Waste sorting in apartments: integrating the perspective of the user

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Abstract

In order to increase resource recovery from solid waste, better sorting of household waste is needed. This article reports on a case study about waste sorting infrastructure performance carried out in two buildings in Gothenburg, Sweden. Results from the study reveal mismatches between users' needs and what the system offers, affecting the sorting rates and quality of the sorted material. Frequent sorting errors were observed from the tenants in these apartment buildings, where more than 70% of the discards that go in the mixed waste could be sorted out into other available fractions, with biodegradable waste being the most neglected. Hazardous waste was often discarded wrongly and recurrent errors were observed in the containers available for sorting different packaging material. Given the performance observed, initial suggestions are made for housing companies to rethink the sorting system they offer to their tenants (i.e. accessible space for electronic waste, more space for biodegradable waste, possibility of sorting textiles, etc.). Most importantly this paper makes the case that housing companies have the opportunity to provide sorting infrastructure that is designed for the user, rather than just fitted to the waste management system.

Keywords:
Household waste; waste composition analysis; user perspective; sustainable waste handling; sorting behavior; apartment buildings.

1 Introduction

In recent decades, continuous efforts in research, policy-making and municipal administration have led to improvements towards more sustainable urban waste management systems (El-Haggar 2007; Ludwig, Hellweg, and Stucki 2003). Nevertheless, the amount and complexity of waste continues to increase (Basel Convention 2012) and waste handling remains a major challenge for society. Today, the motivation behind improving waste management systems is not only to contain waste in one location (i.e. landfills), in order to avoid pollution and improve public health, but also to enable the use of material resources in a more sustainable way (Wilson et al. 2012). Advocates of closed-loop systems (Ellen MacArthur Foundation 2012; McDonough and Braungart 2002) often argue that waste management should evolve into resource management, and effectively channel discarded materials into new production.

Reuse and recycling of discarded materials requires urban waste flows to be sorted, which is already done in many ways (e.g. source separation systems, material recycling facilities). The choice of waste management system depends on several factors that vary greatly from one city (or even district) to another (Dahlén and Lagerkvist 2010). This variation of influential factors has led many researchers to state that no single waste sorting solution has the capacity to suit the needs of every waste management scenario (Gallardo et al. 2011; Griffiths, Williams, and Owen 2010; UN Habitat 2010). For instance UN Habitat (2010) suggested that: "A reliable approach is to be critical and creative; to start from the existing strengths of the city and to build upon them; to involve all the stakeholders to design their own models; and to 'pick and mix', adopting and adapting the solutions that will work in any particular situation."

The adaptation of waste management systems to particular situations thus requires engaged and knowledgeable actors who are able to improve local waste sorting solutions by finding a balance between policy-requirements and what particular actors (e.g. households) are able and willing to do.

Urban waste management systems are fairly complex and include everything from collection to final disposal (Ludwig, Hellweg, and Stucki 2003; Seadon 2010). As a result waste management systems are usually divided into sub-systems when it comes to system analysis and design. Source separated waste collection is just the initial part of a complete waste management system, but it can be regarded as a sub-system on its own right and thus it can be studied independently (Gallardo et al. 2011). When looking into the entire spectrum of a typical waste management system, several actors are responsible for different stages and have varying degrees of freedom to determine how to best perform their task. For example, a municipal regulation may state how waste collection is to be conducted, while private waste companies usually execute this task with the technological means they have at their disposal. Municipal regulations and waste collection routines in turn require residential areas and housing companies to provide specific

infrastructure for the collection of household waste. Finally, individual household owners decide how to organize their home to gather and dispose the waste that is generated.

Recent years have seen progressive increments in material recovery targets to be achieved within the European Union (EU). As a consequence, local authorities all over Europe are aiming to improve their waste management systems towards increased resource recovery. Thereby, particular attention is paid to biodegradable waste (i.e. any waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, paper and cardboard). Composting is expected to increase significantly, while anaerobic digestion is expected to become an important source of renewable energy (EU 2008) that will significantly benefit societal well-being. This brings forward the need for a high separation rate for biodegradable waste.

In Gothenburg, Sweden (like in many other cities) a weight based billing system was introduced for mixed waste in different parts of the municipality. Furthermore, the municipality recently installed a biogas generation facility. Biogas is strongly promoted by local authorities due to its contribution to renewable energy supply. In practical terms, this appreciation of biogas means that correctly sorted biodegradable waste is collected by the municipality free of charge (penalizing incorrect sorting). The combination of a weight based billing system with the collection of biodegradable waste free of charge motivated housing companies to strive to improve source separation of waste in order to reduce waste handling costs. Special attention is given to sort out the biodegradable fraction, since it is suspected to be the heaviest fraction currently not sorted out of the mixed household waste. A usual setting for waste collection in apartments in Gothenburg is that tenants have access to a garbage disposal room, where they find several containers for the different fractions that the district collects. This setting is known to have strong variations in the quality and quantity of waste collected in different districts, pointing towards the importance of user participation and what influences their sorting behavior. In order to improve waste separation in apartments and hence reduce waste handling costs, housing companies need to better engage their tenants in the correct sorting of household waste.

Researchers in the field of waste management (Andersen and Larsen 2012; Refsgaard and Magnussen 2009; Henriksson, Åkesson, and Ewert 2010) as well as in other domains of interest for sustainable development (e.g. energy use) have started to go beyond a pure systems perspective that neglects human factor considerations and in addition investigate the role of users, which often results in general recommendations for the improvement of the waste management system. However, the implementation of real-life solutions based on the findings of behavioral research is still uncommon. In addition, most of the case study scenarios that have been the focus of research meaning to address the role and perspective of the user have concentrated on how to motivate individual houses to separate their waste, but have not looked into how waste sorting behavior is perceived by users living in apartments. Specific policies aimed

at waste prevention may work well in individual houses, but they might not have the same effects or impact in apartments. As an example, the introduction of a weight based billing system has been reported to have a positive effect in reducing waste quantities in some Swedish municipalities (Dahlén and Lagerkvist 2010). However, areas with individual houses are more affected by this policy (since it is the same tenants that both generate waste and pay the waste collection fees) than households located in apartment blocks where the housing company pays the waste collection fees.

The case study presented in this article investigated the performance of the current waste sorting infrastructure in two buildings housing 92 independent apartments located in Gothenburg. The aim of the study was to answer two research questions: what are the problems that may arise in the context of waste sorting in apartments, and how can housing companies improve the waste sorting system in order to facilitate more effective sorting of household waste for their tenants?

2 Material and Methods

2.1 Case study background

This research was conducted in close collaboration with a local housing company in two buildings located in a suburb of Gothenburg. This specific district was chosen because it was known to have problems in engaging its tenants in source separation, obtaining on a consistent basis worse outcomes than other districts with similar collection systems. The housing company administrates 28 buildings in this district, all of which are two to five story apartment buildings that are organized in blocks around central yards with access to one garbage disposal room per yard. This block configuration around a yard is considered as a building unit, even though each building around the yard has a different configuration (i.e. the type and number of apartments) and the buildings are otherwise independent from each other. These building units will henceforward be referred to as yards. Two yards with the same number of apartments and similar layout were chosen for the study (henceforward referred to as yards A and B). Each of these yards consists of 46 apartments ranging from 42 m^2 to 96.6 m^2, with layouts of one room plus kitchen up to four rooms plus kitchen respectively.

Both yards have a garbage disposal room, referred to in this study as waste room, where the tenants have access to several containers for disposing their household waste. These rooms are accessible to tenants by the narrow sides (i.e. from the inner yard or the street) using keys and are otherwise locked to the public. Details on the type and amount of containers (as well as their abbreviation) are provided in Table 1; the layout and dimensions of the waste rooms is illustrated in Figure 1.

Table 1: Containers available at the waste rooms in the study.

N° of Containers	Volume	Material collected	Abbreviation
5	660 Lt.	Mixed Waste	MW
2	660 Lt.	Paper packaging	PP
2	370 Lt.	Plastic packaging	Plst
2	370 Lt.	Newspaper and print	NP
2	190 Lt.	Glass packaging: transparent and colored	GP
1	370 Lt.	Metal packaging	MP
3	140 Lt.	Biodegradable Waste	BW
3	24 Lt.	Batteries, light bulbs: normal and energy saving	HZD

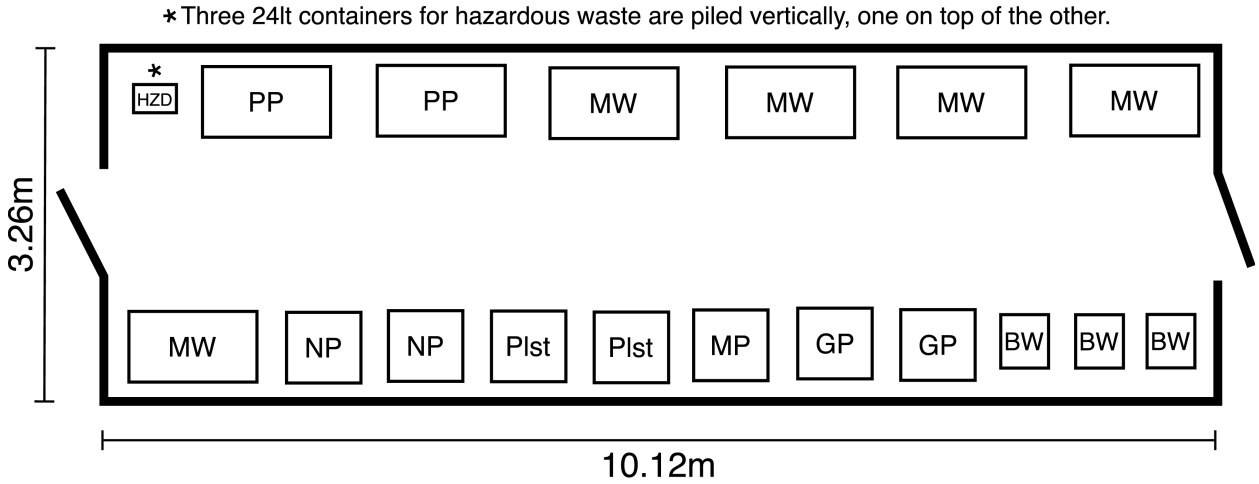

Figure 1: Layout of the waste rooms used for the means of the study.

Information about how to sort the waste is located on the walls of the waste rooms. This information consists of illustrations and short descriptions of what should be discarded into which container (Figure 2). Tenants also receive this information, summarized in a brochure, when they move in. The schedule for cleaning the waste rooms and the collection of the different fractions is also displayed on the walls of the room (Table 2). As of now, all information is provided in Swedish, despite the fact that many non-native Swedish speakers (whose comprehension of the Swedish language can vary greatly) live in this area. The authors do recognize that this language barrier may have an adverse impact on the potential of some people to adopt the intended waste handling behavior because they simply could not be properly introduced to how the building's waste sorting system should be used.

Figure 2: Example of information for sorting waste at the waste rooms.

Table 2: Weekly schedule for cleaning and collecting waste from the waste rooms.
x: collection every week x_e : collection on even weeks; x_o : collection on odd weeks.

	Mon.	Tue.	Wed.	Thu.	Fri.
Mixed Waste	x			x	
Biodegradable					x
Newspaper					x_e
Glass Packaging				x_o	
Paper Packaging				x	
Plastic Packaging					x_o
Metal Packaging					x_o
Cleaning	x			x	

Besides the availability of the waste room facilities, the tenants have the possibility to discard bulky and electronic waste in separated rooms dedicated for this purpose. Initially, these rooms were open for tenants to access by themselves, but after some problems of getting mixed waste and loose rubbish discarded there, the housing company decided to limit access. Now tenants must first contact a member of the maintenance personnel to gain access to the rooms assigned for discarding bulky and electronic waste. Currently the collected mixed waste is much more than the separated biodegradable waste (with a weight ratio of approximately 10:1 (obtained from the waste weight data collection, described further in Section

3.1), corresponding to the large difference in available volume in the containers for the respective fractions. The containers for mixed waste normally get filled with closed bags that come from different households. Loose items can also be found in the containers, which can have fallen out of a ripped bag, or simply been discarded separately by the users.

2.2 Methodology

The research design strategy meant to specifically address the two research questions of this study. In order for this to be viable an evaluation of the waste sorting infrastructure and the tenants waste handling behavior was needed. This was achieved using four different research methods: waste weight data collection analysis, a waste composition study, field observations and a user survey. The performance of the existing sorting infrastructure was evaluated mainly through the analysis of waste weight data and the waste composition study, while opportunities for improvement were explored mostly via the field observations and user survey.

2.2.1 Waste weight data collection analysis

The targeted district started to work under a weight based billing system in January 2012. The gathered information is later delivered to the housing company aggregated quarterly in waste collection invoices. Through collaboration with the municipal recycling office, access to the detailed information was granted for the year of this study. Note that the waste data obtained in this way shows the amount of waste collected from this location, rather than the amount of waste generated. There could be discrepancies between these two parameters, but for the purpose of this study, these will be considered as equivalent.

The information regarding the amount of people living in these apartments and their demographics was obtained through the national tax registry database.

2.2.2 Waste composition study

The waste composition study was designed following literature recommendations on how to perform household waste composition studies (Dahlén and Lagerkvist 2008). It was not possible to follow their procedure for extracting the samples from the total studied waste, given that the space designated for this task was too small. An alternative procedure was chosen and is described further in Section 2.2.2..

The scope of data collection in this study was to determine:

- From the mixed waste container, how much waste was:
  - Biodegradable
  - Packaging and print
  - Hazardous

(All fractions measured as % of total mixed waste weight)

- From the biodegradable waste container, how much waste was:
  - Non biodegradable (of which)
    - Packaging and print
    - Hazardous

(All fractions measured as % of total biodegradable waste weight)

The fractions considered in the study are shown in Table 3.

Table 3: Fractions measured in the study.

Paper	Packaging
	Non packaging
	Newspaper & prints
Plastic	Packaging
	Non packaging
Glass	Packaging
	Non packaging
Metal	Packaging
	Non packaging
Hazardous	Light bulbs
	Batteries
	Small appliances
	Impregnated wood
	Larger electronics
	Other
Biodegradable	
Wood	
Textile	
Others	Combustible
	Non combustible

2.2.2.1 Delimitations

This study focused on characterizing the mixed and biodegradable fractions. The packaging waste fractions may contain waste incorrectly sorted. However, a thorough characterization of packaging waste was deemed beyond the scope of this project. Nevertheless, checking if there were any cases of improper sorting or whether mixed waste bags were placed into the packaging containers, was done together with each sampling, as part of the field observations.

The sampling avoided holidays and vacation periods. The seasonal variation of waste generation is only going to be regarded through the review of the waste data generated during the year 2013 (kg/month), since seasonal characterization of waste was not possible due to time and monetary restrictions.

2.2.2.2 Procedure

Sampling was done over a six-week period, starting in January 2013. In order to have samples that cover a full week of waste production, each sample consisted of two partial samples, one taken on Monday mornings (collecting the waste generated on weekends) and one taken on Wednesdays. Each partial sample was sorted and processed on the same day of its extraction, using the facilities that the housing company assigned for this task (referred from this instant and onwards as the garage).

For each partial sample, the sorting personnel took all biodegradable waste to the garage. For the mixed waste, they went through all the containers, placing every fifth bag in the sample. Loose items were gathered to an amount that would be approximately fit into a bag and counted as one bag, which could be sampled or not.

The procedure for both fractions was the same. The samples were maintained in four distinct groups: mixed waste from yard A (Mix A) biodegradable waste from yard A (Bio A) mixed waste from yard B (Mix B) biodegradable waste from yard B (Bio B). The samples were sorted into the defined fractions and their weight was registered. If anything unusual appeared, photographic documentation was taken using the corresponding sample identification card (i.e. Mix A, Bio A, Mix B or Bio B).

The procedure was designed in this way to addresses the seven sampling errors common for waste characterization studies found in the literature. The errors addressed were: long-range heterogeneity fluctuation error, periodic heterogeneity fluctuation error, fundamental error, grouping and segregation error, incremental extraction error and preparation error. For more information about these error sources please refer to Dahlén and Lagerkvist (2008). Of these errors, the increment delimitation error does not really apply to this study since the separation was not done from a pile, but rather by taking out elements from the containers. However, this introduces a different bias that should be considered. When the sorting personnel was going through the containers the order in which they chose the bags or items determined what was collected into the sample. They were encouraged to do this without “thinking too much about it” but inevitably some bags might have been chosen or avoided on purpose.

2.2.3 Field observation

In parallel to collecting the samples for the waste composition study, the sorting personnel was asked to observe if there was bulky waste discarded in the waste room. They were also asked to observe for any wrong sorting in the containers. This included the containers for mixed waste (waste that was not included in the sample) and the containers for packaging waste. If any of this occurred, they were asked to note it and additionally document it via photographic proof. This resulted in a frequency of occurrence chart and in extensive photographic documentation. The collection of weight and volume data for these

occurrences was beyond the scope of this study and would have required more time and personnel than what was available.

2.2.4 User survey

In order to have more information on the users' intended waste handling behavior, a user survey was employed looking to frame the respective attitudes of all the tenants living in the buildings that served the purposes of this study. The user survey that was based on a primarily quantitative questionnaire was a postal one and it was delivered by the housing company. Tenants were asked to leave the completed questionnaires in the housing company's post box. Only fully completed questionnaires were evaluated in the analysis. A more qualitative research method approach was deemed not to be applicable for the means and time frame of the study. Qualitative methods are used for exploratory or interpretation purposes examining in depth the mechanisms behinds questions of *why and how* of the decision-making process (see for example Bernard, 2000). This study meant only to develop a baseline understanding of the variations in users' attitude. The research design choice for doing a survey was taken so that the study could use the common and established communication channel between the housing company and the tenants so that this process would seem official and part of their ongoing improvement work.

Using the language standards normally employed in the letters of the housing company to its tenants and avoiding technical or unusual terminology was also a choice designed to make the survey easier for eventual respondents. The authors recognize that using Swedish for the questionnaire in theory might have had an adverse impact on the response rate because some tenants of international background could not understand the content of the survey and thus respond to it. But in practice, apparently most residents with immigrant background speak an acceptable or even advanced level of Swedish. Furthermore, the established communication between the housing company and the tenants is only in Swedish, so a different approach could provoke feelings of uncertainty about the survey's origin and the motivations behind it. More importantly though, having a survey translated into multiple languages would negatively affect the cohesiveness of the content and the homogeneity of the message, since for several terms used there is no exact translation.

The survey aimed to investigate tenants' attitudes towards sorting waste at home. In order to make the survey as clear and concise as possible, only ten questions were posed, using a mix of five-point Likert scale items (six questions) and multiple choice questions with an open alternative (four questions). A piloting procedure was undergone, where a number of questions were tested to an audience including research experts, practitioners working in the field of waste management and members of the general public (14 respondents in total). This process allowed the authors to choose the questions that fitted better the context of the research work and come up with an exact format for each question item so that every

single one of them could be at the same time rigorous, meaningful in terms of reflecting practical realities and understandable to the average respondent. Pre-notification (Maheux et al., 1989; Shiono and Klebanoff, 1991) and financial incentives (Gilbart and Kreiger, 1998; Halpern et al., 2002) have been reported to produce consistent improvements in response rates and therefore both were used for the means of the survey (Nikitaset al. 2011). Together with the survey, the waste information brochure (mentioned in Section 2.1) was delivered.

It is commonly stated that self-reported waste sorting behavior tends to be exaggerated or unaware (Tonglet, Phillips, and Read 2004; Timlett and Williams 2008; Martin, Williams, and Clark 2006). That is why this survey is not used as a tool meant to identify the actual waste sorting behavior, but rather to investigate users' attitudes towards waste sorting.

3 Results

The results are briefly presented here for each separate research method.

3.1 Waste weight data

The mixed waste generated during 2013 in the studied buildings is of an average of 0.89 kg/pp/day in yard A and of 0.75 kg/pp/day for yard B. As a reference, the Swedish national average for mixed waste generation for 2012[1] was slightly lower with 0.6 kg/pp/day (Avfall Sverige 2013).

Unfortunately weight data for the collected biodegradable fraction was sporadic, counting with only one trimester per year, for the years of 2012 and 2013. The trimester corresponding to the study period was covered, and showed an average of 0.09 kg/pp/day for yard A and 0.05 kg/pp/day in yard B. As reference, the national average for biodegradable waste generation in 2012 was more than double these amounts: 0.2 kg/pp/day (Avfall Sverige 2013). This may be due to seasonal variations that could not be taken into account in the study, given that only data for the first trimester of 2013 was available.

3.2 Waste composition study

The samples covered on average 19% of the total mix waste generated in Yard A (varying between 16% and 24%) and 18% in Yard B (varying between 11% and 31%). The largest sampled fractions in yard A correspond to the weeks when sorting personnel increased the sampling from 1/5 of the bags to 1/3 (since the waste volume they had to sample from was considered too small). The highest sampling rate in yard B is a week before this occurred.

1 The national averages for mixed and biodegradable waste generation for 2013 were not yet published at the time this article was written.

From the sample of the mixed waste generated, the composition study shows that little over 40% is biodegradable waste (i.e. 42% in yard A and 41% in yard B); about a quarter is packaging that is not sorted out correctly (i.e. 26% in yard A and 22% in yard B) and only one third corresponds to other mixed waste (i.e. 32% in yard A and 37% in yard B). From the packaging waste not sorted out correctly, the largest amounts were plastic material (i.e. 37% of total packaging in yard A and 36% in yard B) and paper packaging (i.e. 29% in yard A and 33% in yard B). The composition of the third part of mixed waste (i.e. other mixed waste that is neither biodegradable nor packaging waste) can be observed in Figure 3. As observed in the figure the main part of this sub-fraction corresponds to mixed combustible materials. However, the second and third largest groups of waste generated are interesting to discuss further: textiles and other paper.

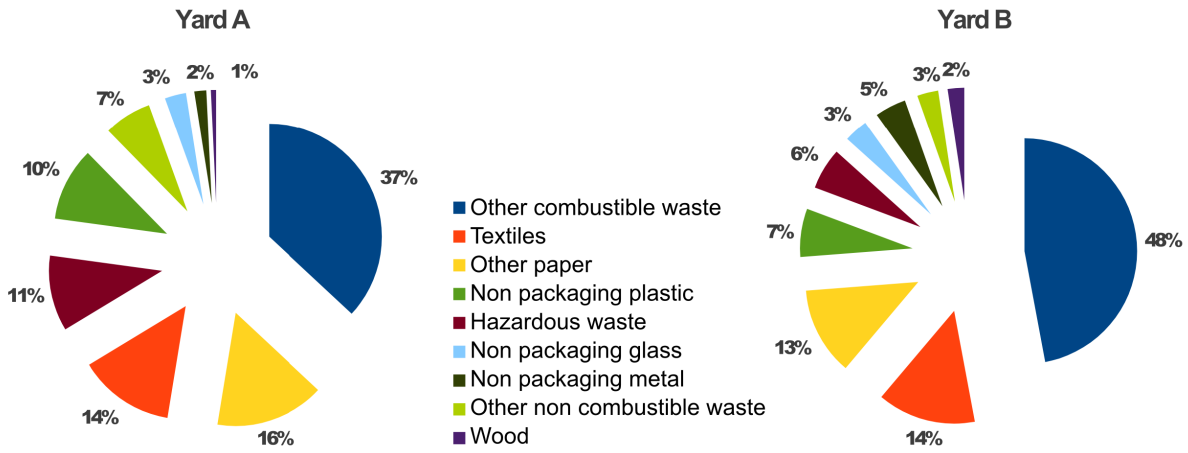

Figure 3: Detailed composition per yard of the mixed waste fraction excluding biodegradable and packaging waste.

When found in the sample, textiles often appeared in a bag of their own, not mixed with the rest of the waste. “Other paper” was defined as paper that was deemed clean enough to be recycled and could not be sorted as paper packaging or newspaper and prints. Some paper would be sorted into the biodegradable fraction (e.g. greasy napkins disposed with food waste) and some into the combustible waste (e.g. toilet paper). The rest would fall into the other paper category (e.g. books, notebooks, envelopes, post cards, bills, receipts).

On the other hand, almost 100% from the sorted biodegradable fraction corresponds to biodegradable material. In yard A only 0.3% corresponds to packaging waste (an average of approximately 3 grams from a total of 8.3 kg) while in yard B it is closer to 1% (i.e. approximately 3 grams from 5.3 kg). However, this does not mean that the sorting of biodegradable waste is without problem. On two occasions, personnel found hazardous waste in the biodegradable fraction (i.e. batteries and discarded medicine). Figure 4 shows that food wrappings are often found in this fraction. In all cases the materials

found are very light in comparison to the biodegradable waste, so it does not show up when comparing only weight. In yard A improper sorting was the case in 10 out of the 12 occasions, whereas in yard B this occurred on every occasion. Photos were taken to document the found quantities for each yard on every occasion, showing that plastic and aluminum wrappings are the sorted materials most commonly disposed of in a wrong way. Table 4 shows a summary of the biodegradable waste generated during the study period and where it was collected.

Figure 4: Plastic and Aluminum fractions from the sorted biodegradable waste in yard B, on the 9th of January.

Table 4: Summary of biodegradable waste generation in the study.

		Yard A	Yard B
Total biodegradable waste sampled in the composition study (obtained from mixed and biodegradable waste)	(kg/hh/day)	0,10	0,10
	(kg/yard/week)	31,3	31,8
Total biodegradable waste generated (including volumes sampled an non sampled by the composition study)	(kg/hh/day)	0,42	0,47
	(kg/yard/week)	135,24	151,34
Biodegradable waste obtained from mixed waste samples	(kg/week)	23,1	26,6
	(%)	74%	84%
Biodegradable waste obtained from samples of the biodegradable waste sorted out by tenants	(kg/week)	8,2	5,2
	(%)	26%	16%

3.3 Field observations

The field observations were registered by the sorting personnel in two ways: as notes on the forms they filled out at each occasion and by photographic documentation. Table 5 shows the occurrence of bulky waste in the waste rooms and wrong sorting in the packaging containers (i.e. first two rows of Table 5). Table 5 furthermore shows the number of the containers that had incorrectly placed elements. When more than one item was misplaced in a given container, this was only counted as one incorrect container. As Table 5 shows, the behaviors observed were quite similar for both waste rooms.

Table 5: Occurrence of bulky waste and incorrect sorting in packaging containers and number of containers affected.

Room A	**Collection dates**	1	2	3	4	5	6	7	8	9	10	11	12	**Totals**
Occurrence	Bulky waste	x	x	x	x	x				x		x		7
	Wrong sorting		x	x	x	x		x		x	x	x	x	9
Number of containers with incorrect sorting	Hazardous in mixed waste	x	x	x	x	x	x	x	x	x	x	x		11
	Paper packaging		x		x	x					x			4
	Newspaper & print					x		x						2
	Plastic packaging			x	x					x		x		4
	Glass packaging			x	x	x						x		4
	Metal packaging			x	x	x							x	4
	Hazardous									x			x	2
	Total/day	1	2	4	5	5	1	2	1	3	2	3	2	31

Room B	**Collection dates**	1	2	3	4	5	6	7	8	9	10	11	12	**Totals**
Occurrence	Bulky waste	x	x	x		x				x	x	x	x	8
	Wrong sorting		x	x	x	x	x			x	x	x		8
Number of containers with incorrect sorting	Hazardous in mixed waste	x	x	x		x	x	x	x	x	x	x		10
	Paper packaging		x		x	x				x		x		5
	Newspaper & print		x			x								2
	Plastic packaging		x				x				x	x		4
	Glass packaging			x		x								2
	Metal packaging		x			x					x			3
	Hazardous				x					x	x	x		4
	Total/day	1	5	2	2	5	2	1	1	3	4	4	0	30

3.3.1 Bulky waste

Currently there is no control of how much bulky waste gets sorted into the mixed waste containers. During the study period, personnel just observed if it occurred but did not measure it in any way. It was intentionally left out of the sampling, given its more irregular generation. These kilos of bulky waste that

are discarded into the mixed waste stream generate peaks in the weight data used, introducing another error source in the estimations of the composition study presented in Section 3.1. Some of the bulky waste observed was in good conditions, meaning that it could potentially still be used.

3.3.2 Hazardous materials in mixed waste

This was one of the most frequent sorting errors observed. The most common hazardous elements found in the mixed waste were light bulbs and various sorts of electronic waste. Less frequent hazardous elements found were batteries, medicine and paint or other chemicals.

3.3.3 Quality of sorted packaging

From the field observations it was possible to identify two types of problematic sorting behavioral norms: material related sorting and unrelated sorting. Material related sorting mistakes occur when a tenant uses the available packaging containers to dispose of waste that is not packaging but that is made of the material specified in the sorting container (e.g. metal pipes in metal packaging container, Figure 5a). Unrelated sorting mistakes occur when a user discards something that has no relation with the specific sorting container (e.g. textiles and shoes in paper packaging container, Figure 5b). Unrelated sorting mistakes were more common (with 30 registered occasions) than material related sorting mistakes (with 12 occasions).

Regarding sorting in the hazardous containers, the three errors observed here were that tenants discarded elements that they deemed hazardous, but were not the elements asked for in the containers (e.g. small electronic waste, medicine packaging).

(a) Material related sorting mistake. (b) Unrelated sorting mistake.

Figure 5: Examples of wrong sorting in packaging containers, 9th of January.

3.4 User survey

A total of 19 completed surveys were returned, corresponding to a 21% response rate. Similar studies aiming at sorting behavior have reported much higher response rates (of about 70%) (Sidique, Lupi, and Joshi 2010; Tonglet, Phillips, and Read 2004; Berglund 2006). So additional efforts were made to gather more reliable information from the tenants, described further in Section 4.3.

From the fully completed questionnaires that were received and subsequently analyzed for the means of this initial study, it became clear that most respondents claimed to think that sorting waste is important (90%) and declared to always sort waste at home (84%). Almost all respondents reported that they sort waste because they consider it to be better for the environment.

When asked what type of waste they sorted at home, the most sorted fractions were newspaper and prints (94%), paper and plastic packaging (89%), followed by metal packaging, biodegradable waste, lamps, batteries and glass packaging (raging between 84% to 79% according to the order aforementioned). Bulky and electronic waste was marked by roughly half of the respondents. Chemicals were the least sorted fraction, with 36%.

When asked how often they sorted each specific fraction, most tenants marked “always”, with the exceptions being bulky waste, electronic waste and chemicals. Most respondents stated that it is not difficult to sort the different fractions at home with the exception of bulky waste and chemicals. Some of the results indicated that there was a degree of confusion between the newspaper and print fraction and the paper packaging fraction among the respondents. In the case of bulky waste comments included that it was annoying to retrieve the key from the housing company every time, or simply not knowing where it was supposed to go. Denying unlimited access to the bulky waste room in order to safeguard correct sorting behavior was probably the main reason that this fraction (together with electronic waste) were the least likely to be sorted by the respondents. Regarding chemicals, some respondents stated that there is no room for this or that they do not know where it is supposed to go, while few respondents stated that they do not have chemicals at all.

Over 70% of the respondents considered that sorting out biodegradable waste is very important, with most of them claiming to know that it was used for biogas production or composting. Even though 70% stated they always sort out biodegradable waste, two respondents stated never to sort it out. It was also suggested to use containers with a lid for facilitating biodegradable sorting (current containers are open and use a paper bag).

Roughly half of the respondents stated that they would require more containers in their kitchen to make waste sorting easier. Less than a third said that they would need more room in their apartments. Few respondents added that they were happy with how the system was and that they did not need anything

else, while one respondent pointed out that sorting feels unnecessary if all waste ends up in the same place.

4 Discussion

Given the results from the case study presented herein, it is possible to start defining some possible strategies for housing companies to improve their source separated collection of solid waste.

4.1 Resolving the mismatch between the technical system and the desired user behavior

The first thing to consider is that if users are expected to sort out most of their biodegradable waste, there should be enough space for it. In this case study, the containers available did not have enough volume to hold the amount of biodegradable waste generated. The housing company must increase the volume of biodegradable containers (almost double it), while reducing the amount of containers for mixed waste. Reducing the mixed waste containers is important in terms of not allowing for an overall increase in waste volumes.

Currently tenants have no feedback whatsoever about their sorting behavior, meaning that they have no facts about how much waste they generate or what type of waste they generate the most. The size of the containers for mixed and biodegradable waste are the only indicators users have to guess a relative volume of waste generation for each type. The existing container volumes do not represent the amounts generated in reality nor the amounts targeted by the housing company; they merely reflect the amounts currently collected. This failure to inform the tenants about the desired goals for sorting is detrimental to any attempt for improving waste sorting behavior.

Better information, motivation and engagement campaigns should be developed and deployed, where residents can make their needs and preferences known while learning more about how to separate their waste in a more efficient manner. A more collaborative development of waste collection systems seems to have a much stronger effect on engaging users and ensuring the systems long term performance (Wilson et al. 2012). This means that better consultation and participatory mechanisms, which could allow people to contribute in the decision-making process of improving (or even enjoying the full potential of) the waste handling infrastructure and services they have access to, may be necessary for them to appreciate their own decisive role in the 'recycling equation'. Exploring how to motivate, and even how to provide better, more explicit feedback on sorting behavior to the different buildings, should be addressed in further research.

4.2 Resolving the mismatch between the technical system and the perspective of the users

This case study shows, in line with previous research, that there are mismatches between the technical system and the user's perspective. The discrepancy between how users naturally categorize their refuse and what containers they have available for sorting their waste, is what generates the problems observed in Section 3.3.3.

4.2.1 Material related sorting mistakes

Users do not categorize between packaging and non-packaging waste in their everyday life, they simply categorize by material. Material related sorting mistakes have been discussed in the literature and correspond to "...the structural mismatch between the layman logic and the logic of the waste management system that causes uncertainty." (Henriksson, Åkesson, and Ewert 2010). The "layman logic" is what users expect given that the material fits the description (despite that the discard is not packaging) assuming that it would get recycled for its material. There is no clear layman explanation to why people should not sort non-packaging material in the packaging containers. This is only due to administrative issues regarding how the recycling system is financed. The waste management system in Sweden has more availability of packaging sorting facilities, because the packaging and paper producers are held responsible for financing the take back systems for their products (Henriksson, Åkesson, and Ewert 2010). This does not extend to all type of products, which is why non-packaging discards are supposed to be sorted at recycling centers, where the local authorities are responsible of financing the collection. This information is rarely received by normal users, who usually are unaware of how the waste management system is financed. This mismatch makes this type of sorting behavior a mistake from the system's perspective, but not necessarily from the user's perspective.

An observed behavior that could be considered as a material related sorting mistake is when electronic discards are incorrectly placed in the buckets for light bulbs or batteries. In this case, the error lies in interpreting the buckets for light bulbs, as containers to place all types of electronic waste. Users correctly associate electronics and bulbs as hazardous waste, considering this broader category to be covered by this container. Again, here the layman logic groups in a different way than the waste management system perspectives implies.

4.2.2 Unrelated sorting mistakes

Regarding unrelated sorting mistakes, no clear pattern could be observed. These mistakes therefore appear to be random (i.e. no particular reasoning seemed to be behind them). They can be due to an accident, result of disinterest, lack of attention or sloppiness from the user's side. These mistakes are easily identifiable by the tenants as incorrect sorting and could be discouraging some of them, in response, to spend much time on sorting efforts. Based on this, an argument could be made for linking

this particular discouragement effect with the answer as to why these types of mistakes were more frequent than the material related ones and were often observed as several mistakes in the same container.

4.2.3 Ambiguous sorting possibilities

Paper discards generate uncertainty. This was commented in the survey and also observed during the waste composition study, when even the personnel carrying out the study was uncertain at times of where to place paper elements. The collection system has two categories (i.e. newspaper and print, and paper packaging). One could wonder if this separation is relevant or even necessary, given the possibilities to do this by more automated means in a paper recycling facility. The information brochure has a list of example items for each category that do not cover a wide array of household paper elements (e.g. books, notebooks, home printed paper, receipts, envelopes, letters, napkins or tissue). It could be argued that the first six types of discards listed in the parenthesis could be recycled as prints, but they do not appear in the list of what is accepted in this category in the brochure (as they escape the packaging producers responsibility). So, in the composition study this was what mainly composed the category of ``other paper''. Of that group, books are elements that have good potential for being reused instead of just recycled, so this is something that could be targeted separately.

4.2.4 Lack of sorting possibilities

The waste composition study showed that clothes and textiles are normally disposed of in a bag on their own or grouped, meaning that this is a natural category for the users. This may be due to the fact that textiles tend to be kept and handled in places of the household where other waste is not gathered nor generated (i.e. closet or laundry room, as opposed to kitchen or bathroom areas). Since it is also the main non-packaging fraction to appear in the mixed waste, it would be interesting to consider collecting textiles separately, despite that it is not required by the local authorities. If this is done, it should cover both clothes that could be reused and other textiles that should just be recycled. This has been suggested to the housing company and they are currently testing this possibility in some buildings. Further research will include follow-up studies to determine the impact these measures have in the overall quantities of mixed waste.

4.2.5 Inconvenience of sorting possibilities

Electronic and bulky waste are the items that were most often observed as being discarded wrongly, meaning that having a different room or location for these fractions is not a good solution. This is consistent with the results from the survey, where these fractions together with chemical waste were reported as the most difficult to handle. Since tenants see the possibility of just leaving these elements in the waste room, that is what they do. Here it would be better for housing companies to accept this need and designate containers for bulky and electronic waste that are located in the same area as the rest of the

waste containers. This suggestion has been discussed with the housing company, where they commented that bulky waste being discarded with the mixed waste was a problem per se, since both fractions get incinerated. Because of this the housing company will not consider designating containers for bulky waste in the waste rooms. However they did recognize the need to allocate specific containers for electronic waste.

4.2.6 Waste in reusable conditions

Bulky waste, as well as other fractions like books and clothes, were found in the waste rooms still in usable conditions. The persons discarding them may not want them anymore, but it could be possible that they would still be found useful by others. However, the current sorting system has no place to accommodate this sort of material exchange. An option to reduce the volume of reusable waste discarded is to offer a space to dispose elements that users wish to discard but that are otherwise in good conditions to use. This could be done in a constant physical space (like a reuse room that the same housing company has in a different district, Figure 6), as a web page (e.g. free-cycle networks) or organized temporarily (e.g. garage sales or flea markets) where tenants could offer their discards for other people to take. This can be something that the housing company could have incentives for doing, but normally would be carried out mainly by the tenants.

Figure 6: Reuse room from another district managed by the same housing company.

4.3 Backing up the user survey results

Given that the user survey respondents' sample was small and that the response rate was significantly lower than what was expected and listed as normal in literature, a bachelor thesis project was proposed to address the issues of how to improve sorting of biodegradable waste in the apartments from this housing company. Six students from the Technical Design program at Chalmers University of Technology worked on this thesis during the spring semester 2014. During the initial research for their thesis they sent out a user survey to a larger number of apartments and asked tenants to return the filled surveys in a box

specially assigned for this at the entrance of each building, instead of at the housing company's mail box. This resulted in a response rate of 70%. Some preliminary findings are reported in the thesis to support the results of the user survey work described herein. The final sample of this supporting user survey mechanism was referring to 137 fully completed questionnaires. The respondents were people living in residences catered by the same local housing company that was running the two buildings of the main survey. So the case studies were similar and thus directly comparable. The format of the questions employed was replicating closely the context of the items used for the primary survey but perhaps the focus was more limited focusing rather on biodegradable waste handling. The language used, for all the reasons explained in detail in Section 2.2.4, was Swedish. All the figures reflecting behavioral waste handling norms refer to self-reported assessments of the respondents' actual waste handling behavior. The vast majority of the respondents (82%) thought that sorting biodegradable waste was important or very important to them. Most of the respondents (69%) claimed that they sorted biodegradable waste with the age group between 36 to 45 years of age being the more active in doing so (88%) and the group aged 26 to 35 the least active (44%). A question trying to assess whether the respondents sorted any other waste other than biodegradable waste produced similar results with the ones of the basic study. The most sorted fractions were glass and batteries (each with 95%), followed by newspaper and prints and lamps (each with 91%), paper, plastic and metal packaging (89%, 87% and 87% respectively), while electronic and bulky and waste was sorted by 82% and 69% of the respondents. Chemicals were the least sorted fraction again, with 58% (Aasa et al. 2014).

5 Conclusions

This paper argues that housing companies are the linking point between their tenants and the waste collection system. This position gives housing companies the opportunity of significantly contributing to improve waste separation rates. It also provides them with the responsibility to facilitate and improve how users interact with the system, bridging user centered design gaps that the waste management system currently has. This allows housing companies to better cater for their tenants. Given that housing companies manage higher volumes of material than regular households, this allows for certain economy of scale that could be taken into account and used for the improvement of the source separated collection, even beyond what is required by legislation and local authorities.

This research supports the view that it is important to address the existing mismatches between the technical system and the perspective of the users by engaging the tenants more actively in discussing the problems the current system presents, while helping them voice what they need for the system to work in a better way. The same system will have different results on different groups of tenants and the only way to understand why this is the case is by getting to know and understand the users. By allocating resources

for participatory activities, housing companies could gain invaluable insights on their users' needs, spread effectively information about the sorting system and perhaps more importantly educate their tenants on what is expected of them and on what goals the housing company has for sorting waste. In other words, two-sided communication between the housing company and the tenants about the waste sorting system would help improve the sorting conditions, as long as the users' questions are adequately addressed. It is crucial to include the users in the process of improving waste collection systems so that the solutions developed are aligned with the actual needs of the users.

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Figure Captions

Figure 1: Layout of the waste rooms included in the study (for abbreviations see table 3).

Figure 2: Example of information for sorting waste at the waste rooms.

Figure 3: Detailed composition for mixed waste per yard.

Figure 4: Plastic and Aluminium fractions from the sorted biodegradable waste in yard B, on the 9th of January.

Figure 5: Examples of wrong sorting in packaging containers, 9th of January. (a) Material related sorting mistake. (b) Unrelated sorting mistakes.

Figure 6: Reuse room from another district managed by the same housing company.

Table Captions

Table 1: Containers available at the waste rooms in the study.

Table 2: Weekly schedule for cleaning and collecting waste from the waste rooms.
x: collection every week x_e : collection on even weeks; x_o : collection on odd weeks.

Table 3: Fractions measured in the study.

Table 4: Summary of biodegradable waste generation in the study.

Table 5: Occurrence of bulky waste and wrong sorting in packaging containers and number of containers affected.