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Guidelines to increased collection of plastic packaging waste from households

Background information

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Summary

The packaging industry is the largest consumer of virgin plastics in the EU why it is important to emphasise collection and recycling of plastic packaging waste. Unsorted plastic packaging waste in residual waste fractions represent one of the largest potentials for increased collection and recycling of plastic packaging in the Nordic countries. In order to exploit this potential there must be a well-functioning infrastructure targeted on collection of plastic packaging waste.

Collection of plastic packaging waste from households can be carried out in a number of different ways, and different strategies are used on the local level in the Nordic countries. Guidance based on Nordic experience on how plastic packaging waste can be collected could help increasing overall recycling of plastics, which the produced *Guidelines to increased collection of plastic packaging waste from households* is an answer to. This report entails background information as well as references to these guidelines.

The aim of the guidelines is to inspire, inform and give recommendations on how plastic packaging waste can be collected, and how different aspects concerning collection of plastic packaging can be taken into account without recommending a certain collection system in front of another. The project group hopes that the guidelines will encourage to action. The intended target groups for the guidelines are primarily actors responsible for the collection of plastic packaging waste in the Nordic region.

This report is part of the outcome of part two in the project *Improvements in existing collection and recycling systems for plastic waste from households and other MSW sources* initiated by the Nordic Waste Group (NWG).

The guidelines were developed based on (1) a screening of currently used systems in the Nordics (part 1), (2) identification of aspects found particularly important to evaluate when making decisions on what collection system that should be introduced on a local level, and (3) summary of the most important information to communicate under each aspect. The aspects explored in the guidelines were:

- Collected amounts
- Quality of the collected material
- Economic aspects
- Environmental impact
- Service level and communication
- Flexibility

This report is part of the Nordic Prime Ministers' overall green growth initiative: "The Nordic Region – leading in green growth" - read more in the web magazine "Green Growth the Nordic Way" at www.nordicway.org or at www.norden.org/greengrowth

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1. Introduction and project background

This report is part of the second deliverable within the project *Improvements in existing collection and recycling systems of plastic waste from households and other MSW sources*. The report has been prepared by IVL Swedish Environmental Research Institute, Ostfold Research, VTT Technical Research Centre of Finland, Aalborg University and Environice in Iceland. The project is initiated by the Nordic Waste Group (NWG).

The outcome of part 2 of the project *Improvements in existing collection and recycling systems of plastic waste from households and other MSW sources* includes three separate documents:

1. Guidelines to increased collection of plastic packaging waste from households
2. Background information - Guidelines to increased collection of plastic packaging waste from households
3. Future solutions for Nordic plastic recycling

1.1 Project background

The background to this project starts in 2011 when the working group formed in 2010 by the Nordic Prime Ministers presented its report on favourable areas for Nordic cooperation and future priorities within the area of green economic growth. The report contained eight specific target areas where a joint Nordic cooperation was considered beneficial for the Nordic countries. All of the target areas were accepted by the Nordic Prime Ministers and it was decided that the work should be carried out by the Nordic Council of Ministers. The Prime Ministers' green growth initiative is called *The Nordic Region – leading in green growth*.

One of the eight priority areas was waste aiming at resource efficiency and life cycle thinking in the waste management sector. To carry out the work under the target area, NWG was asked to develop a Nordic project activity. As a response to this, NWG initiated the overall project *Resource efficient recycling of plastic and textile waste*. In 2012 a pre-study was performed in order to explore the potential for increased recycling of plastic and textile waste in the Nordic region.

NWG developed six associated recycling projects based on the pre-study, three concerning plastic waste and three concerning textile waste. *Improvements in existing collection and recycling systems for plastic waste from households and other MSW sources* is one of the three plastic projects. The project has apart from the three reports listed above published the report *Improvements in existing collection and recycling systems for plastic waste from households and other MSW sources – part 1*.

1.2 Goal and Scope

The overall aim of the project *Improvements in existing collection and recycling systems for plastic waste from households and other MSW sources* (part 1 and part 2) is to pave the way and provide conditions for more efficient collection and recycling of plastic waste from households and other MSW in the Nordic countries, striving towards higher recycling rates.

The project considers:

- Plastic packaging waste from households and other MSW sources
- Plastic bulky waste from households and other MSW sources
- Small plastic waste other than packaging from households and other MSW sources

Other municipal waste sources commonly refer to waste generated by other sources than households, but with the same composition as household waste. In some Nordic countries the term household waste includes “similar waste” from businesses. An example of similar waste is waste generated in canteens.

Plastic bulky waste is large items of plastic waste that do not fit into bins and bags and therefore need different handling. Examples of plastic bulky waste are plastic garden furniture and buckets.

Non-packaging small plastic waste other than packaging is items that by its size fit into the same collection system as plastic packaging waste, e.g. tooth brushes and dish brushes. For more definitions used in the report, see Appendix 1.

Waste classified as hazardous, WEEE (Waste Electrical and Electronic Equipment), waste from end-of-life vehicles, leisure boats and plastics from the agricultural sector are not included in the project.

1.3 Part 2

The focus of Part 2 is based upon two pillars; to develop Nordic guidelines on plastic packaging waste collection from households (published as a separate report), and to propose future solutions for how recycling of plastic waste under the scope of the project can increase. The guidelines is presented in a separate document and has the aim of inspiring and give recommendations on how plastic packaging waste can be collected, and how different aspects concerning collection of plastic packaging can be taken into account. The guidelines are based on Nordic experience in order to encourage knowledge transfer and to give examples of how plastic packaging waste is collected in the Nordic region. The target group for the guidelines is primarily municipalities or other actors involved in collection and recycling of plastic packaging waste from households. Background information as well as information not suitable for the format of the guidelines is found in this report.

The future solutions for Nordic plastic recycling are targeted for national and regional policy makers with the possibility to change the conditions for collection and recycling of plastic waste in the Nordic countries.

The results from the project have derived from analysis of existing literature sources, interviews with stakeholders and experience and knowledge from the partner organisations. Valuable project input was also received from two workshops organised within the overall project *Resource efficient recycling of plastic and textile waste*. The first workshop was held in November 2013 in Oslo, and the second in Copenhagen in October 2014. The focus of the first workshop was to receive input and acceptance for the project, whereas the aim for the second workshop was to anchor the project's results and conclusions.

2. Key findings from part 1 relevant for the Guidelines

Responsibilities

Municipalities are responsible for collecting plastic packaging waste in the entire Nordic region (including regions where plastic packaging waste is not subject to separate collection), apart from Sweden. In Sweden the producers of plastic packaging are responsible for collection and recycling of plastic packaging waste discarded in the collection and recycling systems they provide. Five of the Nordic countries have implemented producer responsibility obligations on packaging and packaging waste, including plastic packaging. Sweden, Finland, Åland and Iceland have a legal form of producer responsibility, whilst Norway has chosen a different approach in the form of a voluntary producer responsibility. In Denmark the packaging directive has been implemented without use of a producer responsibility scheme. The responsibility for recycling of plastic packaging waste rests on the producers in the countries with producer responsibility (in Finland only from industries).

Collection systems in place

Two strategies of separate collection of plastic packaging waste can be distinguished in the Nordic region. One is to collect and recycle plastic packaging waste from MSW sources (Denmark, Norway, Sweden and Iceland), and the other is to separately collect the plastic packaging waste for energy recovery as a fuel of high calorific value (Finland and Åland). Bring systems are the most common way to separately collect plastic packaging waste from MSW sources in Denmark, Iceland, Sweden and Åland, as opposed to Norway where kerbside collection is dominating. Kerbside collection includes a broad range of practical solutions such as multi-compartment bins and source sorting in differently coloured bags prior to optical sorting. Rigid and flexible plastic packaging is collected together throughout the Nordic region apart from Finland and Åland. In Finland packaging and non-packaging plastic waste is collected and treated together and in Åland only rigid plastic packaging waste from MSW sources is source-sorted and separately collected.

The collected amounts of plastic packaging waste in Norway and Sweden follow the same sorting and recycling route. Förpacknings- och tidningsinsamlingen FTI and Grønt Punkt Norge have four contracted sorting facilities for their collected plastic packaging waste, one operator in

Sweden and three in Germany. The polymer types currently sorted out from the Norwegian and Swedish plastic packaging waste flows, thus subject to recycling, are LDPE (low-density polyethylene), HDPE (high-density polyethylene), PP (polypropylene), and PET (polyethylene terephthalate). PS (polystyrene) is sorted out at the German facilities. Other possible polymer types present in the plastic packaging waste flow are not subject to recycling. The sorting into different polymers is roughly based on NIR (Near Infrared) technology. The secondary raw material from rigid plastic packaging waste is generally recycled into plastic products such as flower pots, pipes and benches, and not back into plastic packaging. Flexible plastic packaging waste is frequently recycled back into packaging in the form of plastic bags.

3. Developing guidelines

3.1 Method

The guidelines were developed with the following aspects in mind: it should be communicative, and kept short to the point. It was also important that the aim of the guidelines was made clear to inform about different ways of collecting plastic packaging waste without recommending a certain collection system in front of another, accepting that local circumstances must be taken into account.

The development of the guidelines are summarised in three activities:

1. How plastic packaging waste can be collected – a screening of currently used systems in the Nordics

Information to this activity was mostly taken from part 1 of the project where descriptions of the main collection systems for plastic packaging waste in each Nordic country were presented. Key facts were summarised and in the guidelines presented as a catalogue of possible collection systems. The collection systems were divided on kerbside collection and on bring systems.

2. Important aspects for evaluation of a collection system

A decision to introduce collection of plastic packaging waste in a certain way must be supported by an evaluation of the available choices. The project group therefore developed a manageable list of aspects found relevant when evaluating a collection system. The aspects were identified during internal workshops within the project group where experience from other studies performed as well as experience from the project group itself served as input. Feedback on the aspects was also given by NWG. The final list of aspects became:

- Collected amounts
- Quality of the collected material
- Economic aspects
- Environmental impact
- Service level and communication
- Flexibility

3. Relevant information under each aspect

With the knowledge gathered from part 1 of the project as a starting point, information under each aspect was summarised into the most important messages on what to think about when plastic packaging

waste is/will be collected. Interviews were conducted and specific information searched for when further knowledge and experience from municipalities was needed.

Feedback on the guidelines was given by Annika Dahlberg from FTI AB in Sweden, and Helena Dahlbo from SYKE in Finland.

3.2 Background information

This section contains information, which was considered too detailed for the format of the guidelines or regarded as more background information than key messages.

The guidelines approach five different collection systems for plastic packaging waste (Figure 1). There might be other collection systems in place, but the ones listed are the most common and therefore chosen to be covered in the guidelines. The collection systems have in common that plastic packaging waste is collected for recycling.

The collection systems are based on one of two strategies: kerbside collection and collection based on bring systems. The meaning of kerbside collection is not explicit, but the definition chosen within the project is that kerbside collection is a collection system where households are able to discard their plastic packaging waste within the boundaries of the estate. Kerbside collection systems are as opposed to bring systems not for public use.

Kerbside collection of plastic packaging waste for recycling can either be based on source-sorting or based on collection of a certain mixed waste fraction subject to central sorting. There are different levels of source-sorting, but they have in common that households make an effort to sort their waste in a certain manner. Plastic packaging waste can either be source-sorted into a single stream, e.g. into a fraction meant to contain plastic packaging waste only or into a fraction containing other recyclable materials or plastic waste other than packaging.

Figure 1. Collection systems for plastic packaging waste covered in the guidelines.

3.2.1 Kerbside collection of source-sorted plastic packaging waste

Kerbside collection –only for urban areas?

The population in the Nordic countries is characterised by geographically uneven distribution with generally higher population densities in the south and lower in the north. This means that the accumulation of waste varies by region, as do collection and transport distances. The accumulation is high and transport distances relatively short in urban areas whereas the situation is the opposite in remote rural areas.

There are different opinions on the need for kerbside collection in sparsely populated areas, such as in rural areas in the northern Sweden, Finland and Norway. It is a question of sufficient level of service. On one hand one can argue that people living in sparsely populated areas are used to not having direct access to their daily business, and would therefore not place a high value on the service that they are willing to pay more for it. In Gällivare municipality in Sweden, for example, extended opening hours of a recycling central was in focus. This would have led to an increase in the municipal waste fees – the higher level of service the more it costs. As it turned out, the households were after all not willing to pay extra for the service (Gällivare kommun, 2014).

Based on the arguments above kerbside collection of plastic packaging waste in sparsely populated areas could focus on apartment buildings and institutions, with recycling stations as a base. Alternatively, “small collection points” where village inhabitants share containers or bins could be an option. In Surahammar municipality in Sweden small collection points in villages in the countryside for residual waste, packaging waste and newsprint were tested. It did, however, not turn out well and a conclusion was that people often want their own waste bin (Surahammars KommunalTeknik, 2014). In Gällivare municipality there are plans to try out a mobile solution where households in remote villages

can leave their packaging during a couple of days before the mobile sorting solution is moved to the next village (Gällivare kommun, 2014). FTI AB, the major producer responsibility organisation in Sweden, has not seen a big interest for kerbside collection from sparsely populated municipalities (FTI, 2014).

On the other hand there are arguments that kerbside collection is even more important for sparsely populated areas. “If you have 15 km to the nearest recycling station you value that packaging waste is collected outside your door” (HEMAB, 2014). This is one of the arguments that Härnösand municipality used for implementing multi-compartment bins in 2014. Over 60 percent of the single-family homes have chosen multi-compartment bins (currently at an extra cost of 20 euros per year compared to the alternative). The high support for kerbside collection from single-family homes in the municipality favours the argument that the service is desired also in sparsely populated areas (HEMAB, 2014). Notably, the kerbside collection system in Härnösand has not yet been evaluated.

The experience of Grønt Punkt Norge is that as long as there is a municipal system for waste, plastics packaging could be collected as well. Together with other source sorting systems, the amount of residual waste might be reduced extensively. Thus, in some areas, the frequency of collecting residual waste has been reduced to once a month. These areas are typically combined countryside and small /medium towns (Rødsvik, 2014).

Multi-compartment bins

The principle of multi-compartment bins is that different waste fractions have their own compartment. It is a way of dividing the bin instead of having separate bins for different waste fractions as multiple bins would increase the area needed for waste management.

It is up to each municipality to decide the organisation of compartments, i.e. which compartment to be used for which waste fraction. When deciding the organisation of compartments it is important to consider the compositions of the waste generated from the households, foresee trends in changes in composition, collection frequency and the waste management goals in the municipality.

The major difference is the size of the compartment for plastic packaging waste. Trelleborg and Härnösand municipalities in Sweden are introducing multi-compartment bins in 2014. They have both chosen to have plastic packaging waste in a compartment with room for 140 litre. The plastic packaging waste fraction is collected once every month together with paper packaging waste, metal packaging waste and transparent glass packaging waste. The second bin with a collection frequency of

every second week contains residual waste, food waste, coloured glass and newsprint. Examples of compartment organisations are presented in Figure 2.

Bin nr 1 (13 times/year):		Bin nr 2 (26 times/year):	
Paper packaging 135 L	Newsprint 135 L	Food waste 135 L	Residual waste 135 L
Transparent glass packaging waste 45 L	Metal packaging waste 45 L	Coloured glass packaging waste 45 L	Plastic packaging waste 45 L

Bin nr 1 (13 times/year):		Bin nr 2 (26 times/year):	
Plastic packaging waste 140 L	Paper packaging waste 140 L	Food waste 120 L	Residual waste 160 L
Transparent glass packaging waste 45 L	Metal packaging waste 45 L	Coloured glass packaging waste 30 L	Newsprint 60 L

Bin nr 1 (13 times/year):		Bin nr 2 (26 times/year):	
Newsprint 135 L	Paper packaging waste 150 L	Food waste 60 L	Residual waste 155 L
Transparent glass packaging waste 35 L	Metal packaging waste 45 L	Coloured glass packaging waste 30 L	Plastic packaging waste 115 L

Figure 2. Three examples of compartment organisation.

Some of the early introducers chose a relatively small compartment for plastic packaging waste (45 L) (example 1). This organisation makes it difficult to sort out both rigid and flexible plastic packaging waste as the flexible plastic packaging waste clog in the compartment making the bin difficult to empty. Loose flexible plastic packaging waste might blow away in windy weather. As a result some of these municipalities encourage the households not to throw the flexible plastic packaging waste in

the compartment for plastic packaging waste or use public drop-off points for packaging waste (VMAB, 2014).

One of the larger compartments are consequently recommended to use, such as in Trelleborg and Hörnösand. Trelleborg and Norrköping municipality have also invested in a practical solution compressing the flexible plastic packaging waste. The so-called “minimizer” is used for compressing flexible plastic packaging waste at home (Figure 3). Information to households on how to compress the flexible plastic packaging waste might also be a solution, even if a larger compartment is used. In Hörnösand municipality the households are informed to use discarded plastic bags, such as the bread bag, as a collector of other flexible plastic packaging waste before thrown in the waste bin (HEMAB, 2014).

Figure 3. “Minimizer”.
Source: PWS AB.

Multi-compartment bins are collected with special, rear-loaded vehicles containing four compartments. The vehicle manages bins from the size of 80 litres to the size of 660 litres. The emptying time is around 15 to 20 seconds. Each compartment of the vehicle compresses the collected waste fraction (NTM, 2014a).

Multi-compartment vehicles are slightly longer than the traditional vehicles with a single or a double compartment. There are approximately 3.9 meters between the wheelbases compared to 3.45 m on traditional collection vehicles. Furthermore the multi-compartment vehicles are heavier and higher. Despite these differences the multi-compartment vehicles have rotation on a third axis making them almost comparable to smaller collection vehicles in terms of availability (Göteborgs Stad, 2012). It is generally possible to empty 280-350 multi-compartment bins in the vehicle before emptying it (NTM, 2014b). It is, depending on the compartment organisation, in some cases possible to empty tradi-

tional waste bins in the multi-compartment vehicles. This is useful when multi-compartment bins are not used by all households.

Separate containers

Kerbside collection of plastic packaging waste from apartment buildings is commonly collected in containers of various sizes. There are containers on the market ranging from 80 to 1000 litres. However, the most common sizes are 190 to 660 litres. The containers are usually made of plastics. The largest containers are equipped with four wheels, unlike the smaller ones with two wheels. Three-wheel containers are also available on the market, and it is possible to complement a two-wheel container with an extra wheel (Avfall Sverige, 2009).

Figure 4. Examples of separate containers for plastic packaging waste (Avfall Sverige, 2009).

Underground containers come in different design and size, although they have some advantages in common; they are managed without heavy work as they can be emptied with crane vehicles, that the majority of the volume is stored underground, and that the temperature is kept low reducing the risk for smell (Avfall Sverige, 2009).

Vacuum technology

Waste fractions, there among plastic packaging waste, can be transported in pipelines underground over long distances to a terminal with stationary pneumatic waste collection system. While, in the terminal the waste is compressed in closed containers.

The waste is transported with the help of air produced by fans creating a negative pressure in the pipelines. Each waste fraction has its own chute, but is transported in separate bags in the same pipeline to the terminal where the waste is transported to a dedicated container. Commonly, two to four waste fractions are handled in the same stationary pneumatic system. As the waste is transported to the terminal at different occasions there is not risk that the waste fractions are mixed (Envac, 2009).

Pneumatic collection systems might also be mobile. The waste fraction is collected with the help of air, but the pneumatic system is in the collection vehicle. Under each waste chute there is a container. Containers are linked together through underground pipes to a collection point up to 300 meters from the containers. The collection vehicles connect to the collection point, and the waste fraction is transported from the containers to the collection point and into the vehicles (Avfall Sverige, 2009).

Colour sorting

Colour sorting or optical sorting is based on source-separation of waste into plastic bags of different colours. All plastic bags, one colour for each fraction, are thrown in the same bin, and sorted out at a colour sorting facility. The plastic bags are normally of a size of 30 litres, but plastic bags up to a volume of 125 litre and 15 kg are possible to handle in the colour sorting facilities (Optibag, 2014).

Colour sorting, where plastic packaging is managed in a separate fraction, is in place in Norway and Sweden where systems managing up to six fractions are in place. Glass waste is not treated within the colour sorting systems as the glass might brake and cause contamination. The colour sorting facility provider states that up to nine different waste fractions can be sorted out in a colour sorting facility, and that the system can manage to correctly sort 97 percent of the plastic bags. In general, a colour sorting facility includes 1-4 sorting lines. Every individual sorting line has a capacity of 5-8 tonnes per hour (Optibag, 2014).

The bags are all placed in the same container and transported by a single-compartment vehicle to a sorting facility where the bags are optically sorted into the different fractions. The system detects the colour and the size of the bags. The bins are emptied and the bags are thereafter transported on conveyor belts to optical readers that identify the colour of each bag. The bags are pushed into separate containers and opened. The content is separated from the bags and the fractions are either sent to further sorting (e.g plastic packaging waste), subject to biogas production or incineration. Bags that are not approved or loose material passes straight forward in sorting and treated as a residual fraction.

Eskilstuna municipality was the first (in 2011), and still is the only municipality in Sweden with an optical sorting system of six fractions (Göteborgs stad, 2012). The reason why Eskilstuna's choice fell on colour sorting was the aim to increase the source-sorting of packaging and newsprint, increase source-sorting of food waste for biogas production and decrease the amount of residual waste to incineration (EEM, 2012).

The system in Eskilstuna is only used for single-family homes (16 000 households), which can be regarded as a drawback of the system. They tried applying the system on apartment buildings, but the results were unsatisfying. Apartment buildings are instead offered kerbside collection in separate containers.

3.2.2 Kerbside collection of mixed waste subject to central sorting

Central sorting of residual waste is developing in Europe. In the Nordic region, the solution exists until now only in Norway where the first central sorting plant was opened in 2013, owned by eight municipalities (Enebakk, Fet, Gjerdrum, Lørenskog, Nittedal, Rælingen, Skedsmo and Sørumsund) within the intermunicipal collaboration ROAF (Romerike avfallsforedling). The plant is located about 25 km north of Oslo. The Norwegians having access to the system discard the following fractions:

- Food waste in a separate green bag.
- Residual waste containing plastic packaging waste and non-plastic packaging waste. Food waste and the residual waste are collected in separate bags in the same bin.
- Paper and cardboard packaging is source-sorted and kerbside collected in a second bin.
- Glass- and metal packaging waste are collected through bring systems.

Both households in single-family homes and in apartment buildings have access to this system.

At the central sorting facility the plastic bags with food waste and the residual waste bags are separated based on the colours of the bags with optical readers, and the food waste is further treated in a biogas plant. The sorting plant is based on NIR (near infrared) spectroscopy, which is an optical sorting technology which sorts materials dependent on their different reflection of infrared light. The NIR technology thus makes it possible to sort out the specific wanted plastics materials from the residual waste and the plastic packaging and other plastic wastes are separated by polymer type. Currently, five different polymer fractions (LDPE, HDPE, PET, PP and a mixed polymer fraction) are sorted and

separated at the sorting plant, and sent directly to recycling plants without any further sorting requirements.

In addition to the sorting of plastics material, the facility also sorts paper and metals “residuals” which have been left in the residual waste (not source-separated), thus increasing the sorting and recycling rates of these materials. The final residual waste is incinerated with energy recovery.

In addition to the existing central sorting plant north of Oslo, a new facility based on the same technology is planned to start operating in 2016. This facility will be located in the Stavanger region at the south west of Norway and will be owned by five intermunicipal companies, covering 23 municipalities or about 300 000 inhabitants. One major difference, however, compared to the ROAF plant, is that this plant will implement one further step of the recycling value chain: the extrusion of the sorted LDPE, HDPE and PP plastics into granulates. Thus, this recycled plastics granulate can be sold directly to plastic manufacturers while the PET and PS plastics still need to be sent to external recycling plants due to melting points different from the other plastics types.

3.2.3 Bring systems

The use of bring systems, or public drop-off points for plastic packaging waste/plastic waste and/or other recyclables, is very common in the Nordic countries, and is available in almost all municipalities in Sweden, Norway, Denmark, Iceland and Åland. Both manned and unmanned drop-off points are available. At manned so-called recycling centrals the public is welcome to discard different types of waste fractions there among plastic packaging waste and other types of plastic waste. Unmanned so-called recycling stations are often for a limited number of waste fractions, such as for different packaging types. Bring systems are used for both single-family homes and apartment buildings, and are, as opposed to kerbside collection systems, for public use.

3.2.4 Sorting of plastic packaging waste into different polymers

Sorting of plastic packaging waste to enable recycling includes a series of process steps within a sorting plant. Sorting into different polymers from a mixed plastic packaging waste fraction involves several steps, such as):

- manual sorting
- washing and drying
- size reduction

- sorting of flexible plastic packaging waste from rigid plastic packaging waste
- Near Infrared (NIR) sorting of rigid plastics

NIR technology

Near Infrared (NIR) spectroscopy is the most common technology for automated sorting of plastics by polymer type (Dvorak et al., 2011). The technology utilises the fact that individual polymer types reflect and absorb different spectra under infrared light. Near Infrared is a small part of the infrared spectrum, between the visible spectrum and the medium infrared spectrum (Figure 5). NIR automated sorters compare the spectra of the detected item with the spectra stored in the software library of each machine (Gardner et al., 2010).

The mixed rigid plastic waste is spread out on a conveyor belt and fed underneath an identification sensor. A NIR beam identifies the polymer, which triggers air nozzles with compressed air. Once an item is detected and identified by the sorting machine the item is removed from the stream by a jet of compressed air. Unrecognizable items are ignored by the machine. The NIR units are capable of sorting PP, PE, PET, PS and PVC, and can also be programmed to identify PLA, card board and metals (Foster, 2008).

Figure 5. Electromagnetic spectrum (Gardner et al., 2010).

The typical NIR process can briefly be described as follows (Gardner et al., 2010) (Figure 6):

1. Mixed rigid plastic waste is evenly fed onto a conveyor belt (acceleration belt).

2. A scanner/detection unit is normally positioned above the belt and scans the acceleration belt. Sources of light sending out NIR light are positioned to reflect light back up from the belt and into the NIR detectors. The NIR light that is not absorbed by the material on the belt is detected by the scanner unit. The scanner unit identifies the polymer type for each item.

3. If the material is detected a valve opens and a jet of compressed air is fired at the detected item. The detected item is lifted by an air jet over a deflector/splitter plate and into the eject/selected fraction.

Figure 6. Example of a NIR sorter diagram. Source: Gardner et al. (2010).

When an item contains more than one material or polymer the NIR sensors may not recognise the item or sort the item based on one of the components. If items are stuck together or placed inside another (e.g. laminates) the items might also be incorrectly identified. NIR systems can also be designed to sort according to colour. A single NIR unit can separate a single-polymer from a single-colour fraction, but multiple units for each polymer are in that case required (Foster, 2008).

The black plastic problem

NIR sorting systems cannot identify black items coloured with so-called carbon black as carbon black absorbs infrared radiation as well as visible light. As a result the NIR light is not reflected into the detectors, and

the items remain undetected and end up in the residual waste fraction, irrespective of the polymer type.

Carbon black, produced by combustion of petrochemical feedstock, represents the most common black colorant in plastics, especially in food contact packaging. The reasons are its low cost and its ability to provide a contrasting background clearly pointing out the colours of the food. Plastics can be coloured either by pigments or dyes. Carbon black has also got good dispersion and masking properties, which allows for manufacturing of black items when other colours are mixed together (Dvorak et al., 2011).

In a project carried out by the British organisation WRAP, four possible approaches to enable automated sorting of black plastic packaging were evaluated:

- alternative spectroscopic techniques
- physical sorting method
- addition of detectable markers
- development of alternative colourants

In the study it was concluded that only one of the explored alternatives would be possible within the existing automated sorting facilities based on NIR technology – the use of alternative colourants. A range of black colourants are available on the market for the plastics packaging industry, which would make black plastic packaging possible to be sorted out at the automatic NIR sorting facilities, recycled and used in new applications as substitutes for virgin plastics. Detectable colourants are more expensive than carbon black colourants, but further development will in time allow for economies of scale (Dvorak et al., 2011). Black plastics can be sorted by polymer using techniques other than NIR (e.g. sink and float), but as far as known such techniques are not highly used for plastic packaging.

Sorting efficiency

Besides the presence of contaminants in the collected plastic packaging waste fraction the efficiency of the actual sorting plant influences how much of the collected amounts that are actually recycled. How much of the collected waste fractions that are turned into recyclable plastics thereby depend both on the input feed and on the losses in the sorting plant. It is also depending on the prices for the sorted material. Several polymer types can be sorted and reprocessed, but will only be subject for sorting if it is regarded profitable enough. Losses occur in all process steps, both in the mechanical steps, as well for the NIR sorting units.

The efficiency of NIR units is measured in hit rate and in purity of the sorted fraction. The mechanical preparation before the NIR units affects, as previously mentioned, the efficiency of the entire sorting plant.

The hit rate is approximately 90 – 94 percent¹ and the purity of the sorted plastic is approximately 92 – 96 percent² (Tomra, 2014). The hit rate is measured from an input to the NIR unit of, for example, 100 percent polypropylene (PP). The unit will sort out 94 percent. The purity is defined as the percentage of free articles/materials among the target fraction. For example, an HDPE item is considered 100 percent pure even though it is dusty and dirty, and has got a label and residues inside (Tomra, 2014).

In terms of hit rate, 70-75 percent of the LDPE film, and 85-90 percent from HDPE and PET will be recovered in a state-of-the art sorting plant (Tomra, 2014).

3.3 Aspects considered in the guidelines

Six important aspects considered important to take into account when evaluating a collection system for plastic packaging waste were described in the guidelines. In this subchapter, necessary background information and further developments of the recommendations from the guidelines are described when needed.

The six aspects were:

- Collected amounts
- Quality
- Economic aspects
- Environmental impact
- Service level and communication
- Flexibility

3.3.1 Collected amounts

Collected amounts of the fraction plastic packaging waste is an important measure, but is important to evaluate in combination with the quality of the collected material.

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¹ Valid for NIR units manufactured by Tomra.

² Valid for NIR units manufactured by Tomra.

Kerbside collection tends to favour the amounts of collected plastic packaging waste, i.e. in terms of collecting the most plastic packaging kerbside collection is preferable compared to bring systems. Different kerbside collection systems are, however, documented to a various extent. For example collected amounts from multi-compartment bins are relatively well-documented compared to results using separate bins or containers in apartment buildings (Göteborgs stad, 2013). The results from bring systems vary to a high extent and the results should be seen in the light of the current bring systems in place. The expected collected amounts from a denser net of drop-off points in a bring system are not known.

Some of the most recent studies on collected amounts of plastic packaging waste using different collection systems was finalised in 2013 by Dahlén et al. (2013). The overall aim of the study was to present basis of decision for choosing collection systems for plastic packaging waste from households. Five Swedish municipalities of different sizes and location were studied from where source-sorted plastic packaging waste was collected and analysed. Results from the study showed that more plastic packaging waste is collected from municipalities with fully developed kerbside collection compared to the national average. The results were the most apparent for single-family houses; the difference for apartment buildings was less obvious (Dahlén et al. (2013).

Kerbside collection of source-sorted plastic packaging waste was studied for multi-compartment bins and separate bins, not for collection in coloured bags prior to optical sorting. However, kerbside collection includes a number of different varieties, and the varieties represent significant differences in collected amounts. Engaged communication to the households was also seen as an important key success factor (Dahlén et al. (2013).

Similar results are also obtained in older studies. In Hage and Söderholm (2008) (within the research project SHARP³) it was concluded that in municipalities with a high level of kerbside collection of plastic packaging waste the collected amounts are in general higher per person in comparison to other municipalities. In addition it was concluded that a higher number of drop-off points when using bring systems increases the amount of collected plastic packaging waste. The study was carried out based on the municipal collection data of FTI AB, bearing in mind that the data is actually not reliable enough to make comparisons on a municipal level.

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³ Sustainable Households, Attitudes, Resources and Policy. www.sharpprogram.se

Collection results from Norway correspond well to results from the Swedish study. According to Grønt Punkt Norge (2014), the corresponding average collected plastics amounts from kerbside collection of plastic packaging waste (coloured bags prior to optical colour sorting is separated from other kerbside collection), as well as minimum and maximum values are as follows:

Table 1. Collection results from Grønt Punkt Norge (2014),

	Average (kg per capita and year)	Max (kg per capita and year)	Min(kg per capita and year)
Kerbside collection	7.1	14.7	0.9
in coloured bags prior to optical colour sorting	4.0	7.1	2.9
Bring systems	4.0	6.3	0.7

Corresponding figures enabling comparison between kerbside collection systems and bring systems have not been found for the other Nordic countries.

Also the unsorted plastic packaging waste left in waste fractions to incineration is important to measure. By measuring both the collected amounts of source-separated plastic packaging waste and the plastic packaging waste left in the residual waste fraction, it is possible to get a more complete picture on how much of the generated plastic packaging waste that is source-separated for recycling. To leave out plastic packaging waste left in the residual waste fraction means that the individual consumer behaviour might have a great impact on the results, where collection results from a consumer generating a relatively small amount of plastic packaging waste naturally becomes comparatively low.

Plastic packaging that is not source-separated and instead thrown in residual waste fractions to incineration has in this project previously been identified as one of the main potentials for increased recycling (see Report 1). According to waste analyses from Sweden less plastic packaging waste is found in the residual household waste fraction when the households have access to kerbside collection of plastic packaging waste in comparison to access to current brings systems (Avfall Sverige, 2011).

Looking at the total share of packaging waste in the residual waste fraction in Sweden - multi-compartment bins have the lowest share (25 %) of packaging waste (note: packaging waste in total) in the residual waste. Using coloured bags prior to optical colour sorting generates the highest share (42%) and separate bins for residual waste and bring systems for the packaging waste generate a share of 36 percent (Avfall Sverige, 2011).

Other parameters that are known to influence the amount of collected plastic packaging waste are collection frequency and the space dedicated for collection. Weekly collection seems to increase the amounts collected compared to collection every second week (WRAP, 2009).

For kerbside collection of mixed waste subject to central sorting it is not relevant to look at plastic packaging waste in the residual waste fraction. Comparison between kerbside collection systems based on source-separation and kerbside collection systems of mixed waste subject to central sorting, should be clean, recyclable secondary plastics (the output of the central sorting plant), and the clean recyclable secondary plastics from the sorting facilities of source-separated plastic packaging waste.

3.3.2 Quality

When it comes to quality issues the total amount of collected plastic packaging waste is not recycled due to different reasons:

- Parts of the fraction contains contaminations not wanted in the recycled fraction.
- The efficiency of the NIR equipment and possibilities to sort for example black plastics as well as laminates.

With regard to the quality aspects of the collected amounts of plastic packaging waste, Grønt Punkt Norge collects data about the amount of pollution in the source-sorted plastic packaging waste. The polluted material typically represents non-plastic contaminants, moisture and dirt, which needs to be sorted out at the sorting facilities (Sweden/Germany). In addition, some of the collected material cannot be recycled due to its complexity, polymer type, barrier materials etc. and is therefore sorted out for energy recovery.

Updated average data for 2013 for the share of contaminants in the different collection systems are (also in Figure 7) (Grønt Punkt Norge, 2014b):

- 9.2 percent , kerbside collection with transparent plastic bags, 48 samples
- 10.6 percent, kerbside collection in coloured bags prior to optical sorting (optibag), 8 samples
- 13.8 percent, bring system, 6 samples

The sample sizes typically represent collected plastic packaging amounts between 350 – 1000 kg.

As seen in the figure, the minimum and maximum values of pollutants in the different collection systems vary to a large extent: from 1.2% to 22.4% for kerbside systems, from 8.4% to 17.3% for kerbside collection in coloured bags prior to optical sorting (Optibag), and from 5.4% to 28.1% for brings systems.

Figure 7. Average level of contaminants/pollution in the plastic packaging waste fraction using different collection systems (Grønt Punkt Norge, 2014).

When taking the contaminants in source-sorted plastic packaging into consideration (using the average value of 9.2% for kerbside systems), the central sorting plant needs to sort at least 13.4 kg plastics per inhabitant in order to compete with the existing maximum sorting amount in Norwegian kerbside systems (14.7 kg plastics per inhabitant). If the average sorting amount in the Norwegian kerbside systems (7.1 kg plastics per inhabitant) should be rejected, the sorting plant has to sort 6.4 kg plastics per inhabitant. The current number for ROAF is 13.5 kg plastics per inhabitant (Brevik, 2014). It is important to note that other forms of mixed collection with food waste or other contaminants collected in the same fraction would make it impossible to have equal quality as listed above.

Dahlén et al. (2013) have also evaluated the quality of the collected plastic packaging waste. According to their study plastic packaging waste collected at the kerb proved to be of higher quality compared to bring

systems. The only statistically significant difference is that kerbside collection from single-family homes is purer (94% plastic) than plastic from drop-off points (85% plastic) (both packaging and non-packaging). It was not possible to observe a statistically guaranteed difference in purity in the plastic packaging waste collected at drop-off points compared to kerbside collection at apartment buildings. Collected amounts from public drop-off points showed an uneven quality with large variation. Specimens from the drop-off points represented everything from very well-sorted material to material with a high share of incorrectly sorted material (Dahlén et al., 2013).

3.3.3 Economic aspects

Collection of plastic packaging waste is followed by potential costs and potential income, like any other change in the municipal waste management. It is extremely difficult to look separately at one waste stream as a change in a particular waste stream might result in changes in other parts of the waste management chain. Collection of plastic packaging waste will most likely include investment costs, operational costs such as collection of the waste, maintenance costs as well as costs for information and administration. Typically, these costs cannot be allocated only to plastic packaging waste.

Potential income

An important aspect in a calculation is of course the potential income from the sorted secondary plastic raw material. The prices for secondary plastic raw material are commonly the same no matter if the polymers stem from source-separated sources or from centrally sorted mixed waste (as in Norway), given that the quality is the same (Tomra, 2014). Updated market prices for secondary plastic raw materials can for example be found at the EUWID Recycling and Waste Management⁴ that regularly researches and publishes market reports for various secondary raw materials and waste management services. For some information a subscription is needed. Another page providing some relevant information is the market place for virgin plastics, recyclates and plastic waste Plasticker⁵.

Indicative prices for sorted household plastic waste are (Tomra, 2014):

- LDPE film: 40-60 €/tonne (mixed colour), 200-250 €/tonne (transparent/white).

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⁴ <http://www.euwid-recycling.com/>

⁵ http://plasticker.de/index_en.php

- PET: bottles clear 350-400 €/t, bottles mixed color (>90 % bottles) 200-250 €/tonne, PET mixed bottles/trays (50%/50%) 20-50 €/tonne (more difficult to sell currently compared to bottle fraction)
- HDPE: 260-300 €/tonne
- PP: 180-220€/tonne
- PS: 100-150 €/tonne

Collection of plastic packaging waste reduces the amount of incinerated waste, and thus also the economic calculation of a collection and recycling system of plastic packaging waste. Increased collection of plastic packaging waste will reduce the amounts of wastes to incineration and thus costs in the form of gate fees. In Norway the average incineration cost for municipalities was in 2012 135 €/tonne (1100 NOK/tonne) (Avfall Norge, 2014), in Sweden around 65 €/tonne (Avfall Sverige, 2014), and in Finland answers from a number of incineration plants indicate that the cost is around 80 €/tonne (Åbo Energi, 2014; Uleåborg Energi, 2012).

Potential costs

The costs for collection of plastic packaging waste are affecting by the number of containers/bins to be collected, the number of waste fractions (can other recyclables be collected at the same time), the frequency of collection, the emptying of the collection vehicles (can several fractions be emptied by the same vehicle or not), and the capacity and possibility for comprimation in the collection vehicles (Avfall Sverige, 2014).

The collection cost (transport and emptying) for kerbside collection is higher per tonne of collected waste compared to bring systems. This has to do with higher number of stops necessary to collect the material, making it more labour intensive. The higher collection costs have to be seen in the light of potential income for selling the collected material and cost savings for reduced amount of waste to incineration, and be allocated to all recyclables fractions collected. As an example, three municipalities in the region of Blekinge Sweden has estimated the collection costs for emptying two bins, one for residual waste and one for food waste (the alternative to multi-compartment bins) every second week represents 55 percent of the costs compared to emptying two multi-compartment bins (VMAB, 2014). In the case of collection of residual waste and food waste the households are referred to public drop-off points to discard packaging waste. Lund municipality in Sweden has estimated that it takes 20 seconds to empty a multi-compartment bin and 5-7 seconds for a traditional bin (Göteborgs stad, 2013).

Changes in the waste management system also need to include expenses for administration and communication, and investment costs such as

equipment for the households (e.g. bins and bags), sorting facilities, and collection vehicles (more detailed info is found in the guidelines).

Collection of household plastic waste in Finland – economic aspects

In 2010 the Finnish Ministry of Environment commissioned a report on the cost effects arising from the requirements of Finland's new waste legislation on the collection network of packaging waste from households (FCG Consulting, 2010). This text is a summary of this report. Potential income as a result of the plastic packaging waste collection from households was not part of the report.

The reform of Finland's waste legislation (The Waste Act [646/2011]): plastic packaging has been covered by a partial producer responsibility covering only industrial waste, but the producer responsibility is to be complete and cover also household packaging as of 1st of May 2015. This means that requirements for the density of packaging producers' drop-off point network will be set.

There are no statutory demands on the equipment level of the drop-off points. It is assumed that the drop-off points will have asphalt covers and include smaller mobile or larger underground containers. Normally several different fractions are collected at the same drop-off point (at a drop-off point with a 62 m² surface area the fractions have been assumed to have the following share: glass: 18 %, metals: 18 %, cardboard: 41 % and plastic: 23 %).

The containers must be emptied regularly, avoiding littering related to over-filling of the containers as well as recyclable fractions ending up in the mixed waste due to lack of capacity of the collection system. Emptying intervals should be optimised, so that the containers are as full as possible, but still avoiding the above-mentioned risks.

Costs

Annual costs include:

- Investment costs (costs for construction of the drop-off points and purchase of containers).
- Emptying
- Maintenance: snow clearance, cleaning, repair work, washing containers etc.

The investment costs are dependent on the surface structure of the drop-off point as well as the number of containers and different fractions to be collected. The costs for the construction of the asphalt cover is approx. 50 €/m².

The type of collection container affects the investment costs. List prices for containers are:

- Manually operated containers 0.6–1.1 m³: 130–370 €
- Mechanically operated containers 1.3–4 m³: 1100–1800 €
- Mechanically operated containers 5–8 m³: 1100–1800 €

Emptying costs:

- Manually operated containers: ~10 € (more expensive in remote areas)
- Mechanically operated containers, 0.6–1.3 m³: 16 € (one data source)
- Mechanically operated containers, 3 m³: 30–40 €
- Underground containers <3 m³ (more expensive in remote areas): 17–30 € (areas where underground containers are widely in use), 50–60 € (areas with only few underground containers), 17–160 € (small underground containers).

Emptying prices are more expensive in remote areas due to longer transport distances. The costs can be reduced if collecting several waste fractions in the same collection vehicle.

Annual maintenance costs are reported to be 150–250 €, divided among the waste fractions it is 10–20 €. Washing of the containers is commonly conducted once or twice a year depending on the cleanliness of the waste fraction. For manually maneuvered containers the costs are approximately 10 € and for larger containers 50–150€.

Currently households pay for waste management of packaging through the waste management fees. Due to the reform of the legislation, the producers will cover the waste management of packaging materials and the costs will be transferred to the packaging and product prices. The increase in prices will be very low, as the additional costs for the package are approximately 1–2 c/kg (FCG Consulting, 2010).

3.3.4 Environmental impact

There are a high number of studies carried out where the environmental impact from the different management options for plastic waste is studied. It is not difficult to understand that the results are depending on the alternatives taken into account, the assumptions made and the type of studied polymer. It would not be possible to look at the complete number of studies carried out within this project, but there are, however, studies where overall conclusions based on a number studies are summarised. In a study carried out by WRAP in Britain it was concluded that recycling of plastic is the most favourable option in terms of climate impact, resource and energy use. The conclusion was drawn based on

eight life cycle assessments where the environmental impact based on different scenarios for PP, PE, PS, and PVC was evaluated. The life cycle assessments represented a selection of analyses considered of high quality. Furthermore, it was concluded that key to the recycling performance compared to other alternatives is that virgin plastic production is avoided and to which extent, as well as the quality of the plastic waste. (WRAP, 2010). LCAs carried out in the Nordic countries confirm the overall conclusions from international studies. Several LCAs have been carried out on the recycling of household plastic packaging (e.g. Lazarevic et al., 2010; ten LCA studies including 37 different scenarios). In the majority of these studies the recycling of plastic packaging to replace virgin plastic has proven beneficial from an environmental perspective. However, depending on the degree of contamination and the replacement of fossil fuels, incineration of household plastic packaging may be the more beneficial alternative (Moliis et al., 2012).

According to Modahl et al., (2013), recycling is environmental beneficial over energy recovery with respect to GWP, independent of local conditions for transport and energy recovery (degree of utilisation and replaced energy).

Lyng and Modahl (2011) have calculated the net benefits of plastic recycling to about 900 kg CO₂-equivalents per tonne plastic packaging waste being collected (Figure 8). Figure 8 also shows that, compared to incineration, recycling is about 2 – 2.5 times more beneficial as the incineration cases result in net burdens of 1000 and 1700kg CO₂-ekv per tonne waste plastics, dependent on the energy source being replaced by incineration.

Figure 8. Net GWP for waste management of plastic packaging in Norwegian municipalities (Lyng and Modahl, 2011).

The reason why recycling is more beneficial than incineration can be explained by Figure 9. As seen here, the burdens from recycling (shown by purple, green and dark blue shares of the bars) are about half of the burdens from incineration (which mainly comes from emitting CO₂ when the plastics is burnt). In addition, the benefit from replacing virgin plastics with regranulate is much larger than the benefit of replacing district heating or oil/electricity with the energy generated from the burned plastics. It should be noted that it is assumed that the plastics packaging collected for recycling includes about 20 percent plastic packaging which is not recyclable (due to plastic types, dirt etc.), and is therefore sent directly from the sorting plant to incineration. The burdens/benefits from this are, however, included in the recycling case.

Figure 9. GWP, shown for each life cycle phase, for waste management of plastic packaging in Norwegian municipalities. For each data set, the burdens from different life cycle stages are stacked above the origin with the benefits appearing below it (Lyng and Modahl, 2011).

A case study conducted by the Finnish Environment Institute SYKE has assessed the life cycle impacts of packaging waste collection in northern Finland, Finland's most sparsely populated area. The study focuses on environmental and cost effects of collection logistics, the impacts of the collection stage are compared with the benefits gained from recycling collected waste.

The environmental benefits of separate collection of packaging waste are apparent, whereas cost analysis proves that waste recycling does not yield cost savings high enough to balance out the costs incurred from the collection and transport phase. However, separate collection meets waste management needs and waste collection is always costly. It is

essential that collection is organised in a logistically efficient way, at locations that people frequent while conducting their daily business.

3.3.5 Service level and communication

Different ways of collecting plastic packaging waste corresponds to a certain level of service for the households. The current legislation in the Nordic countries does not differ between sparsely and densely populated areas. In the Swedish ordinance on producer responsibility on packaging waste a "suitable" collection system is easily accessible, facilitates for the generator of the plastic packaging waste to discard the packaging waste in the system and provides a good service level. Special attention should be paid to the local circumstances in the municipality. The service level is not defined further, which means that there are no requirements on the service level in the current Nordic legislation.

According to a survey carried out by FTI AB and Swedish Waste Management (Avfall Sverige) about Swedish people's attitude, knowledge and behaviour towards waste management, the majority (86 %) answered that they think collection and source-separation of plastic packaging waste functions rather well or well in their local environment. Among the respondents with the opinion that the collection and source-separation functions rather bad or very bad, 50 percent answered that it is due to lack of service, the distance to drop-off their packaging waste or the need of a car to discard their packaging waste. The respondents with no access to kerbside collection of plastic packaging waste were asked if kerbside collection would make them source-sort separate more waste. The results showed that a majority of the people claim that they would source-separate around the same amount as today where around 30 percent mean that they would source-separate more plastic packaging waste if they had access to kerbside collection (FTI AB and Avfall Sverige, 2013).

Different collection systems of plastic packaging waste correspond to level of service. The sufficient service level is a subjective measure and is not the same for everybody- some people require a higher certain service level than others to be motivated to throw their waste in the dedicated spaces, and some people are unlikely to reach independently on the service level. Physical availability, i.e. the distance to discard plastic packaging waste, and user friendliness –if the system is logical and user-friendly, are factors here used to define the service level for various collection systems.

Physical availability:

All approached collection systems offer the availability to discard plastic packaging waste at the boundaries of the estate, except for bring sys-

tems. In general terms, brings systems can therefore be said to represent a lower service level in terms of physical availability compared to other collection systems. However, bring systems include a number of different solutions why the distance to the nearest drop-off station is varying to a high extent among citizens. In the same way, kerbside collection systems might in practical terms be located right outside of the front door or more far away.

Kerbside collection systems of plastic packaging waste require extra bins at the property if the waste is source-separated into different fractions. Nevertheless, assuming that the waste amount generated is the same no matter if source-separating occurs or not, the total bin volume would be the same, the difference is that instead of a larger bin there is need for a number of smaller bins or different compartments in the bin. This is not necessary when using coloured bags and optical sorting or kerbside collection of mixed waste subject to centralised sorting. Bring systems naturally saves space at the property.

Source-separation of plastic packaging waste requires space at home to store the source-separated fractions before discarding the fractions into bins or containers. The lowest need for such a space is required by kerbside collection of a composition of mixed waste subject to central sorting as the waste is thrown in the waste bin together with other types of waste. However, glass packaging waste, as well as paper and newsprint is not accepted in the same bin, which requires a certain amount of space. Bring systems and kerbside collection in multi-compartment bins and in separate containers or transparent plastic bags require the same order of space at home/in the kitchen, as the fraction need to be source-separated. As opposed to source-separating in coloured bags prior to optical sorting the recyclable fractions can be disposed of in the same bin/container/bag before the fractions are source-separated at the final place of the disposal. Source-separating in coloured bags prior to optical sorting requires more place at home.

User friendliness:

It is regarded an advantage to avoid separation of rigid and flexible plastic packaging waste, which is not needed for any of the studied collection systems. It is also seen as an advantage in terms of service level to be able to avoid source-separation, which is possible when kerbside collection of mixed waste subject to central sorting is used (note that it is a composition of mixed waste not containing food waste). It is thus important to note that glass packaging, food waste, and paper and newsprint require source-separation.

How to communicate changes in the waste collection system?

Just a fraction of all the information a household receives is paid attention to. The likeliness that households changes their behaviour or inten-

sifies the existing behaviour due to information is rather low why information should be carefully developed and take different groups of individuals and their needs into account (Andersson et al., 2011).

Information can be of two types; give information about effects and consequences and in practical terms describe how the collection system should be used. The first thing when imposing a change could be to make the user pay attention to one's own behaviour. When the user pays attention to the behaviour, information about alternative behaviours and their positive effects can be communicated. At last it can be useful to inform the individual that the behaviour is in harmony with the behaviour of others that could make the individual feel solidarity towards the group (Andersson et al., 2011).

The information source should be taken as trustworthy, reliable and relevant for the individual. The power to motivate a change in behaviour is also dependent on the perceived expertise of the source of information, the recognition and identification. Challenges with information:

- To get the households attention on the information. The interest for collection and recycling in general are more for dedicated people with a true interest. Waste is in general a problem that should be solved as quickly as possible. The environmental benefit of the effort is more of a bonus in addition to the fact the waste is taken care of (Avfall Norge, 2011).
- It is voluntary both to pay attention to and reflect on the information. Individuals that are not interested can simply just avoid the information (Andersson et al., 2011).
- If the information is unclear or if contradictory information is given it might be challenging for the receiver of the information to decide which piece of information that is more relevant than another piece. Information about waste management is rarely compiled into one place (Dahlén et al., 2011).

Communication about the fate of the plastic packaging waste

According to WRAP there is no evidence that households have anything against source-separation. What households often lack is information about where the source-separated material ends up to be assured that their efforts are motivated, independently of the collection system (WRAP, 2009).

Information about what happens with the plastic packaging waste after collection seems important to make people loyal to the collection system. How the plastic packaging waste is taken care of, how it is further sorted and recycled into new products is information relevant to de-

scribe in order to increase the trustworthiness of the system and ensure that the efforts make a difference. The environmental benefit of recycling plastic packaging waste as well as the actual recycling rate (the higher rate the better motivation) is also important. Besides, to make people evaluate the difference between rigid plastic packaging and flexible plastic packaging hampers source-separation and increases the risk of finding unsorted plastic packaging waste in the residual fraction (Avfall Norge, 2011).

The need to communicate about the fate of the plastic packaging waste is emphasised in the survey mentioned above, carried out by Förpacknings- och tidningsinsamlingen (FTI) and Swedish Waste Management (Avfall Sverige). The interviewees were asked what they think will happen to the collected plastic packaging waste. 20 percent answered that they think plastic packaging waste is incinerated and 14 percent that they do not know. The knowledge about the fate of the plastic packaging waste was lower than for all other packaging waste fractions. 86 and 78 percent believed that glass packaging waste and newsprint respectively is subject to recycling (FTI AB and Avfall Sverige, 2013). Apparently, there is need for communicating more how plastic packaging waste is taken care of after collection.

Communication based on target groups

Communication about collection and recycling of waste could preferably be adjusted based on target groups. The reason is that the receiver of information should be able to link the information to its behaviour and lifestyle in order to get motivated. Information targeted on households in apartment buildings might for example not be relevant for households in single-family homes. Communication towards target groups is also about having access to information that is specific and easy recognizable, such as rules applicable in the actual residential area (Andersson et al., 2011).

Devoted communication is especially important when the collection system is relatively anonymous, such as bring systems and separate bins for apartment buildings. Kerbside collection systems where each household has their own bin or disposal solution implies by its existence tangible information about the possibility to source-sort waste (Dahlén et al., 2013).

3.3.6 Flexibility

Implementing plastic packaging waste collection systems can be associated with high costs and effort. Surrounding circumstances, such as national and international legislation and goals, and changes in other parts of the waste management chain might alter the conditions of the waste collection systems. For those reasons there is value in having a flexible

collection system with possibility to adaptation if needed. Below follows a discussion of the flexibility of the plastic packaging waste collection systems in the guidelines. The discussion is based on the flexibility in the technical setup, and the possible adaptation to increased collected amounts.

Technical setup

The technical setup of multi-compartment bins is flexible in the sense that the organisation of compartments can be changed. A change in compartment organisation thus requires information and communication to the households and a certain time of adaptation. The alternative use of multi-compartment bins is limited if source-sorting would no longer be required, but the inset can be removed and the bin converted to a more “traditional” waste bin or be rebuilt to a two-compartment bin. Depending on how the compartments in the multi-compartment containers are organised the same vehicle can be used for emptying ordinary waste bins from households not choosing collection in multi-compartment bins. The alternative use of a multi-compartment vehicle is more limited than for single-compartment vehicles. Second-hand markets for multi-compartment vehicles thus exist.

Collection of plastic packaging waste in separate containers or transparent plastic bags have a high flexibility due to the fact that standard single- or two-compartment vehicles are used, where emptying of bins with different sizes is possible. The number or size of bins can rather easily be adjusted.

Collection in coloured bags prior to optical colour sorting requires investment in optical sorting facilities (not only for plastic packaging waste). This is a large investment making it very costly to change to another collection system. The flexibility is therefore regarded as lower than for the other collection systems studied. It is however possible to adapt the sorting lines to a higher or lower number of fractions. Ordinary waste bins are used why the system is flexible in terms of waste bins. The same arguments are valid for kerbside collection of mixed waste subject to central sorting.

Bring systems are highly flexible in the sense that the containers can find alternative uses if no longer needed. Ordinary crane vehicles are commonly used for emptying the containers.

All collection systems described can handle larger amounts of collected plastic packaging waste. The collection routine and/or the bin sizes then need to be adjusted accordingly. A higher number of source-separated plastic packaging waste fractions would require another bin or another compartment organisation (multi-compartment bins), another bin or plastic bag (separate containers or transparent plastic bags), another

coloured bag fraction (optical colour sorting), and an additional container/containers (bring systems). For collection of mixed waste subject to central sorting the question is not relevant.

Collection of both packaging and non-packaging plastic waste (material based) would be possible in a collection point of view for all described collection systems. Changes in amounts and quality of the secondary plastic raw material would then need to be evaluated, as well as the risk of introducing potential hazardous substances in the recycling systems.

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Appendix 1:

Definitions used in the report

Bring systems

Manned or unmanned drop-off points for public use where households are able to discard plastic packaging waste, and commonly several other waste fractions.

Kerbside collection

The meaning of kerbside collection is not explicit, but the definition chosen within the project is that kerbside collection is a collection system where households are able to discard their plastic packaging waste within the boundaries of the estate. Kerbside collection systems are as opposed to bring systems not for public use.

Plastic packaging waste

“All products to be used for the containment, protection, handling, delivery and presentation of goods, from raw materials to processed goods, from the product to the user or the consumer”, as stated in the Packaging Directive.

Source-sorting

There are different levels of source-separation, but they all have in common that the households make an effort to sort their waste in a certain manner. Plastic packaging waste can either be source-separated into a single stream, e.g. into a fraction meant to contain plastic packaging waste only or into a fraction containing other recyclable materials or plastic waste other than packaging.