Pneumatic waste collection in central Stockholm

A Study of world-class waste management

A REPORT PRODUCED WITH SUPPORT FROM VINNOVA ON WHAT A STATIONARY PNEUMATIC WASTE COLLECTION SYSTEM IN STOCKHOLM'S INNER CITY WOULD ENTAIL: TECHNICAL, ECONOMICAL, AND ENVIRONMENTAL ASPECTS

Contents

The photo on the front is a montage showing how Fjällgatan in Södermalm could look if a stationary pneumatic waste system was installed. On the left side of the image, there is a waste inlet where residents would dispose of their waste.
In the right photo, there is a public litter bin connected to a pneumatic waste system in Nyhavn, Copenhagen.
Revised May 2024 by Envac regarding translation to english, font types and logos, as well as the naming of companies.

Foreword

This report has been developed to show the technical, economic, and environmental prerequisites and effects that a newly developed stationary pneumatic waste collection system (Quantum) can have in an inner-city environment. The work has been financed by the Swedish innovation agency Vinnova and the report was prepared by:

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A stationary pneumatic waste system in Stockholm's city centre can:

- Improve the local urban environment
- Provide lower costs for waste collection
- Reduce environmental impact from traffic
- Contribute to a better work environment
- Free up valuable space
- Facilitate Stockholm in meeting its goals for food waste collection

Summary

The waste collection in central Stockholm is facing major challenges and the current manual collection needs to be changed or replaced. The current waste collection affects the local cityscape to a large extent by obstructing traffic flows, creating noise, and contributing to air pollution. There is also a workplace safety issue associated with waste collection that needs to be addressed.

Many properties in the inner city use only larger bags for waste collection even though it is not compatible with regulations for a good working environment. These bags need to be replaced by containers/bins and placed at ground level, facing the street, to make it easier for the waste collection workers and provide the necessary conditions for a good working environment. This places high demands on property owners in the form of renovations and lost income from areas that may need to be utilised.

In cases where work environment problems have been remedied, it was made possible mostly by improving the existing manual collection, alternative collection systems have been used on very few occasions.

Stationary pneumatic waste collection systems are usually installed when a new urban development project takes place, but newly developed technology improves the possibility of installing them even in existing buildings. To investigate the feasibility of the installation of a pneumatic waste collection system in Stockholm's inner city, a case study for the Norra Sofia area on Södermalm has been carried out. In this case study, the new Envac Quantum concept was designed for the area, which is developed to be used in, among other things, existing buildings.

The results from the case study were compared to a modified manual collection scenario where measures were implemented to achieve an acceptable working environment. The comparison shows that a stationary pneumatic waste collection system can free up valuable surface area in properties as the area of the existing waste/environmental rooms is no longer needed and can therefore be used for other value-creating purposes. A modified manual collection would instead require additional surfaces for waste/environmental rooms.

The property area that would be needed in the event of a changed manual collection could instead be used for student apartments, which in Northern Sofia, could correspond to more than 50 apartments, each one measuring 25 square meters. The comparison also shows that a pneumatic waste collection system in the inner city can contribute to a more vibrant urban environment compared to a modified manual collection when property areas on ground level can be used for businesses instead of rooms for waste storage.

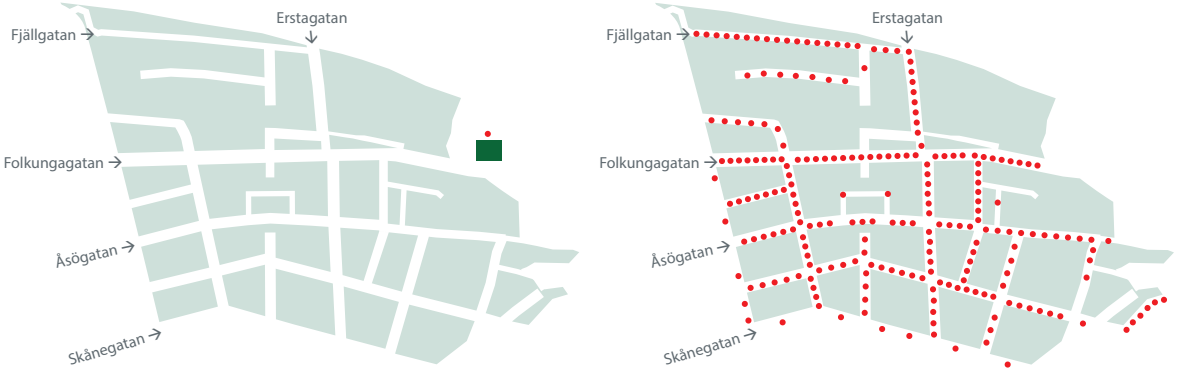
The flow of heavy traffic through the inner city would decrease significantly, and thus also emissions and generation of particles. The street can also be used to a greater extent by pedestrians and cyclists as well.

as green areas. Furthermore, the introduction of a pneumatic waste collection system does not require investments as high as the ones for a modified manual collection, it would also result in lower costs for collection and transport.

The illustration below shows one of the differences between a stationary pneumatic waste collection system and manual collection.

The picture on the right shows the number of collection points available in Norra Sofia for the manual collection of household waste. The left one shows the only collection point that would be needed if a stationary pneumatic waste collection system is used. Shorter transports means less impact on the environment and residents in the area. Different types of financing models have been investigated for the introduction of a stationary pneumatic waste collection system in Stockholm's inner city and four proposals have been presented. In these models, the financing of the investment varies between taxes, fees, and connection fees. The investment can be covered by the city of Stockholm or a private investor. Common to several studies is that a municipal entity should play a major role, as stability and long-term commitment are desirable. The design of a Quantum system in Norra Sofia has provided answers to the technical feasibility of the system.

Calculations based on this design have given answers to the economic and environmental feasibility, in the form of total costs over time and emission quantities. A number of benefits are achieved for many actors at a lower cost. The large number of stakeholders advocate for a municipal intervention.



To the left is the collection point for the stationary pneumatic waste system (terminal). To the right are all the collection points for manual collection (waste rooms).

Sanitation workers collecting bags of waste in Stockholm. Photo: Lennart Johansson.

Background to the complicated waste collection in Stockholm

Currently, the collection of waste has a significant impact on the local cityscape in Swedish cities. When ever increasing volumes of waste must be collected from households, the number of waste collection trucks in the city streets increases. These waste collection trucks are manned by staff who collect waste containers manually from properties. Manual waste collection leads to reduced accessibility on the city streets, noise, littering, air pollution, and wear and tear on properties and street space. The vehicles can be difficult to maneuver safely in tight spaced streets with a lot of traffic, and in combination with a stressful work environment creates a larger risk of accidents.

Manual waste collection is problematic from a work environment perspective because it often involves a physically demanding workload for the staff. According to Stockholm Water & Waste, there are several thousand collection points with more than half having problems with fulfilling current regulations and recommendations. Over half of the properties in central Stockholm still use bags for the collection of waste, despite the fact that it goes against recommendations for a good working environment. The reason bags are still used is that they take up little floor space and are easier to move through properties that have tight spaces, stairs, or uneven surfaces.

In order to replace the bags with bins, larger spaces in the property needd to be set aside for waste collection. The city of Stockholm also has ambitious goals in terms of collection of food waste from households. To fulfill the targets through a manual collection with separated fractions, separate collection bins are needed for residual and food waste. This means that the space for collection and storage needs to be even bigger than before, something that is not so easy to accommodate in a densely built city. In addition, the waste rooms need to be located close to the street to facilitate bin collection by waste collection trucks.

Stockholm has developed over many hundreds of years, we have so many older buildings and infrastructures left which is something we should be proud of, but at the same time this poses major challenges for today's and tomorrow's opportunities for good and efficient waste management.

The improvements that have traditionally been implemented to deal with the lack of a good working environment have focused on developing the manual collection so that it becomes less physically demanding for the waste collection staff. Incentives for this work are often the lack of a good working environment in combination with "penalty fees".

However, there is an alternative that can meet both, the traffic-related environmental problems and the shortcomings in the working environment, and that is to use a stationary pneumatic waste collection system in the inner city, with inlets on sidewalks. Because the waste can then be picked up at a single place on the outskirts of the area. the heavy traffic does not have to pass through

the local urban environment. The collection of waste is completely automated, and the waste collection staff is not exposed to the risky and stressful work environment that a manual collection involves. Pneumatic waste collection systems have already been used in Stockholm for over 40 years and over 100,000 households are connected. Larger stationary pneumatic waste collection sites are mainly installed in new developments but with newly developed technology, there is a possibility to install them in existing buildings and areas as well.

Recommendations for waste management
Stockholm City's waste plan says that waste management in the city must be planned based on a human perspective. A way to do so is, according to the City of Stockholm, to use mechanical solutions for the collection and to avoid manual collection as far as possible. The City of Stockholm's handbook for the design and construction of waste areas also advocates for mechanical collection of waste, mainly for the heavier fractions where reference is made to the Norwegian Work Environment Authority's recommendations. Avfall Sverige's (Swedish Waste Management) handbook for waste spaces recommends that property owners should investigate possibilities for mechanical retrieval when modernisation work takes place.

"Over half of the properties in central Stockholm still use bags for the collection of waste, even though it goes against recommendations for a good working environment."

Purpose of the report

The current situation in Stockholm's inner city is not sustainable in several aspects, and measures need to be taken to create a more sustainable collection of waste.

The purpose of this report is therefore to investigate the feasibility of installing a stationary pneumatic waste collection system in central Stockholm from a technical, economic, and environmental perspective.

The report answers the following questions:

- What is the technical and economic feasibility of a stationary pneumatic waste collection system in central Stockholm?
- How does a stationary pneumatic waste collection system differ from the manual collection with bins, from different stakeholders' perspectives?
- How big is the environmental impact of a future waste collection system?
- How can the introduction of a stationary pneumatic waste collection system in the existing environment be organised and financed?

Structure of the report

In the section "Actors", the reader is given an insight into which actors are involved and affected by a changed waste collection. Actors who influence and are affected by waste collection in Stockholm, a description of the various actors, their roles, and responsibilities.

In the section "Sustainable waste collection in Stockholm", guidelines that a changed waste collection method needs to adapt to, together with the alternative collection methods are examined.

A site-specific study is carried out to investigate the consequences of a waste collection installation in the central part of the city. Prerequisites and results of this are presented in the section "Norra Sofia in Stockholm".

In addition to the feasibility of a pneumatic waste collection system and its consequences, an account of organisational aspects and how installation and operation can be organised is also given. These are presented in the section "To organize and finance the introduction of a pneumatic waste collection system in an existing environment".

In "Conclusions", the answers to the questions used to investigate the feasibility of a pneumatic waste collection system in the heart of Stockholm are presented.

Stakeholders influencing and affected by waste collection in Stockholm

Many different actors influence and are affected by the waste collection in Stockholm. Below is an account of some of these and what their role is.

The public can form an opinion and create a demand for how they want waste collection to be handled in their city. The public choose which politicians sit in the municipal council and therefore influence, indirectly, what decisions are made there.

The municipal council decides on the waste management regulations and tax. They also make decisions for operations within the City of Stockholm and can control major changes by changing the frameworks that municipal companies, like Stockholm Water & Waste must comply with.

Stockholm Water & Waste (SVOA) is a municipal company responsible for organising the waste collection in Stockholm. They make suggestions for waste fees, waste plans, and waste regulations. SVOA creates incentives for how waste collection should be designed and charges for it in the form of a waste tax. SVOA procure contractors to take care of the physical collection of waste from properties.

The task of **the Traffic Office** is to ensure accessibility and traffic safety in the city. They make sure Stockholm is an accessible and clean city. They are responsible, among other things, for keeping streets clean, snow removal, and parking.

The Environmental Administration is the authority responsible for the environment in the City of Stockholm, both outdoors and indoors. The administration works actively to ensure Stockholm residents live in a healthy environment. The administration has supervision and monitoring as its main task.

Stockholm Business Region AB develops and market Stockholm as an establishment and visitor location with the goal of making it Europe's leading sustainable growth region.

District administrations are responsible for the part of the waste collection that takes place in most of the city's parks and green areas.

The Development Office is responsible for land management and residential development. The office develops neighbourhoods, streets, parks, and natural areas owned by the city. The goal is for Stockholm to be attractive to live in, for businesses to be offered good conditions, and for ecological considerations to be taken into account in planning and execution.

The City Planning Office plans how the land owned by the City of Stockholm is to be used and who is to use it. The office is responsible for general and site plans and grants building permits.

The Beauty Council reviews detailed development plans and building permit cases from the City Planning Office. They can also receive cases from, among others, the Development Office, the Traffic Fffice, and District Administrations if they have questions relating to the urban environment.

The waste management contractor is hired by SVOA to take care of the collection of household waste and do so in consultation with property owners. The contractor has staff and safety representatives and through these receives notifications about deficiencies in the working environment. It is then up to the contractor to report and remedy or ensure that, for example, the property owner remedies these deficiencies to avoid any stops in operation.

The contractor's staff are those who collects waste from the properties, and they therefore affect the households' experience of collection. They must report the collection points that do not meet the requirements.

The safety representative brings the personnel's case in matters relating to their work environment and if deficiencies are present, they must report this to the employer and/or directly to the Work Environment Agency if the deficiency is serious enough.

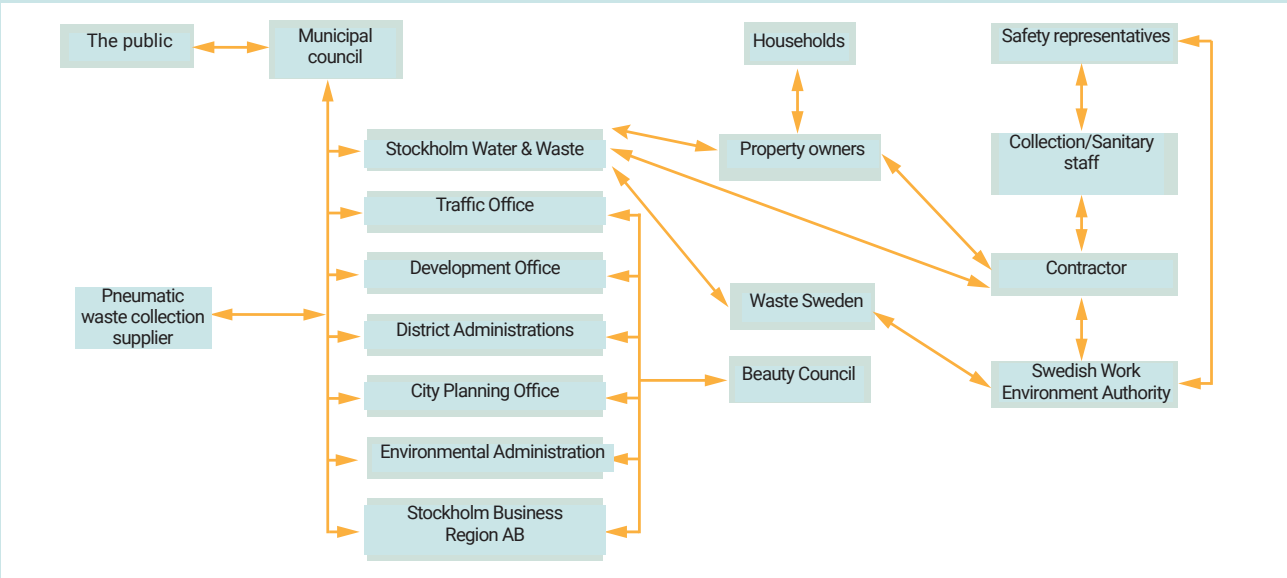
The Swedish Work Environment Authority has the option to stop the collection of waste from properties that have serious deficiencies in their working environment.

The property owners are responsible for their customers, in the form of households and businesses, have access to a good waste collection solution. They arrange collection for residual and food waste but can also organise the collection of packaging materials and newspapers. Residual and food waste is collected by the waste management contractor procured by SVOA, the other waste fractions are collected by the contractor of their choice.

Households sort and dispose of their waste in the collection system provided by the property owner.

Suppliers of pneumatic waste collection systems can spread information and knowledge about the products and services they offer in mechanical waste management. Swedish suppliers are world leaders in automated waste management and can contribute with experiences from international installations and existing inner-city environments, for example in Barcelona and Bergen.

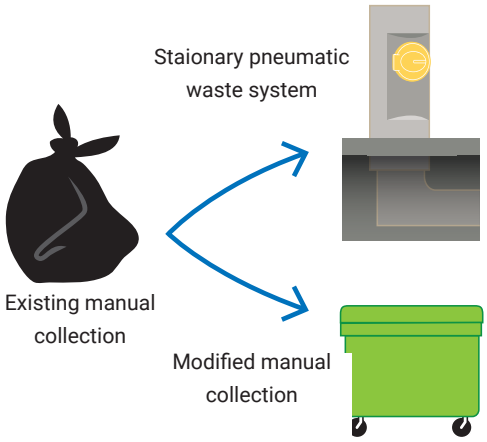
Avfall Sverige (Swedish Waste Management) is the swedish industry organisation for waste management and recycling, where the country's highest competence in the area is gathered.



Sustainable waste collection in Stockholm

Course of action going forward

Because the current collection solution in Stockholm in many cases lead to a poor working environment for the waste collection staff, it is not a sustainable alternative for future waste collection. What is investigated in this report is therefore the possibilities for a pneumatic waste collection system and its alternative in the form of a modified manual in collection.



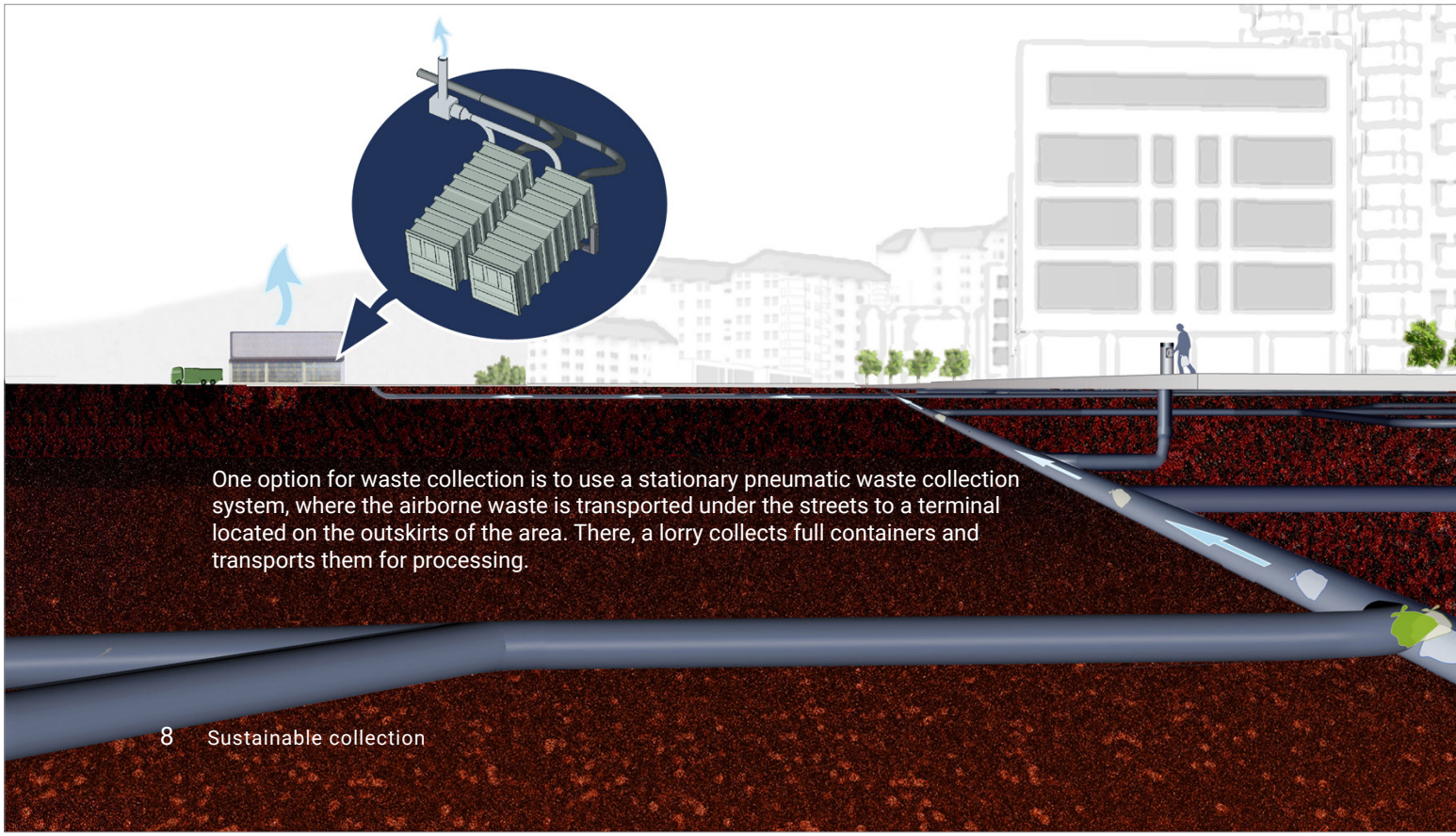
Stationary pneumatic waste collection system – Envac Quantum

A pneumatic waste collection system is a type of pipe-based underground infrastructure for transporting waste via negative pressure and air. A distinction is made between a mobile pneumatic waste collection system where the waste is collected in a tank and picked up by a pneumatic truck, and a stationary pneumatic waste collection system where the waste is transported through the pipes to a terminal and stored in a container pending retrieval by a truck. The mobile system is mostly used for smaller areas or individual properties. The pneumatic waste collection system solution studied for the central part of the city is a stationary one as it is more suitable for larger areas.

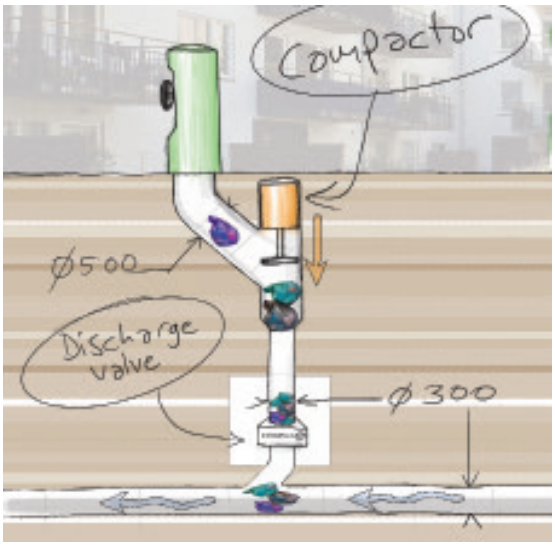
Large-scale stationary waste collection systems are usually installed in new urban development projects because it makes it possible to create a cost-effective and practical coordination of the installation of other new infrastructure. Envac Quantum is a new concept that lowers the costs for the installation of a pneumatic waste collection system in an existing urban environment.

The Quantum concept entails both a reduction of investment and operating costs. In the Quantum system, the waste bags are compacted at the collection points. This means that the system's handling capacity increases by up to 200%. In addition, the Quantum system is gentler on the waste bags as the airspeed is lower than in a traditional pneumatic waste collection system.

The containers in the terminal are tilted to increase self-compaction and the degree of filling. More waste is then placed in the same container, which reduces the number of transports. The transport pipes in a Quantum system are also of smaller diameter than before, which reduces the energy use. A lighter construction material together with a smaller diameter decreases the installation cost by up to 30%.



One option for waste collection is to use a stationary pneumatic waste collection system, where the airborne waste is transported under the streets to a terminal located on the outskirts of the area. There, a lorry collects full containers and transports them for processing.



Envac Quantum compacts the waste in the inlet, allowing smaller pipes to be used.

The benefits of the Quantum system in comparison with a traditional stationary pneumatic waste collection system can be summarized as follows:

- Lower installation cost
- Faster installation
- Space saving
- Lower initial investment
- Lower energy consumption
- Lower operating costs
- Greater storage capacity
- Less wear and tear on waste bags
- The cost of the inlets is roughly the same

Modified manual collection

Manual collection means the kind of collection where the waste collection staff themselves move containers with waste (bags or bins). Avfall Sverige (Swedish Waste Management) has the following recommendations for how manual collection should be managed to meet requirements of a good working environment:

- An approved manual collection should be within 50 meters from the entrance to a residential building.
- The space for waste storage should be placed on ground level.
- The vehicles used for collection must be able to carry out their work in a traffic-safe manner
- Containers used for waste collection must be placed as close to a loading point as possible.

Approved alternatives to the current waste collection may be to use waste cabinets or ground containers. It is then possible to live up to the recommendations that the collection should take place at ground level

Waste cabinets provide a better working environment but take up space in front of properties.

and/or mechanically. In order to be able to place the storage area close to entrances and at the same time close to loading areas, space needs to be available in front of properties, facing the street. n a densely built city, however, there are few property owners that actually have the surface space available, and even though they have available space, there are often requests for other uses for it. If the waste cabinet or ground container takes up this place it will, instead of alternative uses, become a surface that is easily soiled, attracts pests, and creates odour problems.

For those property owners who do not have space available, the waste collection needs to be placed inside the property but still on ground level and near loading areas and entrances. You then need to build waste storage rooms that have entrances facing the street, where waste bins can be rolled directly from the waste room to the waste collection truck.

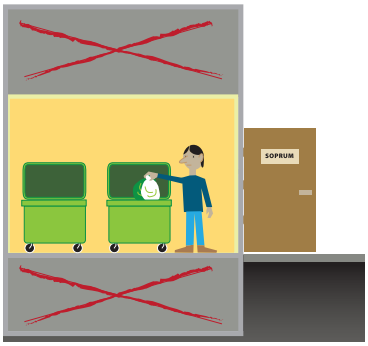
Rebuilding the waste rooms to be able to handle containers is the most common measure to fix the work environment problems related to the bag collection. Bins are a common type of container and do not affect the user's way of disposing of waste. They can therefore be perceived as easy to implement and bin collection also does not require any new type of infrastructure.

If the property does not have a waste storage room with an entrance towards the street, however, space must be freed up to make room for it. That surface might today be used as business premises, storage space, apartments or, for example, a bicycle room, and then needs to be vacated. A business or tenant who has to move means a lack of income for the property owner. Claiming living space is difficult to justify given the housing shortage that exists in Stockholm.

To then adapt the space so that it fulfils the requirements for a waste storage room can mean a large cost for the property owner. The building cost will be even greater for properties where the waste room ends up between two floors. The rebuild then affects both the floors and requires an even greater construction effort.

Current waste collection with poor working environment.

Waste collection with pneumatic waste systems frees up space and provides a better working environment.



Modified manual collection improves the working environment but requires new space.

Conditions for waste collection in Stockholm

This report assumes that the municipality can act as the principal in some form.. It will be clarified in a later section why municipal leadership is assumed to be a prerequisite for the reasoning in this report.

Household waste consists of, among other things, residual waste, food waste, packaging material, recycled paper, bulky waste, and hazardous waste. Currently, there is a producer responsibility that governs the collection of packaging material and recyclable paper. It has been decided to let the municipality take over the responsibility for collecting these fractions, but it is not decided how it will be implemented. This report will briefly highlight the effects of these changes if the City of Stockholm would want to increase the near-property-collection, depending on which collection method is used.

The starting position is that the distribution of responsibilities is the same as at present.

However, bulky waste and hazardous waste are not covered by the report.

Because it was decided to build a facility for post-sorting of waste bags in Högdalen in Stockholm, it is assumed that one is in operation. Based on that it is also assumed, that food waste is collected separately regardless of the collection method.

The city of Stockholm needs to find new solutions to reach its high targets for food waste collection. The goal is that 70% of food waste must be collected by 2020, which means that they have a long way to go seeing as the collection rate is currently at 15%.

The area of Norra Sofia seen from Ersta. In the background, Sofia Church in Vitabergsparken can be seen.

Norra Sofia in Stockholm

To answer what consequences a changed method of waste collection would have in Stockholm, an area of Södermalm is investigated, which lies north of Sofia Church and east of Renstierna Street. The area is called Norra Sofia and the choice of area was made in consultation with Stockholm Water & Waste. This area is interesting both because it has many problematic collection points and because parts of the area have a typical inner-city character. The buildings are relatively old and the percentage of properties that collect their waste in bags ais high. At the same time, there are plenty of small streets that are not ideal for the traffic that the current manual collection entails, and this has a negative impact on traffic flow through the district.

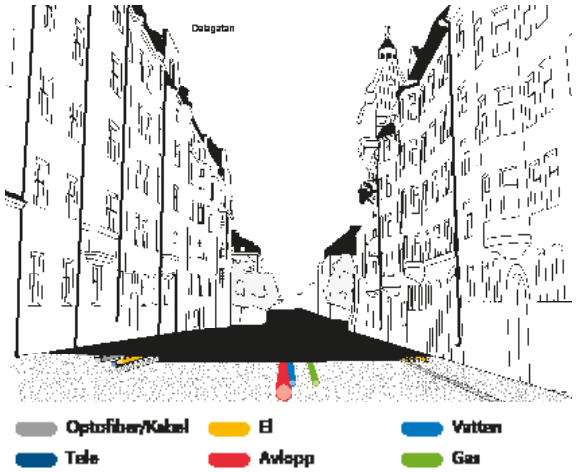
The district has many property owners who are lacking space in front of their properties to be used for a modified manual waste collection. A pneumatic waste collection system with a municipal principalship can be placed on municipal land, with inlets placed on pavements, and used by households of several properties. This means that less space is used for waste collection compared to if the property owners themselves would use waste storage rooms, manage waste cabinets, or ground containers.

Stockholm and Södermalm.

Södermalm and Norra Sofia.

Technical prerequisites and possibilities

To explore the conditions for installing pneumatic waste collection system pipes in the ground in Norra Sofia, Stockholm Water & Waste was consulted, and utility maps were studied. A detailed design was not done at this stage, instead opting to schematically draw the facility because it has been established that sufficient space is available in most of the intended piping routes. There are experiences from inner-city environments with more difficult conditions, for example, Barcelona, having twice the size of pipes. The feasibility of pipeline installation is therefore considered to be good even in Norra Sofia.



A survey of infrastructure in Vasastaden shows that a pneumatic waste collection system can be installed relatively easily since there is no district heating. If there are district heating pipelines, coordination of the infrastructure is facilitated. Image source: Stockholm Vatten Avfall.

The dimensioning of the waste collection system is based on the amount of waste that is collected in Norra Sofia now. The benefit of a Quantum system is that the capacity per inlet is higher than with a traditional pneumatic waste collection system and thus the number of inlets can be kept to a minimum. Regarding the placement of inlets, sidewalk locations with a space in between that meet the set accessibility requirements were favoured.

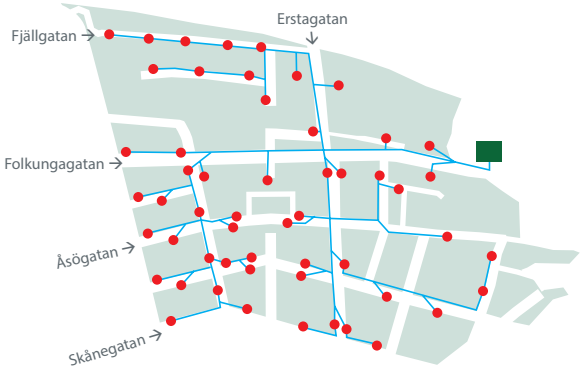


Illustration of how the pipeline layout and placement of inlets for a pneumatic waste collection system in Norra Sofia might look. The dark square represents the terminal building for the waste collection system.

It is also technically possible to have pipes go through properties, if a property owner, for example, wants to be able to continue using their existing waste disposal inlet or have a waste disposal inlet in the courtyard. However, the system design is based on the assumption that inlets are placed outside properties since it is unknown how many property owners are interested in having their own inlets.

The terminal building is preferably placed on the outskirts of an area and a parking area in the northeast, towards Stadsgårdsleden, appeared as the natural place in the case study area. Such a terminal building can be used for more purposes than placing containers. For example, a local recycle initiative can be set up or use it as a collection point for bulky and hazardous waste.

Collection capacity

Amounts of waste in a district vary over time and a pneumatic waste collection system has a greater ability to handle changes in waste volumes than manual collection. The manual waste collection has its set schedule for emptying, which needs to be adjusted to handle the increased quantity of waste, while the pneumatic waste collection system can be emptied as needed. In case of an increased amount of waste, for example, during major weekends or events, the bins can be emptied more often while the manual collection bins are at risk.

Prior to the introduction of a stationary pneumatic waste collection system in Stora Ursvik, in Sundbyberg, simulations of emptying capacity were made. These calculations show that stationary pneumatic systems has a significantly lower amount of time with full inlets than the manual collection over time1. Whenever inlets or bins are full the households, as customers, cannot use the service they are paying for. In addition, it contributes to the negative effects such as litter and pests, as described in more detail later. It is therefore of interest to keep the time the inlets are full, as short as possible.

Connecting public litter bins

If a stationary pneumatic waste collection system is installed in the inner city, there is a possibility of connecting public litter bins to the system and these can then be emptied automatically when they become full, by installing level sensors. In urban environments where a lot of people gather, litter bins need to be emptied often, which is costly and traffic-generating. In Norra Sofia, in just over a week, 150 manual emptying of public litter bins takes place. It is also possible to supplement the litter bins with ashtrays

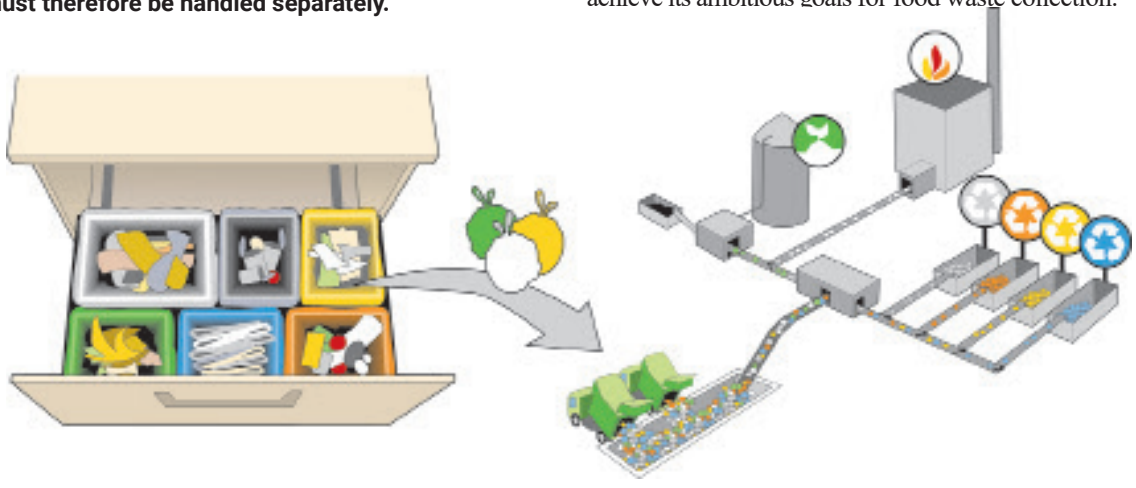
so that cigarettes can be transported in the same pipe as the other waste. “Håll Sverige Rent” describes cigarette butts as the worst waste because it is toxic. In their waste report2, they say that roughly 60% of all waste in Swedish cities are cigarette butts.

Self-emptying litter bins connected to a stationary pneumatic waste collection system can be found at Mariatorget in Stockholm. The bins in the park were previously emptied manually three times daily. The stationary pneumatic waste collection system now continuously empty them when needed, without increased personnel costs, even in case of increased amounts of waste. Once or twice a month, the container that is located underground is picked up.

Improved emptying of litter bins reduces littering in the city, which contributes to a more pleasant environment for those staying in the area. It also contributes to the fact that problems with rats and birds are reduced, there is not enough available food for them when the waste fits in the bins.

The self-emptying litter bins at Mariatorget in Stockholm look the same as the city’s regular litter bins.

Below are six fractions of household waste sorted into differently colored bags in the kitchen and then placed in the same pneumatic waste collection system inlet. They are then sorted optically. Glass would damage the waste collection system and must therefore be handled separately.



Source separation/Household sorting

Household sorting and recycling is an important part in achieving a more resource-efficient and sustainable society. It is therefore of interest that the waste collection methods that are used, create good conditions for households to achieve this.

Optical post-sorting

One way to facilitate the collection of household sorted material is to use an optical post-sorting of drop bags. Optical post-sorting of household waste can be used regardless of the collection method. Different coloured bags that are distributed to households are thrown away in manual waste bins or pneumatic waste collection systems. The mixed fractions are transported to an optical sorting facility where they are sorted by colour. Optical sorting enables sorting without changes to the existing waste infrastructure. However, it assumes that households use different coloured bags for the waste fractions that are collected.

With optical sorting, there is also a possibility to collect more fractions than food waste. In Eskilstuna for example, six fractions are collected from households to then be sorted optically3. The factions that can be collected are, for example, residual waste, food waste, paper packaging, plastic packaging, metal for packaging, and recycled paper.

Quality and quantity

A common prejudice is that the use of a pneumatic waste collection system deteriorates the quality of sorted waste fractions, for example, food waste. However, studies show that this is not necessarily the case and with the right measures and information to users, a high degree of purity is achieved4, and large amounts of food waste can be collected. If Stockholm City can make it easy to do the right thing, using optical sorting and maintaining good availability thanks to a pneumatic waste collection system, it is reasonable to assume that large volumes of food waste would be sorted and collected. A pneumatic waste collection system supplemented with different coloured bags that are sorted optically can therefore help Stockholm City achieve its ambitious goals for food waste collection.

Safe waste collection

Operational saftey

A waste collection that has a high degree of operational reliability creates conditions for a good urban environment and happier residents. Weather conditions can affect the operational reliability of waste collection. Sometimes waste collection trucks are not able to do their duties, due to heavy snowfall, so the household waste cannot be collected. For example, the manual waste collection could be cancelled due to non-existent snow removal in the central parts of the city. The vehicles that empty the stationary pneumatic waste collection systems from the terminal buildings, on the other hand, travel primarily on the major traffic routes and are therefore not equally dependent on all streets in the area being free from snow.

Even heavy rain can affect the reliability of manual collection to a greater extent than that of stationary pneumatic waste collection systems. An example of the pneumatic waste collection system's better ability to handle storms occurred in New York in 2012 where almost all waste collection was cancelled due to hurricane Sandy. The 40-year-old pneumatic waste collection system at Roosevelt Island, on the other hand, functioned as usual and collected residents' waste during the hurricane.

Using a pneumatic waste collection system for collecting waste in a city can therefore be a part of climate adaptations as it can be seen as a more robust waste collection system.

Fire hazard

Storing waste in properties entails a certain risk of fire, and fires that occur at waste collection points are often arson. Burning materials that are thrown away in plastic containers or plastic bags develop easily into a larger fire that can cause great damage to the property. In a pneumatic waste collection system, however, there is a limited supply of oxygen and the risk of burning materials developing into a fire is therefore minimal. There are several cities, including Bergen, where fire safety has been a driving factor for investing in pneumatic waste collection systems.

Storing waste posed a fire risk in the inner city of Bergen, so they sought an alternative collection method.

With a pneumatic waste collection system, the risk of fire development decreases and also creates a better urban environment. (Photomontage)

Urban environment

The impact of pneumatic waste collection system on the cityscape

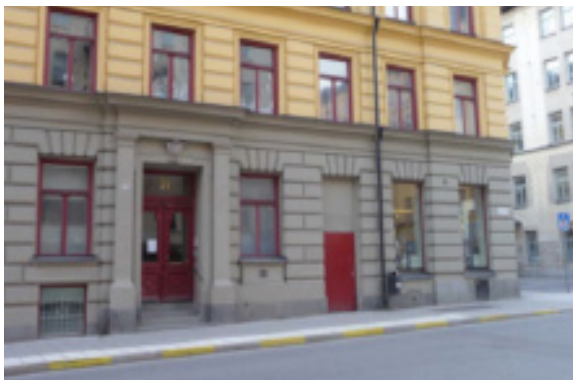
The choice of waste collection method affects the local city environment and the experience by those who live there. If today's manual collection is adapted to the work environment requirements that exist and placed ground level, facing the street, waste storage rooms would in many cases replace existing businesses. The cafés, shops, and other service facilities that are located at street level contribute to a vibrant urban environment, and if they were to disappear, natural meeting places would also disappear from the city.

In Stockholm's general plan, lively ground floors are said to have a positive effect on perceived safety and that, it is, therefore, something to strive for. Using ground floor areas to store waste does not create a living environment and therefore does not fit in line with the objective.

Building waste storage rooms with an entrance facing the street also often affects the building's facade and architecture. The right-hand image below shows a property that would be affected by the introduction of ground-level bins, where a window in the regular facade has been replaced by a door to a waste storage room.

If a stationary pneumatic waste collection system is used instead, the existing businesses can remain and contribute to security and social meeting places in the city. Since the existing waste rooms are then no longer

Att kunna låsa in cyklarna istället för soporna skulle vara värdefullt för de boende i en sådan här fastighet.



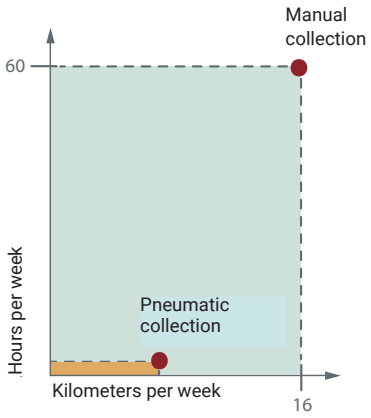
Bilden visar hur en fasad kan förändras om ett fönster ersätts av dörren till ett soprum. (Fotomontage)

needed, even more such places can be created. These spaces could then be rented out as premises or converted into apartments, bicycle rooms, or pram rooms. If inlets are placed along sidewalks, property owners also do not have to carry out measures that involve interventions on their property.

The impact of waste collection on traffic

A manual collection means that vehicles stay in the area for a longer time than if a pneumatic waste collection system is used. This has to do with all the waste rooms that need to be visited during a manual collection and the vehicles being stationary for a while at each location. Even though the vehicles are stationary, they affect the environment when their engines are running to compact the waste. The manual collection service covers all streets to visit all collection points. Folkunga Street and Ersta Street will be the most traffic-congested in the studied area.

If a pneumatic waste collection system is used, vehicle traffic associated with waste collection would be limited to the location at the outskirt of the area where the terminal building is located. As all household waste from the area is collected from one place, the traffic flow at this place becomes relatively large, but the rest of the area avoids heavy traffic. The proposed location for the terminal building is at a car park next to Stadsgårdsleden, and increased traffic there would not affect the residents of the area.

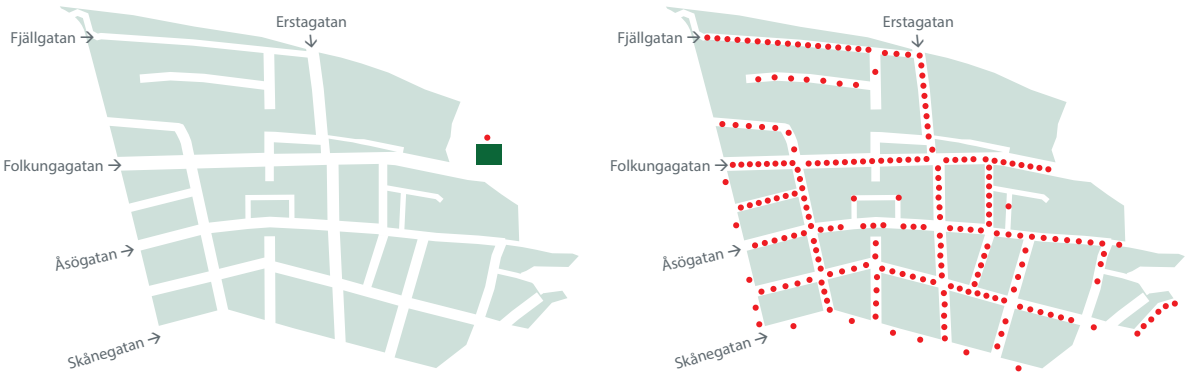


	Kilometer per vecka	Timmar per vecka
Manual collection	16 km	60 h
Pneumatic system	7 km	2 h

Calculations of vehicle distances and time in the area show significant differences.

The fact that vehicles stay for a longer time in Norra Sofia when a manual collection is used means a greater risk of accidents and other traffic-related problems. For example, waste collection trucks cause problems on narrow streets where they have to stop outside parked cars, block the way for buses, and create risky situations for cyclists as they block bicycle lanes. They also contribute to wear and tear on the city's road network.

Each red dot in the figure below corresponds to a stationary waste collection truck, once a week, and thus the risk of the above situations on the city's road network increases.



On the left, collection point for the pneumatic waste collection system (terminal). On the right, all collection points (waste rooms) for manual collection.

An example of how the urban environment in Norra Sofia could look if a pneumatic waste collection system is used. Garbage trucks would not need to travel on the street, and sidewalks could be widened. Instead of waste rooms, businesses could use ground floor spaces.

Noise from waste collection

Manual collection leads to waste vehicles staying in the area 30 times as long and therefore contribute to more traffic noise to a corresponding degree. Pneumatic waste collection systems are not completely silent, but the noise when emptying is less noticeable and located in less sensitive places. It also occurs for a shorter period of time.

Noise is one of the most serious environmental problems in Stockholm and road traffic is the most common cause of this. Stockholm City's guidelines state that property owners must plan waste collection so that noise disturbance is as small as possible, and that the principle of best possible technology must be used.

In Stockholm, a comparison of manual collection and a pneumatic waste collection system has been made for Västra Hammarby Sjöstad area, and there, among other things, a noise study has been carried out. This study shows that a conventional manual collection would lead to noise for more than twice as many hours and with higher noise levels, as a stationary pneumatic waste collection system[6].

[6]Envac. *Economic analysis and environmental assessment.*

Pests, odours and litter

In Stockholm, like many other cities around Europe, there is a growing problem with rats and other pests, such as birds. This is partly due to how waste in the city is managed. The media shows how the number of reports concerning rats has increased dramatically over the past few years and that Södermalm is one of the worst affected districts in Stockholm[7]. Another reason for this is that the district has a difficult-to-manage waste collection method, which creates conditions for the animals to find food and places to live when waste and rubbish accumulate in and around litter bins.

Before the project in Stora Ursvik, a simulation of the waste collection was carried out and, among other things, the number of hours with full pneumatic waste collection inlets was calculated in comparison with the number of hours with full traditional waste bins. Full bins and inlets provide both the

[7]http://www.dn.se/sthlm/mer-rattor-an-nagon-sin-i-stockholm/

Rats happily eat food scraps from the city's rubbish bins, on streets and squares.
Image source: Pixabay

An example of how the urban environment in Norra Sofia could look if manual collection is changed. Garbage trucks would block traffic, and more waste rooms would be needed on the ground floor. Sanitation workers would still need to maneuver bins between parked cars and over snowbanks.

conditions for rats to thrive and problems with bad smells, especially during the summer. According to this simulation, bins for manual collection stand full more than a hundred times as long time than the pneumatic waste collection system inlets, and the use of a pneumatic waste collection system would therefore reduce the risk of problems with both rats and smell. In addition, problems with odours are generally less from a closed pneumatic waste collection system than from one manual collection with traditional bins. Waste is also only stored for a few hours at the point of collection as opposed to a full week in containers on the property.

Overflowing rubbish bins can be a problem if they are not emptied as needed.

Littering has a negative impact on the local environment of a city. The most common cause of littering is the absence of litter bins or bins that are full. An already littered area leads to even more litter and it is therefore, important to actively work to avoid littering. Stockholm City has goals to reduce littering in the city and instead collect this waste for treatment. There is a goal to reduce littering by 10% annually, which will help Stockholm become the cleanest city in the country and Europe's cleanest capital[8].

It is the municipal units that are responsible for cleaning up the public environment and this is one of the activities that cost a lot of money today.On Södermalm in Stockholm, waste management costs are increasing, and the district administration calculates that the cost of keeping parks and green spaces clean costs around SEK 8.5 million in 2015. In the city as a whole, litter costs SEK 100 million per year[9]. In addition to the direct cost of cleaning streets and parks, there is a social cost in the form of increased perceived insecurity, affected tourism, and reduced property values.

If the city's trash cans are connected to a pneumatic waste collection system, it would reduce the risk of full litter bins and litter. A stationary pneumatic waste collection system with connected bins therefore provides a cleaner urban environment.

[8]Trafikkontoret, 2013. *Tjänsteutlåtande Stockholm Ren och Vacker. Lägesrapport 11.*

[9]Stockholm stad, 2015. Det lokala brottsförebyggande rådet Södermalm.

Environmental impact from greenhouse gases and particles

In Stockholm, there are problems with particles in the air which causes health problems. These particles arise primarily because of studded tire use and trials with banning the use of studded tires have been done on Hornsgatan in Stockholm, among others. Measurements show, however, that bans are not enough and, according to the Swedish Traffic Agency, you also need to work on reducing traffic in the exposed areas.

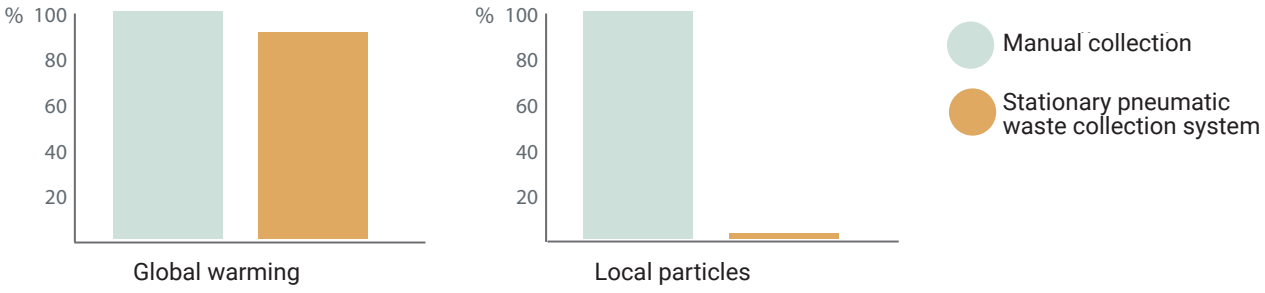
To compare the environmental impact of the waste collection in Norra Sofia on Södermalm, a life cycle analysis for the respective alternatives has been carried out[10]. The environmental impact has been calculated for the collection of residual and food waste with a stationary pneumatic waste collection system and a modified manual collection. The calculations are based on the amounts of waste that are present in the case study area.

The environmental impact is calculated for the manufacturing of included components and for the operation of the collection system. Installation of both collection systems has been exempted, which means that the environmental impact of neither the construction of the waste room nor the excavation work for the pneumatic waste collection system has been taken into account. The life cycle analysis for Norra Sofia shows that emissions leading to global warming are approximately equal for the two collection methods. If one studies the amounts of air particles that the collection methods give rise to, they show large differences. Particle quantities from a stationary pneumatic waste collection system are only a few percent of that for a manual waste collection!

Both the collection methods lead to approx. equal emissions of carbon dioxide. Equivalents depend on the fuel used in the manual collection waste collection trucks are exchanged for the electricity use of the pneumatic waste collection system. Waste collection trucks in Stockholm are often powered by biogas, which means that their carbon dioxide emissions do not become so large, at the same time, the electricity mix used in the calculations has a Nordic composition that has a smaller proportion of renewables than the Swedish one. Exchanging waste collection trucks for the use of electricity therefore gives no major environmental gain if you only see to global warming, based on these conditions.

Life cycle analyses of the waste collection have previously been done as a comparison of manual collection and stationary pneumatic systems but in environments other than Stockholm. The results from these studies show large differences in environmental impact depending on whether the focus is global or local. At the local level, it is the traffic load that is the heaviest factor while on a global level it can be the composition of the electricity mix which gives the greatest result.

[10]/Svensson, I., 2015. *Implikationer av förändrad avfallsinsamling.*



For the manual collection, the environmental impact is calculated for:
- building materials for waste rooms
- lighting and ventilation in waste rooms
- materials in waste bins
- transportation by rubbish truck.

For the stationary waste suction system, the environmental impact is calculated for:
- the materials used in chutes, pipes, terminal buildings, fans, and containers
- electricity usage
- ventilation
- lorry transport

Despite waste rooms on the ground floor, a modified waste collection process results in a physically demanding work environment. Image source: Stockholm Vatten

Work environment

Stockholm City has a goal that waste management should be characterized by a human perspective. To achieve that goal, the use of mechanic collection is recommended over manual, which should be avoided wherever it is technically possible and economically reasonable. The driving factor behind this is the problematic work environment that has long characterized the waste industry. Stockholm City wants the entire chain of waste management to be characterized by a good working environment, from the generation of the waste, through the collection, until it is finally disposed of and processed. By using a stationary pneumatic waste collection system for waste collection in Norra Sofia, the problems that exist with the current manual collection in work environment can be avoided. To change the manual collection with the help of renovations, the waste collection staff's working environment is indeed improved where they don't have to lift bags and climb stairs. Over half of the properties that use bag collection would have to switch to waste containers.

However, there are obstacles to a complication-free work environment, and it is not completely achieved by rebuilding the properties waste storage rooms. There are still problems with curbs and parked cars which mean that the staff cannot roll the waste bins straight to the waste collection truck but have to take a detour. This becomes particularly problematic in winter when the vessels do not roll as they should because of the snow. A stationary pneumatic waste collection system, on the other hand, collects the waste fully automatically and therefore completely avoids the physically demanding workload of manual collection.

Although collection with bins allows for a better work environment, it is weather-dependent, and factors such as snow affect manual collection more than a stationary waste suction system.
Image source: Stockholm Vatten.

What happens if Stockholm City gets responsibility for collecting packaging and recyclable paper?

If the city of Stockholm gets responsibility for collecting, packaging, and recyclable paper, this can be done in the same collection system that exists for waste and food waste. Using optical sorting, at least six waste fractions are collected in Norra Sofia and the need for public recycling stations decreases as only one glass fraction remains. The residents of Norra Sofia could then throw all waste fractions (except glass) close to the property and do not need to look for a recycling station. In Stockholm City's handbook, it is recommended that waste with producer responsibility should be collected close to the property and specify a limit of 50 meters for how far it should be to the collection points from the apartment building. This recommendation becomes easier to follow even if the fractions that had the producer's responsibility are collected with a pneumatic waste collection system.

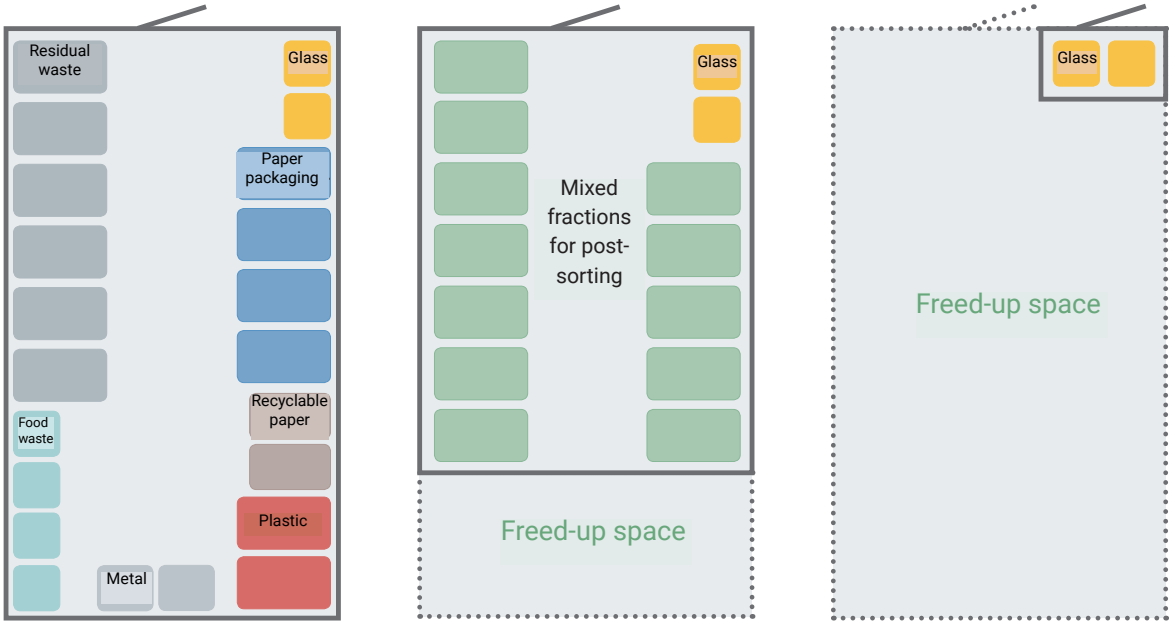
If all six fractions are instead to be collected manually and close to the property, more waste bins are needed in waste storage rooms, which are currently sized according to only residual waste, and in some cases food waste. More waste bins require a larger floor area, and the waste rooms therefore need to be made larger, which means increased costs for the property owner. If all waste rooms should have room for all fractions, more than 3,000 square meters of waste room is needed in Norra Sofia. Comparatively, that area corresponds to more than 100 student apartments of 25 square meters.

If different coloured bags were introduced for all fractions, fewer vessels will be needed due to a better degree of filling, but still, large areas are needed for the storage of waste and packaging, in or adjacent to the property. If a pneumatic waste collection system is introduced, almost all of this space can be used, for example, for housing. The exception is the significantly smaller space needed for glass collection. Collecting all fractions with the pneumatic waste collection system has major advantages for traffic flow in the inner city. Currently, various waste fractions are collected by various waste-collecting organizations which means that most of the 235 collection points in Norra Sofia are served by several vehicles, in addition to the ones that pick up the residual and food waste.

Even if all waste fractions that are collected manually undergo optical sorting, this will entail a greater traffic flow than if a pneumatic waste collection system is used. If more fractions are to be collected from properties, more waste collection trucks are required per week than if only residual and food waste are collected. This increases the number of waste collection trucks throughout Norra Sofia. If packaging is instead collected with a pneumatic waste collection system, it only increases traffic on the outskirt of the area where the terminal building is located.

The number of vehicles in the area increases the vehicle noise, but the pneumatic waste collection of packaging fractions only gives rise to increased noise on the outskirts of the area. The manual collection has a greater negative impact on the residents of Norra Sofia than collection with a pneumatic waste collection system.

With all fractions collected ogether with the residual and food waste close to the property instead of at recycling stations, it should also reduce littering, cleaning needs, and noise.



The property area required for property-close collection of household waste, packaging, and recyclable paper varies depending on the choice of collection method and whether optical post-sorting is used.

Economic effects of a modified waste collection

The economics of waste collection methods have been compared in previous studies and reports and a general conclusion is that pneumatic waste collection is beneficial in areas with high population density, high personnel costs, and high real estate prices[11].

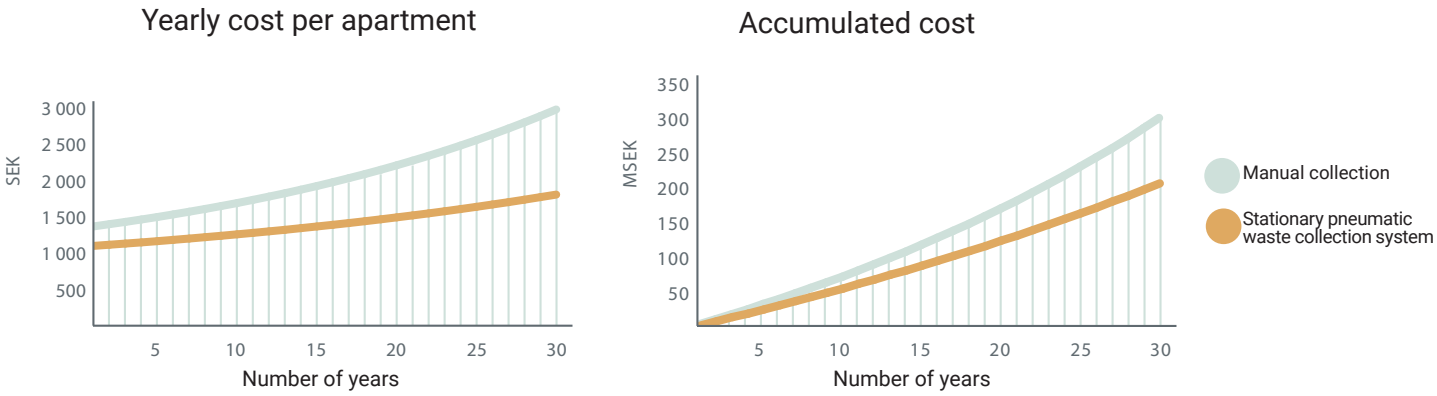
Norra Sofia has a high population density and in Sweden, both salary and housing costs are relatively high. This indicates that the area is suitable for a pneumatic waste collection installation. To determine which collection method is the least costly to use in Norra Sofia, the annual cost is calculated 30 years into the future.

The current waste fee is used to calculate the cost of a future manual waste collection with bins in Norra Sofia. However, it is assumed that all properties have arranged approved collection conditions. The cost for this is compared to the alternative of collecting household waste with a stationary pneumatic waste collection system instead, and with the existing fee for this. The investment required for installing a pneumatic waste collection system is calculated as an annual cost including depreciation and interest on the investment. The annual cost of waste collection is shown in the chart for annual cost per apartment, where it can be seen that the manual collection is expensive from day one and it also gets more expensive over time because it has higher cost development. The accumulated costs chart shows the accumulated cost over 30 years, which is greater for a manual collection than for a collection with a stationary pneumatic waste collection system.

[11]Nakou et al., 2014. *Assessing the financial and environmental performance of underground automated vacuum waste collection systems.*

Miller et al., 2014. *Costs and benefits of pneumatic collection in three specific New York City cases.*

Teerioja et al., 2012. Pneumatic vs. *Door-to-door waste collection systems in existing urban areas: a comparison of economic performance.*



The cost of investment and operation of a stationary waste suction system and a modified manual collection.

	Manual collection	Pneumatic solution
Installations	**Refurbishment cost.** The cost of constructing waste rooms that meet the required standards. One-third of the total waste room area is assumed to need rebuilding. **Redemption area.** The cost of acquiring a condominium to build waste rooms. It's the same one-third of the total waste room area assumed to need rebuilding. **Lost rental income.** The revenue that is at risk of disappearing if an apartment or commercial space is taken over to build waste rooms. One-third of the total waste room area is assumed to be former rental space.	**Technology.** The cost of purchasing the technical components, such as chutes, pipes, fans, and containers. **Construction and groundwork.** The cost of excavation work, building terminals, and installing the system. **Freed-up space.** The value of the area released when waste rooms are no longer needed and can be used for other purposes. One-third of the total waste room area is assumed to be available for release.
Operation	**Waste fee.** The cost for the collection of bins and treatment of waste paid by the property owner. **Operation of waste rooms.** The cost of maintaining waste rooms in operation, such as electricity, cleaning of the space, and bin washing. **Reinvestments.** The cost of regularly replacing existing bins with new ones.	**Waste fee.** The cost for the collection of containers and treatment of waste paid by the property owner. **Operation of pneumatic system.** The cost of operating the waste suction system and terminal, such as electricity and maintenance. Service for pneumatic system.The cost of service measures.
Other	The above costs only cover residual and food waste, but in the future, the municipality will likely also be responsible for packaging materials and recyclable paper. The cost of this collection would then need to be added to the calculation. The choice of collection method also affects factors that are difficult to quantify economically, such as effects on the urban environment. However, these are challenging to quantify and therefore are not included in the calculation.	
Assumptions	The property value in the Norra Sofia area is assumed to be 60,000 SEK per square meter. The refurbishment cost is assumed to be 30,000 kronor per square meter, based on similar studies. Rental income is assumed to be 1,500 SEK per square meter per year. The total waste room area used as a parameter in the calculations is the area needed in Norra Sofia to have an approved bin collection, slightly over 1,500 square meters. This is based on recommendations for waste room design. The cost of excavation in Norra Sofia is assumed to be 10,000 - 15,000 SEK per meter. The depreciation period for investments is set at 30 years. The discount rate for investments is set at 4%. The waste fee often evolves differently depending on whether it's manual or mechanical collection. Traditionally, the fee is governed by manual collection, so it is assumed to have a faster percentage growth rate than the waste suction system's fee, 4% and 3% respective-	

Cost items considered in the comparison and assumptions made include, among others, interest rates.

Pneumatic waste inlets in Barcelona, where the municipality owns the facility financed through a local tax.

To organise and finance the introduction of a pneumatic system in the existing environment

Below is a brief description of the prerequisites for ownership, law, and financing of a pneumatic waste collection system which is installed in an existing urban environment with property owners and users who are already in place.

Ownership

Who owns a pneumatic waste collection system varies from case to case. There are examples where a municipality is the principal, but the most common situation in Sweden is that property owners, private or municipal, and associations own and operate the facilities.

Pneumatic waste collection systems owned by larger communities tend to encounter challenges over time due to the different conditions and agendas of the co-owners. As a response to this, for example, property owners have asked the City of Stockholm to take more collective responsibility for the planning, construction, and operation of the larger pneumatic system that are currently being planned and built in the city. They want the city to be responsible for waste collection, just like with other types of infrastructure, for example, water and sewage. A municipal ownership, according to them, also contributes to a more long-term and stable ownership.

Avfall Sverige (Swedish Waste Management) has carried out a study on the ownership of waste collection facilities and according to it, municipal ownership would be compatible with the wishes put forward by developers and property owners in Stockholm. The Development Office and the Traffic Office in Stockholm[12] has supported the idea of incorporating larger pneumatic systems into the city's other infrastructure.

A general conclusion from previous studies is that extensive municipal commitment is required to set up and operate a pneumatic waste collection system with something other than municipal leadership. In addition, the municipality has a better overview of waste management and its conditions in both short and long term. Fastighetsägarna Stockholm[13] therefore also propose in their report that the City of Stockholm should plan, finance, build, and operate such facilities in the inner city in-house. The report refers to several good examples where the municipality has already taken on the leadership role of pneumatic systems, including in Bergen, Norway and Barcelona in terms of the existing environment, and Barkarby in Järfälla for new development.

[13]Exploateringskontoret och trafikkontoret, 2010. Huvudmannaskap för sopsugsanläggningar. Svar på uppdrag från exploateringsnämnden och trafik- och renhållningsnämnden i oktober 2008.

[13]Fastighetsägarna, 2014. *Hållbar sophantering för ett attraktivt Stockholm.*

Conditions for mandatory connection

To introduce a new system in an existing district, the conditions must be clear in terms of capacity and utilization of the system. To achieve several of the advantages a pneumatic waste collection system brings with it, it is important to ensure that as many people as possible will use the chosen system.

A municipality can prescribe in its waste regulations where waste must be disposed, and for example, indicate that waste must be disposed of in a pneumatic waste collection system. This is based on their authorization found in environmental legislation[14]. The prerequisite for being able to designate a place for waste collection outside the area of the property is that it is within a reasonable distance and that it is not possible to ensure an approved collection on the property. There is currently no practice regarding the general benefits of an alternative waste collection and whether they can be included in the reasonableness assessment of a designating collection site, for example, the environmental impact.

[14]Avfall Sverige, 2014. *Kommunalt huvudmannaskap.*

However, there are limitations in what can be prescribed, for example, a change in the collection method that requires intervention in an existing property can be difficult to implement. A municipality may prescribe that waste must be disposed of in a pneumatic waste collection system, but not that these waste disposals must be installed within the boundaries of the property. Installing pneumatic waste collection pipes and their inlets in the property, to increase accessibility for their residents is thus up to the property owner.

A general regulation on the use of pneumatic waste collection systems is given for a geographical area, potentially the property owners who have already invested in, for example, work environment-related measures may experience that they are affected by a double cost. Case law for how this should be handled is currently missing and the issue needs further investigation.

Inlets on municipal land

A legal issue that is affected when a municipal principal is investigated, is how the use of communal land can be managed. To grant public land for waste collection, it needs to be seen as a general interest. If the municipality has principal management and its stationary pneumatic waste collection systems can demonstrate the advantages that exist in it, public interest should, therefore, be able to be placed on public land.

However, there are different types of legislation and administration concerns within the city and that is not yet fully tested practically on how it should be handled.

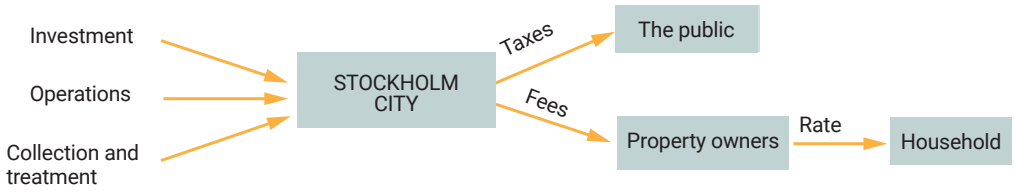
Finansiering

There are various examples and proposals for how a pneumatic waste collection system installation can be paid for, and above all, who should provide the initial financing. One method, which is common in new construction, is to let property owners pay a connection fee and an operating fee (tariff). The connection fee is charged by the property owners who build in the area to cover the joint investment in the same way as you do for water and sewage. In Järfälla, where the municipality has invested in pneumatic waste collection for new construction, the investment has been financed by builders including a connection fee in the land allocation agreements. After that, affected property owners pay a fee to cover the operating costs.

However, this type of procedure is not possible in an existing urban environment, where property owners already exist to establish them, as there is a lack of legal support. The investment therefore needs to be covered in other ways. An example of how to solve the financing of a stationary pneumatic waste collection system in existing buildings can be found in Bergen, Norway. There, they have chosen to charge everyone who lives there with the cost of the investment with the help of the waste tax and everyone has to pay for this, but those who use the pneumatic waste collection must pay a larger share[15]. In Barcelona, on the other hand, the municipality has chosen to finance its investment through a local tax.

[15]BIR Nett AS, Bossnett Renovasjonsgebyr

A traditional financing model for a pneumatic waste collection system in the studied area would build on a municipal leadership where the municipal administration (alternatively a municipal company) is responsible for costs for both installation and operation. This cost is financed partly through the tax collective and partly through the case rate and is therefore relatively uncomplicated. The operation and the investment should, however, be reported separately to enable the correct waste collective to be charged.



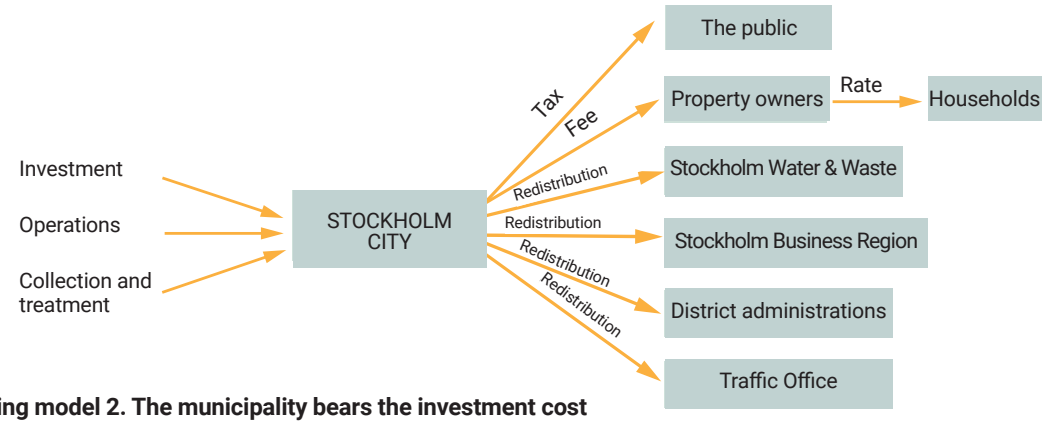
Funding model 1. A traditional funding model for a stationary waste suction system. The arrows represent financing requirements.

The installation of a pneumatic waste collection system generates more benefits than only an efficient collection of waste. These benefits also accrue to actors other than the more obvious ones such as the municipality, the waste company, and the residents. The table above provides a qualitative picture of such benefits. A number of these benefits could be quantified in their individual case and given an economic value, while others are more qualitative in nature. In this context, it is interesting to find out about some of these benefits can be translated into willingness to pay and co-finance the project.

	The stakeholder perceives it as a value to:	Households	Property owners	The public	Stockholm Business Region	Stocholm City	District administrations	The traffic office	SVOA	Contractors
Space saving	existing waste room area is freed up	■	■							
	the need to terminate tenants is avoided	■	■							
	the need for reconstruction is avoided	■	■							
Maintenance	reduced wear and tear on properties	■	■							
	reduced wear and tear on public spaces	■		■	■			■		
Traffic	increased street accessibility	■	■	■	■			■		■
	reduced traffic noise	■	■	■	■	■		■		
	reduced air pollution	■		■	■	■		■	■	
Acces-sability	accessibility for property-close collection increases	■								
	the need for public recycling stations decreases	■	■	■	■					
	the capacity of waste collection increases	■							■	
Littering	reduced littering in public areas	■	■	■	■	■	■	■	■	
	reduced cost of public area cleanliness						■	■		
	reduced pest problems	■	■	■	■	■	■		■	
Urban environment	the city's image improves and attracts more tourists			■	■	■	■			
	Stockholm can continue to be a vibrant city	■	■	■	■	■	■			
Safety/Risk	reduced risk of fire during waste collection	■	■	■		■	■		■	
	reduced risk of traffic accidents	■		■	■	■	■	■		■
	increased resilience to climate change	■	■	■	■	■			■	
	improved working environment for waste management personnel									■

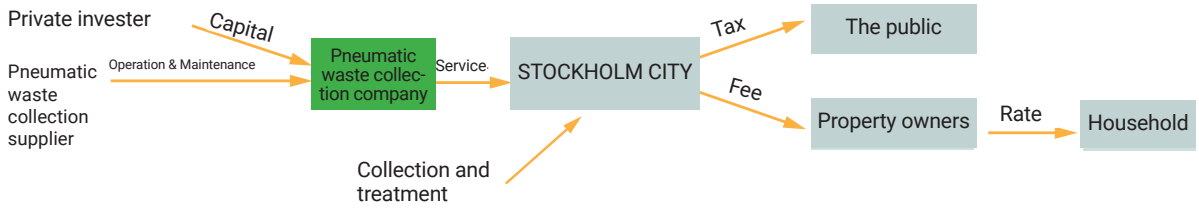
Table with a compilation of potential benefits that a stationary waste suction system in Stockholm's city center can bring, in addition to waste collection. Grey shaded boxes indicate that a specific actor receives a specific benefit.

To illustrate the funding requirements in a different scenario, a couple of financing models in addition to the traditional ones are presented below. The first step in distributing benefits could be to investigate which different administrations and companies within the municipality receive benefits, and thus have a willingness to pay. With such an inventory, a discussion can be held as to whether different parts of the municipal organization can partially finance the investment. The same kind of inventory can be done for property owners and thereby identify those who, for example, desire better accessibility and have a willingness to pay to achieve it, based on these benefits.



Funding model 2. The municipality bears the investment cost but distributes the cost among various municipal authorities.

Additional partial financing of the system can then be achieved, and this arrangement is reported as financing model 2, where operations are financed in the same way as in the first model. An alternative for financing is also that a private investor forms a company together with the supplier that offers the waste collection system. Such a company can then own the pneumatic waste collection system where the investor provides the capital, and the supplier is responsible for operation and maintenance for a predetermined number of years. A waste collection company can then sign a separate agreement with the City of Stockholm to deliver the comprehensive stationary pneumatic waste collection system service. Stockholm City avoids such financing at the initial stage of investment which can be difficult to finance in a city with many other current projects. It is this arrangement that is shown in financing model 3. Stockholm city chooses how to distribute the cost of the waste collection at once, this type of arrangement is open, but based on the benefits accruing to the public, they are distributed between property owners and the public, like the first model. One possibility is also to distribute as in the other model, where the cost is redistributed among Stockholm City's administrations.



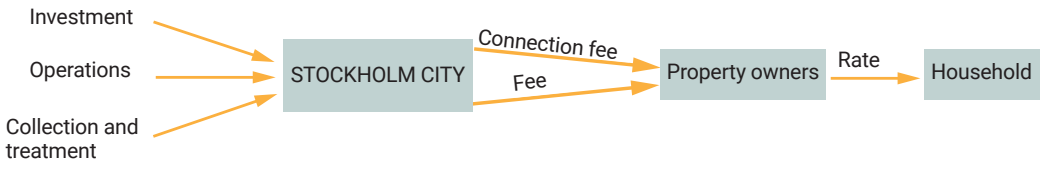
Funding model 3. A private investor bears the initial investment, and the City of Stockholm purchases the comprehensive pneumatic waste service from a company.

An actor who could act as an investor as mentioned in the third financing model is Infranode, which works with investments in infrastructure. While working with the payment models, a meeting with representatives of Infranode took place to unconditionally discuss solutions of this type. Below is a statement from them.

"As a Swedish infrastructure company focusing on long-term and local investments in infrastructure, Infranode is interested in evaluating a potential investment in a stationary waste suction system in an existing district in Stockholm. Infranode seeks long-term and stable return investments and has a particular interest in investing in sustainable projects that generate societal benefits. We believe that an investment in a stationary waste suction system in Stockholm could meet these criteria." - Infranode, 2015-10-19.

A more radical change in the way of financing a stationary pneumatic waste collection would be to charge a connection fee even from existing properties. A comparison can be made to the water and sewage-area where mandatory connection, with associated fees, is widely practiced. Currently, this is not possible without amended legislation. However, financing model 4 presents how the funding requirement could look in the case of such an organization.

Which financing model should be chosen is determined by the bargaining power of the various actors and how clear and quantifiable the various benefits are for different actors



Funding model 4. The City of Stockholm bears the investment but finances it by allowing property owners to pay a mandatory connection fee.

Conclusions

What is the technical and economic feasibility of a stationary pneumatic waste system in Stockholm city centre?

Installing a stationary pneumatic waste collection system in Norra Sofia on Södermalm is technically possible. There is room for a terminal building on the outskirts of the area and the inlets can be placed on pavement areas for good accessibility. It certainly is cramped in the ground along some streets but the Quantum system's relatively small pipe diameter makes it easier, and supported by experiences from other European cities, it is deemed to be technically feasible.

The introduction of a pneumatic waste collection system in the inner city would require investments but the same applies to a future modified manual collection to improve working environment. By investing in a pneumatic waste system, the costs of adding or rebuilding the waste storage rooms and property maintenance are avoided. In addition, the costs for the collection and transport of household waste would be reduced.

If a pneumatic waste collection system is installed, there is no further need for large waste storage rooms. You can even free up the area that is currently used. These areas could be used for smaller apartments or business premises, which in the city has great value. In Norra Sofia, over 1,000 -> 1,000 estimated square meters could be freed up if the existing waste rooms are no longer needed and an additional 500 square meters would not have to be used to create new improved waste rooms.

How does waste collection with a stationary waste suction system differ from manual collection with bins, from the perspective of various actors?

Thanks to the pneumatic waste collection system letting air do the heavy work of transporting the waste it eliminates a series of work environment challenges. Even if the property's waste room is rebuilt, parts of the work environment remain problematic for container handling outside properties. The waste collection staff would still have to drag containers through snow, over curbs, thresholds, and stairs, between parked cars, and over bike lanes.

A series of positive effects, for the design and use of properties and common areas, arise when introducing a pneumatic waste collection system. Manual collection entails waste storage rooms, waste collection sites, and heavy transport, instead, with the pneumatic system, a living city with shops, restaurants, and less traffic can be obtained. A pneumatic waste collection system provides the conditions for a more vibrant urban environment that benefits those who live, work, and stay in the city.

An extended municipal collection responsibility, which includes packaging and recyclable paper, in combination with a stationary pneumatic waste collection system and optical post-sorting, would enable a more widespread property-close collection of all factions without using larger space. Households would generally receive a better service and the public would avoid littering and noise from the public recycling stations.

Additional advantages of pneumatic waste collection systems are improved accessibility for both collection and households. In addition, the collection system becomes less sensitive to changes in waste quantity over time. This applies to both household waste and waste bins in a public environment. Littering reduces and creates better conditions for a clean urban environment

What is the environmental impact of future waste collection?

The introduction of a pneumatic waste collection system in Norra Sofia would result in a number of positive environmental effects. The local driving with heavy vehicles for household waste would be more than halved, measured in kilometers. The time that is spent in the area decreases even more. From having spent 60 hours a week in the area it would only need 2 hours for reloading in the area outskirts. The local emissions to air and the generation of particles are much smaller for a pneumatic waste collection system, while the global impact from greenhouse gases is somewhat less for a pneumatic waste collection system than for manual collection.

How can the introduction of a stationary waste suction system in an existing environment be organized and financed?

To organize and finance the introduction of a pneumatic waste collection system in the existing environment places new demands on the city. There are various proposals as to who should own such a system and the consistent recommendation is that a communal actor should play a major role. Stability, long-termism and public benefits are highly valued parameters when choosing waste management from a larger perspective. Stockholm Water & Waste, for example, as a municipal company, is a natural system owner.

The financing of a pneumatic waste collection system in existing developments cannot be accomplished through one-time fees, as in newly developed areas, under current laws and regulations. Instead, financing should primarily occur through a waste fee, municipal tax, or a combination of both. Even within this area, there are clear parallels and potential synergies with Stockholm Water & Waste's existing operations.

Pneumatic waste inlets in Barnängen, Norra Hammarby.

A stationary Pneumatic waste collection system in Stockholm City can:

- **improve the local urban environment**
- **provide lower costs for waste collection**
- **reduce environmental impact from traffic**
- **contribute to a better work environment**
- **free up valuable space**
- **facilitate Stockholm in meeting its goals for food waste collection**

Related materials

- Kommunalt huvudmannaskap för sopsug. Avfall Sverige, 2013.
- Hållbar sophantering för ett attraktivt Stockholm. Fastighetsägarna, 2014.
- Avfallsplan 2013-2016. Stockholm stad.
- Projektera och bygg för en god avfallshantering. Stockholm stad.
- Handbok för avfallsutrymmen. Avfall Sverige, 2009.
- Huvudmannaskap för sopsugsanläggningar.
- Svar på uppdrag från exploateringsnämnden och trafik- och renhållningsnämnden i oktober 2008.
- Tjänsteutlåtande, stationär sopsug vid Avenyn. Göteborg stad, 2011.
- Pneumatic vs. Door to door collection systems in existing urban areas: a comparison of economic performance. Teerioja et al., 2012.
- Costs and benefits of pneumatic collection in three specific New York City cases. Miller et al., 2014.
- Assessing the financial and environmental performance of underground automated vacuum waste collection systems. Nakou et al., 2014.
- Västra Sjöstaden- Jämförelse av manuell avfallshantering och stationär vakuumsug för tre fraktioner. Stockholms Gatu- och fastighetskontor och SWECO VIAK AB, 2004.
- Bilaga till skrivelse om sopsug. 13D. Fördjupning, sopsug i Barkabystaden.
- Economic analysis and environmental assessment Hammarby sjöstad. Envac och SWECO.
- Stora Ursvik, SWECO och Envac.

Some findings from the study and facts about waste collection in Stockholm

A waste suction system in the city centre can reduce littering in the urban environment, which currently costs the City of Stockholm **100 million SEK per year**.

If all waste rooms in Norra Sofia were to accommodate both household waste, packaging, and recyclable paper, **over 3,000 square meters** of waste room space would be needed. This area corresponds to more than **100 student apartments.**

The City of Stockholm aims to **collect 70% of the city's food waste by 2020**. Currently, 15% is achieved.

From requiring waste vehicles **for 60 hours per week** in Norra Sofia, **only 2 hours** with waste suction would be needed for transfer at the outskirts of the area.

In Norra Sofia, there are **150 emptyings** of public bins every week. With pneumatic waste collection they are emptied automatically when they are full.

Over half of the properties in Stockholm city centre **use bags** for their waste collection.

A stationary pneumatic waste system's contribution to local **particle emissions is 3%** of the contribution from manual collection.

235 collection points for manual collection, **1 collection point** for a stationary pneumatic waste system.

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