

Who is in charge? An analysis of waste electrical and electronic equipment management in Brussels

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EDITOR'S NOTE

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AUTHOR'S NOTE

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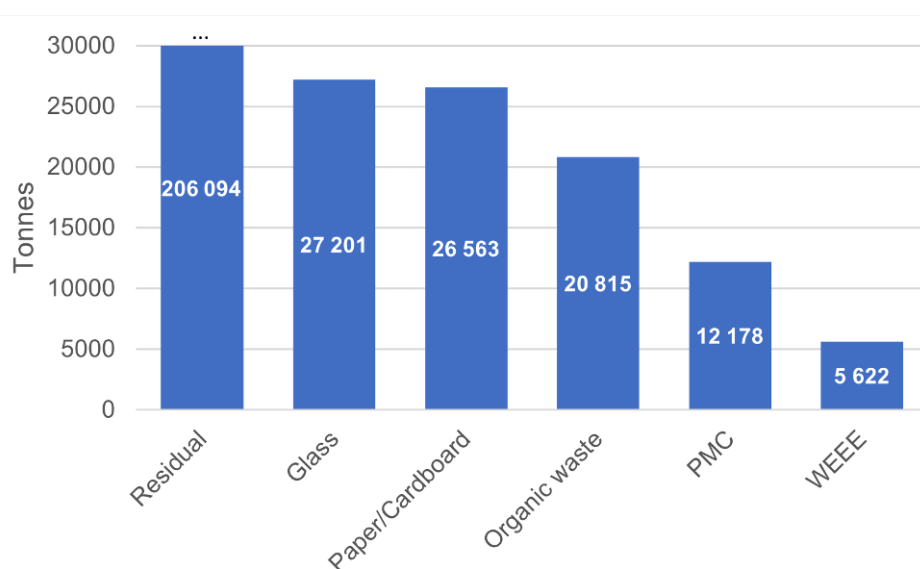
Introduction

- 1 Although little publicised, it is probably one of the most important judicial sagas of recent years involving a Brussels public administration: on May 4, 2018, the Brussels Court of First Instance condemned Bruxelles-Propreté, the public administration in charge of household waste collection, for illegal state aid [Deglume, 2019]. This conviction followed years of (still ongoing [Sente, 2020]) disputes between Denuo (representing companies active in waste management) and Bruxelles-Propreté. At the

heart of this case were the waste collection operations of Bruxelles-Propreté in competitive sectors, particularly those of domestic waste electrical and electronic equipment, considered by Bruxelles-Propreté as household waste.

- 2 *Waste electrical and electronic equipment (also referred to as WEEE or e-waste)* is “a term used to cover items of all types of electrical and electronic equipment and its parts that have been discarded by the owner as waste without the intention of re-use” [StEP Initiative, 2014]. This definition integrates prepare-for-reuse activities, consisting of operations (such as repairing, refurbishing, or remanufacturing) bringing a used product or its components into a condition that meets the requirements of a next potential user. However, it excludes redistribution activities, both direct (for example through online platforms or garage sales) and indirect (for example through a second-hand retailer) [Paden and Stell, 2005].
- 3 WEEE contains hazardous substances that can harm human health and the environment [Kiddee *et al.*, 2013], as well as materials that have both a strategic importance for the economy and a risk of supply shortage [Buchert *et al.*, 2012; Blengini *et al.*, 2020]. In order to ensure adequate treatment of WEEE, the European law holds producers of electrical and electronic equipment responsible for managing their products at their end of life. This system is called an *extended producer responsibility (EPR)* [Lindhqvist, 2000]. In Belgium, waste directives are transposed at regional level. The current waste legislation of the Brussels-Capital Region adopts the European EPR approach and aligns its objectives with the European targets [European Parliament and Council of the European Union, 2012; Région de Bruxelles Capitale, 2016]. The Region also has the ambition to increase the volume of domestic WEEE (1) collected and (2) prepared-for-reuse by 50 % each between 2017 and 2024 [Région de Bruxelles Capitale, 2018]. In 2019, 5622 tonnes of WEEE were collected in the Brussels-Capital Region (Figure 1; for a deeper overview of waste flows in Brussels, see Zeller *et al.* [2019]). This corresponds to 4,65 kg/inhabitants [Recupel, 2020], which is more than twice below the national average (10,77 kg/inhabitants) [Eurostat, 2021]. Different aspects can explain this lower collection rate in Brussels. A first explanation is related to a lower production of WEEE. Indeed, Brussels’ households claim to discard 15 % less WEEE than the Belgian average [GfK, 2018]. Yet, this only partly explains the difference. A second explanation could be related to statistical artefacts, as WEEE produced in Brussels could be accounted for in the data of other regions. For example, two large retailers send all WEEE they collect to their Flemish warehouses. However this is already accounted for in the above-mentioned estimates. Finally, WEEE can be collected through unregistered channels [Habib *et al.*, 2022]. These channels represent more than 50 % of WEEE collected in Belgium, of which only 20 % is documented [Deloitte, 2018].

Figure 1. Tonnes of domestic waste collected in the Brussels-Capital Region in 2019



Sources: Bruxelles-Propreté [2020]; Recupel [2020]

- 4 Although there is no unique explanation for the lower collection rate in the Brussels-Capital Region, collection through unregistered channels seems to play an important role. WEEE contains a residual value which many stakeholders are eager to capture. This leads to conflicting demands regarding waste collection and recovery [Mayers and Butler, 2013]. The purpose of the present article is to *understand the roles of each stakeholder in the current WEEE management system of the Brussels-Capital Region*. By doing so, it aims to better describe the role of unregistered channels and their stakeholders in the management of WEEE in Brussels, and to provide ways to limit the volume of WEEE entering these channels. After introducing the different stakeholders active in WEEE management (section 1), an analysis of the networks formed by their relationships is presented (section 2) and suggestions to limit the extent of unregistered channels are provided¹ (section 3).

1. Stakeholders in the management of domestic WEEE in the Brussels-Capital Region

- 5 The management of WEEE involves many actors active in different stages of the life cycle of electrical and electronic equipment. The present article further considers stakeholders of the EPR system, i.e. any group or individual who can affect or is affected by the achievement of the objectives of producers (as responsible entities) in terms of WEEE management [Freeman, 1984]. More precisely, it considers as a stakeholder any person (moral or physical) with an interest, be it monetary or not, in domestic WEEE produced in Brussels. The following part introduces such stakeholders and describes their activities related to waste management. Stakeholders were primarily identified through desktop research, using regional (e.g. Godart *et al.* [2011] or PwC [2012]), national (e.g. Huisman [2013] or Deloitte [2018]), and international (e.g. Baldé *et al.* [2015] or Huisman *et al.* [2015]) sources. Semi-structured interviews were then conducted with stakeholders in charge of supervising WEEE management in

Brussels (Bruxelles Environnement and Recupel) in order to validate the list of stakeholders for Brussels, and to potentially add new ones. Identified stakeholders were grouped based on their activities (both primary (main) and secondary) in order to enable further analysis (Table 1). Additionally, stakeholders primarily active in consolidation, transport or recycling were subdivided based on their relationship with the EPR system in order to allow structural equivalence [Lorrain and White, 1971; Sailer, 1978].

Table 1. Stakeholders and their activities (both primary and secondary) in the EEE life cycle

Name	Production	Distribution	Usage	Waste management				
				Supervision	Collection	Consolidation & Transport	Prepare-for-reuse	Recycling
Manufacturers	Primary			Secondary				
Importers		Primary		Secondary				
Wholesalers		Primary				Secondary		
Retailers		Primary			Secondary	Secondary		
Delivery companies		Primary			Secondary			
Consumers			Primary					
Recupel				Primary				
Bruxelles Environnement				Primary				
Municipalities					Primary			
Bruxelles-Propreté					Primary	Secondary		
Waste pickers					Primary			
Finely-meshed collection subcontractor						Primary		
Chartered collectors						Primary		
Scrap dealers						Primary		
Transport in bulk subcontractor						Primary		
Exporters						Primary		
Reuse centres					Secondary	Secondary	Primary	
Contracted recyclers								Primary
Chartered recyclers								Primary
Scrap recyclers								Primary

Source: Authors' fieldwork [2020]

1.1. Stakeholders in the supervision of WEEE management

- 6 The Brussels legislation makes *manufacturers* and *importers* accountable for the WEEE they put on the market. In practice, Belgian manufacturers created one collective take-back scheme, managed by a “producer responsibility organisation”, *Recupel*, to delegate this responsibility. Individual take-back initiatives by manufacturers are negligible for domestic WEEE [Deloitte, 2018]. In addition to drafting waste regulations, *Bruxelles Environnement* monitors *Recupel*'s operations and provides it with guidelines through “environmental conventions”.
- 7 *Recupel* manages both domestic and professional WEEE. It classifies WEEE in six categories², based on recycling requirements: (1) big white goods (BW), consisting of large household appliances, such as washing machines or ovens; (2) cooling & freezing equipment (CF), such as refrigerators or air conditioners; (3) screens (TVM); (4) other WEEE (OTH) grouping all devices that cannot fit in another category; (5) lamps (LMP); and (6) fume detectors (FD). The present work will focus on the first four categories, as lamps, fume detectors and professional WEEE are managed differently.
- 8 Domestic WEEE management always starts with *consumers* disposing of used products. To finance its operations, *Recupel* collects a financial contribution (or advanced recycling fee [Nixon *et al.*, 2007]) with each product sold. In exchange, consumers have access to *Recupel* services for free. To encourage them to use their system, *Recupel* has to inform consumers about how they can dispose of their WEEE. Yet, it does not perform any logistics operations: it works with a network of collection points and subcontracts transport and treatment operations.

1.2. Stakeholders in WEEE collection

- 9 To collect WEEE, Recupel directs consumers towards retailers and container parks operating collection points on its behalf. *Retailers* selling electrical and electronic equipment are legally enjoined to take back used equipment. The law introduces two take-back obligations: a 1-for-1 obligation, requiring retailers to take back free of charge one product with a similar function for each product sold; and a 1-for-0 obligation forcing retailers to take back very small equipment (all dimensions below 25 cm) free of charge. The former theoretically extends to deliveries, affecting *delivery companies*. The latter only applies to retailers with a retailing area dedicated to electrical and electronic equipment larger than 400 m². Recupel provides retailers with in-shop recycling points to deal with this 1-for-0 obligation. Retailers collect 15 % (in units) of WEEE disposed of by Brussels' households, including 7 % through in-shop recycling points [GfK, 2018].
- 10 Consumers can also dispose of WEEE in container parks. In Belgium, *municipalities* are responsible for household waste management operations. In practice, municipalities usually join forces to create inter-municipal companies, i.e. public companies offering public services. In Brussels, *Bruxelles-Propreté*, a regional administration, acts as an inter-municipal company. It operates fixed and mobile container parks and offers a pick-up service for bulky waste, which sometimes collects electrical and electronic equipment. Several municipalities also operate fixed and mobile container parks, as well as pick-up services. Public authorities collect 42 % of disposed of WEEE (in units) in the Brussels-Capital Region, 35 % in container parks, and 7 % alongside bulky waste [GfK, 2018]. *Bruxelles-Propreté* can also collect WEEE with household waste (white bags), an option that is particularly significant in Brussels, where it is used twice as much (8 % of WEEE in units) as in other regions [GfK, 2018].
- 11 For products that can be reused, consumers are also directed towards *reuse centres* preparing WEEE for reuse and selling it. From an economic point of view, preparation for reuse may be limited by hoarding behaviours [Wilson *et al.*, 2017; Thiébaud (-Müller) *et al.*, 2018] that impact products with a high time-sensitive residual value in particular, such as IT [Gobbi, 2011]. From an ecological point of view, environmental benefits depend greatly on the energy efficiency of products [Boldoczki *et al.*, 2020; Pini *et al.*, 2019]. These limitations restrict the scope of WEEE prepared for reuse, which consists mainly of large equipment and IT products (such as smartphones or laptops). While large equipment mainly comes from households, IT products mainly come from companies due to a larger homogeneity in quality and more recent equipment. Companies active in preparing IT for reuse are, therefore, considered to be outside the scope of the present paper. There are two social enterprises active in preparing domestic WEEE for reuse in Brussels, both of which are members of Ressources, the professional association that represents the interests of social enterprises active in prepare-for-reuse in Wallonia and Brussels. Ressources has an agreement with Recupel allowing its members to access products collected through the Recupel network. In exchange, Ressources members commit to recycling all the equipment they cannot prepare for reuse through the Recupel system. Reuse centres only account for 3 % of disposed of WEEE in Brussels, far behind consumer-to-consumer reuse initiatives (24 %) [GfK, 2018].

- 12 Finally, consumers can participate in unofficial collection channels, for example by dumping their WEEE in the street, later collected by *waste pickers* [Florin and Garret, 2019]. Waste pickers also collect WEEE intended to be collected by the Bruxelles-Propreté's bulky waste collection service. Waste pickers usually sell WEEE they collect to chartered collectors or scrap dealers.

1.3. Stakeholders in WEEE consolidation and transport

- 13 Once collected, WEEE must be transferred to a reprocessing (e.g. recycling) facility. While some stakeholders have sufficient storage space to send a full container to recycling, others (e.g. small retailers) lack such storage space. WEEE coming from these stakeholders must therefore be consolidated first, that is collected and stored in a warehouse referred to as a transshipment centre, until there is enough to send a full container to recycling. In the Recupel system, the collection of WEEE to be consolidated is termed "finely meshed". It is performed by a *subcontractor* which also operates the transshipment centre and deals with the redistribution to reuse centres. This role was allocated to Bruxelles-Propreté from the start of the EPR system in 2001, but this allocation created many tensions [Van Ruymbeke, 2018] which led to the conviction of Bruxelles-Propreté and a change of subcontractor in 2020. Nonetheless, Bruxelles-Propreté still consolidates WEEE collected in container parks (regional and municipal). Retailers can also give WEEE back to their *wholesalers*, also subject to the 1-for-1 take-back obligation. Parallel to the Recupel system, stakeholders collecting WEEE can also forward it to companies active in trading and pre-processing WEEE. Some of them are approved by Recupel as *chartered collectors*. Others are not approved and act as *scrap dealers*. Charters only relate to a specific WEEE category and chartered collectors can therefore be considered as scrap dealers for other WEEE categories.
- 14 Once a WEEE container is full, it is sent to recycling. Recupel provides this "bulk" transport to its partners, performed by a *subcontractor* and routed to a *contracted recycler*. In addition, according to their contracts, chartered collectors must send the WEEE they collect to *chartered recyclers*, while scrap dealers can sell it to *scrap recyclers* (9 % of WEEE produced (in weight) in Belgium is recycled as scrap) or *exporters* (3 % of WEEE produced (in weight) in Belgium is exported illegally, mostly from the port of Antwerp [Huisman *et al.*, 2015; Deloitte, 2018]). From a Brussels perspective, recycling largely stands for export outside the Region, with only one Brussels recycler being chartered (but not contracted) by Recupel.

2. Interactions between stakeholders in the WEEE management system

- 15 A significant source of power comes from the position of a stakeholder in a network of stakeholders [Cook *et al.*, 1983; Markovsky and Willer, 1988]. This position impacts the influence a stakeholder has on others, and thereby its capability to support its interests. It will therefore direct the strategies stakeholders adopt to reorganise the network. To uncover this source of power, we analysed the network structure induced by WEEE management in Brussels, using a sociocentric approach.

- 16 In order to investigate a social network, an analysis of relational data must be carried out, modelling the relations between stakeholders. The network around WEEE management is fundamentally a supply network, in that many stakeholders consider WEEE as a source of secondary supply. Hence, the present analysis considers resources usually exchanged in supply chains, i.e. *product*, *information* and *financial* flows³ [Mentzer *et al.*, 2001; Sarkis, 2012], as ties (relations). Exchange of resource flows (and therefore ties) are directed. In addition, we considered a binary network (ties are either present or absent, but not weighted) due to a lack of data availability⁴ and difficulty in quantifying information flows. Data on the presence of flows between stakeholder groups were initially collected using desktop research, starting from the Recupel network. Semi-structured interviews were then conducted by phone with involved stakeholders to validate formal ties and identify informal ones. These were performed either with professional associations or with a sample of stakeholders. Additional clarifications were requested by email when needed. The analysed social networks represent the state of the system as of January 2022. Nonetheless, social networks are fundamentally dynamic, and relational data are sometimes supplemented by qualitative data on the changes the authors observed during the past three years.
- 17 Several positions are particularly strategic (or central [Das *et al.*, 2018]) in a social network [Burt, 1976]. A first set of such positions are granted to prominent stakeholders, that is those with many ties [Wasserman and Faust, 1994]. In a directed network, these stakeholders can either have influence or prestige, characterised by high degree centrality [Freeman, 1978]. Influence relates to the outdegree of a node (number of ties starting from that node), while prestige relates to its indegree (number of ties coming to the node). A second advantageous position is the broker position [Gould and Fernandez, 1989]. This position is particularly strategic, in that it bridges two otherwise unconnected networks. It is characterised by a large betweenness centrality (defined by the number of times a stakeholder is in the shortest path linking two other stakeholders [Freeman, 1977]). Such a centrality measure is less suited to directed networks, not accounting for the direction of a tie, but remains quite interesting for transferable flows such as used goods [Borgatti, 2005]. Centrality measures supporting these positions were obtained using the UCINET software [Borgatti *et al.*, 2002] and are presented in Table 2. Figures were created based on geodesic distances using NetDraw.

Table 2. Centrality measures of the WEEE network

Stakeholders	Product			Information			Money		
	Influence (Outdegree)	Prestige (Indegree)	Brokerage (Betweenness)	Influence (Outdegree)	Prestige (Indegree)	Brokerage (Betweenness)	Influence (Outdegree)	Prestige (Indegree)	Brokerage (Betweenness)
Manufacturers	0	0	0	1	1	0	1	3	4,97
Importers	0	0	0	1	1	0	2	2	4,97
Recupel	0	0	0	7	10	30,41	4	2	10,82
Bruxelles Environnement	0	0	0	0	1	0	0	1	0
Consumers	5	0	0	3	3	11,40	4	0	0
Municipalities	3	1	0,15	3	0	0	0	1	0
Delivery companies	1	1	0	0	1	0	0	1	0
Waste pickers	2	0	0	0	0	0	0	2	0
Bruxelles-Propreté	1	3	0,15	2	2	0,68	0	1	0
Retailers	7	2	5,41	2	1	3,90	4	4	10,53
Wholesalers	4	1	0,44	1	0	0	2	3	3,80
Finely-meshed collection subcontractor	2	2	0	0	1	0	0	1	0
Chartered collectors	2	3	2,05	1	0	0	2	2	2,05
Scrap dealers	3	3	2,19	0	0	0	3	3	4,68
Transport in bulk subcontractor	1	5	2,92	0	1	0	0	1	0
Exporters	0	2	0	0	0	0	2	0	0
Reuse centres	1	4	0,15	1	1	0,68	0	0	0
Contracted recyclers	0	1	0	1	1	0	0	1	0
Chartered recyclers	0	2	0	1	0	0	2	0	0
Scrap recyclers	0	2	0	0	0	0	2	0	0

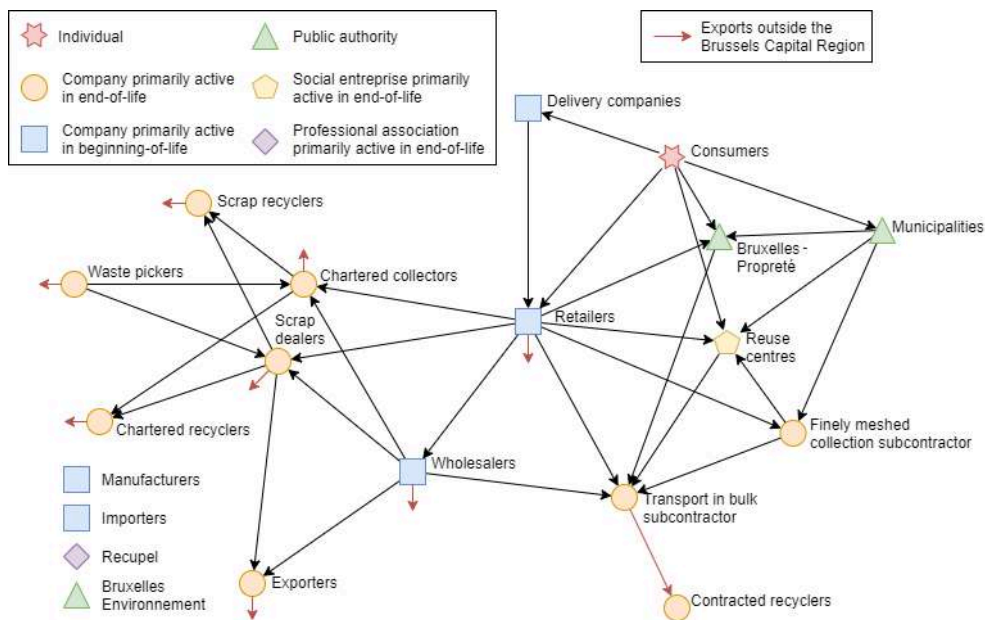
The higher the outdegree, the more a stakeholder can influence the direction of flows. The higher the indegree, the more a stakeholder centralises flows. The higher the betweenness, the more likely a stakeholder is to serve as an intermediary between other stakeholders.

Source: Authors' fieldwork [2020; updated in 2022]. Computed with UCINET

2.1. Circulation of used products

- 18 The analysis of the used product network reveals the presence of two parallel subnetworks: the Recupel network for domestic WEEE (on the right in Figure 2) and a less formal market-based network (on the left in Figure 2). The latter includes stakeholders chartered by Recupel for professional WEEE as well as stakeholders fully operating outside the Recupel ecosystem. Those two subsystems follow different approaches with different interests: the Recupel network aims at minimising costs, while the market-based network aims at maximising revenue. Stakeholders primarily active in distribution (retailers and wholesalers) are situated in between and can opt for either subnetwork. They therefore have a key position to channel WEEE, as can be seen by the high level of influence and brokerage (Table 2). This position is strengthened by the take-back obligations giving them access to WEEE. Hence, the distribution sector constitutes a major source of supply for the market-based network. Another source of supply comes from gleaning by waste pickers. Due to its illegal nature, this type of activity is hard to quantify. Waste pickers operate on the margins of the system, as illustrated by their null indegree. Despite there being no ties between them, much of the WEEE collected by waste pickers comes from consumers indirectly, who play a pivotal role in the channelling of WEEE by being at the origin of any used product flow.

Figure 2. Network of product flows exchanged between stakeholders

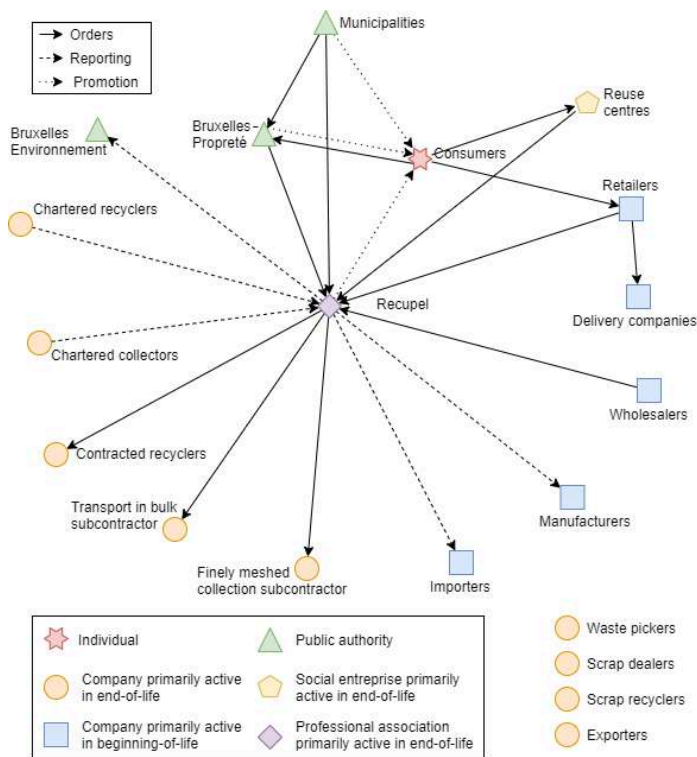


Source: Authors' fieldwork [2020; updated in 2022]. Layout obtained using Netdraw

2.2. Circulation of information

- 19 Different types of information are exchanged by stakeholders in the WEEE management system. These may concern collection orders, reporting or promotion. An analysis of information flows uncovers the highly centralised nature of the Recupel network (Figure 3), with most information transiting through Recupel (as underlined by its high influence, prestige and brokerage shown in Table 2). This control of information by Recupel even pertains to the relationships between retailers and chartered collectors, mediated through the Smartloop⁵ platform in which Recupel acts as a market maker. Figure 3 also depicts stakeholders operating outside the Recupel ecosystem as isolates (not connected to other stakeholders). This does not mean that they have no interactions with other stakeholders, but rather that the interactions are informal and could not be traced in the present analysis. For example, they may consist in delivering WEEE directly without a prior appointment. Additionally, the information network also shows that Bruxelles Environnement, which monitors WEEE management, depends on Recupel to obtain information, either from its own network or from operations reported in the BeWEEE⁶ platform. While Bruxelles Environnement has a high level of power due to its legal prerogatives, it has a very low level of network-related power, which can lead to little control over the system. This raises a principal-agent problem, which is related to the nature of EPR systems as a public service delegation.

Figure 3. Network of information flows exchanged between stakeholders

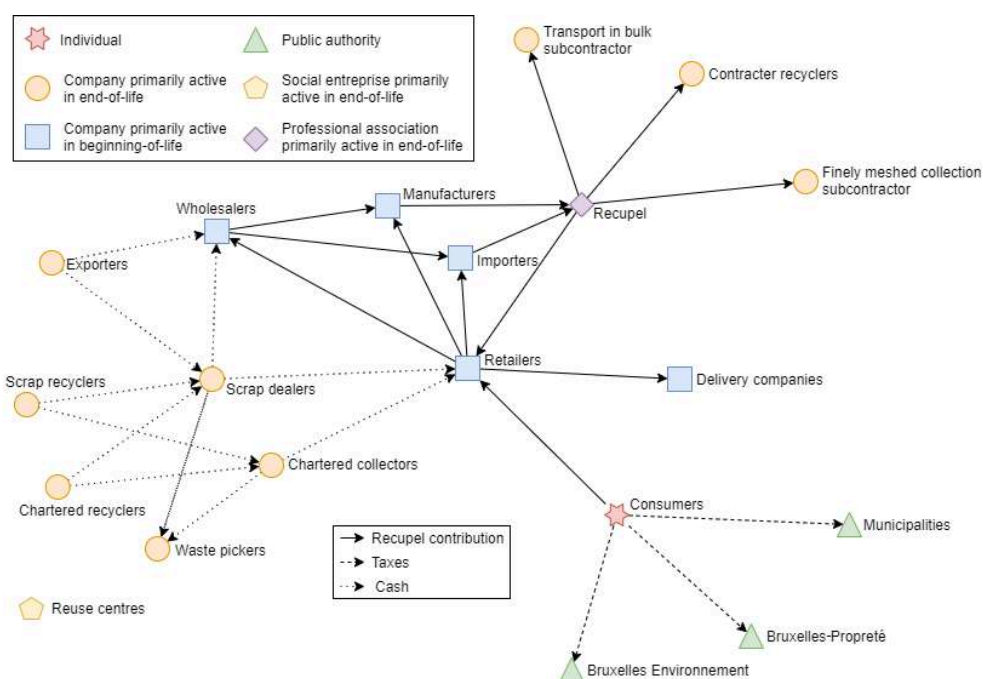


Source: Authors' fieldwork [2020; updated in 2022]. Layout obtained with Netdraw

2.3. Circulation of financial flows

- 20 Several types of financial flows support WEEE-related operations, for example taxes, cash or the Recupel contribution. Taxes and the Recupel contribution finance the Recupel network. Taxes are used for the supervision of the system and the management of public collection points, both considered as non-competitive. The use of tax-related revenue for competitive activities is what led to the trial between Denuo and Bruxelles Propreté. The Recupel contribution is used for activities open to competition and is only shared with Recupel subcontractors (on the top right of Figure 4) representing a very small fraction of all stakeholders interested in WEEE management. It was recently extended to retailers to cover their logistics costs. Such compensation might incentivise retailers to channel domestic WEEE to the Recupel network rather than to the market-based one. This market-based subnetwork only operates with cash and, therefore, only deals with economically profitable operations. Hence, the market prices of secondary materials have a great impact on the behaviour of its stakeholders. It mirrors the market-based subnetwork for used products, in that every exchange of products is directly compensated by a financial transfer. On the contrary, the Recupel subnetwork is intermediated, as producers (Recupel and its members) have a brokerage position (Table 2) which they do not occupy in the used product network.

Figure 4. Network of financial flows exchanged between stakeholders



Source: Authors' fieldwork [2020; updated in 2022]. Layout obtained using Netdraw.

3. Strategies to limit unregistered WEEE flows

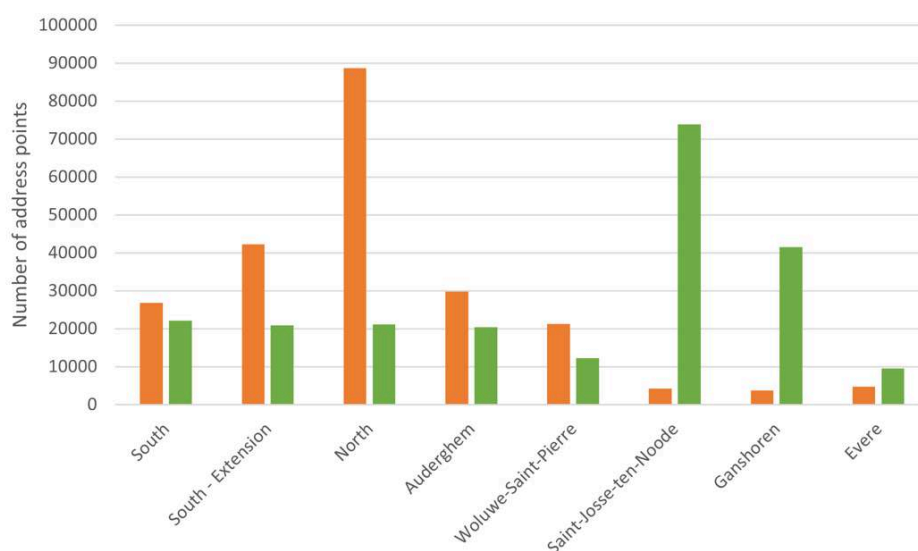
- 21 As underlined in the previous section, the social network around domestic WEEE is characterised by the presence of stakeholders operating in parallel to the Recupel system. Only a small set of collectors and recyclers have access to the WEEE collected by Recupel (which represents 45 % of all WEEE collected in Belgium [Deloitte, 2018]). Others, whose turnover depends on the volume of WEEE they process, must find alternative sources of supply. Such an alternative source of supply can come from professional WEEE. Yet, they only represent 11 % of the weight collected in Brussels [Recupel, 2020]. Hence, many companies compete with the Recupel system to access domestic WEEE. This discrepancy between high demand and limited supply creates tensions with respect to access to WEEE, exemplified by the trial between Denuo and Bruxelles Propreté. It further complicates the monitoring of WEEE management and can lead to unregistered WEEE flows. Based on the results from the previous analysis, we present two directions in order to avoid the collection of WEEE through unregistered channels by either (1) including stakeholders from the market-based subnetwork in the official WEEE management system or (2) reducing the supply of WEEE to these stakeholders through better channelling of WEEE flows.
- 22 The integration of stakeholders from the market-based subnetwork into the official WEEE management system can be done through three different approaches: a coercive approach, a deterrent approach, and an inclusive approach.
- 23 The coercive approach condemns illegal operations. The Brussels-Capital Region already fines companies which collect, transport or treat waste without the required regional approval [Région de Bruxelles-Capitale, 1999]. Illegal operations can be traced through tracking campaigns, like the one used by Recupel in 2017. Yet, this method is

costly, not very efficient (1/4 of the WEEE tracked in 2017 was lost) and might make offenders more cautious. In addition, only a portion of operations performed in the market-based subnetwork are illegal. Hence, implementing such a coercive approach is likely to require a legal obligation to redirect WEEE to the Recupel system [Kalimo *et al.*, 2015].

- 24 A deterrent approach consists in designing a system preventing the diversion of WEEE. For example, it might consist of collection methods that take into account the risk of collection by waste pickers [Friege *et al.*, 2015]. Such collection methods include collection at home instead of at curbside (as carried out currently by Bruxelles Propreté's pick-up service) or secured drop-off and storage locations.
- 25 Finally, a more inclusive approach consists in creating formal positions for informal stakeholders within the Recupel system. These positions must provide enough (financial and non-financial) incentives to convince stakeholders to join the official system [Chi *et al.*, 2011]. The creation of a new producer responsibility organisation would provide more opportunities for collectors and recyclers by dividing the market and allowing different subcontractors. However, this solution would make the system more complex, requiring the establishment of a clearing house to allocate WEEE to the different producer responsibility organisations [Kunz *et al.*, 2018]. Another way to take into account existing stakeholders within the current Recupel system consists in dropping pluriannual contracts and providing a more flexible allocation procedure, selecting different subcontractors for each shipment. This could be done through an allocation model selecting collectors and recyclers to minimise cost. As cost depends on driving distance, such an allocation could also lead to a decrease in fuel consumption and CO₂ emissions. It could be extended to collection, using the free capacity of logistics service providers [Esposito *et al.*, 2018] or taxi cabs [Chen *et al.*, 2017]. This would optimise the load factor of delivery vans and reduce the total kilometres driven, leading to environmental benefits. However, potential rebound effects might reduce such benefits, for example due to on-purpose collection trips [Buldeo Rai *et al.*, 2018].
- 26 In addition to integrating stakeholders from the market-based subnetwork into the official WEEE management system, the amount of WEEE entering unregistered channels could also be limited through better channelling at the source. As underlined by our analysis, consumers play a key role in directing product flows in the domestic WEEE network, influencing the final recovery of WEEE. They must decide whether their electrical and electronic equipment is intended to be reused or to become waste. Nonetheless, assessing the residual value of a product is complex, and consumers are likely to dispose of products that could technically be prepared for reuse [Bovea *et al.*, 2016] and have a resale value [Pocock *et al.* 2011]. Another channelling issue is related to street dumping, which may be carried out with the intention of giving used products to neighbours, but leads to collection by waste pickers. Hence, adjusting the channelling of WEEE disposed of by consumers is an efficient means to reduce the supply of WEEE to unregistered channels.
- 27 A first approach to improve the channelling of WEEE consists in improving the sorting of WEEE at the source by influencing the disposal behaviour of consumers. This can be done either by (1) raising awareness, (2) providing monetary incentives or (3) improving the convenience of collection services. Consumers are often under-informed. For example, many do not know that delivery companies should, in theory, collect their used equivalent products [Lagey *et al.*, 2017]. Thus, consumers could be

informed via awareness campaigns [Martinho *et al.*, 2017]. Awareness campaigns conducted by Recupel could be extended to target street dumping, which could be done in partnership with Bruxelles Propreté. In addition, monetary incentives could also be provided to support specific collection channels, particularly for high-value WEEE such as mobile phones [Yla-Mella *et al.*, 2015]. To reduce their cost, these incentives could take the form of deposit-refund systems [Kahhat *et al.*, 2008]. Yet, Recupel has already been advised against this solution due to high complexity and financial risks [Desmet and Hanquet, 2013]. Finally, the disposal behaviour of consumers could also be steered by aligning collection services (both public and private) with their preferences [Mansuy *et al.*, 2020]. For public collection services, the accessibility of container parks could be improved, for example by extending opening hours [Godart *et al.*, 2011] or removing restrictions regarding the municipality of residence [Arcadis, 2011]. The latter option should, however, be conducted with caution, as it might overwhelm small container parks like the ones in Saint-Josse-ten-Noode and Ganshoren (Figure 5). For private collection services, the number of in-shop recycling points (72 as of July 2019) and collection opportunities alongside deliveries could be extended. The efficiency of such an extension depends on the choice of retailers, which also play a key role in directing WEEE to registered channels. The recent adoption by Recupel of monetary compensation for retailers might prompt them to participate in the Recupel system. Nonetheless, there is still insufficient information regarding current WEEE management operations carried out by logistics service providers and retailers [Bressanelli *et al.*, 2020] and further research is needed to assess the impact of such a compensation.

Figure 5. Impact of residence-based access restrictions on the likely use of container parks



The above graph is based on the number of postal addresses which a given container park is closest to. The higher the number, the closer a container park is to many Brussels households. Access restrictions are related to the municipality in which an address point is located, with several container parks being accessible only to households in certain municipalities. The restricted access scenario (orange bars) accounts for current residence-based restrictions, while the full access scenario (green bars) assumes that any household can go to any container park.

As an example, many Schaerbeek households live closer to the container park in Saint-Josse-ten-Noode. However, they are not allowed to use that container park and are redirected to the North container park. Removing access restrictions (hence replacing the orange scenario with the green one) is likely to greatly increase the use of the container park in Saint-Josse-ten-Noode, while the North container park would be underutilised.

Please note that the graph does not directly represent the number of households. The extrapolation of the results to households depends on the distribution of households according to address point.

Source: Authors own calculations based on straight line distances, using the QGIS software

- 28 A second approach to improve the channelling of WEEE by consumers is to postpone waste sorting [Jahre, 1995]: consumers put all their WEEE in the same container, and products are later sorted centrally. This is convenient for consumers but can reduce opportunities to prepare for reuse due to damage during logistics operations [Messmann *et al.*, 2019]. In practice, the Recupel system already partially integrates such an approach by sorting products collected in shops for reuse.

Conclusion

- 29 The management of waste electrical and electronic equipment in the Brussels-Capital Region involves many stakeholders with potentially competing interests. Conflicts arise from the complex interactions between these stakeholders. This study identified stakeholders involved in such a system and analysed the relationships between them. By doing so, it identified network characteristics that could explain several issues faced by the current EPR scheme, such as the presence of a significant market-based subnetwork, a high level of centralisation and the importance of consumers and retailers in the channelling of WEEE within the network. Based on these findings, we suggested two ways to address these issues: the first one would involve the integration of existing informal practices into the official WEEE management system (either through a coercive, deterrent, or inclusive approach); and the second one would

involve directing WEEE to registered channels, notably by adjusting the disposal behaviour of consumers and by influencing the decision of retailers to participate in the Recupel system.

- 30 These proposed solutions should be implemented through enhanced collaboration between stakeholders and the strong commitment of local public authorities [Cahill *et al.*, 2011]. Collaboration between stakeholders has already led to positive outcomes in the past few years. For example, the collaboration between Recupel and Ressources increased the amount of WEEE prepared for reuse, the implementation of SmartLoop allowed a better distributed allocation of professional WEEE among collectors, and the participation of recyclers in the BeWEEE platform improved the reporting of collected WEEE to regional authorities. Further aligning the WEEE management network with the interests of stakeholders (including society) is key to meeting the regional goals for the collection and preparation of WEEE for reuse.

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NOTES

1. The present research only considers solutions that can be implemented with the existing European WEEE legislation. While we acknowledge that the EPR principle can be questioned, we took a pragmatic approach more aligned with the prerogatives of the regional authorities.
2. This classification is not shared among stakeholders (for example with reuse centres) and is not aligned with the European classification or the UNU keys. Further alignment of categories used in practice might improve the collection and recovery of WEEE [Mansuy *et al.*, 2020].
3. Compared to Mentzer *et al.* [2001], the analysis excludes service flows, the system mostly including logistics services already accounted for through other flows.
4. The lack of reliable data is a major limitation of the present work. Extended producer responsibility creates a principal-agent problem, with most data transiting through Recupel (see Figure 4). Recupel is open to sharing information on physical flows, but less on their use of the Recupel contribution, considered as confidential. In addition, many stakeholders do not report their activities to Recupel or to the public authorities (although reporting has improved since the implementation of the BeWEEE platform). Data collection is quite challenging at retailer level (as many retailers have a low level of interest in WEEE). Finally, the division of data according to Belgian regions is complex, with much data being reported at national level.
5. <https://smartloop.be>
6. <https://www.beweee.be/>

ABSTRACTS

The management of waste electrical and electronic equipment (WEEE) underperforms in the Brussels-Capital Region. This lower performance is partly related to the collection of such WEEE through unregistered channels. Using a relational approach, this study aims to understand the roles of WEEE management stakeholders. It reveals the existence of a market-based network, conflicting with the official network centralised around Recupel. It also highlights how the choices of consumers and retailers channel WEEE in either subnetwork. Based on these results,

we suggest solutions to limit unregistered channels, either by further integrating the market-based subnetwork in the official one or by influencing the behaviour of consumers' and retailers.

La gestion des déchets d'équipements électriques et électroniques (DEEE) est peu performante en Région de Bruxelles-Capitale. Cette contre-performance est en partie due à la collecte des DEEE via des filières non enregistrées. Fondée sur une approche relationnelle, cette étude vise à comprendre le rôle des parties prenantes de la gestion des DEEE. Elle révèle l'existence d'un réseau basé sur le marché, en conflit avec le réseau officiel centralisé autour de Recupel. Elle montre également comment les choix des consommateurs et des détaillants orientent les DEEE vers l'un ou l'autre sous-réseau. Sur la base de ces résultats, nous suggérons des solutions pour limiter les filières non enregistrées, soit en intégrant davantage ce sous-réseau marchand au réseau officiel, soit en influençant le comportement des consommateurs et des détaillants.

Het beheer van afgedankte elektrische en elektronische apparatuur (AEEA) is ondermaats in het Brussels Hoofdstedelijk Gewest. Deze slechtere prestaties houden gedeeltelijk verband met de inzameling van AEEA via niet-geregistreerde kanalen. Aan de hand van een relationele benadering tracht deze studie meer inzicht te krijgen in de rol van de belanghebbenden bij het beheer van AEEA. De studie wijst op het bestaan van een marktgebaseerd netwerk dat in strijd is met het officiële netwerk dat rond Recupel is gecentraliseerd. Daarnaast wordt belicht hoe de keuzes van de consumenten en de detailhandelaars AEEA naar een van beide subnetwerken oriënteren. Op basis van deze resultaten stellen we oplossingen voor om de niet-geregistreerde kanalen te beperken, hetzij door het marktgebaseerde subnetwerk verder te integreren in het officiële netwerk, hetzij door het gedrag van de consumenten en de detailhandelaars te beïnvloeden.

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