Household organic waste recovery as key element for a circular economy

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ABSTRACT

It is of utmost importance to collect organic waste from households as a separate waste stream. If collected separately, it could be used optimally to produce compost and biogas, it would not pollute fractions of materials that can be recovered from residual waste streams and it would not deteriorate the quality of some materials in residual waste (e.g. paper). In rural areas with separate organic waste collection systems, large quantities of organic waste are recovered. However, in the larger cities, only a small fraction of organic waste is recovered. In general, citizens dot not have space to store organic waste without nuisances of smell and/or flies. As this has been the cause of low organic waste collection rates, collection schemes have been cut, which created a further negative impact. Hence, additional efforts are required.

There are some options to improve the organic waste recovery within the current system. Collection schemes might be improved, waste containers might be adapted to better suit the needs, and additional underground organic waste containers might be installed in residential neighbourhoods.

There are persistent stories that separate organic waste collection makes no sense as the collectors just mix all municipal solid waste after collection, and incinerate it. Such stories might be fuelled by the practice that batches of contaminated organic waste are indeed incinerated. Trust in the system is important. Food waste is often regarded as unrein. Users might hate to store food waste in their kitchen that could attract insects, or the household pets. Hence, there is a challenge for socio-psychological research. This might also be supported by technology, e.g. organic waste storage devices and measures to improve waste separation in apartment buildings, such as separate chutes for waste fractions.

Several cities have experimented with systems that collect organic wastes by the sewage system. By using a grinder, kitchen waste can be flushed into the sewage system, which in general produces biogas by the fermentation of sewage sludge. This is only a good option if the sewage is separated from the city drainage system, otherwise it might create water pollution. Another option might be to use grinders, that store the organic waste in a tank. This tank could be emptied regularly by a collection truck.

Clearly, the preferred option depends on local conditions and culture. Besides, the density of the area, the type of sewage system and its biogas production, and the facilities that are already in place for organic waste collection are important parameters. In the paper, we will discuss the costs and benefits of future organic waste options and by discussing The Hague as an example.

KEYWORDS

Household Organic Waste, Waste Collection, Composting, Biogas, Circular Economy, Recycling.

INTRODUCTION

The Netherlands aims to be 100% circular by 2050 (Government of the Netherlands 2016). This implies that virgin raw materials will only be used minimally, products are to be repaired and reused, and waste material will be recycled at highest quality possible.

The circular economy goals apply to every material flow. All waste flows must be reused and recycled in the best way possible (Government of the Netherlands 2020). This applies to household organic waste (HOW). In the Netherlands, on average 2/3 of all HOW is collected and processed separately. This ratio drastically decreases for larger cities. Large cities are struggling with separate waste collection, especially that of HOW. In cities, HOW such as the peel of vegetables and the bones of fish are often collected as part of the residual waste. Sorting studies reveal that about 40% of urban residual waste consists of HOW. This is the largest fraction in urban household residual waste.

Currently, almost all of the residual waste ends up in waste incinerators. HOW in residual waste contaminates the other residual waste fractions, like plastics, metals, and laminates. Thereby, it creates a barrier for after-separation of this residual waste, as all fractions are polluted and have to be cleaned before re-use. Hence, the high content of HOW in residual waste is not only wasteful for these organic materials, but it also prohibits the recycling of other materials in residual waste. It is the aim of this paper to explore options for better collection of urban HOW.

HOUSEHOLD ORGANIC WASTE

Separate collection and processing of HOW would make an important contribution to the circular economy:

- the organic waste itself would generate more energy
- its mineral content could be recycled for agricultural production
- post-separation of other residual waste streams becomes a more interesting option

Separate collection has not been successful in large cities [4]. Little HOW is collected and what is collected is often polluted by plastics or glass. What are options to collect more HOW separately? What are possible alternatives for the urban HOW system in the context of a circular 2050?

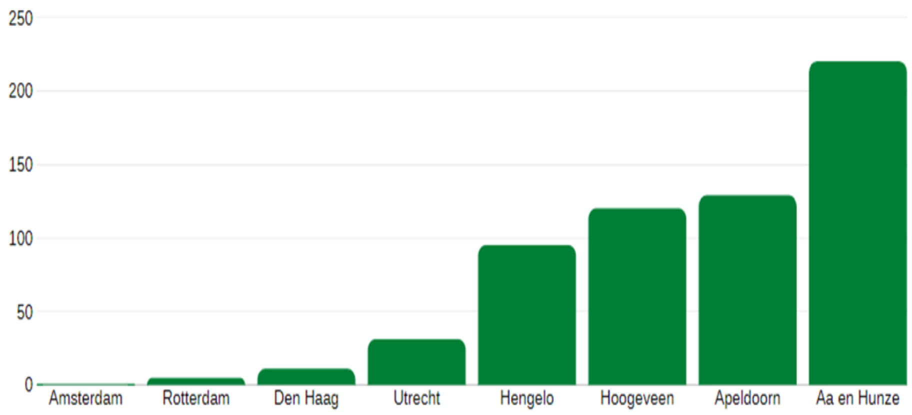

Figure 1 Separately collected HOW per capita for various municipalities in The Netherlands (from urban to rural) [3]

Urban dwellers have less garden waste as many of them do not have a garden. For this reason vegetable-, fruit- and food-waste are the main components of HOW. This could include all kinds of peel, cutting waste, but also coffee grounds, bones and meat residues. In kilograms, organic waste is the largest stream within the residual waste of the average city in the Netherlands. Sorting analyses in large cities show that on average about 40% of the collected residual household waste is HOW [5].
Not all food scrap is organic. The issue can be quite difficult for citizens that are requested to sort their waste. The table below shows what does belong to HOW.

Organic Waste	No Organic Waste
Fruit and vegetable peel	Ash from the ashtray, fireplace or barbecue
Food scraps (cooked, fried, raw)	Dead pets and animals
Shells of peanuts and nuts	Human and animal hair
Eggshells	Chewing gum
Shells, (fish) bones	Fertilizer, Matches, Diapers
Tea (loose), coffee grounds and coffee filters	plastic foam for flower arrangements,
Kitchen paper, tissues and toilet paper	Paper
Garden and pruning waste	Tea bags and coffee pads
Corks	Faeces from dogs and cats
Small pet manure (guinea pig, rabbit)	Cigarette butts
Oil and fat (except frying fat)	Sand, Bird cage sand, Cat litter
Flowers and (indoor) plants	Tree stumps and thick branches
Garden and potting soil	Bio plastic

Table: Allowed as HOW [6]

SEPARATION AFTER COLLECTION

Mechanical systems are well able to separate waste streams from residual household waste. For this reason, the city of Amsterdam stopped the separate collection of plastics. Amsterdam claims that separation with a sorting machine yields more environmental benefits than separation at source by Amsterdam residents [7]. However, the large amount of (wet) organic waste in residual waste makes post-separation hard. Waste streams such as paper, textile and even plastic are polluted by the inevitable wet organic fraction. This pollution creates a foul odour and discoloration of materials, making it useless for recycling. Only plastics can be cleaned by heating and washing in soda. However, this process is labour intensive and

increases the environmental impact of recycling [8]. HOW actually pollutes the other waste streams, making recycling of materials more difficult.
However, separately collected HOW is increasingly contaminated with plastics and glass. The main reason is that people do not know what belongs to HOW. Sometimes this ignorance is caused by product designs. For example, most tea bags can be processed as HOW, but the rather recent luxury pyramid tea bag cannot be processed as HOW, as it is made of plastic materials. Hence, product policies are needed. For example, producers should only use compostable tea bags and coffee pads. The current situation is confusing for the consumer and leads to pollution of HOW.
For good HOW processing, it is important that the percentage of pollution is as low as possible. Moerman's ladder [9] indicates the most desirable form of HOW processing.

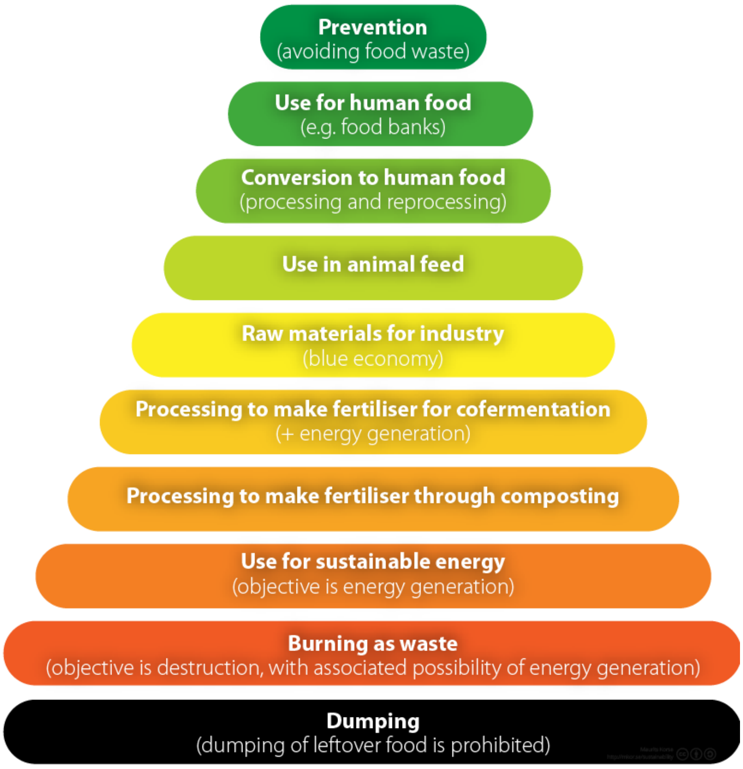

Figure 2 Moerman's ladder (Source: https://mauritskorse.nl/nl/ladder-van-moerman-2/)

PREVENTION AND REDUCTION

Preference should not be with prevention and reduction of organic waste. In the Netherlands, about a third of all food is wasted, which translates to a waste stream of about 61 kilos per consumer per year. Of these 61 kilos, about 41 kilos are avoidable and 20 kilos are unavoidable. Preventing and reducing food waste can save money, water and emissions [10]. Therefore, waste prevention should receive priority. However, cutting residues and peels will remain as HOW. The use of HOW in animal feed has been legally prohibited since 2003 [11].
Food waste might sometimes be re-used directly. In Rotterdam, for example, a company turns mango peels into a leathery product. Another example of waste re-use is the cultivation of oyster mushrooms on coffee grounds. These initiatives are yet small-scale (Cf. e.g. https://haagsezwam.nl/).

Larger scale industrial options might also be within reach. From 2013 to 2015, Paques, Attero, Novamont, Delft UT, the municipality of Venlo and the national government studied making bio-plastic from HOW [1, 12].

COMPOSTING

The most common product of HOW processing is compost: Aerobic microorganisms break down organic matter. Heat and water vapour are released in the decomposition process. Compost is the final product [13]. Compost is used as a soil improver in agriculture. Soil improvers are important to keep the soil fertile. Fertilizing the soil with compost is preferable from a circular perspective since it closes the food chain.
Compost can play an important role in the transition to circular agriculture. This is one of the challenges for the Ministry of Agriculture, Nature and Biodiversity. Figure 3.2 shows how food residues and organic waste are reused in agriculture.

Figure 3 Circular Agriculture

BIOGAS

When HOW is not directly processed into compost, fermentation is the main alternative. In the fermentation process, small organic particles are digested by microorganisms in an anaerobic environment. The organisms emit biogas consisting of methane (CH_4) and carbon dioxide (CO_2). Biogas can be used directly or can be upgraded to green gas, by cleaning and removing CO_2 [14]. Upgraded biogas can be used as fuel for city buses or, for example, for heating historic buildings. If biogas is brought to the same calorific value as natural gas, it can be injected into the gas grid.
After the fermentation of HOW, a digestate remains which contains the minerals of the food. It can be added to a composting process to eventually be used as a soil conditioner.

OPTIONS FOR IMPROVED HOW COLLECTION

To tackle the problem of separate HOW collection in urban areas, various projects have been developed. The project ideas range from behavioural change campaigns to experiments with new technologies. Here we provide an overview of

- behavioural change

and four alternative collection technologies:

- collecting the organic waste via the sewer system,
- collecting using a basin for short-term storage,

- focusing on local processing and
- collecting with an underground waste transport system (UWT).

After these options have been analysed, they are tested against each other using a multi-criteria analysis (MCA).

WASTE SEPARATION BEHAVIOUR

Waste separation behaviour has different phases such as; deciding whether to separate waste, figuring out how to do this, actual implementation. Waste separation behaviour is complex.
Routine decisions are made in actions in which people have a great deal of experience and little interest. The more experience one has and the less important the action, the less need and willingness to collect and process external information [15]. This could also be the case for waste separation. People routinely deal with their waste and are not open to extra information. The less open attitude makes strong arguments in campaigns less effective [16].
With waste separation, there is no individual gain in the short term compared to offering the same waste as residual waste. Waste separation is therefore probably a form of altruistic behaviour. Personal norms can break the behavioural barriers in waste separation, which can lead to actions that require more effort [17].

DIFFERENTIATED WASTE TARIFFS

One way of positively influencing human behaviour in waste separation is to compensate for good behaviour. An example is 'diftar': differentiated tariff for waste collection (instead of a fixed tariff per household). Diftar implies that the household waste tariff depends on the amount of residual waste offered. The diftar based on measuring the weight of the residual waste proved most effective, with a drop of 38% in the amount of residual waste [18].
The introduction of diftar in large cities has practical drawbacks. The lack of space limits the possibility of separating waste. In addition, social control is lower, which might lead to abuse (of public waste bins, litter, etc.). Communication about diftar can also be a barrier due to heterogeneous nationalities and housing situations [18].

CAMPAIGNS

A well-known method for behavioural change is the use of campaigns. To make campaigns work effectively, various subgroups in society should be addressed differently [19]:

- Doers,
- Growers,
- Ignorants and
- Rejecters.

Table 4.1 shows what the current behaviour per group is and what the desired behaviour is for this specific group.

Group	Current behaviour	Desired Behaviour
Doers	Separate waste	Maintain behaviour
Growers	Partially separate waste	Separate more and better
Ignorants & Rejecters	Hardly separate waste	Start separating waste

Desired behaviour per group

Mass media campaigns are often short-lived. The campaigns rarely reach more than 40% of the target group, and this percentage is often much lower [20]. It also appears that the higher educated are reached much more than the lower educated [16].
National mass media campaign (in NL 'Postbus 51') lead to an average change in behaviour of 2% [21]. According to [16] much can still be achieved here. Various review studies show that the direct impacts of campaigns range from a few percent to 17 percent. The impacts are on average 17% for compliance or enforcement campaigns (campaigns on alcohol in traffic or seat belt use), 5% for non-enforcement campaigns (campaigns for donor registration or elections), 3% for prevention campaigns (campaigns on safe sex or safe internet) and 3% for campaigns aimed at ending undesired behaviour (campaigns about quitting smoking or against bullying) [20]. Waste separation campaigns are about changing habitual behaviour without direct personal gain. As a result, the effect of solid campaigns will not exceed 3%.
It was also found that making desired behaviour easier (by shortening the walking distance to the container or by using reminders) was effective [20]. Residents, who feel that separating their waste is easier, separate their waste better than the residents who feel that separating waste is a burden.
Hence, by making separation easier, citizens can be made to separate their waste. Separation should:

- Take less effort (walking distance)
- Take less space (HOW storage could be smelly and attract pests)
- Be simplified (Clear signs of what belongs where)

If campaigns are about routine behaviour, no major changes are to be expected in the short term. The information must be as unambiguous and simple as possible. Merging separate streams and even changing colours or logos of certain waste streams can have a negative effect [20].

HOW COLLECTION BY THE SEWAGE SYSTEM

A behavioural change campaign is often not enough to achieve a significant change in the collection of separated fractions like HOW. A simple collection system for HOW is the collection via the sewer.
In such a system, residents can dispose of their HOW directly in the kitchen. In this system, every household has a food grinder in the sink, which grinds the husks and food residues into a finer substance. This grinder reduces the food remains so that they can be flushed down the drain to the sewer. At the sewage treatment, the HOW is further processed together with the excrements of the sewage. This organic waste is first treated in an active sludge tank and then goes to a basin, where the solid parts sink to the bottom as sludge. The sludge is collected and fermented to biogas [22]. The remaining digestate contains minerals that might be processed into a "green" fertilizer. Figure 4.2.1 shows schematically how the wastewater is processed at the WWTP.

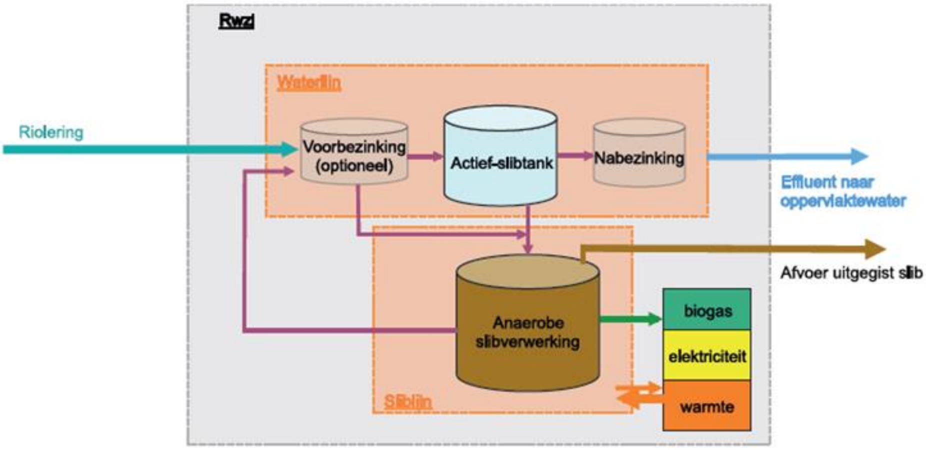

Figure 4 Waste water processing [23]

In theory, every citizen could use such a system, as everyone is connected to the sewer network. However, a **separate** sewer system (rainfall - household sewage) is required for HOW collection via the sewer. If HOW collection would be introduced in a mixed (combined) sewer system, heavy rainfall would lead to sewer overflows that would discharge HOW to surface water. The organic matter would lower the oxygen content of the water body and might wipe out a local ecosystem.

The ideal would be the ‘New water chain’; a sewer system with separate rain-, lightly polluted-, and ‘black’- water (containing excrements and HOW) [24, 25]. The water-poor black water could be directly processed to biogas. The system is applied on a large scale in Sneek. Biogas production provides about 12% of the gas demand of this residential area. The heat of the lightly polluted (shower) water is recovered (Green Blue Networks, 2011). Amsterdam has decided to apply this system to a new large urban area, IJburg II [24].

In the USA, it is common to drain food waste through the food grinder in the sink. However, hardly any biogas is produced from this grinded waste. In Europe, the use of grinders is often not permitted by law [26]. Nevertheless, there are tests. As part of a larger pilot project, a trial was conducted in the municipality of Hengelo with food grinders in the sink of 10 dwellings. The project was primarily intended for apartment buildings, because separate collection of HOW is negligible there. The test showed that the grinders provided enormous ease of use and led to more separate collected HOW [27].

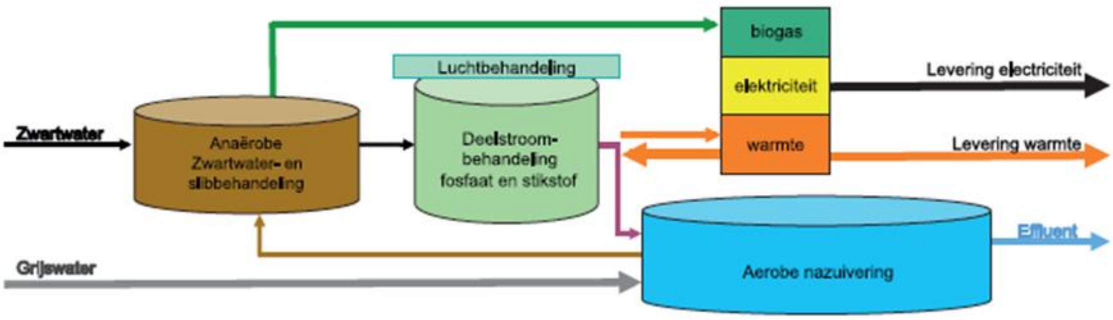

Figure 5 Waste water treatment with biogas production

advantage	Explanation	disadvantage	explanation
Ease of use	Getting rid of HOW by a grinder and the sewer is almost instantaneously, takes no effort, leaves no smell.	Legally prohibited	Disposing of waste by the sewer is prohibited. This applies also to HOW.
Biogas production	Organics fermented to biogas. Biogas production is optimal if the “New water chain’ is applied.	Grinder	A grinder is expensive (€250-300), takes some electricity and the kitchen needs to be adapted.
Ideal for high rise apartment buildings	Could introduce separated HOW collection in high rise apartment buildings.	New buildings	In-house systems can hardly be applied in existing buildings. In-house measures might take adaptations of building codes.
Spatial impacts	The system is ideal for urban dwellers as it takes no space from them.	Separated Sewers	Separated sewers are a condition for removing HOW by sewers. Separated sewers need more underground space, which is often scarce in urban centres.
		Garden waste	Sewers cannot dispose of garden waste. In areas with gardens, garden waste needs to be collected otherwise.
		Compost production	No compost production, only biogas and recycling of minerals.

FOOD GRINDER WITH BASIN

Another option is the food grinder with a basin for local storage. Residents have two sinks, a normal one as they are used to and a separate "dry" drain with the grinder for organic kitchen waste. Under the sink is the grinder with a small storage. Here the heavier organic material settles and the wastewater can be drained via the overhead pipe. This water is drained from the 'wet' washbasin using a different pipe to be filtered for organic residues. The organic mass can then be collected in a larger storage tank using a sludge extraction system [28]. From this tank, the organic waste can be collected by the municipal waste collection and transported to processors who can turn it into compost and/or biogas. The combination of the food grinder and storage seemed to be the solution. It has the same advantages as the other system, ease of use and little use of space, but it fits within the rules.

The Swedish city of Malmö has first tested this idea in two small pilots, in housing blocks Bo01 with 41 apartments and in the Turning Torso with 147 apartments. These pilots were not enough to make a proper evaluation of the system. Hence, it was decided to extent the test with 614 apartments spread over 16 buildings in Fullriggaren. The systems were installed during the construction of these buildings [29]. This process is shown schematically in figure 5 [30].

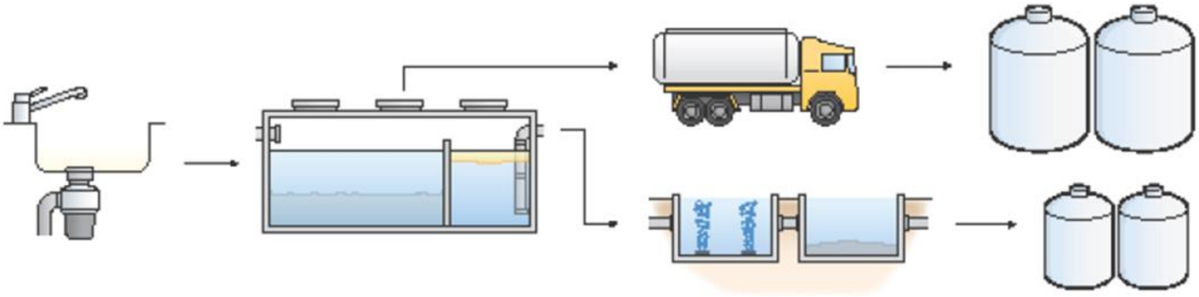

Figure 6 Scheme of HOW collection in Malmo experiment

Two waste analyses (September 2013 and March 2014) showed that about 33-55% of the total HOW could be collected directly. 37% of HOW ended up in the residual waste and the remaining 23-33% went along with the wastewater and ended up in the sewer. The quality of the collected organic waste from the storage tanks is higher than with regular HOW collection and therefore has a high methane potential [29]

The collection using food grinders in combination with local storage is very easy for citizens and has increased collection. However, this option is also more expensive.

Advantage	Explanation	Disadvantage	Explanation
Ease of Use	Disposing HOW by a grinder in the kitchen sink gives no smell and takes hardly any effort	grinder	Costs of a grinder (€250-300), electricity consumption, and adjustments to the kitchen.
Biogas production	Grinded HOW can be fermented to produce biogas.	Confined to new dwellings	Especially of interest for new dwellings. Adapting existing dwellings can be rather expensive.
Ideal for high rise (apartment-) buildings	Separated HOW collection in apartment buildings almost non-existent. This solves problem.	Garden waste	Garden waste has to be collected otherwise.
Legally admitted	Disposal of HOW by the sewer is an offence; storing HOW in a basin is legal.	Organic material in sewers	Malmo tests showed that part of the organic material ends up in the sewer.
Compost production	The organic material can be composted.	Collection	A lorry should empty the basins.
Use of space	Takes no space from residents and no public space underground, but takes some space from building owners.		

LOCAL HOW PROCESSING

HOW could also be collected and processed far more locally: 'urban agriculture' could imply centres of local composting, and small-scale urban area collection services could be developed. With local, HOW processing this would mean that the waste materials are processed close to the source and used locally.

Composting can be done in two ways:

Worm hotel. In these 'hotels', worms eat the organic material, the manure they produce is worm compost. The worms can eat and process half of their body weight per day.

Compost pile or bin. The organic material is collected in a bin or in a heap. In an oxygen-rich and moist environment, the aerobic microorganisms process the waste into compost. It is important that the temperature and moisture content is well controlled, enough oxygen can enter and the composition of the pile should be varied [13]. Ensuring a good compost heap is laborious for the citizen and requires space.
In addition to composting, local fermentation is also an option. Anaerobic microorganisms process the organic waste during fermentation. This process produces biogas. The biogas yield depends on the input, table 4.4 [13] shows the biogas potential in m^3 per ton of input. The gas yield varies greatly due to the freshness and residence time of the input; the table serves as an indication.

Input (1000 kg)	Biogas potential (m^3)
HOW (kitchen waste)	110
HOW & garden	100
grass	72
pitted grass	115
dung	40

Table: Input/output HOW and biogas potential

The biogas that is produced must be processed. The gas can be upgraded to a green gas that can be used as fuel. Processing organic waste with a digester is expensive. The purchase price of a digester is high and managing it requires knowledge and time.
Local composting has been done for years. Especially in neighbourhoods where people have large gardens. Many people have composted their garden waste themselves. If people have more garden waste, they probably also have a larger garden to set up and use a compost pile or container.
Urban agriculture locations are ideal for composting in the city. The compost might be used directly, or sold as a source of income for these centres.
Fermentation generally takes place on a larger scale; by waste processing companies. However, this might also be done locally. In the Wildemanbuurt in Amsterdam, for example, a test was carried out with a mobile bread digester. This test showed that a larger digester was needed and that not only bread but all the HOW of the district could be processed, including that of companies. In total electricity could be generated for 20 households (44,000KWh) and heat for 9 households (322GJ) using Combined Heat and Power (CHP) [31, 32]. The total installation of the digester and CHP requires approximately 28 m^2.
Local composting and fermentation requires space and is a laborious process for citizens. However, with local processing, no collection system for HOW is required. This reduces the emissions of the system.

Advantage	Explanation	Disadvantage	Explanation
Compost production	Organic waste is locally processed to compost (and might be locally used).	Use of space	The installations take space that is scarce in a city.
Biogas production	HOW can be locally fermented to biogas. The energy might be consumed locally.	Compost production laborious	Composting takes a lot of care and work. Peels should be grinded, and the mass should be compacted. It takes weeks before the compost is ready.
Garden waste	Garden waste can be processed in the same system as HOW.	Nuisances	Local processing of HOW might cause stench and attract

			pests.
Only limited local collection system	Local processing requires only small collection system as the HOW is processed locally.	Greenhouse gases	If the composting process is not properly managed, a rotting process might start producing methane.
Local economy	Local processing of HOW might strengthen the local community and economy	Pollution of surface water	Compost piles should not leak into surface water.
		Costs	It is unlikely that composting and biogas production at this scale will reach breakeven.
		Knowledge	Composting and biogas production requires know how which will probably exceed the level of volunteers.

UNDERGROUND WASTE TRANSPORT (UWT) SYSTEM

A vacuum system that was initially intended for waste collection of large buildings such as shopping centres, airports and hospitals is now increasingly being introduced in urban environments [33]. This Underground Waste Transport system (UWT) implies no more large, traffic-congesting garbage trucks in city centres, but underground collection with vacuum tubes. It is another alternative collection option for all household waste flows.
An UWT works with underground pipes, which transport waste fractions from an inlet to a collection point using vacuum suction. Such a system can be applied locally in a (new-build) district and thus relieve the district of traditional collection with containers and garbage trucks. This leaves more exploitable space for the construction of dwellings, offices, parking spaces, etc.
An UWT can be divided into three main elements; inlet points, the tubing and the terminal. The inlet might, for example be in a residential area or shopping centre. The tubing transports the waste to the terminal. The vacuum system is controlled from the terminal, which absorbs the waste fractions. Figure 4.5.2 [34] shows a schematic representation of an UWT.

Figure 7 Schematic representation of the UWT

The tubes that transport the waste have a diameter of 30-50 cm and last for 30 years. The construction of an UWT is therefore a long-term investment. The inlets stations have an opening per fraction or one opening and differently coloured bags per fraction [35]. A UWT requires high investments but far lower operating costs than traditional collection. In addition, it relieves tight urban areas of garbage trucks which prevents congestion and saves emissions, which has a positive impact on local air quality [33]. UWTs have been used for years. In the early 1970s, for example, such a system was installed at Disney World in Florida. In 1992 an UWT system was installed in Villa Olympica, Barcelona for 2,900 households, which was expanded to 16000 in 2009. Similar underground systems can also be found in Wembley-London (Great Britain), Abu Dhabi (United Arab Emirates), Hammarby Sjöstad-Stockholm (Sweden), Romainville-Paris (France) and more [33]. UWT systems are also used in the Netherlands, in Almere and Arnhem. The UWT Almere started in 2003 for the collection of residual waste, paper & cardboard and HOW. The collection of HOW is no longer used, as this fraction was too contaminated [36]. This shows that the user is still the weak spot for making UWTs a success.

Advantage	Explanation	Disadvantage	Explanation
Ease of use	Waste collection by UWT is always available	Separate collection	Citizens should separate their own waste before disposing.
Biogas production	HOW can be fermented to biogas.	Costs	High investments/low operational costs require intensive use and/or high waste disposal service levels
Ideal for high rise apartment buildings	Separate waste collection in apartment buildings by in-house UWT	For new buildings	UWTs require less high investments if included in building design. In the streets, UWT works combined with other infrastructure works.
Compost	Not polluted HOW can be composted.	Garden waste	No garden waste. UWTs for areas with few gardens.
Waste collection	UWTs collect all waste streams, from households and businesses.	Unsuited waste	Glass might create problems in UWTs.
No traditional garbage collection	No garbage trucks: less congestion, and fewer emissions.	Pollution of waste	Especially public inlets in shopping areas might lead to polluted waste streams

TOWARDS A WASTE COLLECTION SYSTEM PER NEIGHBOURHOOD

It is currently impossible to design a single uniform waste collection and disposal system for a city that contributes to a circular economy, offers an ease of use that is required to get the cooperation of citizens, and is affordable for cities.
The advantages of various waste collection and disposal systems might differ per urban area, and therefore decisions on these systems might be taken at urban area level. This will be discussed here for the city of The Hague.

Composting yourself

The municipality of The Hague prefers to compost organic waste itself. This is the local form of processing. Main advantage is that this requires minimal transport. However, it requires space, which is not available everywhere in the city. The map below shows the number of addresses per km^2, which is a measure for density. The lighter green areas have more than 400 m2 per address (including roads, parks etc.) where there is potential for citizens to compost. In the red areas, there is hardly space for individual composting.

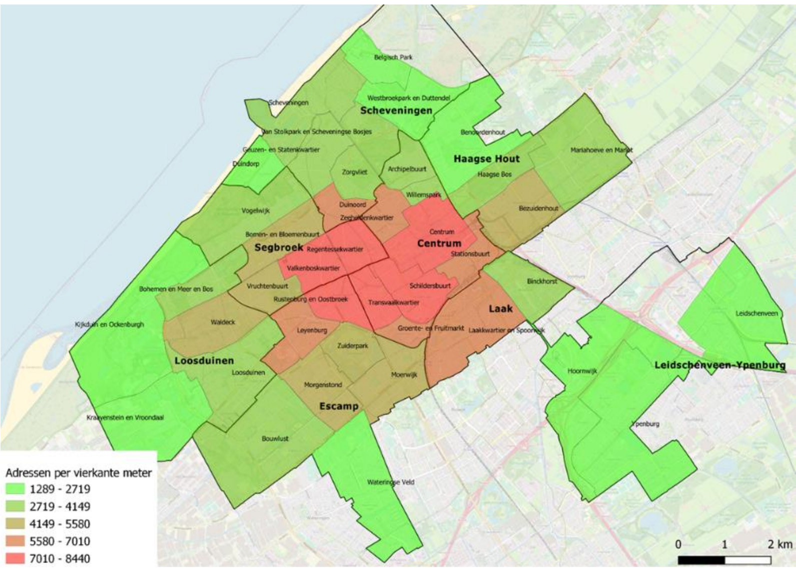

Figure 8 Density of dwellings in The Hague: Red: most dense, over 7010 addresses per km², light green, least dese, 1289-2719 addresses per km²

The Hague has many urban agriculture initiatives such as school gardens and city farms. These initiatives can be interesting partners for educational institutions to teach pupils more about organic waste and its processing. The map below also shows all locations where urban agriculture takes place and where (more) composting is possible.

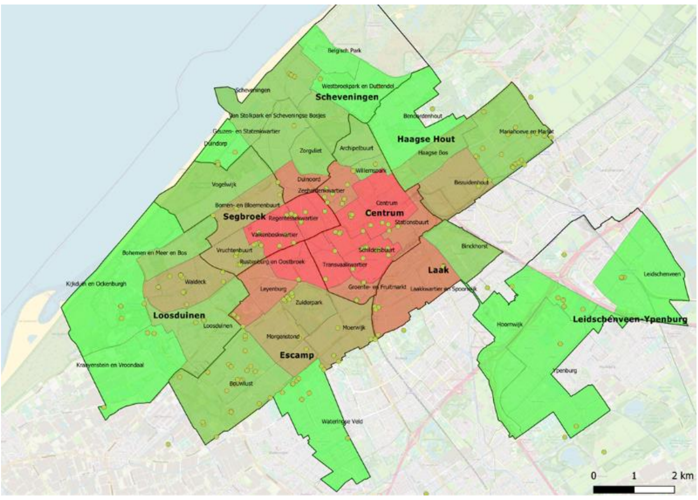

Figure 9 Urban agriculture in The Hague

HOW collection by the sewer

A system with a food grinder in the kitchen to dispose of HOW by the sewage system requires little effort. However, food grinders can only be used in areas with a separate sewer system, or a high degree of separation from the rainwater. The potential map below shows in which neighbourhoods a system with food grinders can be used with the current sewer system.

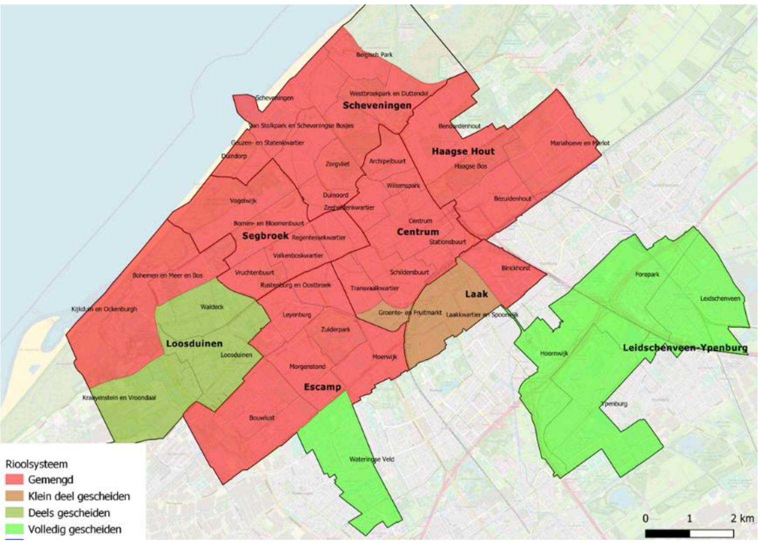

Figure 10 The Hague areas with separatedsewers (green) or partially separated sewers (brown)

Every year, the municipality separates more rainwater discharge pipes from its sewer system. This is expensive, and the process is slow. A great opportunity lies in the construction of a district heating network, as works might be combined.

Indoor HOW system for new apartment buildings

The Hague is planning to create 10,000 new dwellings in the next 20 years. Space is a problem and so the choice has been made for high-rise buildings [37]. An indoor system can be a good option if these areas have no separate sewer. The potential map below shows the areas and districts where relatively much new construction and densification is planned.

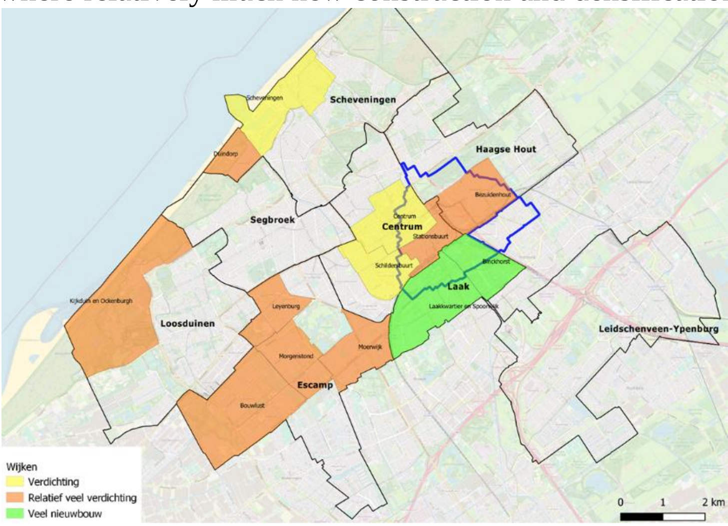

Figure 11 The Hague areas for densification (yellow & brown), new construction (green) and the Central Innovation District (High rise buildings)

In the green areas, new dwellings will be built, in the orange and yellow areas the focus is mainly on compacting and refurbishing the city and the dwellings. The area within the blue lines is the Central Innovation District (CID). This is the area where tall residential towers will be built.

The high-rise projects in the CID in particular offer an opportunity for an indoor HOW system. To achieve this, the municipality must exert influence on the project developers.
If the choice is not made, this would mean that the towers would be delivered without a system, a lock-in as it is very difficult to add such a system afterwards.

Main components for circular HOW collection and processing

In neighbourhoods where the residents have more space, efforts can be made to locally compost HOW waste. Residents near urban farming locations could bring their HOW there. Not every resident of these areas might want to participate. Hence, there also has to be a collection system for HOW. This might be a local service.
Residents of neighbourhoods with a separate sewer system could drain their grinded HOW for fermentation at the WWTP. Separating the drainage- and sanitation function of sewers is a lengthy process as components of the system last long before they need to be replaced. Garden waste still have to be collected.
HOW grinders with an in-house system can be used in large new buildings. For citizens this has the same convenience as grinder that drains to the sewer. The construction of such an indoor system could also be attempted in large-scale renovation projects of apartment buildings.
The applications discussed will not be able to provide the entire city with a new HOW collection method. The densest populated area of The Hague is connected to a mixed sewer system, and the introduction of a separate sewer system is difficult as the underground hardly can provide the required space. Other areas might gradually work towards a solution. The enormous task, of separating the combined sewers, might be combined with the construction/extension of district heating grids that will probably occur as a measure to stop climate change.
It is important that niche experiments will be started, such as reward schemes for self-composting and introducing food grinders to a number of households. Successful experiments can be extended to more neighbourhoods. If more sewers are separated over the coming years, HOW grinding and disposing by the sewers might be further expanded.

CONCLUSIONS, A DIVERSIFIED APPROACH PER URBAN DISTRICT, GENERIC MEASURES AND SEARCHING FOR SYMBIOSIS WITH OTHER POLICY AREAS

Several measures have been discussed to enlarge HOW collection and disposal. There is no one size fits all approach. Urban area characteristics such as density, existing sewage system, local culture and options for symbiosis with other investments might be important. To start the organic waste transition, socio-technical experiments must be started. Successful experiments will be further elaborated and replicated.
In addition to conducting experiments, changes in legislation and regulations will have to take place. In order to use food grinder with drains on the sewer, legislative adjustments must be made.
The municipality will have to take action to prevent high-rise project developers from creating lock-ins that will have long-term negative impacts. Indoor waste separation systems for the residents should mandatory. Without such investments, lock-in situations arise which will prevent circular solutions.
HOW waste is often polluted. Product level measures are required to help consumers sorting their waste. Non-edible parts of food products are bound to be disposed of as HOW: they should not contain plastics (such as fruit stickers, plastic tea bags, and plastic in coffee pads).

Biodegradable materials might be an alternative. To tackle such problems, a product policy will have to be pursued at EU level.

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