SENSE

Social Evaluation of New Sanitation Experiments

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About SENSE

SENSE is a collaborative EU-research project on the large-scale introduction of New Sanitary systems. The focus of this research is on public perception, acceptance, and the role of communication and participation interventions in the success of decentralised water demonstration projects. The selected projects are Cityplot and Schoonschip (Amsterdam), Jenfelder Au (Hamburg), SUPERLOCAL (Kerkrade), Oceanhamnen (Helsingborg) and De Nieuwe Dokken (Ghent). The research is composed of three stages in which research and interventions are planned, executed, observed and reflected upon. The outcome of the research is diverse and can be summarised as follows: (1) valuable knowledge for practitioners has been developed and disseminated; (2) a foundation is set for follow-up social research on decentralised new sanitary systems and sustainable urban water management; and (3) substantial scientific outcomes based on a divers set of research actions across the demonstration projects has been generated. It all includes an evaluation of public perception, acceptance, practice, and the role of communication and participation interventions of new sanitary systems in different contexts and settings. This hopefully could help remove or lessen barriers that project developers and municipalities face.

Introduction

New forms of sanitation have been discussed over decades in and beyond Western Europe. The very high sunk costs of existing centralized systems and infrastructure, a phenomenon referred to as "lock-in or path dependency, as well as public acceptance challenges, have, however, tempered the development of these systems (Blanken, Verweij, & Mulder, 2019; Poortvliet, Sanders, Weijma, & De Vries, 2018; Swart & Palsma, 2013). Yet, with increasing pressure on fresh water sources due to droughts and pollution, the need for alternative ways to handle sanitary waste streams is growing (Blanken et al., 2019).

Moreover, large scale decentralised water demonstration projects have become a reality these nowadays and more projects are following the coming years. In Germany, the Netherlands, Belgium, and Sweden thousands of end-users (Table 1) use vacuum toilets, food grinders, and live in a neighbourhood in which rainwater and grey water are used in several manners. All of these projects have a dual-pipe system separating black and grey wastewater. The black water is digested. Energy, resources and nutrients will be recovered for different purposes. These systems are often referred to as New Sanitation (Swart & Palsma, 2013) or New Alternative Sanitation Systems (NASS) (DWA, 2010). Furthermore, stormwater is managed locally, and potable water demand is reduced and/or supplied by locally produced (drinking)water in these water-wise neighbourhoods. All these neighbourhoods include state-of-the-art solutions for climate change and resource scarcity under the umbrella of the circular economy (resource recovery) and the water-food-energy nexus.

One of the current bottlenecks for the development of new sanitation is the uncertainty among property developers (and other stakeholders) about end-users' acceptance of new sanitation (Swart & Palsma, 2013). The large-scale introduction of these neighbourhoods as described above provided a window of opportunity to undertake a thorough study that addresses this specific issue. The most elaborate studies so far only looked at urine separation, while these types of NASS are not considered in the demonstration projects in this study. Furthermore, some studies also have a specific sample group, namely students (Ishii & Boyer, 2016). Furthermore, other studies had either small samples (Naus & Vliet, 2012) or participants that lack everyday experience with new sanitation (Poortvliet et al., 2018). It is important to extend those analyses to other types of sanitation systems among different publics and actual users, i.e. people who live in houses equipped with such systems on a permanent basis. The SENSE research project is the first that renders representative outcomes with these types of technologies in a variety of contexts in Europe.

Research in public perception of grey water reuse (Hartley, 2006; Smith, Brouwer, Jeffrey, & Frijns, 2018) and rainwater harvesting (Fielding, Gardner, Leviston, & Price, 2015) is richer. Nonetheless, most studies focus on arid regions in developed countries. Drought related problems have been listed high on the public agenda influencing water saving, alternative water sources, and new technologies (Binz, Harris-Lovett, Kiparsky, Sedlak, & Truffer, 2016; Fuenfschilling & Truffer, 2016). In the North-Western European context drought was far less an issue when the demonstration projects emerged which therefore did not influence the uptake of New Sanitation and Sustainable Urban Water Management. Moreover, the reasons for these developments in North-Western Europe are as diverse as the projects themselves. Ranging from resource and nutrient recovery (in waste water) (Swart & Palsma, 2013), adapting to extreme weather conditions (dry spells and extreme rain events) (Hofman & Paalman, 2014), political stability (Rygaard, Binning, & Albrechtsen, 2011), reducing environmental impact (Leigh & Lee, 2019), energy reduction and recovery (Skambraks et al., 2017), increasing the adaptive capacity of the aged centralised infrastructure (Leigh & Lee, 2019) and more. What the impact is of this increased complexity on the uptake in less arid developed regions is so far largely unknown.

Table 1: List of demonstration projects

Project	Location	Number of users	Residents move in
Cityplot	Amsterdam, Netherlands	500	2021
Schoonschip	Amsterdam, Netherlands	45	2019
SUPERLOCAL	Kerkrade, Netherlands	250	2021 - 2022
Jenfelder Au	Hamburg, Germany	1,500	2019 - 2021
Oceanhamnen H+	Helsingborg, Sweden	1,800	2020 - 2022
Nieuwe Dokken	Ghent, Belgium	1,200	2020 - 2022

The partners involved in the demonstration projects are aware of the crucial aspect of social acceptance and public perception. Therefore, innovative communication interventions and participation processes are applied. In this study, the level of acceptance of new sanitation is studied, by looking at vacuum toilets and food waste grinders. Through interviews and surveys, residents had the opportunity to voice their opinions and concerns. Through the questions data was also collected on for instance age, gender, education and broader perspectives on sustainability and water.

What are New Sanitary Systems?

So-called new sanitation provides a system innovation in which elements of source separation, local treatment, the reuse and reduce of water use are combined (Poortvliet et al., 2018). New sanitation aims for the maximum recovery of energy and resources from domestic waste water, whilst minimizing emission and the use of potable water (Poortvliet et al., 2018). Examples of new sanitation appliances are vacuum toilets, NoMix toilets, food grinders and grey water reuse appliances. Besides tempering eutrophication risks, new sanitation appliances also make nutrient recovery from waste streams more efficient (Lienert & Larsen, 2010; McConville, Kvarnström, Jönsson, Kärrman, & Johansson, 2017). Source separation allows for separate treatment of waste water streams, allowing, for instance, the application of urine as fertilizer (Lienert & Larsen, 2010). Accordingly, the use of new sanitation is also found to potentially contribute to food security (McConville et al., 2017). Summarising, new sanitation consists of a wide variety of innovative sanitation techniques with the aim of improving sustainability. This can be focused on water saving, resource recovery, energy recovery, water recovery, improving local treatment quality and preventing transportation of waste streams.

Residents in this study use vacuum toilets, food grinders, and live in a neighbourhood in which rainwater and grey water are used in several manners. All these projects have a dual-pipe system separating black and grey wastewater. The black water is locally digested. Energy, resources and nutrients are recovered for different purposes. Furthermore, stormwater is managed locally and potable water demand is reduced and/or supplied by locally produced (drinking)water in these water-wise neighbourhoods. All of these neighbourhoods include state-of-the-art solutions for climate change and resource scarcity under the umbrella of the circular economy (resource recovery) and the water-food-energy nexus.

Whilst the value of these new sanitation options in increasingly recognized, the implementation challenges in households often tend to be overshadowed in the literature, whereas at the same time, the successful or unsuccessful implementation of new sanitation measures happens in people's homes, and more specifically in their kitchen, bathroom or toilet. Indeed, the introduction of new technologies in these private domains can be severely hampered by both end-user opposition as well as the incorrect use by end-users. In part One an overview of the scientific literature review is presented.

Literature review

Although it is evident that the support and willingness of (potential) end-users is crucial for the successful implementation of these appliances (Anand & Apul, 2014; Brouwer et al., 2015; Lienert, 2013; Poortvliet et al., 2018), empirical data on the acceptance of the technologies, both by end-users and potential users, is scarce. As expanded on below, our own literature search revealed that especially regarding the use of new sanitation measures such as food grinders and recycle showers, empirical knowledge is very limited. Considering the use of alternative toilets this number is slightly higher. Grey water reuse technologies seem to be another strand of literature, with considerably more studies performed on the topic. However, most studies concern a broad range of reuse applications, beyond sanitary reuse only. As we will focus on sanitary purposes, the use of grey water toilets and grey water use for laundry will be included. Other appliances of greywater are beyond the scope of this work.

The following sections present a review of the empirical data on the acceptance of new sanitation appliances by (potential) end-users. To this end, as the user experiences can differ per type of sanitation, each technology will be discussed successively. After this, potential factors influencing the acceptance of these appliances will be identified. Although stakeholders of the water distribution and wastewater management sector in general often assume the social acceptance and openness of the public towards new sanitation systems – as long as they function reliably and without a loss of comfort (Kerber, Schramm, & Winker, 2016) – also several other drivers of acceptance have been identified. Each of these drivers will be discussed in more detail.

Methodology

The empirical data is collected using a snowball search within the researchers own network, as well as a review by peers. Moreover, data collection was supplemented by a structured search on Google Scholar regarding each of the new sanitation appliances discussed. The terms “new sanitation”, “food grinders”, “recycle shower”, “heat recovery shower”, “recycled water laundry”, “source separation sanitation” and “vacuum toilet” have been combined with “public perception”, “public acceptance”, “public resistance” and “end-user” in searches in the Google Scholar database. For each of these combinations the first five pages have been analyzed and all relevant articles have been selected. These papers formed the base for another snowball search into relevant cited articles. All selected articles have been published after the new millennium. Our focus has been on European, Canadian, American and Australian studies, to allow for comparable contexts. In the review of studies on new sanitation, our focus has been on types of new sanitation that are potentially applied on a larger urban scale. As such, appliances like compost toilets are left out of consideration. Furthermore, this review only looked at technologies with direct interaction with end-users. Therefore, the local treatment of (waste)water in close proximity of their homes is not part of this analysis. Finally, the focus considering end-user experiences with these appliances has been on citizens specifically (not on e.g. employees or others actors involved in the implementation). This literature review has been conducted in 2020.

Experiences and acceptance of new sanitation appliances

New sanitation techniques consist of a variety of appliances, raising different responses from (potential) users. In the following section the main appliances used in urban new sanitation projects will be discussed, including toilets (vacuum, NoMix, reused water), food grinders, showers (heat recovery, recycle) and laundry using reused water. For each of these appliances both the perceptions of the general public, i.e. the people without actual experience, as well as the end-user experiences will be discussed respectively if empirical data was available.

Toilets

When discussing the transition to new types of sanitation, the use of alternative toilets seems indispensable. While regular toilets often use a vast amount of drinking water to flush, appliances like vacuum toilets can allow for a high reduction in water use (Naus & van Vliet, 2012). Besides vacuum toilets, also the use of NoMix toilets will be discussed, as well as the reuse of recycled water to flush the toilet.

Vacuum toilets: a toilet in which the flush water, urine and feces are not distributed driven by gravity, but driven by negative pressure. As such, only a small amount of the water normally required to flush the toilet is needed (only ca. 10% of a regular toilet).

Studying the general public's response to new sanitation appliances (through a survey distributed amongst 338 Dutch citizens) Poortvliet et al. (2018) found a positive attitude towards vacuum toilets. 64% of the questioned (potential) house-owners stated to stand positive towards the introduction of these new sanitation measures in their houses (Poortvliet et al., 2018).

Likewise, looking at the limited amount of empirical data on the end-user experiences regarding vacuum toilets, also a generally positive attitude is found (e.g. Naus & van Vliet, 2012; Telkamp, 2006; Hegger, 2007). Interviews with 18 end-users of a demonstration project in Sneek, the Netherlands, showed that the users in general stood positive against the use of the vacuum toilet in their home (Naus & van Vliet, 2012). Corresponding results were found by Telkamp (2006) in his study on the experiences of 20 inhabitants of a student housing project in Norway. In a second case studied by Telkamp (2006), however, less positive reactions were collected. Interviews with 18 homeowners (also in Norway) showed that the majority was dissatisfied or neutral about the use of the vacuum toilets. Their dissatisfaction was mainly due to the malfunctioning of the system. In both the studies of Naus and van Vliet (2012) and Telkamp (2006) around one third of the end-users had experienced malfunctioning of the vacuum toilet. Besides the malfunctioning, also some other negative remarks were made: the toilets were very loud when "flushing". This noise is considered to be one of the main disturbance by the end users (Hegger, 2007; Naus & van Vliet, 2012; Telkamp, 2006). In the study by Telkamp (2006) also the smell of the toilets came out as a main disturbance. The latter was related by the authors to the prohibition of the use of chemicals for cleaning the toilet (Telkamp, 2006). Protection of resources, on the other hand, is seen as one of the main advantages by end-users. Yet, the necessity to flush the toilet with additional (buckets) of water makes them question the real water savings (Hegger, 2007). However, the discussed studies are relatively old, and might be considered dated. As these technologies have developed over the last years, they have become more silent and malfunctioning has possibly decreased.

NoMix toilets: Toilets in which urines source separation is applied through the use of a separate outlet. Urine is discharged to a separate storage tank with or without the use of additional flush water.

Using so-called 'informed focus groups' (citizens were provided with state of the art knowledge) Pahl-Wostl, Schönborn, Willi, Muncke, and Larsen (2003) found that 80% of the approximately 80 Swiss respondents stood positive towards the use of NoMix toilets. This study focused on members of the general public, having no particular experience with the technology. Moreover, over 60% of the respondents in this study stated to be willing to introduce this technology into their household (Pahl-Wostl et al., 2003).

Looking closer into the end-users' experiences with NoMix toilets, a likewise positive attitude can be distinguished. In an extensive study, Lienert and Larsen (2010) have reviewed surveys on the acceptance of NoMix toilets in 38 projects in 7 Northern and Central European countries with in total 2720 respondents. A portion of these respondents use the NoMix toilets in their private homes (N=482). Also, regarding this appliance, the experiences with the new sanitation technique are positive. Approximately 70% of the private home users of the NoMix toilet judged it to be similar or better than conventional toilets (Lienert & Larsen, 2010). Design (79%) and hygiene (85%) raised very positive responses in all countries under study. Also, the smell was judged positively (77%). Cleaning and the maintenance problems raised fewer positive responses (respectively 52% and 59% positive). Blockage and urine drains were the main maintenance problems reported (Lienert & Larsen, 2010). Also, many of the respondents noted that they had to change their behavior to adapt to the requirements of the toilet, e.g. men usually sit on NoMix toilets (60%). The most challenging aspect of the NoMix toilet reported, is the disposal of toilet paper in a separate bin, or the feces compartment (without extra flushing, otherwise no water is saved). Only ca. 50% would dispose lightly soiled paper in a separate bin (Lienert & Larsen, 2010). A likewise number was found in a study on the use of urine separating toilets on university campuses by Ishii and Boyer (2016), as they found only ca. 60% willing to dispose lightly soiled toilet paper in a separate bin. Moreover, non-adequate flushing behavior is another behavior reported frequently throughout the surveys, with the main behavior being the use of the "big flush" (meant for feces); extra flushing to get rid of toilet paper (Lienert & Larsen, 2010).

Water reuse toilets: Water reuse toilets recycle grey water or rainwater to flush the toilet. Grey water is lightly polluted water that can be collected from all household appliances excluding the toilet. Rainwater is often collected on rooftops or from other impervious surfaces. The use of recycled water often requires a storage tank for grey-/rainwater. Using recycled water in the toilet can result in a ca. 13-21% reduction of households water consumption.

As with vacuum and NoMix, toilets, also water reuse toilets gained positive feedback from the general public (Hefter, Birzle-Harder, & Deffner, 2015; Jeffrey & Jefferson, 2003; Keuter & Deeberg, 2009). Jeffrey and Jefferson (2003) found that 89% of their respondents (representative sample for the England and Whales population, n=300) stood positive toward the use of grey water as long as safety is guaranteed. Moreover, 88% of the respondent was found to be willing to use the residue water of their own shower or bath to flush the toilet. The use of waste water from other sources (other private homes or public sources) was less accepted, here only half of the respondents were willing to use the water (Jeffrey & Jefferson, 2003).

Likewise positive responses were collected by interviewing the visitors of the London Olympic Park where filtered black water was reused in, amongst others, toilets. Respondents were provided with some diagrams and information on the reuse scheme and surveyed on their willingness to introduce these technologies into their home. 90% of the 309 respondents stated to support using recycled black water in homes (for irrigation of lanes and toilet flushing). In this particular study, no differentiation was made between different black water sources (Smith, Rutter, & Jeffrey, 2015).

Also the use of rainwater to flush the toilet has yielded positive responses from non-users. In a survey amongst 240 Scotisch households Egyir, Brown, and Arthur (2016) have found that around 90% of respondents considered the use of harvested rainwater for the toilet acceptable. The likelihood that respondents would implement a rainwater toilet in their home, however, was much lower with between 58-74% of respondents deeming this likely for the different areas studied (Egyir et al., 2016).

The end-user experience with grey water reuse toilets was studied by Deffner and Birzle-Harder (2017) in Germany, by surveying 55 end-users on their experiences with grey water toilets. In general, the respondents provided a positive feedback on the system, with the majority of residents valuing the benefits for resource protection and financial benefits only appearing secondary. Likewise, also Domènech and Saurí (2010) reported users to have a positive attitude toward the use of grey water toilets (survey in Spain, n=120). 90% feels it is a positive feature of their home (with the other 10% feeling indifferent). However, ca. 35% of the users feel (very) dissatisfied by the toilet. Moreover, 20% of the respondents who initially stood positive against the technology, noted that they changed their mind after using the toilet. Main issues mentioned relate to the perceived health risks, the operational regime required and costs. Yet, although health risks are an explanatory factor, only very limited people thought there actually were health risks related to the use of grey water toilets (less than 10%). Regarding the costs of the system, ca. 30% reported them as high, which is a factor negatively influencing the attitude towards the system. Finally, in all of the four cases studied by Domènech and Saurí (2010) respondents reported negatively on the odor.

Food grinders

Food waste grinders are common in the United States of America where they are used to dispose food waste in a regular sewage system. The main reason for use is end-users convenience. By combing food waste grinders with source separation, the goal is shifted towards resource- and energy recovery and therefore the technology available is now used for sustainable purposes. Below we only focus on these types of applications.

Food grinder: A technology that crunches food with water into one single stream which can be abducted through the sewage system. The food grinder is installed commonly in the kitchen sink. The use of food grinders reduce the amount of green waste to be disposed through regular waste streams. Also the distribution through the sewage system can lead to composting benefits.

In their study on the acceptance of new sanitation technologies, Poortvliet et al. (2018) have included the use of food grinders. As was stated before a general positive attitude was found regarding the use of food grinders and vacuum toilets, with 64% of the respondents having a positive attitude towards the introduction of these in their homes.

Regarding the empirical data on the use of food grinders in a household setting, it can be concluded that only very little data is available on this topic. The study of Naus and van Vliet (2012) into the experiences of 18 tenants of a housing project in Sneek (the Netherlands) gives some first insights into the way people experience these grinders. First, over 90% of the users would prefer the food grinder over a green waste container and all users feel it is a good replacement. Moreover, as was found with the vacuum toilets, people also feel proud to be part of an experiment in which this technology is applied. Yet, the grinder also received some negative feedback, as the noise disturbed a little less than half of the users. Moreover, the food grinder is found to be prone to malfunctioning by as much as one third of the users. Nonetheless the occasional malfunctioning did not result in an overall negative evaluation of the grinder and users would still recommend the technique to others (Naus & van Vliet, 2012).

Showers

Showering has become a standard ritual in western societies. It accounts for about 40-50% of people's daily potable water usage. Water saving shower heads have been promoted for decades which resulted in quite a high uptake of about 70%. However, recently more innovative technologies have entered the market: Air nozzles, recycling showers and heat recovery showers. In this review we focus on the latter two since they match new sanitation characteristics.

Recycling shower: These systems are based on the reuse of the residue shower water by filtering it within the shower itself and reusing it immediately. This can result in considerable reduces in water use for shower purposes.

The search for empirical data on the (potential) use of recycling shower has not given any results in Google Scholar. The limited empirical data on the topic might be caused by the relative recent introduction of the technology. Commercial providers such as the Swedish Orbital Systems, the Australian Cintep and the Dutch Harmwells have introduced their showers from 2013 onwards. These systems are based on the reuse of the residue shower water by filtering it within the shower itself. As the latter technology can be considered a grey water reuse technology, the empirical data found on the acceptance of grey water reuse can be deemed helpful in understanding the potential motivations and barriers for the introduction of this water saving technology.

Heat recovery showers: heat from the residue shower water is reused to heat up the fresh shower water. This is commonly done by aligning the piping of the residue and the fresh water in a way that allows the heat to transfer to the fresh water. In this technology no grey water reuse is included.

While there are various studies focusing on the technical appliance of heat recovery in showers (e.g. Culha, Gunerhan, Biyik, Ekren, and Hepbasli (2015) focusing on showers specifically or El Hage, Ramadan, Jaber, Khaled, and Olabi (2019) focusing on heat recovery from domestic appliances), the empirical data on the end-user experiences or the potential users expectations is very limited. A possible reason for this lack of data might be the technological base of the measure, requiring no behavioral change of the end-users (after installation). An exception is the study of van der Grijp et al. (2019), which briefly mentioned the end-user experiences with these showers. In their study on demonstration projects of Nearly Zero Energy Buildings in Sweden, the Netherlands and France, they have surveyed and interviewed residents of three different cases. Although the focus of their study was on reviewing the performance of the system as a whole, some remarks on the experiences with the heat recovery showers were included. An aspect mentioned in the Dutch case which was bothering the end-users (reoccurring focus groups with n=12) is the fact that the heat recovery system only starts functioning after showering for over 10 minutes (van der Grijp et al., 2019).

Laundry

Recycled water use in washing machine: **recycled water can be reused to do laundry. A regular washing machine uses 40-60 liters each running.**

While European empirical data on this topic seems to be largely lacking – although it is a common practice in Belgium and some other place – our literature search revealed that the use of recycled (grey) water for laundry has been studied quite extensively in the Australian context (Chen, Ngo, & Guo, 2013; Chen, Ngo, Guo, et al., 2013; Hurlimann, 2011; Mainali et al., 2013). These studies, overall, suggest that the use of recycled grey water for laundry purposes has yielded positive responses with potential users. Chen, Ngo, and Guo (2013), for instance found that over 60% of their respondents (n=223) support this particular application, whereas only 10% opposed. People stated to be mainly concerned on the hygiene, smell and health risks (Chen, Ngo, & Guo, 2013). Also, in a small UK based study (n=46), 100% of respondents were willing to use rainwater collected from their own roof for a number of household appliances, including the laundry (not specified per appliance). Respondents did, however, perceive the use of rainwater for laundry being related to relatively high risks, as they rank the risks a 4.5/10 (higher than e.g. car washing 1.9/10, but lower than personal washing 6.2/10) (Ward, Butler, & Memon, 2008).

Explanatory factors of (potential) acceptance

In most of the studies mentioned in the previous section, authors have also attempted to unravel the drivers of public reactions. Various approaches have been us identify these drivers, as well as the correlation between them. Some studies, working with larger samples (Domènech & Saurí, 2010; Jeffrey & Jefferson, 2003; Lienert & Larsen, 2010; Poortvliet et al., 2018; Smith et al., 2015), were able to identify statistical correlations, whilst others based their results on more qualitative analyses (Naus & van Vliet, 2012; Pahl-Wostl et al., 2003; Telkamp, 2006).

The classical socio-demographic characteristics (like age, education and income) are analyzed in several studies. Although often not linked to motivational drivers, some authors did find correlations between acceptance and individual characteristics. A lower age and higher education were for instance found to have a significant correlation to the acceptance of NoMix toilets at work (Lienert & Larsen, 2010) and grey water toilets at home (Domènech & Saurí, 2010). Moreover, for NoMix toilets, women were found considerably more willing to purchase these then men (47% of women compared to 17% of men). The authors have provided no explanation for the latter (Pahl-Wostl et al., 2003). Many other studies, however, did not yield significant responses between social-demographic characteristics and motivation (Jeffrey & Jefferson, 2003; Smith et al., 2015), or are not reported on (Poortvliet et al., 2018).

Besides these classical correlations, another individual characteristic that was found to influence the acceptance of new sanitation appliances is the division of home ownership. Several studies have found a higher acceptance of new sanitation measures amongst tenants compared to home owners (Domènech & Saurí, 2010; Pahl-Wostl et al., 2003; Telkamp, 2006). The difference between these two groups is attributed to a higher acceptance of technology when its considered to be something temporally (Domènech & Saurí, 2010) and the unwillingness of home-owners to invest in these appliances (tenants commonly do not have to invest themselves) (Pahl-Wostl et al., 2003). Also, its suggested that potential users are less willing to accept these appliances if they are required to take personal responsibility for maintenance (Lienert & Larsen, 2010).

Also related to the individual characteristics is the type of area people reside in. One might expect a higher acceptance of new sanitation measures in ecological housing projects, such as eco-villages, compared to regular neighborhoods. The relationship between attitude and representativeness of the sample, however, is only hardly tested (Lienert & Larsen, 2010). Moreover, if tested, it has yielded mixed results. Whilst over half of the respondents in a Austrian study included in the review by Lienert and Larsen (2010) found the ecological wastewater (NoMix) concept an important motive to move in, the respondents in two Swedish eco-villages did not (only 14%) rank ecological concerns as a main motivation to move there (Lienert & Larsen, 2010). As such the type of area people live in apparently does not always relate to their ecological concerns.

In addition, also the different conditions in which respondents have experienced new sanitation technologies might has influenced their answers. Blume and Winker (2011) for example found that users of source separation toilets (NoMix) were more likely to change their behavior on the toilet (sit down) if urine disinfection spray was made available.

Individual drivers

Although the mentioned individual characteristics provide some insights into the willingness of respondents to accept new sanitation appliances in their homes, they do not explain what factors drive the public acceptance. There are various methods to analyze these drivers, including conventional models such as the value-belief-norm theory (Poortvliet et al., 2018), the theory of planned behavior (TPB) (Ishii & Boyer, 2016) and the so called deficit model (Stenekes, Colebatch, Waite, & Ashbolt, 2006). All of these aim to explain acceptance or behavior, by suspecting a relationship between for instance attitudes, subjective norms, people's perceived behavioral control, and/or their intention to act (Ishii & Boyer, 2016). The drivers identified in these different models are a valuable way of structuring a study into acceptance. Although the casual relationships they are based on are sometimes difficult to prove, they provide insight into the subjective realities of (potential) end-users. Hence, understanding these contributes to the potential design of tailored communication with and involvement of (potential) end-users.

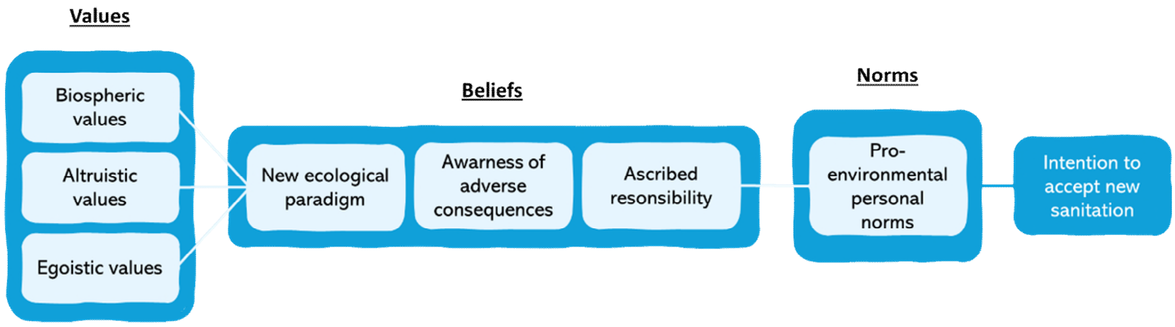
Therefore the following paragraphs will discuss a combination of drivers derived from various empirical studies on new sanitation. Discussed drivers are the values, beliefs and norms people behold (Poortvliet et al., 2018); perceived risks and benefits (Poortvliet et al., 2018; Stenekes et al., 2006); the trust people have in organizations that oversee the service offered (Smith, Brouwer, Jeffrey, & Frijns, 2018; Stenekes et al., 2006); the perceived behavioral change needed to use these appliances (Domènech & Saurí, 2010; Lienert & Larsen, 2010); and the experiences people have and expect to have regarding these new sanitation appliances (Brands, 2014; Smith et al., 2018). In the following sections each of these will be discussed.

Environmental values, beliefs and norms

In their survey on the potential acceptance of new sanitation (vacuum toilet and food grinder) by Dutch citizens, Poortvliet et al. (2018) have found an (indirect) correlation between the environmental values people behold and their attitudes towards this type of technology. By making use of a value-beliefs-norm model, the biospheric, altruistic and egoistic values people behold were compared to their beliefs concerning the new ecological paradigm (related to the relation between humans and nature), their awareness of adverse consequences (off issues related to e.g. to provision of clean water) and the responsibility they personally felt to act (to e.g. reduce their water use). These beliefs in their turn were related to the pro-environmental personal norms people hold themselves to, as well as their intention to accept the introduction of new sanitation (see Figure 1).

Except for their altruistic values (e.g. their valuing of social justice), all variables were predictive of the variable next in the described chain (values-beliefs-norms). Thus, people with strong biospheric values, are also likely to have an ecological worldview (beliefs), to hold strong environmental norms, and have a higher intention to accept new sanitation. Likewise, people with strong egoistic values score low related to the new environmental paradigm (beliefs) and do not hold strong environmental norms. As such they are less likely to accept new sanitation (Poortvliet et al., 2018). By mapping out this chain of values, belief and norms, the influence of having certain biospheric and altruistic values on the intention to accept new sanitation was shown (Poortvliet et al., 2018).

Figure 1 created by Poortvliet et al. (2018, p. 92). Value-belief-norm system to predict intention to accept new sanitation.



These findings correspond with the findings of the empirical studies into the end-user experiences. Although not reviewed related to each appliance, having an environmentally friendly attitude has been correlated positively with the acceptance of NoMix toilets (Lienert & Larsen, 2010). Also considering the use of grey water reuse toilets Domènech and Saurí (2010) have linked the attitude of respondent considering environmental conservation to their acceptance. A positive attitude towards environmental conservation favours a likewise attitude to grey water reuse technologies (Domènech & Saurí, 2010). A likewise correlation is found in the study by Jeffrey (2002) into the general public's attitude in England and Whales. Moreover, although studied in a more qualitative fashion, also many participants in the focus groups organized in the study of Pahl-Wostl et al. (2003) (focusgroups with potential users) stated environmental friendliness and water saving were main arguments in favor of using a NoMix toilet (Pahl-Wostl et al., 2003).

Another interesting approach which is worthy of pointing out here is the typology created by Deffner and Birzle-Harder (2017). Based on interviews with end-users these scholars have identified five individual user groups, each of them sharing similar perceptions and interests toward sustainability and innovative innovation systems. Based on values and motivations people behold, they differentiated between the environmental conscious users, the convenience-oriented users, the cleanliness-sensitive users, the skeptical users and the disinterested and indifferent users. Each of these groups will also react different to presented risks and benefits (Deffner & Birzle-Harder, 2017).

Perceived risks and benefits

Other aspects influencing the likelihood to accept new sanitation, are the perceived benefits and risks. The study of Poortvliet et al. (2018) showed that both the perceived risks and benefits successfully predict the acceptability of new sanitation technology. Interestingly enough, they found that the perceptions people have of the benefits to be contributing more to the intention to accept vacuum toilets and food grinders, than the perceptions people have of the risks. The perceived potential benefits are mainly related to the economic and environmental benefits, while the perceived risks relates mainly to the perceived needed behavioral change for implementation of new appliances (Poortvliet et al., 2018).

The perceived benefits of new sanitation thus seem to be a main driver for the public acceptance and are mainly environmental and financial in nature. Likewise, also Ward et al. (2008) found that the respondents in their small UK based study (n=43) mainly listed environmental and financial factors to be influencing their consideration of installing rainwater reuse systems for, amongst others, laundry purposes. Yet, communicating these only appeals to individuals with a strong biospheric value orientation (Poortvliet et al., 2018). The sole knowledge of benefits is thus not necessarily a significant driver of public response, as it will only appeal to those for whom it related to their personal values, beliefs and norms (Poortvliet et al., 2018). Moreover, the study of Naus and van Vliet (2012) also suggests that, when looking at the end-user experiences of these benefits, understanding them remains challenging. In their small sample study (n=20) evaluating the satisfaction of users (tenants) of a Dutch housing project including new sanitation measures, Naus and van Vliet (2012) found that understanding the financial benefits (or risks) of implementing these technologies is often unclear to (potential) end-users. Moreover, also the environmental benefits, related to the in- or decrease of water and electricity use of the households, were unclear to most respondents. Yet, almost everyone believed these environmental benefits would occur (Naus & van Vliet, 2012).

In general, the financial benefits or risks seem to be influencing the acceptance of residents. As was stated before, the higher willingness of tenants to use new sanitation measures is linked to the willingness to bear financial responsibility for these systems and their maintenance (Lienert & Larsen, 2010). Moreover, in the case of NoMix toilets, the acceptance decreased with the inclusion of willingness to pay as a measure of acceptance (Ishii & Boyer, 2016; Lienert & Larsen, 2010; Pahl-Wostl et al., 2003).

In addition, the perceived risks seem to be more substantial in relation to water reuse appliances, such as a grey water toilet. Although still not deemed significant by most end-users (less than 10% thinks there are health risks related to the use of grey water toilets in the study of Domènech & Sauri), water reuse is more explicitly linked to potential health risks. In the study of Jeffrey and Jefferson (2003) for instance, the idea of grey water reuse within people's own household does not raise concerns with respondents, as long as it does not involve increased health risks.

Perceived behavioural change needed for implementation

As was stated before, Poortvliet et al. (2018), concluded that the need to change behavior is the main perceived risk that was found to influence peoples intention to accept new sanitation. The more people expect that a behavioral change is required for the implementation of new sanitation (and thus the higher the risk of behavioral change is), the less likely they are to accept new sanitation measures. In line with these findings van Vliet and Spaargaren (2010) have argued that behavioral routines, which are rooted in cultural traditions, can serve as important constraints in the implementation of new sanitation. This statement is backed by the findings regarding the end-user experiences with the NoMix and grey water reuse toilet. The need to dispose toilet paper in a particular place and the requirement to use the small flush are required behavioral changes reported for the NoMix toilet. Both of them were also found to link negatively to acceptance of the toilet (Lienert & Larsen, 2010). Moreover, considering the grey water toilet, common behavior like dumping waste in the sewage was found to clog the system and was noted as causing malfunctioning of the system. The malfunctioning negatively affected the attitude of users towards the system (Domènech & Saurí, 2010). For vacuum toilets and other new sanitation appliances this might also be the case, although not looked into specifically.

Another aspect related to the behavior required when using new sanitation appliances is the unfamiliarity potential end-users have with these systems. The study performed by Naus and van Vliet (2012) showed that people found it challenging to envision the use of the new sanitation measures beforehand. Providing a demonstration of the use of these technologies in combination with general provision of information seemed to be the most effective means of preparing future users (Naus & van Vliet, 2012).

Trust in the overseeing organization

Another factor influencing peoples acceptance of new technologies and water reuse in particular, is trust in the overseeing organization (Smith et al., 2018). This organizational trust is considered to be linked to the way people interpret risk-related information they receive in relation to a new technology (Smith et al., 2018). Although not looked into particularly, this is done by Poortvliet et al. (2018) as they link the perceived health and hygiene risks to the trust in the implementation of these new sanitations by responsible bodies. In their study they found that the potential impact of new sanitation on hygiene and public health was not predictive of peoples intention to accept these technologies. Consequently they suggest that the public trusts that these new sanitations will be implemented according to good practices, meeting all hygiene requirements (Poortvliet et al., 2018).

The trust people have in the technology itself, on its turn is considered to be influenced by a number of factors. Regarding the use of recycled waste water, sensorial information is an important factor that is found to influence trust (Smith et al., 2018). This sensorial information relates to the way we experience water and water characteristics, and thus to the odor and sight of the water or the technique itself. These experiences in relation to new sanitation measures will be discussed in the following section.

Experiences

A last item that will be discussed in as individual driver for perception, slightly differs from the previous ones. While the other identified drivers can be related to general knowledge and attitude, this driver relates to the more experiential aspects of new sanitation. The main experiences found in literature are twofold: emotions of disgust and noise disturbances. In the behavioral science literature, the emotion of disgust is linked to the revulsion people can experience in relation to a sight or smell. This revulsion becomes larger with the closer proximity of the object of disgust to the mouth. The emotion is a nurtured feeling, which is strongly influenced by ones' upbringing, age and profession. Those working with e.g. strong odors such as feces in their professional life (e.g. as a farmer or nurse) tend to find these less disgusting compared to those who do not (Brands, 2014). This, as Smith et al. (2018) also call it, yuk-factor, can affect the willingness to accept technology. In the context of wastewater reuse, the emotion of disgust is even linked to so-called magical contamination. Even though the wastewater has been cleaned and treated profoundly and meets all drinking water requirements, people remain suspicious. Once water has been waste water, it will remain waste water in their perception (Smith et al., 2018). Moreover, Smith et al. (2018) even argue that the acceptance of new technologies is driven more by the experiential system than it is driven by the analytical system. The experiential system refers to the way people experience the technology, including its operation and smell, while the analytical system refers to the arguments people could use in favor of using new sanitation measures such as environmental and water saving considerations.

In his review paper on challenges for the implementation of source separated and decentralized sanitation Brands (2014) describes the impact the emotion of disgust can have on the attitudes and perceptions towards sanitation options. As people tend to show avoidance behavior to distinct themselves from the subject of their disgust (e.g. feces), the introduction of a new technology decreasing the distance between a person and their feces (both in sight and smell) could experience significant resistance (Brands, 2014). In addition, negative sensory experiences can even lead to a decreasing trust in the quality and safety of the water itself, disregarding any expert information provided on this topic (Brouwer et al., 2015).

The end-user experiences found in some of the empirical studies on new sanitation show that emotions of disgust can result in a negative experience of the new sanitation appliance. An unpleasant smell was reported as a negative aspect for the grey water reuse toilets (Domènech & Saurí, 2010) and vacuum toilet (Telkamp, 2006). Moreover, the storage of large quantities of water for grey water reuse also sometimes results in unpleasant, nasty smells (Domènech & Saurí, 2010). In addition, another experience which has resulted in negative feedback on new sanitation measures is the noise some of the appliances make. These complaints of end-users were particularly found in relation to food grinders and vacuum toilets (Naus & van Vliet, 2012).

These negative experiences, however, have not resulted in overall negative evaluations by end-users. Only in the study of Telkamp (2006) there is one case in which more than half of the users of vacuum toilets and food grinders were negative or neutral about these appliances. As was stated before, the most important reasons were experiential, as the malfunctioning of the system, as well as the sound and smell were considered to be the main disturbances (Telkamp, 2006).

A final remark that can be made in relation to the experiences, relates to the general unfamiliarity of the public with these technologies. As was mentioned before, people find it difficult to imagine the use of new sanitation measures if they have never used these (Naus & van Vliet, 2012). In some studies this was tackled by questioning people visiting a site in which new sanitation appliances are used, such as the London Olympic Park (Smith et al., 2015). The general attitude of respondents in this study, however, did not differentiate much from the attitude in a more general survey on water reuse as was also set out in England and Whales. In both studies around 90% of respondents welcomed the idea of water reuse in homes (Jeffrey & Jefferson, 2003; Smith et al., 2015).

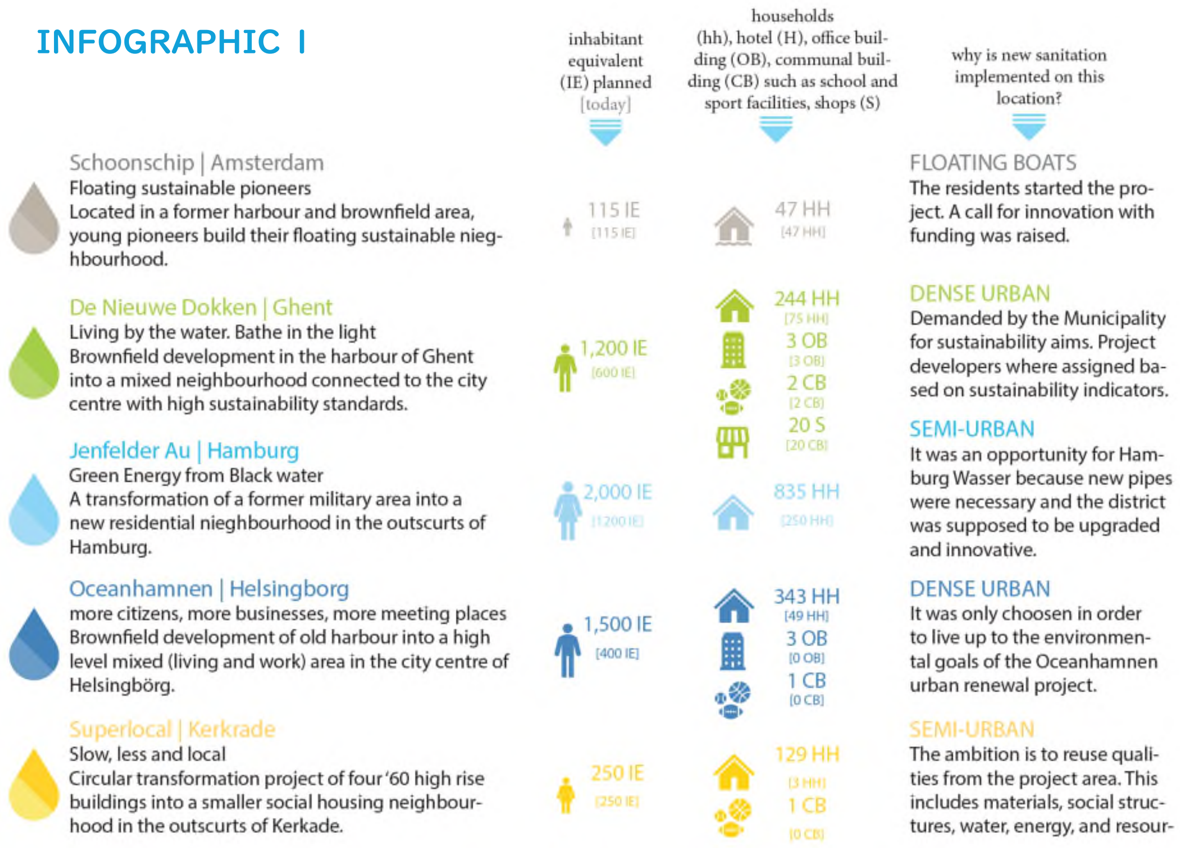
In sum, we are led to the conclusion that identifying these drivers contributes to the further understanding of the complex dynamics individual attitudes and acceptance are based on. However, as they are constantly evolving, they should by no means be seen as static. As was already noted in relation to the unfamiliarity people have regarding these appliances, experiences, for one, can influence people's acceptance of new sanitation schemes. Additionally , also other means such as participation schemes, the provision of tailored information and training of can influence these drivers and the acceptance itself (Brouwer et al., 2015).

Case studies

In five different cities across Northern Europe neighbourhoods have been developed based on new sanitation ideas and practices. In this part we first present the general context of the neighbourhood and involved stakeholders. Secondly, the social context of the different neighbourhoods is described. And finally, the indoor and outdoor technological configurations will be shown.

General description

Although all case studies have vacuum toilets and a mix of other new sanitary technologies they are different in many aspects. For an overview of these differences see Infographic 1. De case studies Jenfelder Au (Hamburg), Oceanhamnen (Helsingborg) and De Nieuwe Dokken (Ghent) are large scale real estate development projects. These projects are characterised by different stages of development. Oceanhamnen and De Nieuwe Dokken are both also multi-functional since they are not only suited for residents, but also recreation, schools and offices. Schoonschip and Superlocal are smaller in scale but provide other relevant insights. Schoonschip is a result of sustainable pioneers that live on floating houseboatsin Amsterdam. While Superlocal is a social housing project that was literally built out of former high rise buildings in Kerkrade.



Infographic 1: Context case studies

Ownership

In the case studies the inhouse technologies are owned by either housing organisations (Superlocal & Jenfelder Au) and/or private homeowners (Schoonschip, Jenfelder Au & Oceanhamnen). In all these cases, the outdoor technologies (water treatment etc.) are owned by specific (waste)water utilities and Governmental organisations. In most of these cases these organisations have a monopoly in providing these different water services stated by National law. The only exception is De Nieuwe Dokken. Here owners and renters of apartments are shareholders of the utility service cooperative DuCoop. When DuCoop makes more than 6% profit, they will receive dividend as a shareholder. They can also financially participate in DuCoop with a maximum of EUR 5,000 which gives them a different status as a shareholder.

The project developer, tripple P investment funds and cooperatives, drinking water utility Farys and CEIP (clean energy investment projects) are shareholders as well in the case of De Nieuwe Dokken.

Technical configuration

Figure 2 shows the technical configuration of the demo sites, both indoors and outdoors. All demo sites have a vacuum toilet with corresponding piping and treatment. Some demo sites have an individual food waste gronder, some a collective food waste grinder and Schoonschip and Jenfelder Au have no food waste grinder.

Technological configuration indoor

	Vacuum toilet	Sound insulation	Individual FW grinder	Collective FW grinder	R-Showers	Shared services
Schoonschip	✓ Supplier: Bio compact Type: [Jets Jade]	✗ No	✗ No	✗ No	✓ Some of the houseboats have a recirculation shower.	No
Cityplot	✓ Supplier: Evac Type: [Evac Optima] & [Optima 5]	✓ Construction measures which were described in the PRD by biocompact have been implemented.	✓ For private homeowners this will be suggested for the kitchen. For social housing/rent it will not since it is too expensive.	✓ A hotel will probably have food waste grinders.	✗ No	No
De Nieuwe Dokken	✓ Supplier: Quavac Type: [Optima 5] Accesible toilets (for disabled and children) are conventional toilets but connected to the sewage system with abreaktank.	✓ Construction measures have been taken.	✗ No	✓ There is a centralized food waste grinder installed that can process 10 L of foodwaste. Supplier is Rödiger which developed this type for DuCoop with a badge for users.	✗ No	Shared mobility services that run on biogas.
Jenfelder Au	✓ Supplier: Rödiger Type: [Silence 95%] Supplier: Jets Type: [Charme 5%]	✓ Construction measures are described in full detail in appendix A. Short summary on previous page.	✗ No	✗ No	✗ No	Fat water collection from kitchen in Hamburg.
H+	✓ Supplier: Jets Type: [3 types] Choice up to project developer	✓ Developers follow Jets installation advice (and newly updated from Amsterdam). Such as polo piping, rubber clamps, not attaching to sound carrying material.	✓ FW grinders in every kitchen (dual sink). So far Insinkerator 100 are chosen by developers.	✓ FW grinders in every entry of office buildings. So far Insinkerator 100 are chosen by developers.	✗ No	Shared laundry services. Public swimming pool using treated water.
Superlocal	✓ Supplier: Quavac Type: [Evac Optima 5S] Supplier: Jets Type: [Jade Soft Sound] Choice up to project developer	✓ Rubber between toilet and wall, strong wall, extra strong piping, flexible kit, insulation of piping, enough space between wall and piping, rubber clamps.	✓ FW grinders in every house (not in appartments). So far Insinkerator LC-50 from Quavac.	✓ Centralised FW grinders in every floor of the appartment building with a badge for users. So far Insinkerator LC-50 from Quavac.	✓ The three experiment dwellings will have recirculation showers.	Shared laundry services including grey water reuse. Shared car wash.

Technological configuration outdoor

	Rainwater	Drinking water	Grey water	Black water	Food waste	Energy
Schoonschip	RWH in some private households for HW purposes (toilet flushing). Rest of rainwater is discharged into surface water bodies.	DW is produced in a centralised treatment facility using ground water and distributed to the neighbourhood.	GW is separatly collected and transported to a mixed sewage system which is treated at a centralised WWTP.	BW is separatly collected and digested in a neighbourhood UASB-reactor. Than the Oland reactor (N removal) and at the end phosphate recovery (struvite).	Standard centralised food waste management.	A surface water heat exchanger is installed for the neighbourhood. The biogas from the UASB-reactor is reused for the digestor itself.
Cityplot	Rainwater is collected in a rainwatersewage system and discharged into surface water bodies.	DW is produced in a centralised treatment facility using ground water and distributed to the neighbourhood.	GW is separatly collected and transported to a mixed sewage system which is treated at a centralised WWTP.	BW is separatly collected and digested in a neighbourhood UASB-reactor. Than the Oland reactor (N removal) and at the end phosphate recovery (struvite).	Some food waste is added to the BW vacuum system and treated localy. The rest follows the standard centralised food waste management.	The biogas from the UASB-reactor is reused for the digestor itself.
De Nieuwe Dokken	RWH in some appartment blocks for HW purposes (toilet flushing). Rest of rainwater is discharged into surface water bodies.	DW is produced in a centralised treatment facility using ground water and distributed to the neighbourhood.	GW is separatly collected, heat is recovered, and locally treated with ultra filtration to HW quality. DW utility Farys will upgrade this using RO to process water standards at the factory.	BW is separatly collected and digested in a neighbourhood UASB-reactor. Struvite precipitation is implemented.	A central food waste point is connected to the BW UASB-reactor process.	Heat is recovered from grey water and in the nearby factory (cooling). The biogas from the reactor is burned. All this heat is used for district heating. Solar panels with batteries provide electricity for installations.
Jenfelder Au	Stormwater is seperatly transported to open infiltration buffers. An overflow to a nearby river is possible in extreme cases.	DW is produced in a centralised treatment facility using ground water and distributed to the neighbourhood.	GW is separatly collected and two types of treatment will be tested (fixed bed bioreactor with lamella separator and membrane bioreactor). Other reuse options will be tested.	BW is mixed before the digester with heated fermenting sludge that is recirculating from and into the digester. Also, fatty water is added to the BW digester.	Fatty water from kitchens in Hamburg is added to the digestion process. Food waste is managed on a centralised scale.	The biogas from the digestor is converted into electricity and heat in a CHP-plant. This is reused in the digestor, used for district heating and delivering electricity to the grid.
H+	Stormwater is discharged in to the ocean.	DW is produced in a centralised treatment facility using surface water (Lake Bohlmen) and distributed to the neighbourhood.	GW is locally treated in a EBPR activated sludge with fecl3 precipitation, nanofiltration and ozonation (for OMP removal). Permeate is post treated to DW standard and the bleed water discharged in to the ocean.	BW is separatly collected and digested in a neighbourhood UASB, nutrient recovery as struvite and ammonium sulphate (ammonia stripper).	FW is collected in a seperate LPS system and treated in a seperate UASB-reactor. Effluent will be joined with BW effluent and undergo the same nutrient extraction steps.	Biogas from both digestors is delivered to the centralised gas grid.
Superlocal	Collective RWH from roofs and paved surfaces. Rainwater is treated to drinking water quality. Overflow to water square and infiltration ponds.	Most of the DW is produced locally from RWH. The rest (ca. 10%) is supplied by the centralised DW system. This source is surface water in Germany.	GW is locally treated in a vertical aerated helophyte-filter. Research will be done to test if it is of good quality to use it as HW for a shared laundry.	BW is separatly collected and digested in a neighbourhood UASB-reactor, nutrient recovery as struvite are currently being developed.	FW is added to the BW vacuum sewage after which it is digested in the UASB-reactor.	Biogas from the digestor is reused for heating the digestor. Energy is produced using a turbine at a nearby location where pressure reduction is necessary in the centralised system.

Figure 2: Technical configuration indoor and outdoor

Research Design

The research design consists of a literature review, data collection and data analysis.

Literature review

The literature review has been developed by KWR based on literature provided by participants and online databases. It discusses the scientific literature on 'experiences and acceptance of new sanitation appliances' such as toilets (vacuum toilets; no-mix toilets; water reuse toilets), food grinders, showers (recirculation showers; heat recovery), laundry (recycled water use in washing machine). In the second part of the literature review 'explanatory factors of (potential) acceptance' have been discussed. This includes standard socio-demographic characteristics but also more individual drivers such as environmental values, beliefs and norms. Other relevant factors include the perceived risks and benefits, perceived behavioural change needed for implementation, and experiences.

Data collection

We have developed three core data gathering protocols which can be adjusted to site specific contexts as has been done for the projects Schoonschip and Oceanhamnen already. The basic idea is learning about social acceptance and attitude towards new sanitation techniques by means of (i) explorative interviews to gain site specific knowledge, (ii) an online questionnaire for a first general picture and analysis of correlations followed by (iii) follow-up interviews for deeper meaning and topics that are less suitable (e.g. social desirability) for a quantitative questionnaire, including questions about behavioural change. A short description and a link to the document is provided below.

Explorative interviews

Experts can be biased towards end-users about what they might see or experience as important. Past research further narrows our perspective into different determining factors and so-called relevant barriers and drivers of change in relation to end-users. Our bias is often translated into surveys and structured interviews with questions that lead to answers that confirm our bias. Therefore, we recommend starting with more qualitative interviewing where there is much greater interest in the interviewee's point of view. This could unravel what end-users see as relevant and important and show you in much more detail how and when vacuum toilets, showers and food grinders are actually used in practice.

The outcomes of the interviews will provide input for the surveys and follow-up interviews (e.g. how to structure, asking certain questions etc.). Furthermore, it gives an opportunity for stakeholders involved into the demonstration projects to really understand how people are (inter)acting and responding on the different technologies. As a side benefit the interviewers gain experience with different types of social (scientific) research practices. As such they are in a better position to communicate about the value, possibilities and pitfalls of these methods in their own organisation and/or in pilot projects in the future.

Online survey

A standard survey that can be filled in by end-users is designed by the project partners. This includes personal questions (demographic, preferences, world views), technology related questions (experiences), and process related questions. In the standard survey all inhouse technologies are made available, and these can be pre-selected by the different projects dependent on which technologies residents have access to.

Follow-up interviews

Participants are asked in the end of the online survey if they are interested to participate in a follow-up interview. These interviews will be conducted by phone and take up to 30 minutes. The interviewer uses the answers as a starting point and tries to better understand the reasoning behind the answers by asking clarifying questions. The interviewer can be a social scientific researcher or a project officer.

Data analysis

Descriptive statistics

Means and frequencies of sociodemographic variables, customer perspectives on drinking water and evaluating items of several sanitary techniques are described.

Correlations

The relation between several items is measured in SPSS (IBM SPSS statistics program 28.1.). Satisfaction with the vacuum toilet is correlated with sociodemographic variables, with evaluations of the separate aspects of the toilet, and with the amount and acceptance of malfunctions and maintenance and repairs. Pearson correlations are measured for continuous (or ordinal) variables (such as age, or level of satisfaction with the vacuum toilet on a five-point scale), and Spearman rank correlations are measured for categorical variables (such as gender). Correlations with values between 0.1 and 0.3 are weak correlations, values between 0.3 and 0.5 are medium correlations, and values from 0.5 and higher are strong correlations (Akoglu, 2018).

ANOVA's

An ANOVA is a statistical model that is conducted to measure whether there are differences between groups. Three ANOVAs are conducted, that measure whether there are differences between the different sites in satisfaction with the vacuum toilet, satisfaction with the food waste grinder and satisfaction with the (waste) water service organization. To determine whether the sites differ from each other, we look at the F value and the p value. The larger the F value, the larger the chance that this is a statistically significant difference. To determine whether the difference is statistically significant, we look at the p value. When the p value is below 0,05, the chance that the difference between the sites is due to coincidence is 5% or lower.

Multiple regression analyses

A multiple regression analysis is a statistical model in which several factors predict or explain the amount of variance in an outcome variable. Two multiple regression analyses are conducted in the current research; to explain which factors predict the satisfaction with a vacuum toilet (outcome variable) in 2021 and 2022. Factors that are correlated medium to strong (see paragraph above) with satisfaction with the vacuum toilet are included in the model.

When interpreting the outcome of the model, we first look at the total model. When this total model is statistically significant (see explanation of the p value above), it means that the predicting factors in the model, together predict the outcome variable. For instance, the evaluation of separate aspects of the vacuum toilet, together predict satisfaction with the vacuum toilet. Thereafter, the predicting factors are investigated separately. When such a factor is statistically significant, this means that this factor is related to the outcome variable. For instance, how positive or negative people evaluate the noise the vacuum toilet makes is related to the overall satisfaction of the vacuum toilet (the chance that this factor is related to the overall satisfaction of the vacuum toilet by chance is 5% or lower).

It is important to mention that with correlations and multiple regression analyses no causal relationships can be drawn. For instance, the acceptance of the number of malfunctions may predict satisfaction with the vacuum toilet, but this does not necessarily mean that the satisfaction with the vacuum toilet is (partly) *caused* by the acceptance of the number of malfunctions. It could also be the other way around, such that satisfaction with the vacuum toilet causes a higher acceptation of the number of malfunctions. Or, that another factor, such as a positive evaluation of the communication with the (waste) water service organization causes both the acceptance of the number of malfunctions and the satisfaction with the vacuum toilet.

Representativeness
In order to draw conclusions for the total groups of residents in the different sites, results should be representative for these total groups. Since we invited residents to fill out a questionnaire, and some people may be more inclined to respond to this questionnaire than others, this may give a slightly biased view of the residents who live in the different sites, and of the overall evaluation of, and satisfaction with, the sanitary techniques applied.

For the sociodemographic variables, there is quite a large distribution of age, so individuals of different age groups are represented in this questionnaire. Half of the respondents are men and half are women, which is representative for the general population. Furthermore, residents that responded to the questionnaire are more often highly educated compared to the general population, and more often have a 'Aware and committed' customer perspective on drinking water compared to the general population. This should be kept in mind when interpreting the results.

Results

Type of residents

Jenfelder Au, Oceanhamnen and De Nieuwe Dokken are neighbourhoods which intended a variety of residents. They have developed (or are still in the process) a mix of social housing, basic housing and market conform housing including luxury housing. Jenfelder Au has only a limited percentage of social housing, De Nieuwe Dokken is still developing and Oceanhamnen none. The two extremes are Schoonschip with only market conform private houses and Superlocal with only social housing for rent. However, in Schoonschip the residents tried to include social housing with a housing corporation, but this effort did not result in a success. In Superlocal a number of residents are granted permission to live in the area even when their income is too high, but they are motivated based on the sustainable character of the neighbourhood. This way the housing corporation creates a more mixed community.

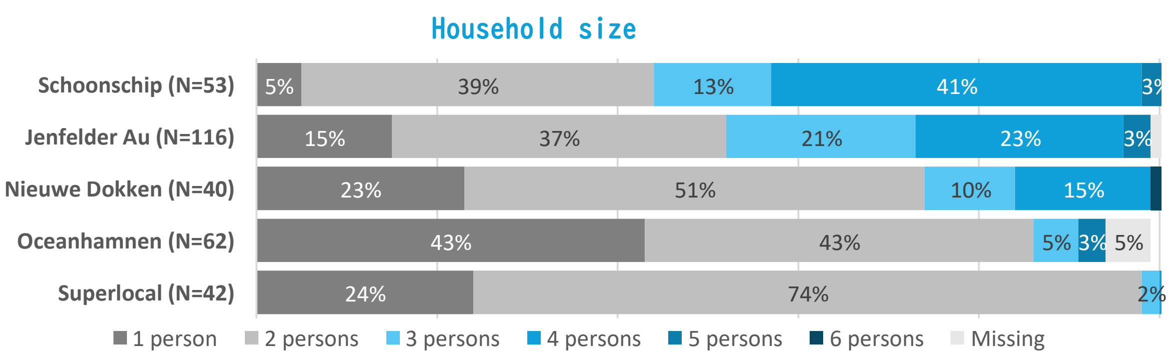
The level of finished education differs per case study. In Amsterdam, Ghent and Hamburg the group of residents that has higher education degree is near or beyond 90%. The relates also to the costs of living in these specific neighbourhoods that are mainly market conform in large European cities. In Kerkrade we see more medium (63%) and lower (18%) levels of education. Which relates to the prices of the social houses which is the lowest of all case studies. Kerkrade is an area with a population decline higher levels of unemployment and lower housing prices.

Table 2: Level of education in different case studies

		Schoonschip Amsterdam, *n* = 21	Nieuwe Dokken Gent *n* = 25	Oceanham. Helsingborg *n* = 32	Superlocal Kerkrade *n* = 36	Jenfelder Au Hamburg *n* = 55	Total group *n* = 169	*Test for differences between sites*
Level of Education	Lower	-	-	3,1%	18,2%	-	4,4%	*χ2 (8,159) = 64.93, p <.001*
	Medium	10,5%	14,3%	40,6%	63,6%	9,3%	27,7%	
	Higher	89,5%	85,7%	56,3%	18,2%	90,7%	67,9%	

In Schoonschip (56%) and Jenfelder Au (48%) roughly half of the households is a three or more-person household (Figure 3: Household size case studies. Both are not situated in the city centre and provide also space for children (e.g. playgrounds). In the other case studies one person and two persons households prevail ranging from 74% in De Nieuwe Dokken, 86% in Oceanhamnen up to 98% in Superlocal. These three neighbourhoods consist mainly of apartments with only a limited number of ground floor dwellings.

Figure 3: Household size case studies according to survey



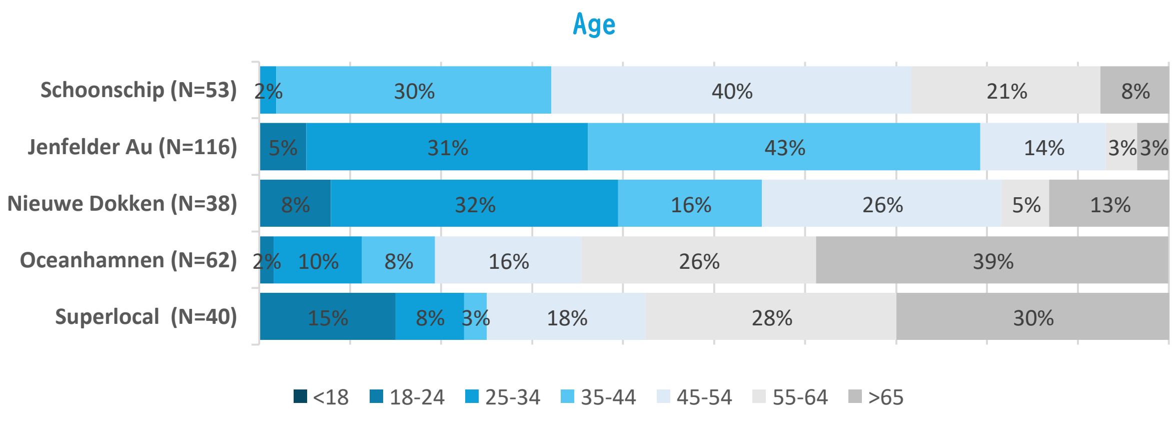
The mean age of the residents in 2021 is 44 years, and 47 years in 2022. In both years, residents of Jenfelder Au and Nieuwe Dokken are (marginally) significantly younger compared to the residents of the *other sites[1]. Moreover, the neighbourhoods with the smallest household sizes have a larger group of older residents beyond 55 years (*

Figure 4: Age groups according to survey

Figure 4). In Superlocal 58% of the surveys have been filled in by the age group 55 years or older ad in Oceanhamnen this was even 65%. The interviews showed that the resident in Oceanhamnen mdoved to smaller apartments in the city centre and often had a secondary home at the country site. While in Superlocal older residents also moved to smaller dwellings (with lower energy costs) due to their age but as their primary home.

Gender is equally distributed, with 48% men in 2021 and 53% men in 2022. In 2021, there are no differences in gender between the different sites, whereas in 2022, in Oceanhamnen and Superlocal less men responded to the questionnaire than in the other sites. The other three sites do not differ in the distribution of gender. For an overview of all socio-demographic variables see table 3.

Figure 4: Age groups according to survey



[1] Bonferroni post hoc tests demonstrate that residents of Jenfelder Au, Hamburg, are significantly younger compared to residents of H+, Helsingborg (p <.001) and compared to residents of Superlocal, Kerkrade (p = .012) in 2021. There is no difference in age between residents from Jenfelder Au, Hamburg, and Nieuwe Dokken, Gent (p = 1.00). Residents of Nieuwe Dokken Gent are also significantly younger compared to residents of H+, Helsingborg (p <.001) and marginally significantly younger compared to residents of Superlocal, Kerkrade (p = .095). For 2022, Bonferroni post hoc tests demonstrate that residents of Jenfelder Au, Hamburg, are significantly younger compared to residents of Schoonschip, Amsterdam (p =.022), compared to residents of H+, Helsingborg (p <.001) and compared to residents of Superlocal, Kerkrade (p <.001). There is no difference in age between residents of Jenfelder Au, Hamburg and Nieuwe Dokken,Gent (p = .52). Residents of Nieuwe Dokken, Gent do not differ in age from the other sites (p >.23).

Table 3: Socio-Demographic Variables

		Schoonschip Amsterdam,	Nieuwe Dokken Gent	H+ Helsingborg	Superlocal Kerkrade	Jenfelder Au Hamburg	Total group	Test for differences between sites
Age, *M* (*SD*) 2021		-	39,2 (13,7) *n* = 18 (1 missing)	59,0 (15,9)	52,9 (20,7) *n* = 8 (2 missings)	37,3 (10,0) *n* = 62 (3 missings)	44,3 (16,1) *n* = 119 (40 missings)	$F(3,115)= 20.78$, $p < .001$
Age, *M* (*SD*) 2022		50,5 (9,3) *n* = 19 (2 missings)	46,2 (17,1) *n* = 20 (5 missings)	55,3 (15,5)	51,8 (17,4) *n* = 33 (3 missings)	39,0 (9,8) *n* = 54 (1 missing)	47,3 (15,1) 1 *n* = 159 (10 missings)	$F(4,153)= 8.62$, $p < .001$
Gender 2021		55,9% men 44,1 % women	47,4% men 52,6% women	41,9% men 58,1% women	50,0% men 50,0% women	45,9% men 54,1% women *n* = 61 (4 missings)	47,7% men 52,3% women *n* = 155 (4 missings)	*ns.*
Gender 2022		52,6% men 47,4% women *n* = 19 (2 missings)	75%men 25% women *n* = 20 (5 missings)	31,3% men 2 68,8% women	42,4% men 57,6% women *n* = 33 (3 missings)	64,2% men 35,8% women *n* = 53 (2 missings)	52,9% men 47,1% women *n* = 157 (12 missings)	$\chi2\ (4,157) = 14.08$, $p = .007$
Education 2021	*Lower*	2,9%	-	3,2%	33,3%	10,0%	7,3%	$\chi2\ (8,151) = 17.83$, $p = .023$
	Medium	17,6%	29,4%	22,6%	44,4%	25,0%	24,5%	
	Higher	79,4%	70,6%	74,2%	22,2%	65,0%	68,2%	
			n = 17 (2 missings)		*n* = 9 (1 missing)	*n* = 60 (5 missings)	*n* = 151 (8 missings)	
Education 2022	*Lower*	-	-	3,1%	18,2%	-	4,4%	$\chi2\ (8,159) = 64.93$, $p < .001$
	Medium	10,5%	14,3%	40,6%	63,6%	9,3%	27,7%	
	Higher	89,5%	85,7%	56,3%	18,2%	90,7%	67,9%	
		n = 19 (2 missings)	*n* = 21 (4 missings)	*n* = 32	*n* = 33 (3 missings)	*n* = 54 (1 missing)	*n* = 159 (10 missings)	

Customer perspectives on drinking water

Drinking water customers differ in their view on drinking water. Research on the perspectives of drinking water customers distinguished four different drinking water perspectives (Brouwer, Sjerps & Etty, 2019; Brouwer & Sjerps 2019):

- The ‘aware and committed’ perspective. Customers with this idealistic perspective have a high trust in humankind and technology. They believe in the power of the collective, in which each has his own responsibility to contribute. They value sustainability to a high extent. This perspective is seen by 29% in a representative Dutch population.
- The ‘egalitarian and solidary’ perspective. Values such as equality, solidarity and care for each other are important for customers with this perspective. Drinking water is viewed not only as a basic need, but also as a human right, that should be accessible for everyone. This perspective is seen by 31% in a representative Dutch population.

- The 'quality and health concerned' perspective. Customers with this perspective, reason mainly from their own needs and wishes, in which their own health takes a central place. They worry about whether the quality of drinking water can be guaranteed in the future. This perspective is seen by 13% in a representative Dutch population.
- The 'down to earth and confident' perspective. This group of customers are fond of ease, do not like hassle, and want to be unburdened when it comes to drinking water provision. They believe drinking water utilities should focus on their core task: providing sufficient drinking water of high quality, as efficiently as possible. This perspective is seen by 27% in a representative Dutch population.

Customer perspectives are measured by a range of stands per perspective, so four ranges of stands, in which residents choose which range of stands best suits their perspective on drinking water (see appendix 1).

The distribution of the four different perspectives on drinking water in 2021 and 2022 are quite similar. The largest part of the residents has the aware and committed perspective (see Figure 5 and Figure 6). Compared to 29% in a general representative group, almost 60% is a large group. This may be explained by the fact that people who value sustainability very much are expected to live in sustainable neighborhoods, like in the current research project, more often. Furthermore, the part of residents with the down-to-earth and confident perspective is much smaller, compared to a general representative group (27%). This may be explained by the fact that people who do not like hassle are more unlikely to buy a house in such a sustainable neighborhood, in which quite much is asked of residents, in order to live sustainably.

Figure 5. Distribution of customer perspectives in 2021 (n = 118)

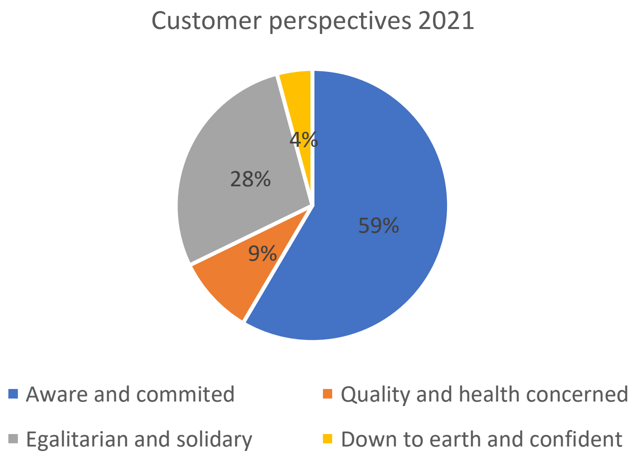
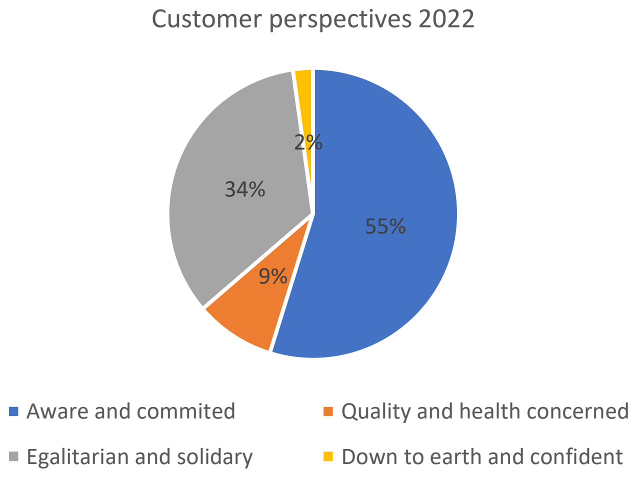
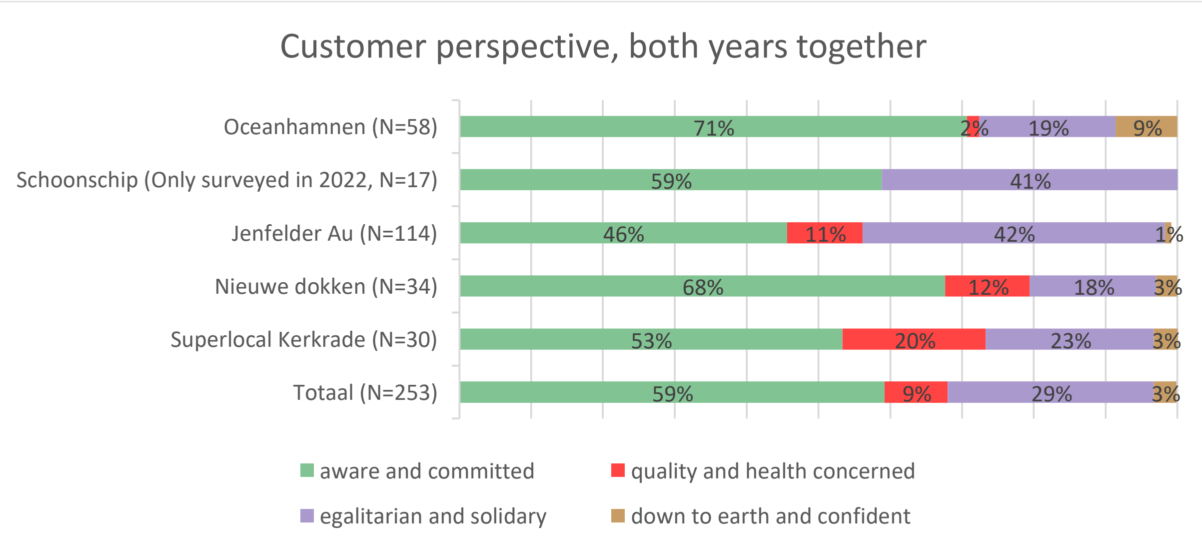


Figure 6. Distribution of customer perspectives in 2022 (n = 135)



In both 2021 and 2022, residents from Jenfelder Au more often have the 'Egalitarian and solidary' perspective, and less often the 'Aware and committed' perspective compared to residents from the other sites. Residents from the other sites do not differ significantly in their customer perspectives (see appendix I). Furthermore, residents from Superlocal, Kerkrade, also less often have the 'Aware and committed' perspective, and more often have the 'Quality and health concerned' perspective compared to residents from the other sites. Since the validity of the customer perspectives measure is never tested in countries outside the Netherlands and Belgium, the results of Jenfelder Au in Hamburg, and H+ in Helsingborg should be interpreted with care.



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Customer perspectives are measured by a range of stands per perspective, so four ranges of stands, in which residents choose which range of stands best suits their perspective on drinking water (see appendix 1).

Evaluation of vacuum toilet

Since all sites have the vacuum toilets installed, the evaluation of the vacuum toilet is included in the questionnaires of all sites. The vacuum toilet is evaluated on the following aspects:

- Overall satisfaction with the vacuum toilet. The question, "What is your overall satisfaction with the vacuum toilet?' can be answered on a five-point scale from 1= very unsatisfied, until 5= very satisfied.
- Residents score the vacuum toilet as better or worse on the following aspects, compared to a traditional toilet: hygiene, easy to clean, use friendly, safe for health[2], safe in use, malfunctions (experienced discomfort), costs (maintenance/ cleaning), odor nuisance, noise pollution, sustainability and esthetics. Scores range from 1= much worse until 5= much better.
- Satisfaction is also measured by the stand 'If I could decide now, I would choose a vacuum toilet again instead of a traditional toilet' Answer options range from 1= totally disagree to 5 = totally agree.
- The amount of malfunctions and maintenance and repairs since living in their house is measured (answer options range from 'never' until 'more than 10 times'), and the acceptance of the amount of malfunctions, and maintenance and repairs on a four point scale ranging from 1= not acceptable at all until 4 = fully acceptable.

Evaluation food waste grinder

The evaluation questions about the food waste grinder are included in the questionnaires of Nieuwe Dokken, Ghent, H+, Helsingborg, and Superlocal, Kerkrade, as these sites have (individual or collective) food waste grinders. The following questions are included in these questionnaires:

- Overall satisfaction with the food waste grinder. The question, "What is your overall satisfaction with the food waste grinder?' can be answered on a five-point scale from 1= very unsatisfied, until 5= very satisfied.
- Residents score the food waste grinder on the following aspects: hygiene, easy to clean, user friendly, safe for health, safe in use, malfunctions, odor, noise, sustainability and esthetics. Scores range from 1= very unsatisfied until 5= very satisfied.

[2] Only in the 2020/2021 questionnaire.

Comparison of satisfaction vacuum toilet between sites

Overall, residents of the five sites are satisfied with the vacuum toilet, and this level of satisfaction did not change from 2021 to 2022 (M = 3,70 in 2021 and M = 3,71 in 2022, see

Table 4). As can be seen in Figure 7, most residents (around 60%) are (very) satisfied, and only a small group (around 11%) is (very) unsatisfied with the vacuum toilet. Remarkably, residents of Schoonschip in Amsterdam score significantly lower on overall satisfaction compared to the other sites in both years, except for Jenfelder Au, Hamburg in 2022. This difference between Schoonschip Amsterdam and the other sites may be explained by the fact that first generation vacuum toilets have been installed in Amsterdam, while other neighborhoods have newer and more silent types. Secondly, the toilets and indoor vacuum piping have been installed by a variety of installers, and no utility or governmental organization have provided instructions for installation, and no review correct installing has been carried out. While in the other neighborhoods installation guidelines and/or checks during and after installation have been carried out by vacuum specialist under supervison of utilities or governmental organizations. Nevertheless, residents from Schoonschip are not *un*satisfied with the vacuum toilet, as their mean score is around 3, which means 'somewhat satisfied'.

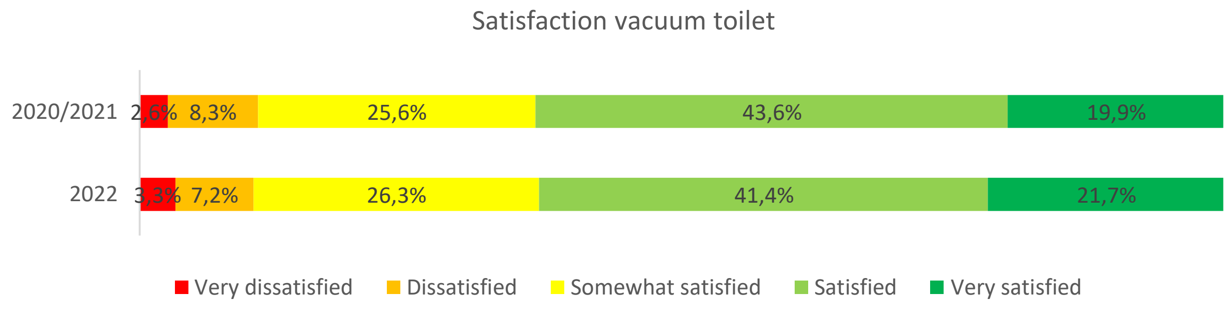
Table 4. Satisfaction with the vacuum toilet on a five-point scale, total group and per site

Legend
1 = very unsatisfied, 2 = unsatisfied, 3 = somewhat satisfied, 4 = satisfied, 5 = very satisfied

	In general, how satisfied are you with the vacuum toilet?						
	Total group	Schoonschip Amsterdam	Nieuwe Dokken Gent	H+ Helsingborg	Superlocal Kerkrade	Jenfelder Au Hamburg	ANOVA test for differences between sites
Satisfaction vacuum toilet 2020/2021	3,70 (0,97) *n*= 156 (3 missings)	3,18 (0,90) [3] *n*= 34	3,89 (0,99) *n*= 19	3,87 (1,01) *n*= 30 (1 missing)	4,40 (0,70) *n*= 10	3,73 (0,90) *n*= 63 (2 missings)	$F(4,151) = 4.63$, $p < .001$
Satisfaction vacuum toilet 2022	3,71 (0,99) *n* = 152 (17 missings)	2,95 (0,91)[4] *n* = 19 (2 missings)	4,00 (0,79) *n* = 17 (8 missings)	4,03 (0,93) *n* = 32	3,87 (1,09) *n* = 31 (5 missings)	3,60 (0,93) *n* = 53 (2 missings)	$F(4,147) = 4.78$, $p < .001$

[3] The post-hoc Bonferroni test shows that residents from Schoonschip Amsterdam score (marginally) significantly lower on general satisfaction with the vacuum toilet, compared to Nieuwe Dokken, Gent (p = .074), H+ Helsingborg (p = .034), Superlocal Kerkrade (p = .003) and Jenfelder Au, Hamburg (p = .055).
[4] The post-hoc Bonferroni test shows that residents from Schoonschip Amsterdam score (marginally) significantly lower on general satisfaction with the vacuum toilet, compared to Nieuwe Dokken, Gent (p = .011), H+ Helsingborg (p = .001), Superlocal Kerkrade (p = .010), but not from Jenfelder Au, Hamburg (p = .106).

Figure 7. Frequencies scores satisfaction vacuum toilet in 2020/2021 (n=156) and 2022 (n= 152)



In order to explain differences between sites in satisfaction with the vacuum toilet, we explore descriptive statistics, satisfaction with the communication with the (waste) water service organization, the evaluation of the vacuum toilet on separate aspects, and the (acceptation of) frequencies of malfunctions and repairs.

Evaluation of the vacuum toilet

Most aspects (9 aspects) are evaluated as comparable or better compared to a traditional toilet. Compared to a traditional toilet, residents especially evaluate the sustainability of the vacuum toilet to be better (*M* = 4,21 in 2021 and *M* = 4,06 in 2022). Two aspects, malfunctions (experienced discomfort) and noise pollution are considered worse compared to a traditional toilet. However, this is an average over all neighbourhoods. As mentioned before differences between neighbourhoods exist mainly based on these two aspects.

Table 5. Scores on different aspects vacuum toilet, for both years

'Compared to a traditional toilet, how do you evaluate a vacuum toilet on the following aspects?'		
Aspect	*M* (*SD*) 2021 *n* = 155	*M* (*SD*) 2022 *n* = 150
Hygiene	3,58 (1,06)	3,18 (0,78)
Easy to clean	3,57 (0,97)	3,04 (0,95)
User friendly	3,43 (1,07)	3,15 (0,76)
Safe for health	3,65 (0,82)	-
Safe in use	3,66 (0,93)	3,05 (0,75)
Malfunctions (experienced discomfort)	2,72 (1,18)	2,44 (0,98)
Costs (maintenance/cleaning)	3,55 (1,11)	3,03 (1,01)
Odor nuisance	3,20 (1,05)	3,33 (0,84)
Noise pollution	2,14 (1,18)	2,01 (0,94)
Sustainability	4,21 (0,91)	4,06 (0,88)
Esthetics	3,55 (1,01)	3,09 (0,69)

Legend
1 = much worse, 2= worse, 3 = comparable[5], 4 = better, 5 = much better

[5] In 2021 a score of 3 was defined as 'neutral', and in 2022 the questionnaire was improved for this (and some other) questions, and a score of 3 was defined as 'comparable'.

Frequencies and acceptation of malfunctions and maintenance and repairs

The frequency of malfunctions appears to be slightly higher in 2022, compared to 2021. The amount of residents that never or one-time experienced malfunctions is lower in 2022, and the amount of residents that experienced malfunctions more often (2 times or more) is higher. This will partly be because the frequencies of malfunctions in 2022 include a longer period.

The frequencies of maintenance and repairs also appear to be slightly higher in 2022, with more residents experiencing maintenance and/or repairs 2 times or more. See Table 6 and Table 7 for an overview of the frequencies of malfunctions and maintenance and repairs. The amount and types of maintenance necessary in these kinds of projects with vacuum systems have been rather unknown in advance. However, in turns out that different types of maintenance are necessary – more than compared with standard systems. For instance, cleaning the vacuum systems to prevent scaling in the piping. This will automatically lead to a higher degree of noted maintenance activities by residents in the future.

Table 6. Frequencies of malfunctions in the vacuum toilet

Frequency of malfunctions	2021 *n* = 150 (9 missings)	2022 *n* = 149 (20 missings)
Never	33,3%	30,2%
1 time	18,7%	14,1%
2-5 times	30,7%	31,5%
6-10 times	8,0%	12,1%
10 times or more	9,3%	12,1%

Table 7. Frequency of maintenance and repairs of the vacuum toilet

Frequencies of maintenance and repairs	2021 *n* = 150 (9 missings)	2022 *n* = 149 (20 missings)
Never	55,7%	56,4%
1 time	23,5%	13,4%
2-5 times	18,1%	21,5%
6-10 times	1,3%	3,4%
10 times or more	1,3%	5,4%

The acceptance of the frequency of malfunctions was quite low in 2021 (M = 2,57; SD = 0,90), and similar in 2022 (M = 2,50; SD = 0,93). The acceptance of the frequency of maintenance and repairs was also quite low in 2021 (M = 2,87; SD = 0,79) and slightly lower in 2022 (M = 2,75; SD = 0,84).

Satisfaction with communication with the water utility

Residents seem overall slightly more satisfied with the communication with the water utility about innovative sanitation techniques in 2022 compared to 2021. This can partly be explained by the high level of satisfaction with communication with the water utility for residents from Helsingborg and Gent in 2022 (see Table 8). The most important explanation for the high level of satisfaction with communication in Helsingborg is probably that all stakeholders communicate the same message and a variety of communication activities have been carried out. For instance, public events. Furthermore, in de Nieuwe Dokken (Ghent) communication is very personal, employees from Ducoop walk around at the site and talk to residents, so they know which challenges they experience, and they can respond to these challenges also via Whatsapp. This personal and close contact results perhaps in higher satisfaction rates. Residents from Schoonschip Amsterdam scored significantly lower on satisfaction with the communication with the water utility compared to the other sites in 2021. This may partly be explained by the fact that the Schoonschip residents are owners of the system in and between their houses. Waternet was not responsible for the installation and maintenance of the in-house technologies. Most issues occurred between homeowners and installers and technology providers. Hence, clear division of responsibilities was not ensured from the start. In the other sites this lesson has been learned and implemented.

Table 8 Satisfaction (waste) water service organization total group and per site

Satisfaction (waste) water service organisation	Total group	Schoonschip, Amsterdam	Nieuwe Dokken, Gent	H+ Helsingborg	Superlocal Kerkrade	Jenfelder Au, Hamburg	ANOVA test for differences between sites
2021	3,44 (0,97) *n* = 122	2,70 (0,97)[6] *n* = 23	4,00 (0,84) *n* = 18	3,50 (0,57) *n* = 30	3,83 (0,75) *n* = 6	3,49 (1,03) *n* = 63	*F*(4,135)= 5,96 *p* <.001
2022	3,57 (1,10) *n* = 127	2,54 (0,66)[7] *n* = 13	4,20 (0,68) *n* = 15	4,26 (1,00)[8] *n* = 31	3,33 (0,99) *n* = 30	3,29 (1,06) *n* = 38	*F*(4,122)= 10,65 *p* <.001

1 = very unsatisfied, 2 = unsatisfied, 3 = not satisfied or unsatisfied, 4 = satisfied, 5 = very satisfied

Correlating factors with overall satisfaction with the vacuum toilet

To investigate which factors predict satisfaction with the vacuum toilet, the first step is to analyze correlations with the satisfaction with the vacuum toilet. In the first place, we look at the sociodemographic variables. Whereas we may expect younger and highly educated residents to be more positive than older residents, age, gender and education are all not significantly correlated to satisfaction with the vacuum toilet in 2021 and in 2022 (p's >.100).

The satisfaction with the communication with the water utility about the new sanitation techniques is correlated with satisfaction with the vacuum toilet in 2021 (r = .40, p <.001, n = 156) and in 2022 (r = .37, p <.001, n = 111)

Evaluation separate aspects vacuum toilet

The 11 aspects on which the vacuum toilet is scored in the questionnaire, are all significantly correlated to the overall satisfaction with the vacuum toilet, which means that these factors all contribute to the overall satisfaction with the vacuum toilet. As can be seen in Table 9, in 2021 the strongest correlating factors are hygiene, malfunctions, noise pollution and sustainability. In 2022, sustainability is only weakly correlated to the satisfaction of the vacuum toilet. In 2022 the strongest correlating factor is malfunctions (the experienced discomfort).

Table 9. Scores on different aspects of the vacuum toilet, per year

Satisfaction vacuum toilet	Hygiene	User friendly	Easy to clean	Safe for my health	Safe to use	Malfunctions (experienced discomfort)[9]	Costs	Odor nuisance	Noise pollution	Sustainabil ity	Esthetic s

[6] Post hoc Bonferroni tests demonstrate that satisfaction with the communication with the water utility was lower in Schoonschip, Amsterdam, compared to H+ Helsingborg (p = .017), Superlocal Kerkrade (p = .07), Nieuwe Dokken Gent (p <.001) and Jenfelder Au Hamburg (p = .004).

[7] Post hoc Bonferroni tests demonstrate that satisfaction with the communication with the water utility in Schoonschip Amsterdam was significantly lower compared to H+ Helsingborg and Nieuwe Dokken, Gent.

[8] Post hoc Bonferroni tests demonstrate that satisfaction with the communication with the water utility is significantly higher in H+ Helsingborg, compared to Superlocal Kerkrade (p = .002), Schoonschip Amsterdam (p<.001) and Jenfelder Au Hamburg (p<.001).

[9] In the questionnaire of 2021 malfunctions was measured as a factor, whereas in the 2022 questionnaire, the measurement of this factor was further specified, by adding 'experienced discomfort' to this factor.

2021 (n = 155)	r = .45	r = .38	r = .39	r = .31	r = .34	r = .45	r = .31	r = .35	r = .44	r = .40	r = .32
2022 (n = 150)	r = .39	r = .39	r = .34	-[10]	r = .36	r = .57	r = .41	r = .26	r = .37	r = .18	r = .35

Malfunctions, maintenance and repairs

The frequency of malfunctions and the frequency of maintenance and repairs, as well as the acceptance of the frequency of malfunctions and of maintenance and repairs are all significantly correlated to satisfaction with the vacuum toilet in 2021 and in 2022. All these correlations are stronger in 2022, which may imply that the longer people experience malfunctions and the more maintenance and repairs people have had, the stronger this correlates with the satisfaction with the vacuum toilet.

Table 10 Correlations of frequencies and acceptation of malfunctions and maintentance and repairs with satisfaction vacuum toilet

	Frequency malfunctions	Acceptation of frequency malfunctions	Frequency maintenance and repairs	Acceptation of frequency maintenance and repairs
Satisfaction vacuum toilet 2021	rs = -.41, p <.001, n = 150	rs = .48, p <.001, n = 153	rs = -.29, p <.001, n = 149	rs = .42, p <.001, n = 148
Satisfaction vacuum toilet 2022	rs = -.55, p <.001, n = 149	r = .54, p <.001, n = 149	rs = -.43, p <.001, n = 149	r = .57, p <.001, n = 149

Which factors are the strongest predictors of satisfaction with the vacuum toilet?

To analyze which factors are strong predictors of the satisfaction of the vacuum toilet, when taking into account all correlating factors, two multiple regression analyses were conducted (for 2021 and 2022). These regression analyses consist of multiple steps/models, in which factors can be added.

In order to predict satisfaction with the vacuum toilet in 2021, three steps are conducted in the model. In the first step, customer perspectives on drinking water and satisfaction with the communication of the (waste) water service organization are entered. The acceptation of malfunctions and acceptation of maintenance and repairs are entered into the model in the second step. In the third and final step of this model, the evaluations on the aspect's hygiene, malfunctions, noise pollution and sustainability are entered. As can be seen in Table 11, the evaluation of the hygiene and of the noise pollution of the vacuum toilet (compared to a traditional toilet) are the strongest predictors of the overall satisfaction with the vacuum toilet. Furthermore, the evaluated sustainability, and the satisfaction with the communication of the (waste)water service organization marginally significantly predict satisfaction with the vacuum toilet.

The adjusted R^2 of this model is .42, which means that 42% of the variance in satisfaction with the vacuum toilet can be explained by these four factors.

[10] This item was left out in the 2022 questionnaires

Table 11. Multiple regression analysis of satisfaction with the vacuum toilet in 2021

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	*t*	*p*
1	(Constant)	2,528	,295		8,575	<,001
	Dummy variable aware and committed perspective	,101	,193	,055	,522	,603
	Dummy variable quality and health concerned perspective	-,451	,309	-,130	-1,458	,147
	Dummy variable egalitarian and solidary perspective	,165	,221	,077	,749	,455
	Satisfaction communication (waste) water service organization	,341	,081	,350	4,235	<,001
2	(Constant)	1,730	,329		5,255	<,001
	Dummy variable aware and committed perspective	,187	,186	,102	1,002	,318
	Dummy variable quality and health concerned perspective	-,108	,298	-,031	-,362	,718
	Dummy variable egalitarian and solidary perspective	,203	,205	,094	,989	,324
	Satisfaction communication (waste) water service organization	,164	,083	,169	1,979	,050
	Acceptance frequency malfunctions	,188	,115	,184	1,634	,105
	Acceptance frequency maintenance and repairs	,299	,130	,261	2,291	,024
3	(Constant)	,517	,389		1,331	,186
	Dummy variable aware and committed perspective	,117	,171	,064	,685	,495
	Dummy variable quality and health concerned perspective	-,024	,267	-,007	-,090	,928
	Dummy variable egalitarian and solidary perspective	,076	,186	,035	,406	,686
	Satisfaction communication (waste) water service organization	,144	,075	,148	1,914	,058

	Acceptance frequency malfunctions	,143	,106	,140	1,350	,180
	Acceptance frequency maintenance and repairs	,148	,119	,129	1,237	,218
	Hygiene	,219	,068	,248	3,226	,002
	Malfunctions	,035	,067	,045	,520	,604
	Noise pollution	,189	,058	,238	3,259	,001
	Sustainability	,140	,074	,140	1,885	,062

In order to analyze which factors are the strongest predictors of satisfaction with the vacuum toilet in 2022, in the first step of the regression model, satisfaction with the communication with the (waste) water service organization is entered. In the second step, acceptation of frequencies of malfunctions and acceptance of maintenance and repairs is entered, and in the third and final model, the significant evaluated aspects of the vacuum toilet (malfunctions and costs) are entered. As can be seen in Table 12, in the final model, satisfaction with communication with the (waste) water service organization is a marginally significant predictor and malfunctions (experienced discomfort) and acceptance of frequencies of maintenance and repairs are significant predictors of satisfaction with the vacuum toilet in 2022.

The adjusted R^2 of this model is .54, which means that 54% of the variance in satisfaction with the vacuum toilet can be explained by these three factors. This is, again, quite a high percentage of explained variance.

Table 12. Multiple regression analysis of satisfaction with the vacuum toilet in 2022

		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	*t*	*p*
1	(Constant)	2,465	,300		8,204	<,001
	Satisfaction communication (waste) water service organization	,339	,081	,360	4,190	<,001
2	(Constant)	,984	,316		3,116	,002
	Satisfaction communication (waste) water service organization	,222	,068	,236	3,265	,001
	Acceptance frequency maintenance and repairs	,453	,146	,365	3,103	,002
	Acceptance frequency malfunction	,252	,133	,224	1,889	,061
3	(Constant)	,745	,303		2,457	,016
	Satisfaction communication (waste) water service organization	,116	,069	,123	1,685	,095

Acceptance frequency maintenance and repairs	,400	,136	,322	2,945	,004
Acceptance frequency malfunction	,010	,133	,009	,077	,939
Malfunctions (experienced discomfort)	,392	,088	,376	4,452	<,001
Costs (maintenance/ cleaning)	,128	,080	,121	1,599	,112

Conclusion

Across the participating sites, residents are generally **satisfied with the vacuum toilet**, with overall satisfaction remaining stable between 2021 and 2022. Despite this broadly positive picture, the results also reveal **meaningful differences between neighborhoods**, **clear determinants of satisfaction**, and **persistent challenges** that influence how residents experience the system.

A key finding is that **Schoonschip Amsterdam consistently scores lower** on satisfaction compared to other sites. Although their scores are not negative (≈3, meaning "somewhat satisfied"), the lower satisfaction appears linked to two contextual factors:

1. the installation of **first-generation vacuum toilets**, which are louder and more failure-prone, and
2. a **lack of centralized installation oversight**, resulting in variable quality of installation and unclear responsibility for malfunctions.

In contrast, sites where installation was supervised by utilities or specialists achieved higher satisfaction, underscoring the importance of **professionalized implementation and governance**.

When evaluating the vacuum toilets compared to traditional toilets, residents rate **nine of eleven aspects as comparable or better**, particularly **sustainability**, which stands out as the strongest positive aspect in both years. However, **noise pollution** and **malfunctions** are consistently perceived as worse than a traditional toilet. These two aspects are also among the strongest correlates of overall satisfaction. In 2022, *malfunctions* became the single strongest contributing factor, indicating that the longer residents live with recurrent issues, the more these problems shape their overall perspective.

The data also shows a **small but clear increase in malfunction frequency** from 2021 to 2022. This trend is partly expected, as the systems age and as residents accumulate longer periods of exposure to the technology. Maintenance frequency also rises slightly, and acceptance of both malfunctions and maintenance remains relatively low. These patterns highlight a central challenge: **vacuum systems require more and different types of maintenance** than traditional systems, such as periodic cleaning of vacuum lines to prevent scaling. This reality was not fully known beforehand but now appears intrinsic to operating such systems at a residential scale.

Communication with the (wastewater service organization emerges as another critical determinant of satisfaction. Sites where communication was **coherent, proactive, and personal** (e.g., Ghent and Helsingborg) show notably higher satisfaction levels. Personal contact, shared messaging among stakeholders, and accessibility via informal channels (e.g., WhatsApp) appear to build trust and improve resident experience. Conversely, Schoonschip Amsterdam again scores lowest, largely due to **unclear responsibility structures**: as homeowners themselves owned the system, many interactions occurred between residents and installers, rather than through a central utility or steward.

Regression analyses strengthen these conclusions. In 2021, overall satisfaction is best predicted by **perceived hygiene**, **noise pollution**, **sustainability**, and—marginally—communication quality. In 2022, satisfaction is mainly driven by **experienced malfunctions** and **acceptance of maintenance and repair frequency**, along with a still meaningful role for communication quality. The explained variance is substantial in both years (42% in 2021 and 54% in 2022), suggesting that these factors reliably capture the aspects that matter most to residents.

Taken together, the evaluation shows that **vacuum toilets are well-accepted and appreciated for their sustainability**, but their long-term acceptability hinges on **reliable functioning, low noise levels, and clear maintenance structures**. The findings also highlight that **technical performance and human factors (communication, governance, and installation quality)** are inseparable in shaping user experience. Where installation was consistent and communication strong, satisfaction levels are high; where system ownership or responsibility was unclear, challenges were more pronounced.

In summary, vacuum toilets are a promising and generally well-received innovation in sustainable sanitation. Yet sustained satisfaction depends on combining technological reliability with structured support systems, clear communication channels, and professional installation and maintenance oversight. Addressing these conditions will be crucial for future scaling and long-term acceptance across diverse residential contexts.

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APPENDIX I Measurement of customer perspectives on drinking water

Please read the stands below thoroughly.

Which group of stands best suits how you think about drinking water?

~ A	~ B
• I believe in working collectively toward a more sustainable world • Water utilities should do as much as possible to provide tap water in a green and sustainable way • Every individual has a responsibility to save water • People will be encouraged to use water more wisely if they have access to information about their own water consumption	• I am concerned about my health • I think tap water should be as natural as possible • Substances should be removed from my tap water, even if they are in concentrations much lower than would be considered harmful. • Water companies are mainly responsible for providing me with safe tap water, and I shouldn't have to pay for anything beyond that • Sometimes I worry about the quality of my tap water in the future and its effects on my health
~ C	~ D
• I believe that water is a human right and everyone should have enough to meet their basic needs • Everyone should have access to the same water services; households should not be able to access better services by simply paying for them • I am prepared to save water now in order to help guarantee sufficient water resources for future generations	• I value convenience and minimizing hassle • I prefer to think about my tap water as little as possible, and I should be able to use as much as I like • Water utilities are responsible for meeting our water needs in the most efficient and affordable way possible • I am not concerned about the future of water resources; I believe technological progress will solve most problems

APPENDIX II Differences in customer perspectives per site

There is a significant difference between sites in 2021 ($\chi2$ (9,118) = 19.75, p = .02) and a marginally significant difference between sites in 2022 ($\chi2$ (12,135) = 19.20 , p = .084).

In both 2021 and 2022, residents from Jenfelder Au in Hamburg less often have the aware and committed, and more often have the egalitarian and solidary perspective compared to residents from the other sites. Furthermore, residents from Superlocal, Kerkrade differ in their perspectives in 2022, such that they less often have the aware and committed perspective, and more often have the quality and health concerned perspective compared to the other sites. The other sites do not differ significantly from each other in their perspectives, in both 2021 and 2022.

Table.. Customer perspectives per site in 2021

	Nieuwe Dokken Gent *n* = 17 (2 missings)	H+ Helsingborg *n* = 29 (2 missings)	Superlocal Kerkrade *n* = 10	Jenfelder Au Hamburg *n* = 62 (3 missings)	Total group *n* = 156 (3 missings)
Aware and committed	70,6%	72, 4%	70,0%	46,8%	58,5%
Quality and health concerned	11,8%	3,4%	10,0%	11,3%	9,3%
Egalitarian and solidary	11,8%	13,8%	10,0%	41,9%	28,0%
Matter-of-fact and fully-trusting	5,9%	10,3%	10,0%	-	4,2%

Table.. Customer perspectives per site in 2022

	Schoonschip Amsterdam *n* = 17 (4 missings)	Nieuwe Dokken Gent *n* = 17 (8 missings)	H+ Helsingborg *n* = 29 (3 missings)	Superlocal Kerkrade *n* = 21 (15 missings)	Jenfelder Au Hamburg *n* = 51 (4 missings)	Total group *n* = 135 (34 missings)
Aware and involved	58,8%	64,7%	69,0%	47,6%	45,1% 1	54,8%
Quality and health concerned	-	11,8%	-	23,8%	9,8%	8,9%
Egalitarian and solidary	41,2%	23,5%	24,1%	28,6%	43.1%	34,1%
Matter-of-fact and fully-trusting	-	-	6,9%	-	2,0%	2,2%