Ciprian Cimpan, Henrik Wenzel

Collection and recycling of waste from households on Funen

Status and analysis on the reference year 2014

SYFRE WP1, November 2016
Colophon

Title:
Collection and recycling of waste from households on Funen - Status and analysis on the reference year 2014

Authors:
Ciprian Cimpan, Henrik Wenzel

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Centre for Life Cycle Engineering, Department of Chemical Engineering, Biotechnology and Environmental Technology, Faculty of Engineering, University of Southern Denmark, Campusvej 55 DK-5230 Odense M, www.sdu.dk/lifecycle

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Summary

This short report provides an overview of household waste generation, recycling rates (determined according to the provisions of the Danish Resource Strategy) and current collection systems (including newest developments) in the 10 municipalities of Funen. Furthermore, it provides insight into cost elements related to collection schemes, based on primary data collected from each municipality. Lastly, it also gives some insight into how different local factors (demography, geography and waste management practices) affect waste generation, recycling and the costs associated with collection systems in the region.

Approx. 216,000 tonnes of household waste collected in the region constitutes the basis for calculating recycling rates to achieve the Danish Government’s target of 50% recycling by 2022. In 2014, approx. 80,000 tonnes of this waste were collected for recycling, putting the region’s recycling rate at 37%. Waste generation rates and recycling rates vary significantly among municipalities. Generation is highest in Langeland (559 kg per inhabitant) and Middelfart (509 kg per inhabitant) and is lowest in Assens (417 kg per inhabitant), followed by Odense (422 kg per inhabitant). Four out of the 10 municipalities had in 2014 passed the 40% line on recycling, led by Kerteminde (46%) and Assens (47%, this rate is however for 2015).

Regarding collection systems, in 2014 five municipalities (Assens, Faaborg-Midtfyn, Middelfart, Odense and Ærø) had already well running household-near schemes for dry recyclable materials, which cover more than 90% of households. One more municipality (Nyborg) runs a scheme with approx. 70% coverage. Two municipalities, Kerteminde and Nyborg, have household-near collection of organic waste with coverages of approx. 45% and respectively 60%. The remaining municipalities plan to implement household-near collection in 2016 (Nordfyns) and 2017 (Langeland and Svendborg).

During the course of this project, detailed data was collected from each municipality regarding collection infrastructure (types and number of collection materials), collection frequencies and cost data (collection materials and emptying costs). This enabled to calculate some of the most important budget costs related to existing collection systems in the region. Again, significant variation was found among municipalities. Upon closer analysis of unit collection costs (kr./tonne) set against different local factors, it was found that there was moderate correlation between variation in cost and variation in population density, shares of single-family vs. multi-family residences and households living in rural areas. However, the variation in the share of secondary housing (vacation and other non-permanent housing) among municipalities was found to explain quite well the variation in collection costs. This means that costs increased (linearly) with increasing shares of secondary housing.

The efficiency of collection infrastructure utilization was also tested, and revealed that in some municipalities the choice of collection materials and/or collection frequencies practiced may be suboptimal. Furthermore, the different levels of infrastructure utilization could explain with good confidence the variation in collection costs. Suboptimal infrastructure utilization is however more than likely connected to shares of secondary housing (the other factor that was found significant), thus presenting a challenging optimization problem to municipalities.
1 Objective and methods

This report was drafted as a result of investigations performed in the SYFRE (Synergi i fynske ressourcestrategier) project, supported by the Danish Ministry of Environment and Food, through the Funding pool for implementation of Government’s Resource Strategy (Pulje til implementering af regeringens ressourcestrategi).

The main objectives of SYFRE is to further develop a knowledge base in the region of Funen which supports decision makers in strategic planning of waste management, specifically in implementation of common strategies in waste collection and treatment systems. In order to identify common strategies that would bring advantages and that will strike a good balance between individual and joint efforts, it is imperative to understand the individual and local framework conditions, the opportunities and challenges regarding waste and resource strategies in the 10 municipalities.

This short report provides an overview of household waste generation, recycling rates and current collection systems, including costs, in the 10 municipalities of Funen. The scope of this overview, i.e. types of waste streams and fractions, is limited to the waste streams generated by households for which the Danish Government has set a 50% recycling target before 2022 under the provisions of the Danish Resource Strategy adopted in 2013 (Danish Government 2013).

The overview and subsequent analysis is based on data provided by representatives from each municipality. The data collection process was started with standard templates provided to each representative and continued with a number of phone and personal meetings between representatives and SDU in order to qualify the data provided. Quantitative waste stream data, detailed per type of collection (household-near, public collection and “scout” collection) are based on direct accounting in each municipality, and therefore in some cases it does not fully agree with amounts that can be retrieved from the national registry, namely the ADS system.
2 Waste from households: generation and recycling rates

In 2014, the 10 municipalities in the region of Funen collected approx. 216,000 tonnes of waste (Table 1), which constitutes the base for calculation of recycling according to the Danish Government’s Resource Strategy (Danish Ministry of Environment 2014). These amounts include the seven fractions of interest for recycling, i.e. paper, cardboard, glass, plastics, metals, wood and organic waste, and mixed residual waste streams which are combusted in waste incineration plants, i.e. residual waste and small/large combustibles. Amounts of packaging recovered in the Danish Return System ("Dansk Retursystem") are not included in this overview.

Around 66,000 tonnes of garden waste, as well as other bulky waste (e.g. household construction/demolition waste, WEEE and hazardous waste) are also collected in the region; however, they have to be excluded when calculating the recycling rate.

Nearly 40% of the total waste is generated in Odense municipality, while Langeland and Ærø municipalities lie at the other extreme with 3% and respectively 1%. As can be seen in Figure 1, generation rates vary significantly between municipalities. The lowest total waste generated per inhabitant occurs in Assens (417 kg), followed by Odense (422 kg) and Svendborg (423 kg), while the highest occurs in Langeland (559 kg) and Middelfart (509 kg). Generation per inhabitant of mixed waste that is incinerated is lowest in Assens (220 kg) and Kerteminde (250 kg) and is highest again in Langeland (404 kg).

![Figure 1 Total waste generation (streams of interest) and generation rates per inhabitant](image-url)
### Table 1: Waste amounts collected in Funen in the reference year 2014 (in tonnes) by type of collection scheme

<table>
<thead>
<tr>
<th>Collection scheme</th>
<th>Household-near (“Henteordning”)</th>
<th>Scout collection</th>
<th>Public collection/ Bring systems (“Bringeordning”)</th>
<th>Total per municipality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cubes</td>
<td>Recycling centres</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Residual waste</td>
<td>Organic waste</td>
<td>Dry recyclables *</td>
<td>Dry recyclables **</td>
</tr>
<tr>
<td>Funen total</td>
<td>112,280</td>
<td>2,412</td>
<td>18,888</td>
<td>624</td>
</tr>
<tr>
<td>Langeland</td>
<td>4,353</td>
<td>140</td>
<td>322</td>
<td>1,519</td>
</tr>
<tr>
<td>Svendborg</td>
<td>13,677</td>
<td>226</td>
<td>264</td>
<td>1,437</td>
</tr>
<tr>
<td>Nordfyn</td>
<td>7,600</td>
<td></td>
<td>802</td>
<td>4,071</td>
</tr>
<tr>
<td>Kerteminde</td>
<td>4,713</td>
<td>1,068</td>
<td>639</td>
<td>3,265</td>
</tr>
<tr>
<td>Nyborg</td>
<td>7,352</td>
<td>1,344</td>
<td>197</td>
<td>3,310</td>
</tr>
<tr>
<td>Ærø</td>
<td>1,664</td>
<td>367</td>
<td>58</td>
<td>619</td>
</tr>
<tr>
<td>Faaborg-Midtfyn</td>
<td>10,066</td>
<td>1,458</td>
<td>23</td>
<td>7,851</td>
</tr>
<tr>
<td>Odense</td>
<td>46,549</td>
<td>9,618</td>
<td>1,194</td>
<td>18,528</td>
</tr>
<tr>
<td>Assens***</td>
<td>7,246</td>
<td>3,265</td>
<td></td>
<td>4,865</td>
</tr>
<tr>
<td>Middelfart</td>
<td>9,060</td>
<td>2,730</td>
<td></td>
<td>4,029</td>
</tr>
</tbody>
</table>

* Dry recyclables = paper, cardboard, glass packaging, hard plastics, foil plastics and metals
** Dry recyclables at recycling centres = paper, cardboard, glass packaging, glass other, hard plastics, foil plastics, metals (including large metals or “kommunejern”) and clean wood (incl. wood sorted from large combustible waste)
*** For Assens the reference year is 2015

### Table 2: Waste amounts collected in Funen in the reference year 2014 (in tonnes) by waste stream, the green shading highlights streams collected for recycling and grey highlights streams which are incinerated

<table>
<thead>
<tr>
<th>Waste stream</th>
<th>Funen</th>
<th>Langeland</th>
<th>Svendborg</th>
<th>Nordfyn</th>
<th>Kerteminde</th>
<th>Nyborg</th>
<th>Ærø</th>
<th>Faaborg-Midtfyn</th>
<th>Odense</th>
<th>Assens</th>
<th>Middelfart</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic waste</td>
<td>2,412</td>
<td>1,068</td>
<td>1,344</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paper</td>
<td>22,248</td>
<td>380</td>
<td>1,922</td>
<td>999</td>
<td>774</td>
<td>1,549</td>
<td>294</td>
<td>1,581</td>
<td>10,264</td>
<td>2,218</td>
<td>2,266</td>
</tr>
<tr>
<td>Cardboard</td>
<td>5,166</td>
<td>154</td>
<td>474</td>
<td>370</td>
<td>389</td>
<td>321</td>
<td>100</td>
<td>1,598</td>
<td>590</td>
<td>469</td>
<td></td>
</tr>
<tr>
<td>Glass packaging</td>
<td>10,520</td>
<td>283</td>
<td>965</td>
<td>719</td>
<td>615</td>
<td>532</td>
<td>147</td>
<td>1,548</td>
<td>3,559</td>
<td>1,184</td>
<td>968</td>
</tr>
<tr>
<td>Plastics</td>
<td>3,681</td>
<td>104</td>
<td>194</td>
<td>115</td>
<td>304</td>
<td>431</td>
<td>46</td>
<td>462</td>
<td>1,260</td>
<td>448</td>
<td>317</td>
</tr>
<tr>
<td>Metals</td>
<td>11,242</td>
<td>428</td>
<td>1,150</td>
<td>870</td>
<td>654</td>
<td>642</td>
<td>154</td>
<td>1,527</td>
<td>3,096</td>
<td>1,247</td>
<td>1,474</td>
</tr>
<tr>
<td>Clean wood</td>
<td>25,147</td>
<td>632</td>
<td>2,849</td>
<td>1,800</td>
<td>1,168</td>
<td>1,533</td>
<td>302</td>
<td>3,592</td>
<td>9,563</td>
<td>2,443</td>
<td>1,265</td>
</tr>
<tr>
<td>Residual waste</td>
<td>112,280</td>
<td>4,353</td>
<td>13,677</td>
<td>7,600</td>
<td>4,713</td>
<td>7,352</td>
<td>1,664</td>
<td>10,066</td>
<td>46,549</td>
<td>7,246</td>
<td>9,060</td>
</tr>
<tr>
<td>Large combustible</td>
<td>5,613</td>
<td>0</td>
<td>34</td>
<td>497</td>
<td>314</td>
<td>431</td>
<td>75</td>
<td>890</td>
<td>740</td>
<td>570</td>
<td>2,062</td>
</tr>
<tr>
<td>Small combustible</td>
<td>18,013</td>
<td>822</td>
<td>3,327</td>
<td>1,036</td>
<td>916</td>
<td>990</td>
<td>270</td>
<td>2,714</td>
<td>5,352</td>
<td>1,248</td>
<td>1,339</td>
</tr>
<tr>
<td>Total</td>
<td>216,321</td>
<td>7,156</td>
<td>24,592</td>
<td>14,006</td>
<td>10,915</td>
<td>15,125</td>
<td>3,052</td>
<td>23,081</td>
<td>81,981</td>
<td>17,193</td>
<td>19,220</td>
</tr>
</tbody>
</table>
In almost all Funish municipalities, as described in section 3.1, initiatives to capture more recyclable materials and stimulate public participation in separate collection have gained momentum in the last 2-4 years. As a result, recycling rates in 4 municipalities were above 40% already in 2014, with Kerteminde and Assens municipalities leading the way (Assens was at 43% in 2013 and reached 47% in 2015). The contribution made by the different collection schemes and the total achieved recycling rates in the 10 municipalities are illustrated in Figure 2. In addition, it was possible to estimate values individually in the 3 "collection districts" of Nyborg municipality. The latter shows that the largest (population wise) district (district 1 or Nyborg city), achieved in 2014 a recycling rate of 45%, above the average in the whole municipality.

Figure 2 Recycling rates and the contribution of different collection schemes to recycling in every municipality plus the 3 districts of Nyborg

Figure 3 shows the amounts collected for recycling (kg per household) for the 7 materials of interest. Paper and wood stand out as the materials with highest amounts. For wood specifically, amounts between 100 and 150 kg per household were recovered in 2014.

The exact potential for each material fraction, i.e. the total generated in the households, is unknown, except maybe for Odense municipality, because no waste composition analyses have been performed in recent years. Nevertheless, during the course of this project, and estimation has been made and is presented in Table 3, differentiated per single- and multi-family residences. Estimation of potential for organic was specifically difficult due to lack of data on amounts that are home-composted. Home composting has been encouraged in almost all municipalities in the past and is this supported to some extent today.
Also presented in Table 3 - source separation efficiencies, which could be calculated based on the estimated potentials in the 10 municipalities.

Table 3 Potentials (kg per household) and estimated source separation efficiencies for six materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Single-family (kg potential)</th>
<th>Multi-family (kg potential)</th>
<th>Organic waste</th>
<th>Paper</th>
<th>Small cardboard</th>
<th>Small plastic *</th>
<th>Glass packaging</th>
<th>Small metal **</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean wood</td>
<td></td>
<td></td>
<td>218-267</td>
<td>156-135</td>
<td>23-30</td>
<td>68-78</td>
<td>44-57</td>
<td>19-28</td>
</tr>
<tr>
<td>Organic waste</td>
<td>38%</td>
<td>15%</td>
<td>4%</td>
<td>14%</td>
<td>3%</td>
<td>68%</td>
<td>66%</td>
<td>3%</td>
</tr>
<tr>
<td>Metals</td>
<td>52%</td>
<td>20%</td>
<td>2%</td>
<td>47%</td>
<td>5%</td>
<td>75%</td>
<td>63%</td>
<td>38%</td>
</tr>
<tr>
<td>Foil plastics</td>
<td>14%</td>
<td>78%</td>
<td>1%</td>
<td>7%</td>
<td>3%</td>
<td>68%</td>
<td>76%</td>
<td>26%</td>
</tr>
<tr>
<td>Hard plastics</td>
<td>60%</td>
<td>65%</td>
<td>6%</td>
<td>6%</td>
<td>8%</td>
<td>77%</td>
<td>78%</td>
<td>21%</td>
</tr>
<tr>
<td>Glass</td>
<td>50%</td>
<td>38%</td>
<td>10%</td>
<td>10%</td>
<td>8%</td>
<td>83%</td>
<td>27%</td>
<td>30%</td>
</tr>
<tr>
<td>Cardboard</td>
<td>78%</td>
<td>14%</td>
<td>3%</td>
<td>3%</td>
<td>63%</td>
<td>68%</td>
<td>38%</td>
<td>19%</td>
</tr>
<tr>
<td>Cardboard</td>
<td>84%</td>
<td>51%</td>
<td>17%</td>
<td>17%</td>
<td>85%</td>
<td>53%</td>
<td>53%</td>
<td>19%</td>
</tr>
</tbody>
</table>

*Plastic packaging and other small plastic
**Metal packaging and other small metal
3 Waste collection systems on Funen

3.1 Collection schemes and collection infrastructure

Waste collection systems vary significantly between the 10 Funish municipalities. All municipalities have made it a priority to optimize existing and to install new collection schemes in order to capture more recyclable materials from households. Table 4 below gives an overview of main characteristics regarding collection in each municipality in the base year 2014. At the time of drafting the present report (2016), a number of changes have already been implemented in some municipalities compared with the table. These changes are documented in the following description sections (3.1.1-3.1.10).

The table shows the material fractions targeted for collection in different collection schemes, the type of collection material used (sacks or bins/containers) and gives an indication of scheme coverage through colour coding. Dark green highlights collection schemes which were implemented homogeneously in the whole municipality and covered more than 90% of households, while light green highlights schemes that had only partial coverage or very low participation rates.

Table 4 Overview of waste fractions and type of collection material used in the 10 Funish municipalities in 2014

<table>
<thead>
<tr>
<th>Collection scheme</th>
<th>Langeland</th>
<th>Svendborg</th>
<th>Nordfyn</th>
<th>Kerteminde</th>
<th>Nyborg</th>
<th>Ærø</th>
<th>Faaborg-Midtfyn</th>
<th>Odense</th>
<th>Assens</th>
<th>Middelfart</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household-near (“Henteordning”)</td>
<td>Organic waste</td>
<td>Bin</td>
<td>Bin</td>
<td>Sack</td>
<td>Bin</td>
<td>Sack</td>
<td>Bin*</td>
<td>Bin</td>
<td>Bin*</td>
<td></td>
</tr>
<tr>
<td>Cardboard</td>
<td>Sack</td>
<td>Sack</td>
<td>Sack</td>
<td>Sack</td>
<td>Bin*</td>
<td>Sack</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glass packaging</td>
<td>Sack</td>
<td>Sack</td>
<td>Sack</td>
<td>Sack</td>
<td>Bin*</td>
<td>Sack</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plastics</td>
<td>Sack</td>
<td>Sack</td>
<td>Sack</td>
<td>Sack</td>
<td>Bin*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metals</td>
<td>Sack</td>
<td>Sack</td>
<td>Sack</td>
<td>Sack</td>
<td>Bin*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

“Scout” collection (“Spejderordning”)

<table>
<thead>
<tr>
<th>Paper</th>
<th>Paper</th>
<th>Cardboard</th>
<th>Cardboard</th>
<th>Glass packaging</th>
</tr>
</thead>
</table>

Public collection/ Bring systems (“Bringeordning”)

<table>
<thead>
<tr>
<th>Paper</th>
<th>Paper</th>
<th>Cardboard</th>
<th>Cardboard</th>
<th>Glass packaging</th>
<th>Glass packaging</th>
<th>Plastics</th>
<th>Plastics</th>
<th>Metals</th>
<th>Metals</th>
</tr>
</thead>
</table>

*In Assens these materials are collected commingled in one 2-chamber bin based on the “DuoFlex” model
Collection of waste from households in Funen is performed in two settings: (1) municipalities have contracts with one or more private transport companies (“private vognmænd”), and (2) collection is handled in-house through municipally owned supply companies or similar setups (“kommunalt ejede selskaber”). It is not possible to point which of these settings is predominant, because unlike the average setting in Denmark, which is nr. (1), on Funen operate a few quite large municipal companies which handle collection, such as Odense Renovation and FFV Genbrug (in Faaborg-Midtfyn).

A short description of the current status of collection in each municipality is given in the following sections.

### 3.1.1 Langeland municipality

Langeland is one of the municipalities that relies today heavily on public/bring collection schemes (“bringeordning”) for recovery of recyclable materials. Scout collection (“spejderordning”) of paper, cardboard and glass also contributes with significant amounts.

The municipality plans to introduce household-near collection (“henteordning”) for selected recyclable materials in 2017. Simultaneously the scout collection scheme will be phased out. To further reduce residual waste and garden waste amounts, the municipality has started in 2015 a scheme to extend home composting by offering free composting containers.
3.1.2 Svendborg municipality
Svendborg is one of the municipalities that relies today heavily on public/bring collection schemes ("bringeordning") for recovery of recyclable materials. Households can also have recyclable materials (paper, cardboard, glass, plastics and metals) collected through a scheduled household-near bulky waste collection scheme (12 times per year). This scheme is however inefficient due to low household participation. Scout collection ("spejderordning") of paper also contributes with significant amounts.

The municipality plans to introduce household-near collection ("henteordning") for organic household waste and recyclable materials (paper, cardboard, glass, plastics and metals) in 2018. The scheme will be based on 2-chamber bins with either comingled or single materials. Pending adoption of permanent schemes, Svendborg started testing both household-near ("henteordning") and enhanced public collection ("miljøstationer") options for organic waste and dry recyclables in 2016 in 5 “front-runner” areas in the municipality.

3.1.3 Nordfyn municipality
Nordfyn municipality relied heavily on public/bring collection schemes ("bringeordning") for recovery of recyclable materials. Until mid-2016 an extensive network on public collection points...
(“Nærgenbrugsstationer”) was used for collection of paper and glass. Mid-2016 all households were fitted with a container for mixed paper and cardboard, which is collected every 4 weeks. Regarding organic waste, the municipalities strategy has been to strongly encourage home composting. Introduction of household-near collection for other materials has been investigated but is not planned in short-term.

3.1.4 Kerteminde municipality
Kerteminde relies on public/bring collection schemes (“bringeordning”) for recovery of recyclable materials. All households have access to an extensive network of public collection points (“nærgenbrugsstationer”) which target paper and glass waste and 3 large recycling centres. Nearly 45% of households (both single- and multi-family) participate in a household-near collection of organic waste (“grøn henteordning”), which targets vegetable food waste and small garden waste. Households that do not participate in this scheme should home compost instead. The municipality is considering making the “henteordning” mandatory over the whole municipality. Introduction of household-near collection for other recyclable materials has been investigated but is not planned in short-term.

3.1.5 Nyborg municipality
Nyborg municipality employs a relatively complex set of collection schemes, involving both household-near and public collection schemes. In terms of waste collection, the municipality is still divided into 3 districts that follow broadly the lines of the old municipalities before the reform (district 1 is Nyborg indre by, district 2 is gl. Ullerslev municipality and district 3 is gl. Ørbæk municipality).

Around 60% of households in the municipality participate in a household-near collection of organic waste (“grøn henteordning”), which targets vegetable food waste and small garden waste. The distribution of the scheme is not equal between the 3 districts, with most households that participate being placed in districts 1 and 3.

Since 2012, a scheme (started as a pilot) for household-near collection of paper-cardboard and plastics has been running in districts 1 and 2, covering today approx. 11600 households. In district 3 on the other hand, paper, cardboard and glass has been collected by scout associations. In addition to households-near collection, districts 1 and 3 have an extensive network of public collection points (“gænbrugsnæer”), covering paper, cardboard, glass, metals and plastics, while in district 2 it is only glass and metals.
Between May 2015 and December 2016, approx. 500 households participate in a pilot scheme, i.e. household-near collection of dual-stream recyclables (2-chamber bins covering paper/cardboard/plastic foil and respectively metals/hard plastics/glass).

Following this period of trials, Nyborg municipality will in short-term decide which standard collection schemes will be applied throughout the whole municipality.

3.1.6 Ärø municipality
Ärø is the smallest municipality in the region, but nevertheless they have for a number of years run a comprehensive household-near collection system (“henteordning”) for recyclable materials. In 2014, paper, cardboard, glass, metals and hard plastics were collected in clear yellow bags 12 times per year. In 2016, a permanent container system for mixed paper and cardboard replaced the sack system, while the other materials continue to be collected in sacks. In addition, there is also a network of glass cubes distributed throughout the municipality. There are no immediate plans to change the collection system, although the municipality has been looking into possibilities to collect organic waste.

3.1.7 Faaborg-Midtfyn municipality
A comprehensive household-near collection system (“henteordning”) for recyclable materials has been running in Faaborg-Midtfyn since 1984. Despite being voluntary, the majority of single-family residences participate in the kerbside scheme. The scheme includes the collection of 5-6 materials (i.e. paper, cardboard, glass, hard plastics, foil plastics and metals) in clear sacks every 14 days.

In addition, a small network of public collection points (“affaldsøer”) for paper and glass is targeting especially areas with vacation housing.

The municipality is involved in research initiatives regarding collection and treatment of the organic fraction of household waste. Home composting of this fraction is supported until implementation of new schemes.

3.1.8 Odense municipality
Separate collection of paper in dedicated containers was started in Odense in 2003 and approx. 90% of households participate today. In 2015, the scheme was updated to include also small cardboard packaging. Glass is collected in a large network of cubes spread throughout the municipality.

The municipality is preparing to implement household-near collection of organics and additional recyclables (glass, metal and plastics) from 2017, with expected full implementation by 2020. In preparation, Odense has and is supporting a number of pilot initiatives and research projects. This
including a characterization study (composition analysis) of residual household waste performed in 2015. Between December 2009 and December 2010, 1500 households participated in a household-near pilot collection of plastic, metals and cardboard packaging, besides paper. In august 2016, two new pilot collection schemes were started in 8 residential areas, covering in total around 2000 households. The two household-near collection schemes are based on 2-chamber containers: (the first) 2x2-chamber containers targeting organic waste and residual waste, as well as mixed paper-cardboard and mixed metals-plastics; (the second) 3x2-chamber containers targeting organic waste and residual waste, paper-cardboard and plastics, as well as metals and glass.

3.1.9 Assens municipality
Assens municipality introduced dual-stream collection of recyclables (“henteordning”) based on the “DuoFlex” model in Jutland, in April 2014. This replaced existing household-near collection of paper-cardboard. The new collection scheme covers more than 90% of households. A previous network of public collection points (“nærgenbrugsstationer”) was reduced and now is directed towards collection of dual-stream recyclables in vacation housing areas. Home composting has been strongly encouraged and supported in the past.

![Typical setup for single-family residences in Assens municipality, including a recycling bin “genbrugsbeholder” and residual waste bin](image)

The municipality is currently investigating different options for the further introduction of organic waste collection, which is recognized as the missing element to achieving the Danish 50% recycling target.

3.1.10 Middelfart municipality
Separate collection of paper in dedicated containers has been running in Middelfart since 2009 and approx. 90% of households participate today. In 2014, further household-near collection of cardboard, glass and metals in a sack system was introduced. Urban concentrations and vacation houses areas have in additions a small network of public collection points for glass and metals. Similar to Assens municipality, Middelfart is currently investigating different options for the further introduction of organic waste collection, which is recognized as the missing element to achieving the Danish 50% recycling target.
3.2 Costs of waste collection

In all Funish municipalities households have a choice between bins and containers of different sizes (volumes), in most municipalities it is possible to choose the collection frequency (typically between weekly and by-weekly for residual waste), and finally in some municipalities it is also possible to choose between full-service (“standplads”) and standard kerbside (“skel”) collection. The waste fees incurred by households are related to the choice (volume) of bins/containers for residual waste plus a fixed base-fee which covers administration costs, access to recycling centres and public collection points. Household-near collection of recyclables is in the majority of cases not listed with a fee, but implicit costs are distributed into the other fees. Furthermore, municipalities also pass on to households the net costs to manage or treat collected waste after collection. This is mainly the cost of incinerating residual waste, which is placed under the main bin/container fee. All these aspects places collection schemes in the region under volume-based “pay-as-you-throw” schemes.

![Figure 9 Collection costs per municipality in 2014 (mil. DKK)](image)

During the course of this project, detailed data was collected from each municipality regarding collection infrastructure (types and number of collection materials), collection frequencies and cost data, specifically emptying prices for collection materials used in the various household-near and public collection schemes (excl. recycling centres). This enabled an estimation of collection costs, as a sum of costs with collection materials (sacks, bins, containers) and costs to empty these collection materials with a given frequency. These costs, in absolute numbers, are presented for each municipality in Figure 9. They are divided per three main household-near collection schemes (i.e. residual, organic waste and dry recyclables) and public collection (i.e. cubes/recycling islands). It is important to stress that these costs represent only a share of the real costs with collection, because they do not include for example costs with administration. Furthermore, the waste fees payed by households also pass on to households the cost to manage or treat collected waste after collection, which is not included in Figure 9.
In general, the cost levels presented in Figure 9 correlate well with the size of the municipality and waste amounts collected herein.

Figure 10 illustrates the same costs as Figure 9 but expressed as unit costs, both expressed per tonne of waste collected with the respective collection scheme and per household in the municipality which is participating in the scheme. At this point, it is of interest to distinguish between different types of households, respectively households living in single-family and multi-family residences, and not least temporary or permanent use vacation housing and other non-permanent housing. This was however not possible with a reasonable level of confidence in most of the municipalities during the short period of this project, and therefore it is not presented here. It will part of further research after the completion of this project.

With the aggregated cost data (all types of housing combined), significant variations can be observed between the municipalities, and some of the reasons for this variations will be discussed in Chapter 4. Unit costs expressed per tonne waste are overall lowest for collection of residual waste. This is to be expected due to the relatively large amounts of this waste stream generated per source and overall in the municipalities. Per tonne waste collected, all other schemes, i.e. organic waste, dry recyclables and also public collection, are more costly. On the other hand, when unit costs are expressed per household, meaning that the costs of a scheme are distributed over the total number of households using it, it was observed instead that residual waste collection was the most costly scheme, with organic waste and dry recyclables following closely. Public collection points had much lower cost than household-near schemes.

![Figure 10 Collection costs (collection materials + emptying) expressed per ton waste collected and per household (estimated or known households using the collection scheme)](image-url)
Finally, in Figure 11 are presented ranges of emptying prices per different standard size bins and containers. The emptying price is a unit cost which represents the cost of emptying a certain bin/container one time. The cost is either passed on to the municipality by a collection company (then it includes both operation costs and profit) or it is an internal cost if collection is handled in-house (then it includes only operation costs).

As can be observed, the difference between the lowest and the highest emptying price per different containers for residual waste was found to be substantial between the municipalities. This cost element explains some of the differences in overall collection costs between municipalities. Costs with collection materials (capital investment and maintenance) vary to a much lesser extent. Lastly, emptying prices for paper containers, and also other household-near collection, do not differ significantly from residual waste. In this case, the total costs of a collection scheme is lower than that for residual waste because of less frequent emptying (between 26 and as low as 8 times per year).

![Figure 11 Emptying prices for sacks/bins/containers (min, max and average)](image-url)
4 Analysis

When compared, the amounts of waste generated (or collected), achieved recycling rates and not least the costs associated with collection systems in the 10 municipalities of Funen exhibit substantial variation. There are a large number of factors which determine this variation, and we can generically, divide between factors which are:

1. **Built in by design** – these are factors which can be controlled and pertain to waste collection system choices, such as collection methods and schemes, collection infrastructure, collection frequency, but they also relate to wider waste management system choices, such as minimization strategies (e.g. home composting) and fee systems (pay-as-you-throw systems)

2. **Catchment area related** – these are factors on which the municipal authorities have very little control, because they relate to geography and demography of a region, such factors are population density, population in rural vs. urban settlements, scale of secondary housing, and geographical remoteness.

In the following sections we present some of the most important characteristics of the region (catchment area related) and we analyse the influence of these characteristics on waste generation, recycling and costs.

4.2 Characteristics of the region

The region of Funen consists of 10 municipalities, which combined account for 486,000 inhabitants and 226,000 permanent households. Except for the city of Odense, all other larger urban concentrations are placed on the coastline.

The region is dominated by Odense municipality, which concentrates approx. 40% of the total population. Every other municipality accounts for below 12% of total population. This high discrepancy is correlated with population density (Figure 12) which is high in Odense at 640 inhabitants per km² whereas it is only 44-140 inhabitants per km² in all other municipalities.

Population living in rural areas, which are defined by Statistics Denmark as disperse settlements with less than 200 inhabitants and buildings spaced more than 200 m apart, is relatively high in all municipalities except Odense. Langeland and Nordfyns municipalities have the largest share of population living in rural areas (~40%), whereas the most common share is around 25% (Figure 13). In the same way, the population distribution between single-family residences (villa and terrace housing) and multi-family residences (apartment buildings and residential halls), is hardly homogeneous in Funen. The high population density in Odense municipality is of course reflected in the very large share (44%) of multi-family residences, whereas most other municipalities have a share of 10-15%. Svendborg and Nyborg municipalities have a slightly larger share (~25%), whereas Nordfyns municipality has the lowest share at 7%. Overall, the region counts 226,000 primary households (2014) divided between 73 % single-family and 27 % multi-family residences.

Another very important characteristic of the region is the high number of non-permanent housing, especially vacation housing, which pertains to it being a preferred vacation destination in the summer season. In this regard, the more remote and scenic Langeland and Ærø municipalities lead, followed by Nordfyn municipality. The distribution between permanent and non-permanent housing in each municipality is illustrated in Figure 13.
COLLECTION AND RECYCLING OF WASTE FROM HOUSEHOLDS ON FUNEN

Figure 12 Population density in the region of Funen (resolution of 500m*500m)
(Author: Marianne Rothmann / Rambøll)

Figure 13 Share (%) of primary and secondary housing (left), share of population in urban and rural areas (right)
4.3 Variation in waste generation and recycling rates

The high influx of non-permanent residents, especially in the summer season, is easily seen in a graph showing the seasonal variation in residual waste generation across the 10 municipalities.

Residual waste generation in the warm half of the year increases substantially in Langeland, Ærø and Nordfyn municipalities, whereas it is almost levelled out throughout the whole year in places like Odense, Assens, Middelfart and Kerteminde.

If residual waste generation (tonne per inhabitant) is plotted against the share of secondary or non-permanent housing in each municipality, as in Figure 15, we can see that higher generation rates tend to be associated with higher shares of secondary housing. The points representing each municipality fit reasonably well a linear regression line, with a correlation coefficient $R^2 = 0.54$. One of the reasons why the correlation is not even stronger could be that generation rates here represent collected waste and not actual waste generated. Collected residual waste does not account for example for home composting, which plays an important role in waste management in some municipalities.

Recycling in the region is influenced strongly by “designed” factors, but also by “catchment area” factors. One such factor is high shares of secondary housing, which affects recycling through lower participation in separate collection schemes by non-permanent residents and tourists compared to permanent residents. Low population density makes it difficult to implement comprehensive household-near collection because driving collection trucks in disperse rural areas is very expensive. The costs of collection in low density areas have to be distributed over the residents of the whole municipality. In some of the Funish municipalities these factors pose important challenges to achieving high recycling rates.

On the other hand, some municipalities have been quite successful in reaching higher recycling rates. This can be seen in Kerteminde and Nyborg where introduction of organic waste collection could be identified as a crucial factor. But it is important to stress that this has been combined with
home-composting, which reduces residual waste in areas not yet covered by the collection scheme. Home composting more than likely plays an important role in other municipalities, such as Assens and Faaborg-Midtfyn. Comprehensive implementation of household-near collection of dry recyclables is the major factor behind high recycling rates in more than half of the 10 municipalities. Last, but not least, another important aspect is public communication campaigns specifically focused on proper sorting, not only in the house, but also at recycling centres.

Figure 15 Correlation between residual waste collected and shares of secondary housing

4.4 Variation in collection costs

The influence of “catchment area” factors on collection costs can be explored taking residual waste collection costs as a base. Figure 10 displays trend lines when unit residual waste collection costs were plotted against population density, the share on single-family residences, the share of secondary housing and the share of households in rural areas in the individual municipalities. Except for the share of secondary housing, the other three factors are to some extent interrelated. For example, if a municipality has low population density, it is likely to also be characterized by larger shares of households living in rural areas, and to have large shares of single-family residences. The intention was to see if any or all of the three factors manifest a particularly strong correlation with collection costs. The outcome of this exercise indicated that all three factors could explain the level of collection costs but only to a moderate level.

On the other hand, the share of secondary housing and residual waste collection costs were strongly correlated ($R^2 = 0.71$). The costs to collect residual waste increased with higher shares of secondary housing in a municipality. One of the reasons for this could be that collection infrastructure, including collection materials and emptying according to a fixed schedule, has to be in place for residences with no permanent occupation, similar to permanent residences. However, the utilization levels for this infrastructure are quite low, i.e. almost the same cost is incurred but for much smaller amounts of waste collected. Therefore the costs of this infrastructure per tonnes of waste are much higher than for waste generated by permanent residences.
Since municipal authorities have little control over their share of non-permanent housing, it is not straightforward to indicate any cost optimization measures.

With regard to “designed” or waste management related factors, we can only look at collection materials and frequency of emptying. The emptying prices for different bins and containers are themselves dependent on many factors, most of them discussed above and therefore “catchment area” related. In addition to these, we can add others, such transport distances to treatment facilities and a lack of competition between collection companies, both of which there is little or no control over.

On the other hand, municipalities or supply companies that represent them, have a good degree of control over what type of collection materials end up being used by households and their collection frequencies.

From a cost perspective, the latter aspect can be subject to optimization. Both using bins or containers which are too large/small and performing too frequent emptying has important cost impacts. An optimal situation would be achieved when a unit amount of waste is collected with the maximum, appropriate, levels of utilization for the collection infrastructure employed. Utilization can be defined as the filling rate of bins and containers before each emptying. Appropriate, pertains to desired levels of service, meaning avoiding overfilling and avoiding storage of the waste over periods.
that could create problems (such as longer than 2 weeks for residual waste). Therefore, “appropriate levels of utilization” are found by finding a balance between bin and container size and collection frequency. This can be mathematically abstracted to a factor expressing the total volume emptied at the household in order to collect one unit (tonne) of waste. This factor was determined for each municipality and can be seen in Figure 17. We found that between 9 and 18 m$^3$ are emptied in order to collect one tonne of residual waste, with a median of 13 m$^3$. For comparison, if the average bulk density of residual waste is 130 kg/m$^3$, and an average filling rate of 80% is considered appropriate, then one tonne of this waste should occupy around 10 m$^3$. This seems to suggest the most municipalities (except Nyborg and Odense) either use too large collection materials or too frequent emptying.

![Figure 17 Volume emptied per collected tonne of residual waste (m$^3$ per ton)](image)

The question was then - can the differences in volume emptied per collected tonne in the 10 municipalities explain some of the variation in collection costs? The answer is provided in Figure 18 which shows that indeed, this factor is highly correlated with unit collection costs. This confirms that several municipalities should seek to optimized collection from an operational perspective. However, one point had to be removed because it was an outlier. This was Assens which had the highest volume emptied per tonne (18 m$^3$), but also one of the lowest unit costs in the region.

![Figure 18 Correlation between collection costs and total volume emptied for the collection of one tonne residual waste](image)
References

