so does household consumption and GDP;
- Import is down and export of waste & recycling goods & services is up, and
- The investment demand decreases indicating a lower need for capital formation.

These results need to be interpreted whilst being mindful of disclaimers from pages 18 & 19.

## Restricting waste exports

For this measure we modelled a restriction on the exports of waste through 'ad valorem equivalents' or a decrease in the revenue of the producer on export from Belgium to the RoW.

The export of W&R commodities to RoW countries which is 888 million units or ~8% of total W&R commodities produced, gradually reduces to zero (see Figure 23) due to the export revenue decrease. In the most extreme scenario, the total production of W&R commodities however only falls with 6.92% (see Figure 24). The production of W&R commodities for the Belgian market increased slightly. We can hence conclude that the reduction in export is for a minor part compensated by an increased domestic demand. The revenue stream from exports is dropped and can only partly be compensated by increased domestic business.

As a result of the decreased activity, prices for the W&R commodity increase. The investment demand in Belgium increases as well. This could potentially be explained by the need for new waste management infrastructure to process the volumes that used to be exported and processed abroad. (see further in Figure 27).

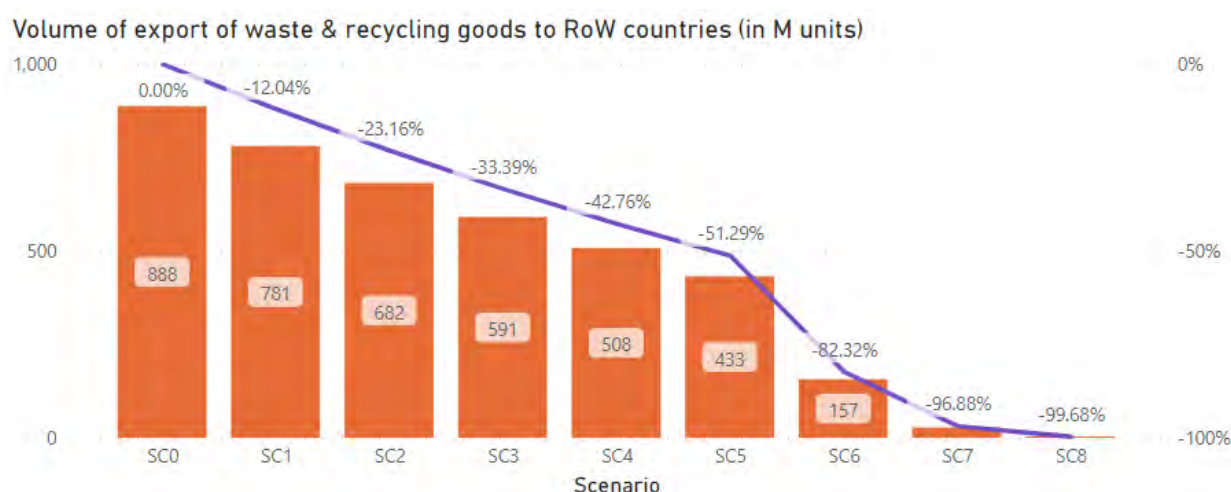


Figure 23: Volume of export of W&R goods to RoW countries (in million units)



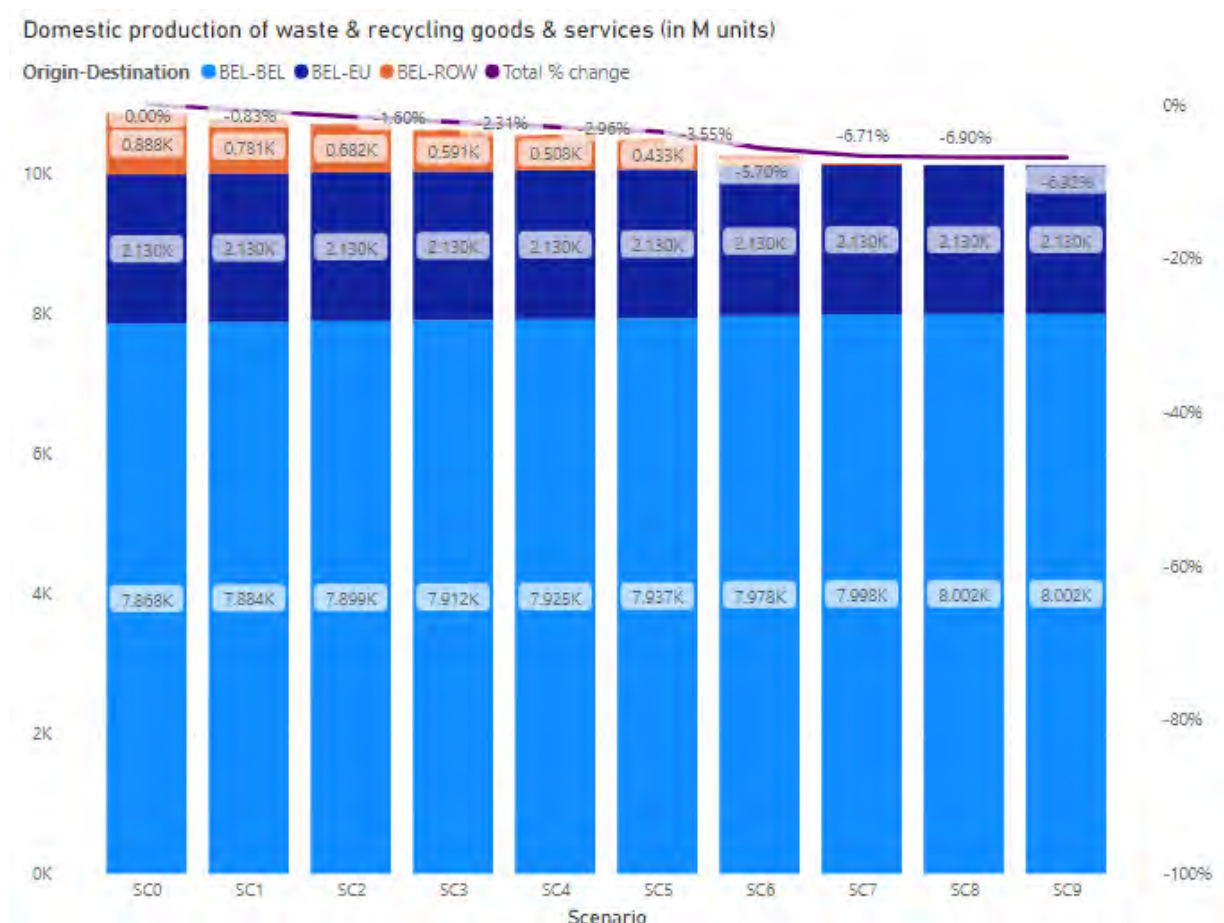


Figure 244: Domestic production of waste & recycling goods and services by origin-destination type (in million units)

Table 10 shows that apart from the W&R sector, there are also minor effects (<1%) on other sectors. The positive shifts are driven by an increased investment demand as the export decreases so increased investments are needed to be able to process the waste domestically. The negative shifts are driven by the decrease in output in the W&R sector.

Sector	% change production	
	SC1	SC9
Waste & recycling	-1.08%	-8.99%
Nonmarket services	0.00%	0.00%
Market services	0.01%	0.06%
Logistics & mail	0.00%	0.00%
Air transport	0.00%	0.03%
Water transport	-0.01%	-0.08%
Land transport	-0.01%	-0.08%
Retail	0.00%	0.02%
Construction	0.06%	0.46%
Energy	0.00%	-0.01%
Manufacturing	0.01%	0.06%
Mining	0.00%	-0.03%
Agriculture	0.00%	0.03%
Total	-0.00%	-0.02%

Table 10: Results for the change in the production of the sectors

For the remaining macroeconomic indicators, this measure has a positive (though small) impact. We see that GDP (Figure 25), as well as household income, utility, consumption, and employment (Figure 26) all increase by 0.01% in the most extreme scenario. Investment demand is up by 0.6% (Figure 27).

#### GDP based on spending approach (€M)

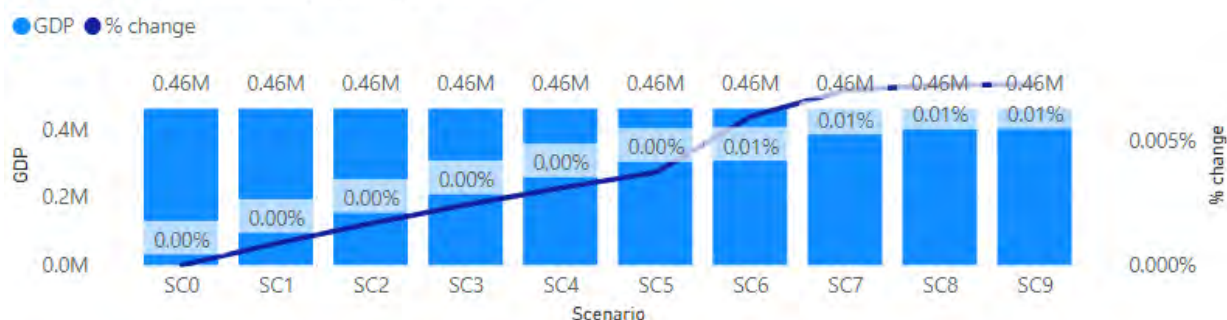


Figure 25: GDP based on spending approach in million euros

#### Input of labour (in M hours)



Figure 26: Input of labour in million hours

## Volume of investment demand (in M units)

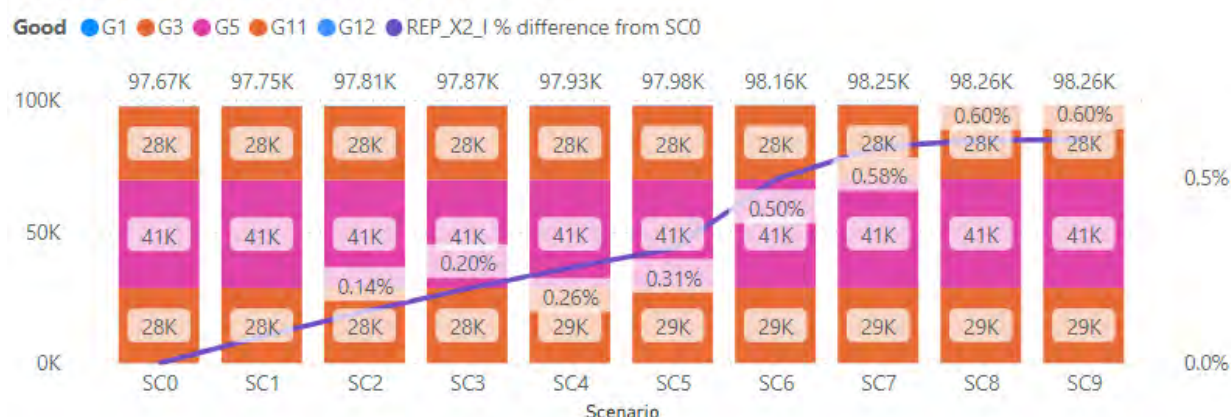


Figure 27: volume of investment demand in million units

## Conclusions

If trade barriers are installed for exporting W&R commodities to RoW countries, model results indicate that:

- The total W&R commodity output decreases indicating that (without additional measures), these waste flows will not (yet) be processed in full by the (domestic) sector (potentially just incinerated<sup>9</sup> with an additional cost for the producer);
- The investment demand increases potentially indicating a need for additional capacity or increased productivity to absorb the reduction in export in the future domestically, and
- A positive impact on employment, GDP and household utility.

These results need to be interpreted whilst being mindful of disclaimers from pages 18 & 19.

## Sensitivity analysis

### Increasing energy prices

The results for the first measure in the context of an increased energy price are in line with the results observed earlier. The results can be found in Table 11. The change in the production per sector is shown on the left. The impact remains similar, though for some sectors the effect is more pronounced. The impact on employment also remains similar. In scenario 9, the employment increases from 6.26% to 7.07%. Next, the impact on trade balance is similar but steeper given the disturbed balance due to higher energy prices.

<sup>9</sup>In Flanders, landfill and incineration bans for waste whose properties make it eligible for reuse or recycling with currently available techniques have been installed. The bans apply both to landfilling and incineration within Flanders and to collection and disposal for dumping and incineration outside Flanders. However, in the model no waste related regulation has (yet) been introduced. Therefore, the model results deviate from what is allowed by (region specific) regulation.

Furthermore, the impact on household consumption and utility is more pronounced (from 5.86% decrease in consumption in the most extreme scenario to 7.44%). This can be explained by the fact that their budget had already shrunk as a result of higher energy prices and corresponding consumer good price rises. As a result another rise in prices hits even harder. The same is true for investment demand. Given the reduced demand for investments due to the increased energy prices (almost halved), the impact of an increase in recycled input and corresponding trade balance shift result in a similar absolute impact but a doubled relative impact. Also the GDP decrease is more pronounced (from 7% to 8%).

Sector	% change production			
	SC1		SC9	
Waste & recycling	11.86%	12.27%	229.05%	253.01%
Nonmarket services	0.04%	0.04%	1.39%	1.42%
Market services	0.50%	0.53%	16.35%	17.40%
Logistics & mail	0.20%	0.25%	7.79%	9.70%
Air transport	0.18%	0.23%	7.43%	8.99%
Water transport	-0.18%	-0.23%	-5.51%	-7.06%
Land transport	0.05%	0.09%	2.55%	3.91%
Retail	-0.30%	-0.35%	-9.61%	-11.27%
Construction	1.91%	2.98%	58.81%	89.06%
Energy	0.52%	0.63%	29.76%	33.29%
Manufacturing	-2.29%	-2.24%	-65.52%	-63.49%
Mining	3.35%	5.88%	141.18%	222.26%
Agriculture	-0.91%	-0.93%	-27.14%	-27.30%
Total	-0.07%	-0.08%	-1.37%	-1.88%

No sensitivity
  Sensitivity applied

*Table 11: Results for the change in the production of the sectors from imposing a minimum recycled input and the comparison with increased energy prices.*

The results for the second measure, enabling high quality recycling, can be found in Table 12. The impact on production volume and pricing for the W&R sector is in line with the baseline scenario, the same holds for the other sectors. Also results for the trade balance, GDP, and household utility are similar. For investment demand the absolute impact is similar, but the relative impact is higher due to a steep reduction in the 'baseline' investment demand as a result of high energy price.

Sector	% change production			
	SC1		SC9	
Waste & recycling	3.98%	3.89%	206.22%	200.94%
Nonmarket services	-0.01%	-0.01%	-0.28%	-0.29%
Market services	-0.03%	-0.04%	-1.42%	-1.54%
Logistics & mail	-0.02%	-0.02%	-0.69%	-0.79%
Air transport	-0.02%	-0.03%	-0.86%	-1.08%
Water transport	0.02%	0.03%	0.93%	1.18%
Land transport	0.01%	0.01%	0.33%	0.29%
Retail	-0.01%	0.00%	-0.08%	-0.02%
Construction	-0.12%	-0.21%	-5.35%	-8.96%
Energy	-0.01%	-0.02%	-0.53%	-1.21%
Manufacturing	0.00%	0.01%	0.60%	0.65%
Mining	-0.02%	-0.06%	-1.67%	-3.75%
Agriculture	-0.01%	-0.01%	-0.22%	-0.18%
Total	0.02%	0.02%	1.22%	1.38%

No sensitivity
  Sensitivity applied

Table 12: Results for the change in the production of the sectors from enabling high quality recycling and the comparison with increased energy prices.

The results in the context of an increased energy price and a tax on export to the rest of the world are in line with the results observed earlier. The W&R sector exports show a similar downward trend, the same relative changes in production are observed (see Table 13). Furthermore, the trade balance (exports & imports), GDP, household utility, and investment demand show similar relative impacts. Again the relative impact of investment demand is higher due to steep reduction in 'baseline' investment demand as a result of high energy price.

Sector	% change production			
	SC1		SC9	
Waste & recycling	-1.08%	-1.13%	-8.99%	-9.40%
Nonmarket services	0.00%	0.00%	0.00%	0.00%
Market services	0.01%	0.01%	0.06%	0.07%
Logistics & mail	0.00%	0.00%	0.00%	0.00%
Air transport	0.00%	0.00%	0.03%	0.04%
Water transport	-0.01%	-0.01%	-0.08%	-0.10%
Land transport	-0.01%	-0.01%	-0.08%	-0.09%
Retail	0.00%	0.00%	0.02%	0.02%
Construction	0.06%	0.10%	0.46%	0.86%
Energy	0.00%	0.00%	-0.01%	0.00%
Manufacturing	0.01%	0.01%	0.06%	0.06%
Mining	0.00%	0.00%	-0.03%	-0.04%
Agriculture	0.00%	0.00%	0.03%	0.03%
Total	-0.00%	-0.00%	-0.02%	-0.02%

No sensitivity
  Sensitivity applied

Table 13: Results for the change in the production of the sectors from enabling high quality recycling and the comparison with increased energy prices.

## Conclusions

When the CEAP waste & recycling (policy) measures are applied to an economy with significantly higher energy prices:

- The waste and recycling sector responds in a similar way;
- Other sectors and market actors behave similarly as in the 'baseline' economy;
- Most pronounced is the decline in investment demand due to the higher energy prices, however absolute impacts are the same for both economies (but in relative terms the impact is more pronounced in the face of higher energy prices);
- Based on these simulation results, we have no reason to believe these policy measures will impact differently when faced with higher energy prices.

## Increasing elasticity of substitution

In the case of the first measure, increasing the share of waste and recycled materials as input, when primary and secondary goods are more substitutable (the less difference there is between using virgin inputs in your production process and using recycled inputs), the less the manufacturing sector is impacted by a minimum recycled input measure. Consequently, the decline in the manufacturing activity becomes less pronounced while the increase in W&R activity becomes more pronounced given there is now more production of manufacturing goods at the same recycled input share. Furthermore, changes in import and export are less pronounced, and as a consequence the increase in investment demand is too. Finally, household utility and GDP are less affected.

For the second measure, enabling high quality recycling, higher substitutability leads to higher impact of this measure. As W&R goods and services are produced more efficiently it becomes increasingly interesting to use them as substitutes for other intermediate inputs. Consequently, there is a larger increase in W&R output and a decreased demand for other intermediates. Furthermore, there is a higher uptake of W&R goods (see Figure 28). Other macroeconomic effects on import, export, GDP, household utility, and investment demand are more pronounced.



### Share of production inputs in Manufacturing sector (Elasticity 5)

Good CAP G1 G11 G12 G13 G2 G3 G5 G6 G7 G8 G9 LAB LOG NRG

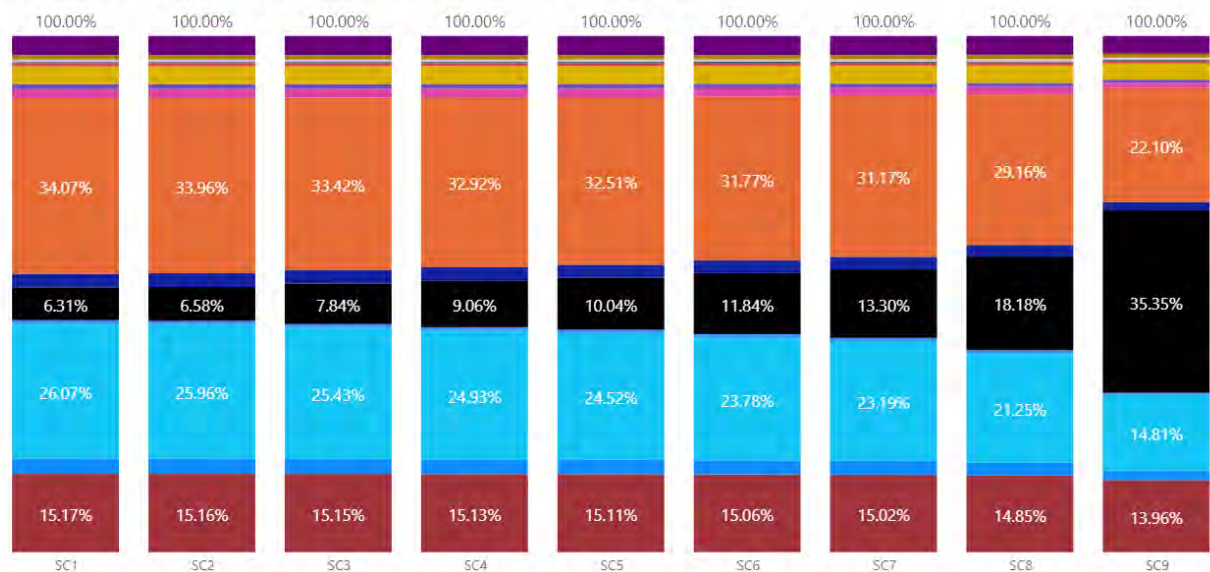


Figure 28: Share of production inputs in the manufacturing sector

The last measure, a tax on the export of waste, combined with a higher substitutability of intermediate inputs for production has the consequence that the decreased consumption from export for W&R goods is partly absorbed by more consumption from other (domestic) sectors.

### Conclusions

If virgin and recycled materials are (perceived as) better substitutes, the positive impact of the CEAP measures implemented is amplified:

- A negative impact on production due to recycled content regulations is mitigated;
- an increased uptake of recycling goods due to higher quality recycling is more pronounced;
- Waste and recycling production decrease due to export restrictions is partly absorbed by more domestic demand.

# 4 Conclusion

This report presented an innovative way to analyse the macroeconomic consequences of an increased uptake of the waste and recycling (W&R) sector. This research is in line with the Circular Economy Action Plan (CEAP) of the European Commission and contributes to the Green Deal (European Commission, 2020). Therefore, this research is highly relevant for policy making in this field.

For this research, we have split off the W&R sector and good from the respective NACE and CPA codes 37-39 and 46.77 in the Social Accounting Matrix (SAM) of a CGE model. An innovative aspect of our methodology is the development of three different representativeness checks to link macroeconomic statistics with the microlevel (companies) and even by making use of “novel” data types found at Inoopa (applying extensive web scraping and AI networks to correct companies NACE codes). The Belgian CGE model was used to model three policy measures derived from the CEAP chapter “less waste, more value”. These three policy measures are: (i) increasing the share of minimum recycled input, (ii) enabling high quality recycling, and (iii) restricting waste exports. Finally, we performed two sensitivity analyses, one for increased energy prices and one for increased elasticity of substitution between primary and secondary materials.

The results show that an increased uptake of recycled input causes reduced output for the manufacturing industry as this industry is forced to shift to secondary materials. Furthermore, there is a negative impact on household utility and GDP and job creation is partly filled by non-Belgian workers. We suggest that an increased uptake of recycled input should be supplemented with additional measures for mitigating negative effects on manufacturing industry.

The second policy measure, enabling high quality recycling, results in increased economic activity as well as increased household consumption and GDP. Note that the efficiency gain came for free, hence without a cost or investment. Future research could, for example, zoom in on digital product passports and make an estimation of the costs of development and roll out. In our results, assuming a “free” efficiency gain, the rebound effect is stringent. The production of the manufacturing industry increases. More W&R inputs are needed for producing the additional commodities. Though and in contrast with the “increased share of W&R materials as input” measure, the overall “recycled content” of those products won’t be affected too much.

Finally, the third policy measure of restricting waste exports to non-EU countries causes a reduction in W&R commodities domestically produced. The total production of W&R commodities decreases too but to a lesser extent. Hence, the reduced export will for a small part be compensated by an increased domestic demand. The remaining waste will be processed domestically. Furthermore, there is a positive impact on employment, investments, GDP, and household utility. We note that the results of this third policy measure are relatively small. Though cautiousness is needed. Foreign countries are in our model considered as “externalities” and so, their possible reaction towards such a measure is not modelled.



The sensitivity analyses of increased energy prices and increased elasticity of substitution influence the results in similar directions as the former results. The W&R sector and other actors respond in a similar way, however, the negative impact on production is mitigated when a higher elasticity of substitution is applied. This can be explained by the higher substitutability of recycled input and conventional input, which eases the change in production processes for the manufacturing sector. We conclude that increased energy prices barely affect (or even enlarge) the results. A better substitution between recycled input and conventional input is beneficial for the manufacturing sector to counter their decreased production when being forced to switch their inputs.

To conclude, CGE models take into account the interdependencies between different sectors, agents and markets in the economy and therefore they shed light on the wider economic impact of policies often revealing indirect and sometimes even unintended effects. For this research a modelling approach linking macro- and micro level data and using novel data types has been developed and applied to CE oriented policy measures for the Waste & Recycling sector. With this research it is demonstrated that many different policy measures can be modelled and consequently its macroeconomic direct and indirect effects estimated. As the model heavily relies on economic theory, and hence miss a behavioural aspects, the model value lies in assisting the policy making process (and not in predicting or simulating effects).

# Annex A

Table A.1: List of commodities in the Belgian SAM

PRODCOM	Name	SAM
01	Products of agriculture, hunting and related services	G1
02	Products of forestry, logging and related services	G1
03	Fish and other fishing products; aquaculture products; support services to fishing	G1
05-09	Mining and quarrying	G2
10-12	Food products; beverages; tobacco products	G3
13-15	Textiles; wearing apparel; leather and related products	G3
16	Wood and products of wood and cork, except furniture; articles of straw and plaiting materials	G3
17	Paper and paper products	G3
18	Printing and recording services	G3
19	Coke and refined petroleum products	G4
20	Chemicals and chemical products	G3
21	Basic pharmaceutical products and pharmaceutical preparations	G3
22	Rubber and plastics products	G3
23	Other non	G3
24	Basic metals	G3
25	Fabricated metal products, except machinery and equipment	G3
26	Computer, electronic and optical products	G3
27	Electrical equipment	G3
28	Machinery and equipment n.e.c.	G3
29	Motor vehicles, trailers and semi	G3
30	Other transport equipment	G3
31-32	Furniture; other manufactured goods	G3
33	Repair and installation services of machinery and equipment	G3
35	Electricity, gas, steam and air conditioning	G4
36	Natural water; water treatment and supply services	G3
37-39	Sewerage services; sewage sludge; waste collection, treatment and disposal services; materials recovery; remediation services and other waste management services	G3
41-43	Constructions and construction works	G5
45	Wholesale and retail trade and repair services of motor vehicles and motorcycles	G6
46	Wholesale trade services, except of motor vehicles and motorcycles	G6
47	Retail trade services, except of motor vehicles and motorcycles	G6
49	Land transport services and transport services via pipelines	G7
50	Water transport services	G8
51	Air transport services	G9
52	Warehousing and support services for transportation	G10
53	Postal and courier services	G10
55-56	Accommodation and food services	G6
58	Publishing services	G11
59-60	Motion picture, video and television programme production services, sound recording and music publishing; programming and broadcasting services	G11
61	Telecommunications services	G11
62-63	Computer programming, consultancy and related services; information services	G11
64	Financial services, except insurance and pension funding	G11
65	Insurance, reinsurance and pension funding services, except compulsory social security	G11
66	Services auxiliary to financial services and insurance services	G11
68	Real estate services	G11
69-70	Legal and accounting services; services of head offices; management consulting services	G11

71	Architecture and engineering services; technical testing and analysis services	G11
72	Scientific research and development services	G11
73	Advertising and market research services	G11
74-75	Other professional, scientific and technical services; veterinary services	G11
77	Rental and leasing services	G11
78	Employment services	G11
79	Travel agency, tour operator and other reservation services and related services	G11
80-82	Security and investigation services; services to buildings and landscape; office administrative, office support and other business support services	G11
84	Public administration and defence services; compulsory social security services	G12
85	Education services	G12
86	Human health services	G12
87-88	Residential care services; social work services without accommodation	G12
90-92	Creative, arts and entertainment services; library, archive, museum and other cultural services; gambling and betting services	G12
93	Sporting services and amusement and recreation services	G12
94	Services furnished by membership organisations	G12
95	Repair services of computers and personal and household goods	G12
96	Other personal services	G12
97	Services of households as employers of domestic personnel and undifferentiated goods and services produced by private households for own use	G12

*Table A.2: List of activities in the Belgian SAM*

NACE	Name	SAM
01	Crop and animal production, hunting and related service activities	S1
02	Forestry and logging	S1
03	Fishing and aquaculture	S1
05-09	Mining and quarrying	S2
10-12	Manufacture of food products, beverages and tobacco products	S3
13-15	Manufacture of textiles, wearing apparel and leather products	S3
16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	S3
17	Manufacture of paper and paper products	S3
18	Printing and reproduction of recorded media	S3
19	Manufacture of coke and refined petroleum products	S4
20	Manufacture of chemicals and chemical products	S3
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	S3
22	Manufacture of rubber and plastics products	S3
23	Manufacture of other non-metallic mineral products	S3
24	Manufacture of basic metals	S3
25	Manufacture of fabricated metal products, except machinery and equipment	S3
26	Manufacture of computer, electronic and optical products	S3
27	Manufacture of electrical equipment	S3
28	Manufacture of machinery and equipment n.e.c.	S3
29	Manufacture of motor vehicles, trailers and semi-trailers	S3
30	Manufacture of other transport equipment	S3
31-32	Manufacture of furniture; other manufacturing	S3
33	Repair and installation of machinery and equipment	S3
35	Electricity, gas, steam and air conditioning supply	S4
36	Water collection, treatment and supply	S3
37-39	Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services	S3
41-43	Construction	S5
45	Wholesale and retail trade and repair of motor vehicles and motorcycles	S6
46	Wholesale trade, except of motor vehicles and motorcycles	S6

47	Retail trade, except of motor vehicles and motorcycles	S6
49	Land transport and transport via pipelines	S7
50	Water transport	S8
51	Air transport	S9
52	Warehousing and support activities for transportation	S10
53	Postal and courier activities	S10
55-56	Accommodation; food and beverage service activities	S6
58	Publishing activities	S11
	Motion picture, video and television programme production, sound recording and music publishing activities; programming and broadcasting activities	S11
59-60	Telecommunications	S11
61	Computer programming, consultancy and related activities; information service activities	S11
62-63	Financial service activities, except insurance and pension funding	S11
64	Insurance, reinsurance and pension funding, except compulsory social security	S11
65	Activities auxiliary to financial services and insurance activities	S11
66	Real estate activities	S11
68	Legal and accounting activities; activities of head offices; management consultancy activities	S11
69-70	Architecture and engineering activities; technical testing and analysis	S11
71	Scientific research and development	S11
72	Advertising and market research	S11
73	Other professional, scientific and technical activities; veterinary activities	S11
74-75	Rental and leasing activities	S11
77	Employment activities	S11
78	Travel agency, tour operator reservation service and related activities	S11
79	Security and investigation activities; services to buildings and landscape activities; office administrative, office support and other business support	S11
80-82	Public administration and defence; compulsory social security	S12
84	Education	S12
85	Human health activities	S12
86	Social work activities	S12
87-88	Creative, arts and entertainment activities; libraries archives, museums and other cultural activities; gambling and betting activities	S12
90-92	Sports activities and amusement and recreation activities	S12
93	Activities of membership organisations	S12
94	Repair of computers and personal and household goods	S12
95	Other personal service activities	S12
96	Activities of households as employers of domestic personnel and undifferentiated goods and services production of households for own use	S12
97		S12

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