Submission to the

Department of Communications, Climate Action and Environment

On

Waste Action Plan for a Circular Economy

From:

Cré – Composting and Anaerobic Digestion Association of Ireland

February 21st, 2020

CONTENTS

1. Introduction

Cré welcomes the opportunity to comment on the public consultation on the Action Plan for a Circular Economy.

About
Established in 2001, Cré is the Composting and Anaerobic Digestion Association of Ireland. Cré (which is the Irish word for 'soil'), is a non-profit association of public and private organisations, dedicated to growing the biological treatment sector. Cré supports the production of high-quality outputs, assists the delivery of Government waste diversion and bioenergy targets and promotes the creation of sustainable indigenous jobs.

Cré has a broad membership base ranging from compost and anaerobic digestion facilities to waste companies, local authorities, technology providers, local authorities, consultants and third level colleges. Cré is recognised by Government and agencies as the voice of the industry in Ireland and Northern Ireland. It is frequently called upon to give the industry view on future policy and legislation. Cré is a member of the European Compost Network, the European Biogas Association and the Biobased Industries Consortium. Cré has a Board of Directors, a Carbon Committee, a Technical Committee, a Public Relations Committee and an Anaerobic Digestion Committee. See www.cre.ie

In 2019, Cré CLG established a wholly owned subsidiary Cré Certification Ireland DAC to provide certification services for the Cré Compostable Certification Scheme.

Focus of the Cré Submission
Cré's submission is not responding to all the questions in the consultation, but is responding to sections, which are relevant to the collection of food and garden waste, the local processing of food and garden waste and the use of the end products- compost and digestate.

Contribution of Composting and Anaerobic Digestion Sector
The composting and anaerobic digestion sector in Ireland have the potential to deliver a significant portion of the new EU Circular Economy recycling target by processing food and garden waste.

There is significant scope for an increase in the amount of food and garden waste captured through the brown bin collections from households and businesses in Ireland. This requires both increasing the participation of householders and businesses in the scheme and increasing capture rates for those already participating. Increasing participation and capture rates have the potential to unlock more than 860,000 tonnes being separately collected for treatment by 2030. By 2030 food and garden waste could contribute to 43% of the 65% recycling target.

Developing the anaerobic digestion and composting sector further will enable organic materials to be managed in a more environmentally sound manner, in line with circular economy principles. The anaerobic digestion and composting sectors, if adequately supported, can play an important role in helping Ireland meet its carbon targets. Carbon sequestration in soils is increasingly recognised as a relevant measure to combat climate change. One way to increase carbon uptake in soils is the application of stable compost and digestate, as it contains a high percentage of stable organic matter.

2. Cré's Call for Action to Develop a Circular Economy for Food and Garden Waste

This section of the submission summarises key action Cré believes would be beneficial for all in order to develop a sustainable circular economy for food and garden waste.

The EU Circular Economy package has new legislative measures to introduce mandatory separate collection of biowaste or recycling at source by December 31st 2023. Therefore this is a key driver to ensure Ireland meets its EU obligations to meet recycling targets. To boost our recycling percentages and reduce methane emissions from landfills, this waste should be diverted, collected and sent to composting/ anaerobic digestion.

The EPA 2018 Waste Characterisation Study indicates that there is opportunity and scope to increase composting/anaerobic digestion of non-household waste, as 33 per cent of non-household residual waste is made up of organic waste.

There is significant scope for an increase in the amount of organic waste captured through:

- The brown bin collections from households and businesses
- Garden waste from households and businesses at recycling centres

To achieve this requires both increasing the participation of householders and businesses and increasing capture rates for those already participating.

Working together we can achieve this by:

Service

- Provision of brown bin (food waste bin) to businesses and householders that are stipulated in the food waste regulations, RED C research has identified a significant number of businesses and households that do not have access to a suitable collection service.
- Pay by weight for commercial sector brown bin should be introduced.
- Increased targeting of the commercial sector brown bin (reduced local authority rates, where businesses recycle food waste)
- Every household on a waste collection service should be given a food waste bin, which is collected weekly.
- Amendment of regulations to facilitate the establishment of more local drop off centres for garden waste and a system to collect green waste from green space nationally to be fed into local compost/anaerobic digestion plants.
- Set targets on the quantity of biodegradable municipal waste in the residual fraction, as this would help divert both food and garden to the brown bin.

Education

- Provision of the correct educational tools (kitchen caddy, compostable liners and information leaflet) for all householders on how to recycle food waste.
- A coordinated national brown bin awareness campaign is required to be developed with input from collectors, processors and regulators. Once developed all stakeholders should support the campaign in order for it to be a success. This multi-million national awareness campaign is funded by Department of Communications, Climate Action and Environment (DCCAE) sustained over a five year period should result in the consumer being educated on their right to a brown bin and how to use it properly. Consumers in turn request the bin from their waste collector and use it correctly, promoting low contamination of the bin for the processor, enabling the production of quality compost/digestate.

- A RED C Survey of households has identified that over 40% of people don't realise that it's illegal to put food waste in their residual bin. Inform people it's illegal to put food waste in their residual bin should be the focus of any initial future PR campaign.
- There should be dedicated resources for food waste prevention and the recycling of food waste.

Improved Enforcement of the Food Waste Regulations
- A review of enforcement powers in food waste regulations in other countries around the world to determine if existing Irish regulations could be changed to aid in the improved enforcement. This could be overseen by a small group of key stakeholders
- Examination of best practice in enforcement measures from other countries in order to determine if existing Irish regulations could be changed to aid in the improved enforcement.
- Local Authorities should be compelled to enforce section 9 (4) of commercial food waste regulations.
- Increased financial penalties are required to act as a deterrent to the waste sector to work within our existing legal framework.
- Establishment of a single waste regulator with powers of 'administrative sanctions' is required and where there are waste collection licence breaches fines commensurate with the company's revenue should be imposed.
- Waste collectors have reported poor participation rates of some householders who have brown bins. A RED C Survey of households has supported this fact; household use of the brown bin is lower, when compared to the residual and dry recycling bins.
- A protocol should be developed where collectors could liaise with Local Authorities to inform them which households who are not complying. At this stage Local Authorities would issue enforcement notices.

Contamination
- Members who process brown bin material are concerned about heavily contaminated materials from householders. A better education programme is necessary to improve householder's behaviour.
- Existing processing facilities in Ireland are in need of immediate investment. Overall, it is estimated that in the region of €50 million of capital and operational expenditure is required to maintain the existing infrastructure and to remove contamination at facilities, in the next five year period.
- There should be a specific consultation with all stakeholders on how to solve contamination.

Research and Innovation
- A research programme examining the rates of carbon sequestration should be conducted through field trialling compost and digestate.
- A sustained research budget to develop markets for compost and digestate is required to order to ensure there are long term sustainable markets.

A Stakeholder Workshop
In order to have decisive targets achieved we believe a workshop inclusive of all stakeholders would provide a pathway to increased food and garden waste collection. This should include statutory and non-statutory organisations.

Topics that would be covered by the workshop are:
- Brown bins for householders only for food waste and encouraged to bring their garden waste to local drop off centres for garden waste / provision of monthly collection service for garden waste during the key four summer months
- Weekly collection of food waste from households
- Collection frequency of the residual waste bin
- Standardising of terminology
- Scope of a national awareness campaign

- How to control contamination

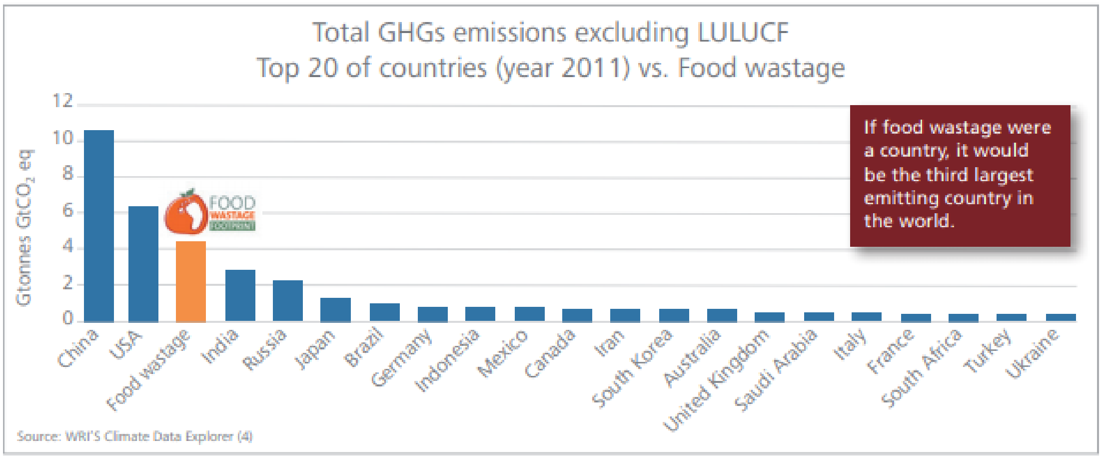
Coordination
Currently the **'**Waste Policy and Resource Efficiency' is within the Natural Resources and Waste Policy Division. We believe it merits a separate division concentrating on the Circular Economy and linked to climate change.

DCCAE should champion this Circular Economy Action Plan similar to the climate action plan. Other Government Departments should support this action plan with DCCAE playing a central role.

3. Background Information on Food and Garden Waste

3.1 Problem of Food Waste

Globally, food makes up a huge part of our waste. Around a third of all the food produced globally is never eaten (See Appendix 1).



If food waste were a country it would be the third biggest emitter of greenhouse gases in the world, according to the Food and Agriculture Organization of the United Nations. When you take into account the carbon footprint created by growing, harvesting, transporting, processing and storing food, the waste is almost equivalent to global road transport emissions.

The first step towards sustainable food waste management is to understand the types and sources of waste being generated and determine the impacts that they cause. The FAO estimates the global cost of food waste to be approximately USD 2.6 trillion; this includes not only the value of wasted food itself but also the greenhouse gas emission, water scarcity, biodiversity loss, soil erosion, nutrient loss, reduced yields, wind erosion and pesticide exposure[1]. Clearly, reducing food waste and managing it more sustainably has the potential to deliver significant tangible benefits to the lives of millions of people around the world, as well as serving to protect the natural environment upon which we all depend for a sustainable future.

[1] Jain and Newman (2019) Global Food Waste Management: An implementation Guide for Cities

3.2 Food Waste Collected in Ireland

To date the roll out of brown bins to households has not been entirely successful. After many years the tonnage of brown bin material collected is below predictions. There are agglomerations where brown bins are not adequately provided.

The processing sector has invested significantly in infrastructure to process brown bin material, however the expected tonnage has not materialised, this has resulted in some plants closing (e.g. Galway City Council), others have diverted capacity to process other temporary waste streams, which are now going to decrease in quantity.

Cré asked the National Waste Permit Collection Office (NWPCO) for data from waste collector's Annual Environmental Reports on tonnes of household and commercial brown bin collected – EWC 20 01 08. The data (see appendix) does show certain areas with low tonnage and those where targeted enforcement is needed.

Tonnes of brown bin material (200108) collected per county per year from 2012 to 2017 are provided in the Appendix 2.

- Nationally in 2017, 61,995 tonnes of commercial food waste collected was reported by waste collectors. In addition to this, industry sources estimated another 30,000 tonnes of supermarket food waste is collected.
- The amount of brown bin (200108) collected from households in 2017 was 124,527 tonnes

Performance in Relation to Indecon RIA

Indecon for the Department of Environment, Community and Local Government in their 2011 Regulatory Impact Analysis[2] for the European Union (*Household Food Waste and Bio-waste*) *Regulations 2013* (RIA) predicted that by 2017, there would be 231,265 tonnes collected. Actually only in the region of 124,527 was collected, 54% below the predicted tonnage by Indecon.

More recent data was not available at time of the preparation of this submission. When the data becomes available it is expected to show improvements.

Based on Department and EPA figures, it is estimated that there is potentially 560,000 tonnes of brown bin material available in Ireland with only in the region of a third of this currently collected.

Potential Tonnes of Available Material

The data below is outdated and it is expected that there is an underestimation.

Table 1 of Potential Tonnes of Household and Commercial Brown Bin Material Available in Ireland

Waste Stream	Potential Tonnes Available
Household Brown Bin	255,803[1] 231,265[2]
Commercial Brown Bin	306,578[3]
Total Brown Bin Material	537,843 - 562,381

1. EPA National Waste Report 2011
2. Statement of Regulatory Impact Analysis Waste Management (Household Food Waste Collection) Regulations 2011. Department of Environment, Community and Local Government, Prepared by Indecon, June 2011
3. EPA National Waste Report 2011

2 Statement of Regulatory Impact Analysis Waste Management (Household Food Waste Collection) Regulations 2011. Department of Environment, Community and Local Government, Prepared by Indecon, June 2011

Performance in Relation National Strategy on Biodegradable Waste
The National Strategy on Biodegradable Waste has a performance indicator for Biological Treatment Tonnage Treated of 331,597tonnes by 2016. Ireland did not meet this performance indicator.

RED C Commercial Food Waste Survey 2019
A survey from RED C Research has found that despite legislation for the last ten years requiring businesses to have and use a food waste bin, only 3 in 4 said they have a food waste bin and only 67% said they use the food waste bin.

The research highlights that among those who don't have a food waste bin, the main reasons are; that their waste collector did not provide it to them (30%), they have no space for the extra bin (14%) and 10% did not know about food waste bins. Cost of collection being expensive was lower down the list of reasons for not having a food waste bin, with only 6% of the businesses surveyed mentioning it.

The main reason why 66% of businesses reported using a food waste bin were; because it's the law (37%), its environmentally friendly (31%) and its leaves other waste cleaner for recycling (24%).

Many businesses report that they are using the weight data provided by waste collectors to examine if they are producing too much food waste (67%) and have systems in place to reduce food waste (83%).

According to the businesses surveyed, infographics of what goes into different waste bins (98%), food waste reduction toolkit (88%), online videos on correct use of food waste bins/segregation of waste (77%) would be useful to help them recycle more food waste. (See Appendix 6).

RED C Household Food Waste Survey 2020
A survey conducted in January 2020 (See Appendix 10).by RED C Research of over 1000 people across Ireland identified the following trends:

- Less than half of Irish adults report using a food waste recycling bin for disposing of food waste at home. In contrast, 3 in 4 report using a dry recycling waste bin. Younger adults and those living in urban areas report more frequent use of food waste recycling bins.
- Of those who don't use a food waste recycling bin at home, the vast majority have not been provided this type of bin by their waste collector. Only 1 in 6 of those who don't use this bin type currently, claim to have been provided with a food waste recycling bin.
- In addition, older adults (55+ yrs) and those living in rural areas, who are more likely to say they don't use a food waste recycling bin at home, also tend to over index in terms of not being provided a food waste recycling bin by their provider
- The barrier posed by the lack of provision of food recycling waste bins is reiterated once again with 1 in 3 of those not using a food waste bin citing this as the main reason. Lack of knowledge and hassle of separating food waste do not feature particularly notably as barriers.
- In addition to tackling the provision issue, efforts should be made to make food recycling easier and more convenient for consumers, such as providing smaller kitchen caddy for food waste recycling as well as providing information and education in relation to correct use of this bin type (e.g. leaflets, media campaigns etc.)

Competition and Consumer Protection Commission

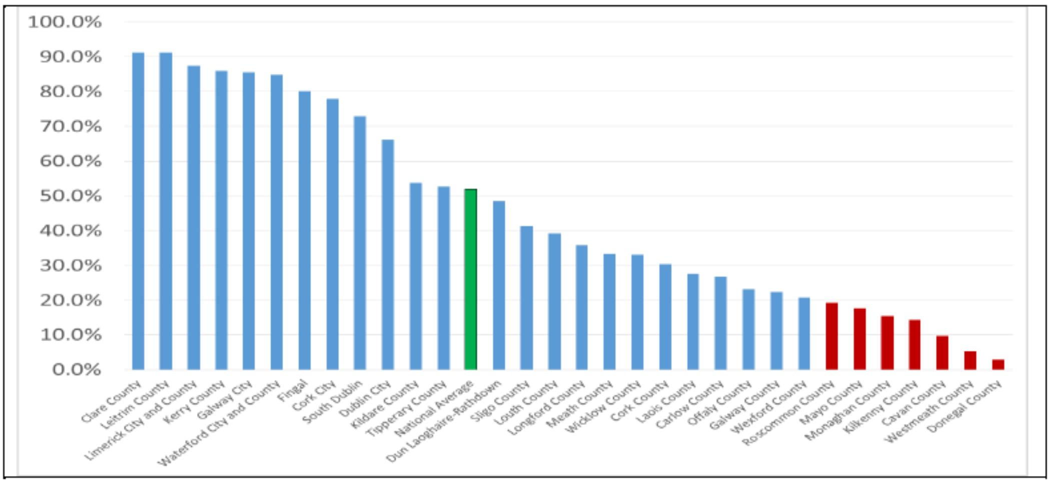
The Competition and Consumer Protection Commission (CCPC) published its report assessing the household waste collection market. In this report there is a section on brown bins, which highlights the low level of compliance in certain counties and has questioned the enforcement regime.

The report states the following:

- To date, the brown bin rollout out has been slow.
- The CCPC has estimated that by 2016 only 50% of all households with a scheduled service had an organic waste bin.
- 19 of the 31 local authorities had provision rates below 50%
- Cavan, Donegal, Kilkenny, Mayo, Monaghan, Roscommon and Westmeath are also highlighted as having rates less than 20%.

Figure 1 estimates organic bin provision based on an analysis of NWCPO data from local authorities.

Figure 1: Organic bin as a proportion of residual bins (2016)



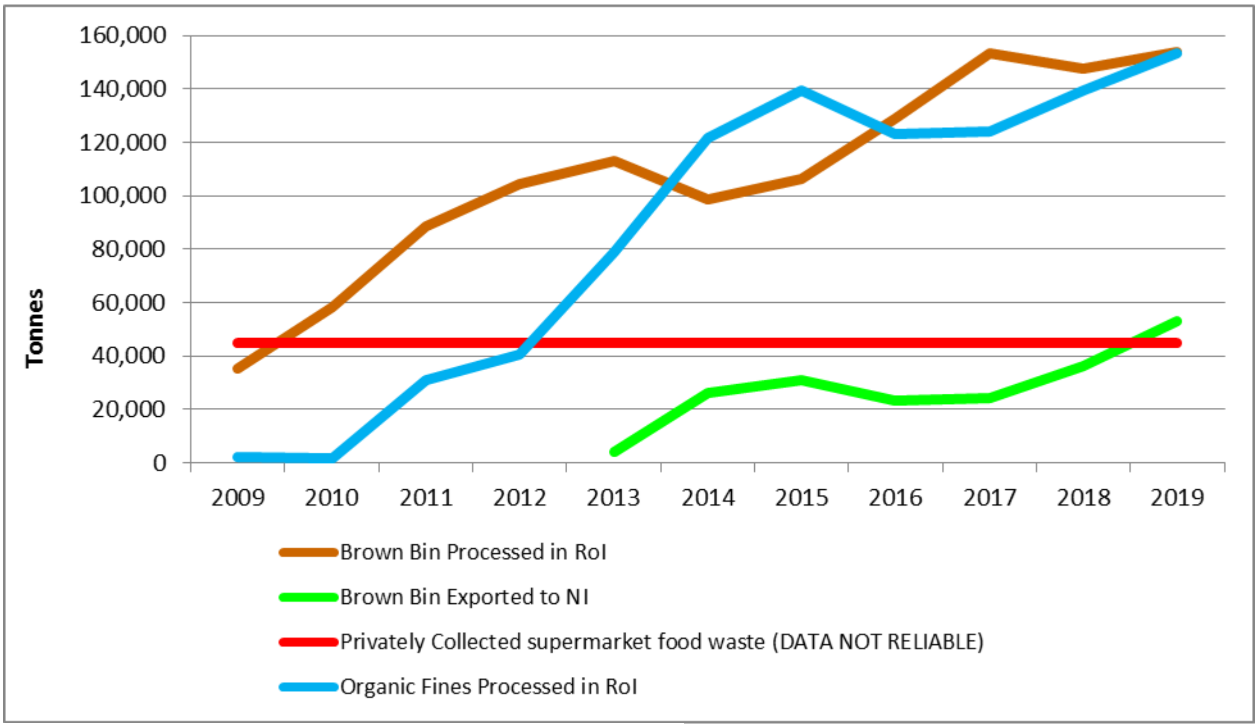
Source: CCPC analysis of NWCPO data

The CCPC analysed the 2016 data from the operator questionnaire which was undertaken as part of this study, in relation to Donegal, Kerry and Mayo households (which have low brown bin coverage) as against Dún Laoghaire-Rathdown (with 50% brown bin coverage). The aforementioned counties' presentation of residual waste is 57% higher than Dún Laoghaire-Rathdown.

These findings are an initial indication that the provision of an organic bin has a positive impact on the ability of households to segregate effectively. The limited provision of brown bins in some areas, which is a mandatory condition of operator permits, illustrates a lack of compliance with the current Regulations and raises questions about the supporting enforcement regime.

3.3 Brown Bin Material from Ireland Processed in RoI and NI in Composting and Biogas Plants

Figure 1: Brown Bin Material from Ireland Processed in RoI and NI in Composting and Biogas Plants



*data from one plant in 2019 could not be obtained, so its 2018 data was used.
* TFS data for 2019 is unvalidated.

On a regular basis Cré conducts a national survey on the tonnage of waste processed in composting and anaerobic digestion facilities in Ireland. The survey asks facility operators to declare the intake tonnage of various waste streams processed in the previous year. The purpose of this survey is to identify trends within the industry.

As facilities could not differentiate between the intake tonnage from commercial and household brown bin material, the data from both streams were combined into a single category labelled 'Brown Bin'.

Organic fines are the organic element from the landfill/residual bin. They are screened out because the incinerators abroad want a higher calorific value. The organic fines are high in metals and as a result are restricted by the EPA to use as landfill cover or incineration. Organic fines cannot be spread on agricultural land.

Figure 1 shows that in 2019, the same amount (150k each) of organic fines and brown bin were processed in Ireland. In addition to this another 53k of brown bin material was exported to Northern Ireland for processing.

There are six sites (with a processing capacity in region of 180,000k) processing organic fines (also another which is now closed) which would prefer to be processing brown bin material. The main they are not processing brown bin material is due to a lack of it.

However, many of the facilities processing organic fines would switch back to brown bin processing if the feedstock was available.

3.4 Garden Waste Collected at Civic Amenity Sites

In Ireland householders and businesses are charged for recycling garden waste at civic amenity (CA) sites. In contrast, in NI, householders do not have to pay additional charges for using CA sites, and the amount of garden waste collected is much higher. Charging for garden waste in Ireland is, therefore, acting as a financial disincentive to increased collection and recycling of garden waste. However, this does encourage greater levels of home composting.

In the international waste review in 2009, it recommended that:

"Legislation [should be introduced] to ensure that all household waste recycling centres are equipped with facilities for the separate collection of garden waste" [3]

Cré conducted a survey in 2017 on CA sites in ROI, which found that some Local Authorities collect garden waste but not all.[4] In Circular WPPR 17/08, it states:

"civic amenity sites should include provisions for the acceptance of green waste from householders. Local authorities should provide such a service free of charge or at a notional fee in order to encourage householders to avail of the additional capacity for green waste diversion"[5]

Regulations should be amended to facilitate the easier establishment of more local drop off centres for garden waste. This would help facilitate greater tonnage collected.

The Department of Rural Development is looking at management of green spaces. There could be an opportunity to coordinate the collection of this cut grass for use in the composting and anaerobic digestion sectors.

3.5 Organic Fines

Organic fines from waste pre-treatment processes provide input for organic waste treatment facilities. Pre-treatment of residual waste allows recyclates and organic fines to be separated from the residual waste, thus reducing the quantity of residual waste. Organic fines started to be separated with the emergence and development of the refuse derived fuel (RDF) export market. The quantity of organic fines being treated has increased as exports of RDF have increased. Furthermore, organic fines are also being removed from waste being sent for domestic treatment. Several operators reported having switched to processing organic fines to backfill capacity that they've not been able to fill through the lack of available brown bin material. The market for processing organic fines is likely to increase and there is a strong possibility that in 2020 for the first time that the total amount of organic fines processed by the industry will be more than source separated food waste. **Processing of organic fines should not be higher than source separated food waste, where source segregated food waste collection has been optimised.**

Organic fines once stabilised through organic treatment can be sent to landfill. However, there is also limited capacity available for the disposal of stabilised organic fines. Several operators identified the significant shortfall in landfill capacity, with operators reporting that there is a shortfall of the landfill capacity they need for stabilised fines. If landfill shortages remain for this material, then there is the potential that operators switch back to source separated materials. This is why it is more crucial to increase the amount of brown bin material in the market.

There should be a greater uptake of brown bins to reduce the number of organic fines needing processing, and then the issue of landfill capacity for outlet would not be an issue.

[3] International Review of Waste Management Policy in Ireland. Eunomia et al. DEHLG, 2009
[4] Unpublished
[5] http://www.cre.ie/web/wp-content/uploads/2010/12/Circular-WPPR-17.08-Roll-outof-Brown-Bins.pdf

3.6 Food Waste Education Pilots in Ireland

Awareness of Separate Collections

Separate organic waste collections typically yield higher participation and capture rates where the schemes are well publicised. A previous report by Cré highlighted the impacts of a Brown Bin Awareness pilot project in Sligo City.[6] The awareness project, which ran between July 2014 and March 2015 included:

- a door-knocking campaign to provide information on the brown bin scheme;
- a locally tailored brown bin information leaflet;
- a launch event at a farmers' market; and
- householders were supplied with a kitchen caddy and compostable liners.

The awareness campaign yielded the following key benefits:

- a 25% increase in participation rates;
- a 59% increase in capture rates; and
- an 86% reduction in contamination (the amount of non-compostable material (plastic, metals, glass) found in brown bins was slashed from 18% to 1%).

The aim of the Pilot was to see how, the provision of an education programme, where waste advisors went door to door providing kitchen caddies and compostable liners to householders, could improve the amount and quality of food waste in the Brown Bin.

The results of the project showed that by giving people a kitchen caddy and compostable liners to use in the kitchen made recycling food waste easier and cleaner for people. Given the positive outcome of the pilot it should be emulated across the country.

In Ireland, every household, in villages with more than 500 people, should have and use a brown bin for food waste, to date, however, getting people to use the bins has been a challenge. By their nature, food scraps are wet and often odorous and not something anyone really wants to handle when collected separately and recycled back to soil through composting and anaerobic digestion they can bring economic and relevant climate change benefits

The results of the Sligo pilot campaign demonstrate that investment in awareness campaigns can yield significant benefits for the sector.

Building on the findings of the pilot project and learnings from the collaborative approach used to create "Recycling List Ireland", a working group was formed to look at standardising awareness and education of the food waste recycling bin.

The working group membership included Cré, the IWMA (Barna Recycling & Clean Ireland Recycling), the Regional Waste Management Offices and the Department of Communications, Climate Action & Environment.

The aims for standardising the awareness and education for the food waste recycling bin are:

- Increase uptake and encourage participation.
- Reduce contamination.
- Create a social norm.

[6] Cré (2019) *National Brown Bin Awareness Pilot Scheme in Sligo City*, January 2019, http://www.cre.ie/web/wp-content/uploads/2010/12/National-Brown-Bin-Awareness-Pilot-Report-Sligo-30.01.2019.pdf

A further pilot scheme has been developed, including:

- Provision of a kitchen caddy and starter pack of 50 compostable liners;
- Information leaflet;
- "No Food Waste Please" awareness sticker on the residual waste bin.

It was tested in three towns following the population agglomerations listed in the Household Food Waste Regulations (10,000 persons, 1,500 persons and 500 persons) to facilitate learnings on costings and highlight any potential logistical issues in the delivery and implementation of the plan. The pilot was funded by the Department of Communications, Climate Action & Environment and was undertaken in 2019.

Policy Approaches

There is a case for introducing a requirement within the commercial and household food waste regulations for organic waste to be collected through the direct emptying of reusable containers or with compostable or paper bags certified to European Standard EN 13432. Furthermore, a limit on contamination levels for household and commercial brown bin waste could be introduced. A review process should be put in place to monitor and review on 5 yearly basis, the use of compostable plastics, the % weight of the collected biowaste and their effect on land/soil used to take the end product compost/digestate.

To limit consumer confusion surrounding compostable packaging, a policy should be introduced to require products to meet the EU standard for composability for claims of compostable to be made on products.

3.7 Contamination in Food Waste

Estimates of contamination levels vary. The EPA's 2018 Waste Characterisation report found that 16% by weight of household brown bin collections was non-target material.[7] Contaminants comprised primarily of plastics and textiles. A further report by the EPA for commercial waste found a 6% contamination rate.[8]

A survey was completed and found that contamination levels reported by the RoI were higher than those reported by NI operators, as shown in Table 2. The largest difference is for AD facilities with 15% contamination reported in the RoI, compared with 1% in NI. It is believed that the high contamination rate is in part due to operators reporting packaging as contamination. However, many facilities are designed with de-packaging equipment and therefore are equipped to receive and manage this material.

Table 2 Reported Contamination Rates

Facility Type	Republic of Ireland (Mean % contamination)	Northern Ireland (Mean % contamination)
AD	15	1
In vessel	9	5
Open Windrow	>1	2

Source: Operator survey

Through in-depth interviews with operators, it was reported by some operators that they aim to rely less on household domestic brown bin waste due to high levels of contamination, and the requirement for additional processing (and associated costs). Some operators report rejecting heavily contaminated loads to maintain feedstock quality, while others note the challenges contamination brings as feedstock is in high demand. Most contaminants are reported to be sent to landfill or incineration, which are accompanied by high gate fees.

An analysis of data on landfilled outputs from composting / biogas plants[9] found that approximately 10 kt of waste outputs were landfilled from mainly brown bin sites in the RoI. This suggests a contamination rate of approximately 5%. However, it should be noted that:

1. the landfill figure from composting sites are dry material as opposed to wet contaminated material entering the plant;
2. as composting plants screen out at different size and some contamination will remain in the oversize and get recirculated in the process;
3. the final product is screened to a certain size and may contain some contamination.

There should be a specific consultation with all stakeholders on how to solve contamination.

Cost of Contamination

Cré has made a high-level assessment of the investment requirements over the next five years for existing facilities in the RoI. Overall, it is estimated that that in the region of €50 million of capital and operational expenditure is required to maintain the existing infrastructure and to remove contamination

7 Environmental Protection Agency (2018) *Household Waste Characterisation Campaign Final Report*, November 2018, https://www.epa.ie/pubs/reports/waste/wastecharacterisation/Household_Surveys_Final_Report1.pdf

8 This was based on a limited sample (14 businesses) and it is understood that businesses were informed of the survey taking place in advanced, which could have resulted in changed behaviours, meaning that the actual level of contamination may be higher than that reported.

9 Based on analysis of AER data, alongside industry knowledge

at facilities over the next five years. Contamination will be removed using picking lines on incoming feedstocks and screens and windshifters to remove plastics from compost and digestate outputs.. Other technologies, such as ballistic separators need to be examined by the sector.

4. Contribution of Food and Garden Waste to EU Recycling Targets

The composting and anaerobic digestion sector in Ireland has the potential to deliver a significant portion of the new EU Circular economy recycling rate by processing food waste.

If food and garden waste collections were rolled out to all households, alongside associated increases in commercial waste, this would result in approximately a further 860,000 tonnes being separately collected for organic treatment by 2030.

By 2030, organic waste could contribute 43% of the 65% recycling target for Ireland.

The EU Circular Economy package has been agreed and new legislative measures will introduce mandatory collection separation of bio-waste or recycling at source by December 31st 2023. Therefore this enforcement initiative will be vital to ensure Ireland meets its EU obligations.

Cré agrees with the statement in the DCCAE Consultation Document:

> The EPA estimates that Ireland's municipal recycling (including organic waste for composting and anaerobic digestion through the organic bin) rate could increase from 41% to 62% if all recyclable (including organic) material was removed from the general waste bins and placed into the correct mixed dry recycling and organic waste bins.

5. Weekly Collection of Household Food Waste

In the International Review of Waste Management, one of the key recommendations was that there should be weekly household food waste collections as it results in higher capture rates of food waste and lower levels of contamination.

Ireland is out of sync with some other countries on the frequency of food waste collection. Other countries do it weekly, whereas the majority of food waste collections in Ireland are NOT weekly.

In 2010, Cré conducted a research project funded by the EPA *'Collectable Source Separated Food and Garden Waste Arising from Households in Ireland'* (See Appendix 8).

Some of the main findings of the report are:

- Results and benefits of food waste only schemes are:
- Specific collection of food waste keeps bulk density higher and volume smaller
- The foregoing implies a significantly lower cost of the single collection round, which in turns makes it possible to increase its frequency
- The increase capture of food and garden waste to a significant extent, which in turn reduced the percentage of organics in residual waste
- Consequently, collection of residual waste may be performed at reduced frequency
- Collection of garden waste may be made cheaper, either through a 'green round' at the kerb, but with much reduced frequency (e.g. monthly) or with direct delivery at local authority recycling centres

As mentioned in section 2 there should be a stakeholder workshop in which weekly food waste collections could be explored with all stakeholders.

Analysis by WRAP[10] of the performance of household food waste collections from across the UK has identified the following 'indicative yields' for food waste for the three common food waste collection profiles – assuming a service is well designed and implemented:

- Separate weekly collection: 1.5kg/hh served/week
- Weekly mixed food and garden waste collections: 0.8kg/hh served/week
- Fortnightly mixed food and garden waste collections: 0.5kg/hh served/week

The main factor is frequency of food waste in comparison to the frequency of collection of residual waste. Food waste needs to be more convenient than residual if it is to be successful, so apart from making it convenient in terms of kitchen caddies, liners and communication, frequency and a good service is key.

In the UK, there are now 14 local authorities on 3 weekly collection for residual waste.

A growing trend in the UK is for residual collection to move to three-weekly, Bracknell Forest is the latest https://www.bracknell-forest.gov.uk/bins-and-recycling/food-waste-collection, there's at least one doing monthly https://www.letsrecycle.com/news/latest-news/recycling-boost-after-conwy-four-weekly-residual-switch/. https://www.letsrecycle.com/news/latest-news/somerset-recycling/

10 WRAP - Household Food Waste Collection Guide

According to the Chartered Institution of Wastes Management (CIWM) four-weekly residual waste collections can boost recycling rates and provide a good standard of service, as long as residents are provided with extra provisions such as weekly food waste and separate nappy collections
https://resource.co/article/four-weekly-collections-can-increase-recycling-says-ciwm-12428

Whilst there are variations on dry recycling and garden waste both are typically fortnightly and garden waste charged separately, the common denominator is weekly food waste collection.

Advantages	Disadvantages
• The optimal collection system to get the highest yields of food waste with low contamination levels. • Uniform collection system across the country makes it easier for national education campaign. • Residual waste collections would be less frequent as householders tend to use a food waste bin more often as it is collected weekly. • As the scheme is for food waste only, there would be no seasonal spikes in tonnage which would allow processing infrastructure to work at optimal capacity all year.	• There could be a cost implication to this for the household/ waste collector. • Collectors would have to rearrange collection frequency of bins. • An education campaign would be required to educate householders of the change. • potential for increased contamination of brown bin

6. Residual Waste Targets

In the International Review of Waste Management, the use of 'residual waste targets' was a recommendation.

The report states that Flanders makes use of a residual waste target of 150kg per inhabitant. At the time the report was written (2009), Wales and England had targets per inhabitant in their waste strategy also, however- the current status of the Wales and England system is unknown.

Flanders aim in 2009 was to reduce waste that is not re-used, recycled or composted to 225kg per person by 2020 (50% below current levels in Flanders).

The following targets for residual household waste were also proposed in the report for Ireland:

- Less than 250kg per inhabitant by 2011;
- Less than 200kg per inhabitant by 2014;
- Less than 175kg per inhabitant by 2017; and
- Less than 150kg per inhabitant by 2020.

However it is considered that setting food waste targets per inhabitant could be problematic as it is could be difficult to account for home composting and food waste prevention. It might be better to set targets on the quantity of biodegradable municipal waste in the residual fraction, as this would help divert both food and garden to the brown bin.

Flanders – Now
Cré has contacted OVAM in Flanders about the residual waste target. This current implementation plan abandons the idea of one single residual waste target for the entirety of Flanders; instead, it adopts a tailor-made approach to the local authorities. The plan aims to achieve eleven targets, distributed over sixteen clusters of municipalities that are similar in a socio-economic point of view. For example, coastal municipalities are assigned a less stringent target since they produce more residual waste due to tourism than rural municipalities, for instance.

If all local authorities achieve their set of objectives, we should be able to reach an on average a max. of 138 kg of residual waste per capita by 2022, compared to 155 kg per capita in 2014.

Advantages	Disadvantages
• Increase the amount of BMW collected by brown bins	• How can a model be implemented in Ireland?

Currently the Flemish Authorities have no enforcement on the objective. Their current approach is working together, support, guide the cities and municipalities.

The Authorities do however, compile a benchmark and name (and shame) the municipalities which are not reaching the objectives (See Appendix 7).

7. Responses to Specific Questions in Consultation Document

7.1 Institutional Arrangements

Consultation Questions:
How are the current institutional waste prevention and management arrangements working and how could they be improved in your opinion?

Have you any other comments or suggestion on how you would like to see Ireland transition to a more resource efficient and circular economy by improving our management practices?

Cré Response:

Positive Aspects of the Current Institutional Waste Prevention and Management Arrangements:
DAFM is effective in it's role as the enforcement body of the Animal By Product Regulations and their role in the waste sector mainly goes unrecognised. DAFM are consistent in regulating and host regular Animal By Product Forum meetings to discuss issues. DAFM has set high standards, which has been positive for the industry.

Environmental Protection Agency (EPA):
The EPA regulates licenced site to a high standard.

Over the last number of years it is apparent to members that the EPA needs more staff to facilitate quicker turnaround of approval / amendments to licences. The unit within the EPA dealing with 'end of waste' applications is under resourced. Additional staff should be recruited as more waste items are going to be examined for end of waste status.

Waste Enforcement Regional Lead Authorities (WERLA's):
The WERLA's are necessary and have provided a positive coordinated enforcement approach. They are streamlining Local Authority enforcement and supporting local authorities in their enforcement role. The WERLA's should play a strategic part in a single waste regulatory body.

Regional Waste Offices
Regional Waste Offices were set up initially to provide waste strategies within regions, however with the development of the current waste infrastructure within the country, perhaps that remit should be reviewed to reflect an all island approach. The Regional Waste Offices have been effective in bringing different parties together to coordinate national educational campaigns.

Local Authorities:
The local authorities are under resourced to provide the required level of enforcement. Local Authorities could play a strategic part in a single waste regulatory body. Their function as an information body to the public and businesses is positive.

National Waste Permit Collection Office (NWPCO)
The NWPCO are efficient in their role. Their role in providing data is welcomed. The provision of more waste data is positive as it highlights illegal operators.

Suggestions:

Enforcement Grant Aid

Enforcement is very important, without appropriate enforcement by the authorities it is very difficult for waste collectors to meet their targets for the roll out of the brown bin.

The enforcement grant aid provided to local authorities in 2014 was linked to their performance in the enforcement of food waste regulations.

It is considered that the linkage of grant aid to performance should be continued and the percentage of grant aid linked to performance.

It is recommended that this enforcement performance should be evaluated on the tonnage of household and non-household (EWC code 20 01 08) waste collected.

Single Waste Regulator

In August 2006, the Department of the Environment, Heritage and Local Government initiated a public consultation process, aimed at examining the possible regulation of the waste management sector. The Department's consultation paper posed the following issues for discussion:

- Is another regulator needed for the waste management sector?
- What model of regulation is most appropriate?
- Who will be responsible for the regulation of the waste sector?
- What services should fall within the remit of a regulator?
- What functions should a regulator have?

In recent years, the suggestion of a single waste regulator was raised during the discussion on the household waste charging.

The concept of a single waste regulator deserves merit for further investigation as there are many regulators involved in regulating the waste sector. Streamlining the responsibility to a single entity would result in efficiencies and development of staff with focused expertise.

Currently, there is need for greater enforcement of the commercial and household food waste regulation.

A variation on this concept could be 'a single waste regulator for the commercial and household food waste regulations'. This could be tendered out. For example, Dublin City Council tendered out the enforcement of the fats, oil and grease regulations and the commercial food waste regulations.

The idea and scope of a single regulator needs further consultation with all stakeholders.

Cré acknowledges that there are issues within the current market such as there are good waste collectors making an effort to promote the brown bin whilst in the same area competitors are not providing the service. The good collector is in effect put at a commercial disadvantage for complying with the law.

There are a number of existing examples of this already in Ireland. There could be a suite of regulatory tools provided to a single waste regulator to manage this.

One possible option is:

Waste collection permits are taken back from all the waste collectors and instead given a licence from the single waste regulator to operate. The National Waste Permit Collection Office (NWPCO) power is limited such as revoking a permit. NWPCO don't have the power of 'administrative sanctions'.

A single waste regulator would have the powers of 'administrative sanctions' the administration sanction range from low end – publish a report highlighting wrong doing and require operators to refund their customers – to gold standard where an operating licence breach could result in operators being fined a percentage of revenue.

Dedicated Crime unit

There should be a dedicated national Crime Unit to deal with illegal waste activities in Ireland.

7.2 Municipal (Household and Commercial) Waste

The DCCAE consultation document has a number of proposed measure and questions. Cré has responded below to the relevant questions.

Short Term Measures 2020

- **Awareness and education campaigns encouraging the prevention and segregation of municipal waste and supporting households and businesses to do the right thing will continue in 2020, supported by market research.**
- **Household and commercial waste management will be an enforcement priority for 2020. This will see local authority enforcement officers calling to homes and businesses to ensure appropriate bins are in place and that waste is being segregated in compliance with applicable legislation, i.e. Food waste regulations and local authority waste bye-laws.**
- **One large and five small to medium Irish enterprises will adopt the MyWaste label to help consumers recycle more.**
- **The Regional Waste Management Offices will conclude a study on the future role of Civic Amenity Sites (Recycling Centres) for managing municipal waste.**

Other Policy Options and Measures

- **Collectors will be required as a condition of their waste collection permit to meet municipal waste recycling targets (i.e. will be required to achieve a 55% recycling rate of municipal waste by 2025, 60% by 2030 and 65% by 2035).**
- **The provision of an organic waste bin will be mandatory as part of a waste collection service for all households.**

Cré Comment on Recycling Targets as a Condition of Waste Collection Permits

The Waste collectors are part of stakeholder group required to meet the MSW recycling targets. They cannot do this alone and require policy support to achieve the targets set done for MSW by 2025.

Cré Comment Provision of Organic Waste Bin for all Households:

Current practices have demonstrated that the existing regulation of agglomerations greater than 500 is still not properly implemented or enforced. The Department of Communications, Climate Action and Environment (DCCAE) needs to provide additional enforcement resources that would be focused on the enforcement of the existing legislation.

Improved enforcement of the legislation is required to ensure all waste collectors are providing a brown bin service as it is unfair to compliant waste collectors.

If there is proper enforcement, an appropriate lead in time for the provision of brown bins and a national PR campaign Cré believe that the proposal of changing the legislation to agglomerations less than 500 is achievable.

The provision of a deminimus of greater than 500 agglomerations, creates potential for a loss of brown bin material required to achieve the EU MSW targets.

There are some waste collectors collecting in rural areas (e.g. Mulleadys/Barna in Leitrim, CleanIreland in Clare). Lessons could be learnt from these collectors on how to make collections efficient in rural areas.

- **The existing national standardised list of items acceptable in the mixed dry recycling bin will be revisited with a view to expanding the list to capture more recyclate.**

Cré Comment:
To avoid confusion by the public a list of continuously acceptable items should be agreed and not changed. When the recycling list was developed, it appeared to change several times, which caused confusion. The list should only be for items, which there have a continued sustainable market for recyclate.

- **Separate litter bins for recycling waste (including organic waste) will be provided on streets and by commercial premises.**

Cré Comment:
The provision of bins for recycling and food waste should be provided. Examples abroad should be studied to determine best practice to ensure contamination levels are kept low. Issues have been raised on high contamination levels in biowaste bin on streets i.e. Portugal and Spain

- **Additional municipal recycling infrastructure will be developed nationally.**

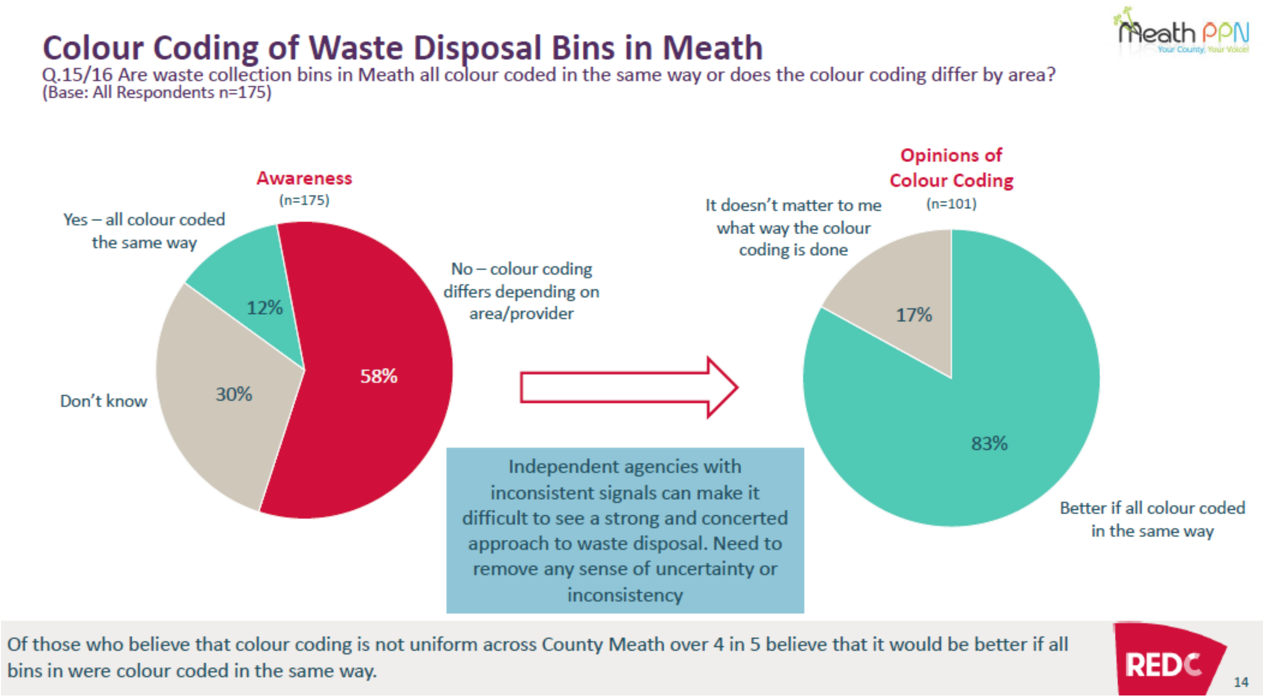
Cré Comment:
Additional waste processing capacity is needed and funding for equipment to remove contamination.

- **The colour coding of bins will be standardised across the State on a phased basis (general waste bin to be designated as a 'recovery' bin: colour black, mixed dry recycling bin: colour green, organic waste bin to be designated as 'organic waste recycling bin': colour brown).**

Cré Comment:
We believe colour coding is important (e.g. colour brown) and should be brought in a phase basis.

Cré recognises there will be a high cost to do this, but if in the longer term it makes educational campaigns consistent across the country, which should improve quality, there is merit in this. It will create a more robust circular economy with improved recyclate quality.

Meath Public Participation Network hired RED C to do a survey on householders in Meath; one of the survey responses supported the standardisation of bin colours.



DCCAE state in their consultation document that "Organic waste bin to be designated as 'organic waste recycling bin': colour brown"

In 2018, a working group was established by the Three Waste Regions, Department of Communications, Climate Action and Environment, Irish Waste Management Association and Cré. This group has discussed terminology.

Cré proposes that the food waste working group take up this action to determine the name of the brown bin and issue a consultation document to all parties.

This consultation document could be as follows:

> This group has been discussed terminology and is recommending that terminology used by all – waste collectors and all other stakeholders should be as follows:
>
> Instead of brown bin/ compost bin/ organic waste bin to NOW refer to it as
>
> "Food Waste Bin"
>
> The reasons are:
>
> - **Compost bin** – this has resulted in the public getting confused with home composting which you cannot compost meat products. This has resulted in the public thinking they cannot put meat product in the food waste recycling bin for collection by waste collector.
> - **Brown bin** – not all brown bins in Ireland are brown in colour, also the description does not tell the public what the bin is for
> - **Organic waste bin** – this is not really a good description and does not inform the public what it's for
> - **Food waste bin** – this tells the public exactly that the bin is for food waste – no confusion. Some waste collectors allow garden waste into the bin and they can say this to their customers in the educational literature.
> - **Food waste recycling bin**- many people associated the term 'recycling bin' as your dry recycling bin. If we use the same term 'recycling' in the description of the brown bin – it might confuse people.
>
> Market research of 1000 people using a company such as RED C would aide in the decision making process on the name of the bin.
>
> The group requests that all stakeholders update the educational tools in order for all to have a consistent terminology. This will assist all stakeholders to have a coordinated message and will aid the success of any future national educational campaigns.

- **A quality waste management assurance award scheme will be developed for businesses (including apartments serviced by management companies) to sign up to. This will verify that premises are complying with best waste management practice in terms of waste prevention and recycling (including organic waste).**

Cré Comment:
Cré welcome this proposal at it will aide in the robust data. This data will inform Local Authorities where to concentration their enforcement activities.

Consultation Questions – Municipal Waste

- **What further measures should be put in place by Government, regulatory authorities (EPA, local authorities, etc.) and industry stakeholders in order to promote and incentivise waste prevention and improve proper segregation and recycling of waste by both households and businesses?**

Cré Comment:

- Enforcement of household and commercial food waste regulations to ensure all households are provided with a brown bin.
- National food waste recycling PR campaign.
- Q Mark for households and merit award for Champion recycling households.
- Provision of kitchen caddies to households.
- Adequate price differential between residual bin and brown bin to encourage segregation.

- **What measures or practices are currently in place that could be improved?**

Cré Comment:

- Source segregation and collection of the 3 waste streams could be provided in one collection vehicle, resulting in shorter transport journeys, more efficient collection and decreased levels of contamination at source.
- On street provision of receptacles for 3 waste streams, could be trialled.
- Provision of labelled kitchen caddies to households
- Increased enforcement of food waste regulations.

- **What other new measures or practices could be put in place?**

Cré Comment:

- National colour coding of bins
- Co-ordinated National PR Campaign with active stakeholder participation
- Reduced LA commercial rates for Businesses achieving recycling targets
- Legislation could be implemented to take national targets to the waste generator level

- **What do you see as the barriers/enablers to these measures?**

Cré Comment:
Enablers:

- Education –people need to know primarily why they are recycling (reduction in GHG and circular economy) and how their actions effect the national targets to be achieved
- Colour coded bins and on street infrastructure
- Uniformity of messaging across the country
- Clear packaging labelling i.e. recyclable/compostable
- Provision of a standard for collection services across the country

Barriers

- Lack of interest, households are not availing of a collection service

- Confused and inconsistent messaging to HH and Businesses regarding waste management
- Cost of collection services
- Frequency of collection services
- Non-standardised collection services nationwide

- **Have you any other comments or suggestions on how you would like to see Ireland transition to a more resource efficient and circular economy by improving our waste management practices?**

Cré Comment:

- A centralised database of all by-product resources produced in the country
- A study to provide direction on the best use of the by-product catalogue entries
- An industry led national plan to use resources identified in the most efficient and effective way that is in line with Ireland s commitment to the Paris Agreement.

Consultation Questions – Household Waste

- **Is incentivised charging working in your opinion? Are households being financially incentivised to prevent waste and recycle correctly through the 3 bin system?**

Cré Comment:

There are approximately six processing facilities that were processing brown bin or would like to process brown bin material. These facilities are processing organic fines. If incentivised charging was working at the optimal level these facilities would be processing brown bin material.

There should be adequate price differential between the residual bin and brown bin to encourage segregation.

The EPA 2018 Waste Characterisation Study indicates that there is opportunity and scope to increase composting/anaerobic digestion of household waste, as 16 per cent of household residual waste is made up of organic waste.

- **Would an incentive scheme which compared your performance on how you generate and recycle your household waste with your area / county etc change your waste management behaviour?**

Cré Comment:

Yes. A pilot project should be conducted to examine this system.

- **What role should Civic Amenity Sites (local recycling centres) play? Should there be a standard service across all Civic Amenity Sites (CAS), such as the waste streams they accept? Should CAS accept general waste or only recyclables? Should CAS be used to provide more reuse opportunities, e.g. areas dedicated to exchange and upcycling? If so, how should this be funded?**

Cré Comment:

- Yes there should there be a standard service across all Civic Amenity Sites (CAS), such as the waste streams they accept.
- Yes, CAS should be used to provide more reuse opportunities, e.g. areas dedicated to exchange and upcycling

- **What can be done to improve recycling (including organic waste) in apartment complexes?**

Cré Comment:

As part of the National Brown Bin Awareness Pilot in Sligo a separate project was done in June 2015 with apartments (details in the Appendix 4). The trial determined best practice to promote the segregation of food waste using a brown bin system in an apartment complex setting.

Design of the Trial:

- Two apartment complexes were selected for the trial, which are serviced by two waste collectors.
- The apartments selected for the trial were Kevinsfort (comprises of 20 apartments) and Millbrook (3 blocks – total 85 apartments).
- Meetings were arranged with the Management Company of both apartment complexes and also the waste collectors servicing each of these apartment complexes.
- Following the initial meetings, correspondence was prepared and the provision of kitchen caddies, bags, info etc, was provided to the management companies for further circulation to all apartments (Example of letter to each apartment on next page).
- The tenant used a compostable bag in a 7 litre kitchen caddy and then carried it down to a 140 litre brown bin which was located in the communal waste area for the entire apartment complex.

Results

- Monitoring of progress was carried out for up to two months after the circulation of material.
- During the trial, there was a notable improvement in the quantity & quality of brown bin material generated from the tenants.
- However towards the end of the trial there was a lack of interest/buy in from both the management companies and waste collectors meant that old practices crept back in.
- Within the second month of monitoring, the compostable bags provided to tenants ran out and quite a lot of contamination in the brown bin was noted from there on as tenants did not buy more compostable bags and instead started to use normal plastic bags.

Recommendations

- Continued provision of compostable bags by the waste collectors to tenants for continued correct use of the brown bin.
- Obligation to be placed on management companies to ensure correct waste management practice at apartment complexes.
- Information to be provided to tenants on how to correctly segregate and recycle waste.

- **Have you any other comments or suggestions on how you would like to see Ireland transition to a more resource efficient and circular economy by improving our waste management practices?**

Cré Comment: No Comment.

Consultation Questions – Commercial Waste

- **How could pricing structures for commercial waste collection be improved to incentivise better segregation and recycling of waste? For example, should pay by weight be introduced for commercial waste?**

Cré Comment:

Yes pay by weight should be introduced for commercial waste with adequate price differential between residual bin and brown bin to encourage segregation.

The EPA 2018 Waste Characterisation Study indicates that there is opportunity and scope to increase composting/anaerobic digestion of non-household waste, as 33 per cent of non-household residual waste is made up of organic waste.

- **What further incentives could be put in place to encourage business to recycle more?**

Cré Comment:
The provision of a food waste bin to all businesses should be mandatory and enforced.

A survey from RED C Research has found that despite legislation for the last ten years requiring businesses to have and use a food waste bin 26% do not have one. The research highlights that among those who don't have a food waste bin, the main reasons are that their waste collector did not provide it to them (30%), they have no space for the extra bin (14%) and 10% did not know about food waste bins. The provision of a food waste bin to all businesses will help recycle more food waste.

- **Should a certification scheme be introduced for businesses to demonstrate that businesses are managing their municipal waste correctly (e.g. using the mixed dry recycling and organic waste bins properly)?**

Cré Comment: Is there a model that is currently working in another country that has shown this to be successful, if yes, then this could be developed here.

- **Have you any other comments or suggestions on how you would like to see Ireland transition to a more resource efficient and circular economy by improving our waste management practices?**

Cré Comment: No Comment.

7.3 Food Waste

Where We Need to do Better

- **Too much food is wasted in Ireland.**
- **Too much food waste is disposed of in the wrong bin. 50% of organic material is being put in the bins intended for mixed dry recycling and general waste.**

Short Term Measures 2020

- **Education and awareness in communities and workplaces will continue via Stop Food Waste Challenge and will double the reach of the campaign to citizens.**
- **Further promotion and follow up of the pilot Resource Pack for Home Economics teachers with a view to wider adoption.**
- **Carbon impact of food waste: EPA has commissioned research providing context for the importance and urgency of tackling food waste for consumers and businesses.**
- **Food Waste Charter: Working with Bord Bia companies, Government Departments, Public Sector Bodies and Agencies the number of bodies pledging to the Charter will increase to 100.**
- **Retail Sector: Agree public awareness campaign promoted by retail sector on understanding 'Use By' and 'Best Before' labelling.**
- **Commercial Food Waste: Promote findings and recommendations of EPA Commercial Food Waste study; provide training and upskilling programme for food service sector.**
- **Data: DCCAE-led Committee examining EU data requirements established. EPA research project looking at data from primary production sector is underway.**
- **Donation: Agree a voluntary target with retailers and processing industry for a percentage of edible food to be donated.**

Other Policy Options and Measures

- **Ongoing commitment to Education and Awareness to cut waste and reduce contamination**
- **DCCAE to work with the Department of Agriculture, Food and the Marine to include food waste reduction commitments in the AgriFood sector.**
- **In 2022, new EU common data gathering methodology will quantify food waste where it arises along the food chain – from farm to fork. Based on the data collected, the EU will consider whether it will adopt food waste reduction targets beyond the UN target.**
- **Support Food Donation across public and private sectors.**
- **Establish a Task Force amongst industry, research bodies, and civil society and government bodies to drive meeting our Food Waste Prevention target.**
- **Develop a strategy with the food sector to deliver our commitment to 50% reduction of food waste in line with Sustainable Development Goal 12.**

Consultation Questions – Food Waste

- **What are the underlying causes of food waste in Ireland?**

Cré Comment:

- Cheap food
- Multiple offers
- Unavoidable by-product of food prep
- Over production of single food items – non diversification of the food market
- Consumption patterns – on the go food

- **Should Ireland introduce a national prevention target in advance of a possible EU target?**

Cré Comment: Yes

- **How can Ireland become a 'farm to fork' global leader in food waste reduction?**

Cré Comment:

- Enhanced local production of imported fruit and veg – targeted investment in niche products
- Promotion of the local artisan food production to business and the community
- Promote and incentivise the use of local and 'imperfect' fruit and veg
- Provide a network and Launchpad for locally produced food

- **Have you any other comments or suggestions on how you would like to see Ireland transition to a more resource efficient and circular economy by improving our waste management practices?**

Cré Comment:

The above section on food waste acknowledges "Too much food waste is disposed of in the wrong bin. 50% of organic material is being put in the bins intended for mixed dry recycling and general waste".

However, the proposed measures by DCCAE are all on food waste prevention. There is nothing to address food waste collections, contamination issues in food waste bins.

The most effective way to reduce the impact of food waste is to minimise its production, preventing it where possible; indeed, there is an SDG to reduce food waste generation per capita by 50% at the retail and consumer level by 2030. To achieve this commitment, action must be taken. This action could include the introduction of regulations or voluntary initiatives designed to drive the redistribution of food to where it is needed and to influence consumer purchasing habits.

WRAP published a report[11] in February 2020 which shows significant association between food waste collection schemes and lower food waste arisings

WRAP regularly calculates the amount of food waste produced in the UK and identifies any factors that might increase it. The new report, looks at household food waste collections by local authorities to try and determine whether targeted collection schemes can reduce food waste arisings.

Food waste arisings were compared among local authorities with and without a separate food waste collection, whilst controlling for other factors that are also known to affect food waste arisings (and which might otherwise mask or exaggerate the effect of food waste scheme type). The study covered a five-year period from 2012/2013 to 2016/2017 and included data from 107 local authorities, covering three nations (England, Scotland and Wales).

After taking into account social deprivation, time, and other factors previously reported to influence household food waste arisings, separate food waste collections were significantly associated with lower total food waste arisings.

Resources by DCCAE should be put into food waste collection, which in turn will help prevent food waste arisings.

[11] https://wrap.org.uk/content/impact-food-waste-collections-household-food-waste-arisings?goal=0_b554dd0387-4262bd5a5c-5043289

7.4 Plastic and Packaging Waste

How can we make it easier for citizens to play a role in delivering on our targets?
Cré Comment:

Compostable Packaging looks similar to disposable packaging and this is where the problem lies. People do get confused and put it in the wrong bin.

Cré Certification Ireland is the certification body for the Cré Compostable Certification Scheme. It is a wholly owned subsidiary of Cré - the Composting and Anaerobic Digestion Association of Ireland, which is the national trade body for the sector.

The Cré Compostable Certification Scheme is the only Irish scheme providing third party independent assessment that packaging/products are compostable in Ireland and is accepted in food waste bins (brown bins).

The Cré scheme involves products certified to European Standards and then tests the products in a typical Irish composting plant to ensure the products compost under Irish conditions. The product then gets awarded a Certification enabling use of the specific Cré logo so that the product can be placed in the food waste bin.

By having this unique Cré logo, it educates the public that the product is compostable and tells the public to put the product in the food waste bin.

BENEFITS OF THE CRÉ SCHEME

- It gives confidence to packaging companies and composters that the product is compostable in Ireland.
- It gives confidence to suppliers that their products will be accepted at Irish composting plants.
- It provides a clear message to the public into which bin compostable products are to be put.
- It reduces contamination levels so that the compost is marketable.

Further details on the scheme can be found on www.compostable.ie and in the Appendix 5.

7.5 Single Use Plastic

Cré welcomes the following under the Single Use Plastic Directive:

- All oxo-degradable plastic (including oxo-biodegradable) products will be banned.
- Tethered caps on beverage containers will be mandatory by 3 July 2024

Have you any other comments or suggestions on how you would like to see Ireland transition to a more resource efficient and circular economy by improving our waste management practices?
Cré Comment:

Improving Food Waste Collections in Ireland

What is the key issue?
Public participation in food waste collections and thus the overall performance of most "brown bin" schemes is limited. One of the main limiting factors is the fact that users are not provided with suitable bags for separating food scraps in their kitchen, consequently a significant proportion either use non-compostable carrier bags or do not participate at all.

The provision of educational tools-compostable liners & kitchen caddys to householders in Sligo doubled participation, significantly increased food waste capture and reduced contamination levels from 18% to 1%. However even with the provision of these tools, it was found that the biggest contamination remaining in brown bin material is single use plastic bags. The Environmental Protection Agency Household Waste Characterisation Report 2018 echoed the findings of the Sligo report with plastic carrier bags being the dominant contaminant in collected food waste.

Compostable Bags
Conventional plastics bags are prevalent in Irish brown bins because the public is trying to do the right thing by separating its food waste for recycling. However, their good intentions is creating significant problems and costs for the organic recycling industry and despite the best efforts of the industry, the presence of conventional plastics in inputs.

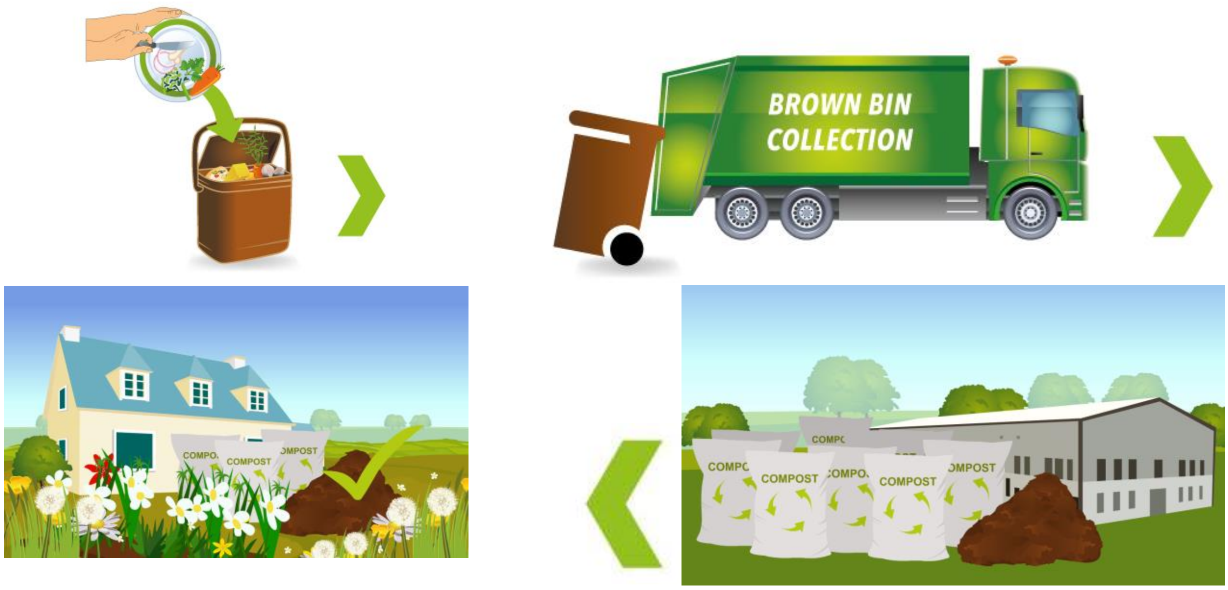
By following Italy, France, Austria and Spain's examples of replacing these single use bags (less than 50 micron) with compostable bags; it will help solve the problem of contamination in compost and help create a new market for bio-based products to be produced more locally in Ireland than importing them. We recognise that biodegradability in end of life is one important 'pull' aspect of the bioeconomy, by promoting the use of bio-based feedstocks in the manufacturing of products will help drive the 'push' factor. We believe compostable bags and products should contain a minimum of 50% renewable (bio-based) material.

Recommendation
Cré recommends that DCCAE prevents the production, sale and distribution of non-compostable single use bags and instead only allow bags (paper or compostable) which are certified to EN 13432 and contain a minimum 50% bio-based content according to IS EN 16440. All bags, paper or compostable should be subject to the tax.

Furthermore, we urgently request that DCCAE implements the ban of oxo-degradable plastic bags in accordance with the Dir 2019/904 along with the definition of biodegradable plastic whereby only plastics which are compostable with EN13432 are considered biodegradable. We propose that the term biodegradable or similar such as bio-transformative or degradable be prohibited with only "compostable in food waste collections" permitted.

7.6 Circular Economy

The composting and anaerobic digestion sector in Ireland have to potential to deliver a significant portion of the new EU Circular economy recycling rate by processing food and garden waste.



Consultation Questions – Circular Economy

- **What are the areas with greatest potential for transformation in Ireland under the Circular Economy?**

Cré Comment:
The composting and anaerobic digestion sector in Ireland has the potential to deliver a significant portion of the new EU Circular economy recycling rate by processing food waste.

If food and garden waste collections were rolled out to all households, alongside associated increases in commercial waste, this would result in approximately a further 860,000 tonnes being separately collected for organic treatment by 2030.

By 2030, organic waste could contribute 43% of the 65% recycling target for Ireland.

The EU Circular Economy package has been agreed and new legislative measures will introduce mandatory collection separation of bio-waste or recycling at source by December 31st 2023. Therefore this enforcement initiative will be vital to ensure Ireland meets its EU obligations.

- **What measures are required to increase understanding of Circular Economy principles and their uptake by relevant actors?**

Cré Comment:
Not all actors understand the principles of the circular economy. The provision of a central website with sources on the topic with the provision of examples in each waste stream would be beneficial.

The circular economy could be integrated into a general messaging on mywaste.ie to inform the general public.

- **What might be a meaningful national waste reduction target and how could it be achieved?**

Cré Comment:
WRAP published a report[12] in February 2020 which shows significant association between food waste collection schemes and lower food waste arisings. Focusing on good segregation will help aid waste reduction because by separating out waste people and businesses will become more aware of what they generate.

In section 6 of this report the submission mentions residual waste targets. These targets will help prevent waste.

- **Have you any other comments or suggestions on how you would like to see Ireland transition to a more resource efficient and circular economy by improving our waste management practices?**

Cré Comment: No comment.

[12] https://wrap.org.uk/content/impact-food-waste-collections-household-food-waste-arisings?goal=0_b554dd0387-4262bd5a5c-5043289

7.7 Citizen Engagement – Awareness & Education

We note in the short term measures Aas part of on-going awareness on MyWaste.ie, a promotional video will be developed to show how organic waste and recyclate is managed from collection to final treatment.

Cré has already developed with DCCAE a promotional video on how organic waste is managed from collection to final treatment.

Other Policy Options and Measures

Cré supports targets to be developed to reduce the contamination levels in specific bins which will inform future awareness campaigns.

Consultation Questions – Citizen Engagement

- **What campaigns would better assist householders and businesses in preventing and segregating waste properly?**

Cré Comment:
A multi-million national awareness campaign funded by Department of Communications, Climate Action and Environment (DCCAE) sustained over a five year period should result in the consumer being educated on their right to a brown bin and how to use it properly. Consumers in turn request the bin from their waste collector and use it correctly, promoting low contamination of the bin for the processor, enabling the production of quality compost/digestate.

- **Should this be funded by Government or should the sector play a role in funding campaigns?**

Cré Comment:
Yes this should be funded by the Government with waste collectors as active participants in the campaign in some shape should as maybe a financial contribution.

- **Waste Collectors have a condition in their permits to maintain on-going communication with their customers in accordance with their customer charter. Do you agree that collectors are giving sufficient information to their customers in relation to separating waste into the 3 bins?**

Cré Comment:
No, not all waste collectors are giving information on brown bins. A review of all waste collectors website by Cré in 2018 identified the following:

The following survey results are based on 50 collectors with websites:

- 41 companies advertise a brown bin collection service on their website
- 9 companies make no reference to brown bin service on their website
- 5 offer a kitchen caddy whereas 45 do not
- 1 offer compostable bags whereas 49 do not
- 28 provide a list of 'what goes into a brown bin', 22 do not
- 2 use the same list as brownbin.ie of 'what goes into a brown bin', 26 do not
- 4 use the brownbin.ie cartoon
- 3 provide a link to brownbin.ie
- None use the brownbin.ie instruction leaflet.

- **Do you think information stickers for bins showing what's accepted in each bin should be rolled out to all households?**

Cré Comment:
Yes. In relation to brown bins, there is no need to put this sticker on the outside brown bin. It should be placed on the 7 litre kitchen caddy located in the kitchen. A pilot is going on in three town where the effectiveness of the sticker on the residual bin 'no food waste please' will be evaluated. If this sticker proves beneficial, it should be done nationally. Another option is if new bins have details imprinted on them like a food waste bin in Portugal (see photo below).

	
Sticker on 7 litre kitchen caddy	Sticker on residual bin

Photo of Food Waste Bin in Portugal

- **Have you any other comments or suggestions on how you would like to see Ireland transition to a more resource efficient and circular economy by improving our waste management practices?**

Cré Comment:

Awareness

Efforts and resources need to be refocused to 'empowerment of the consumer' through a multi million national awareness campaign per year over a five year period, funded by Department of Communications, Climate Action and Environment (DCCAE).

A good national sustained awareness campaign should result in the consumer being educated on their right to a brown bin and how to use it properly. They in turn ask their waste collector for one and use it correctly by having low contamination for the processor to produce compost.

By waste collectors having a large quantity of brown bin collected, it results in increased efficiencies for waste collectors. It then begins to make more economic sense to be adding on rural routes.

Coordinated Brown Bin Awareness Plan

A coordinated national brown bin awareness campaign is required to be developed with input from collectors, processors and regulators. Once developed all stakeholders should support the campaign in order for it to be a success. All stakeholders has experiences in this area and all their expertise should be pooled together to develop the plan and then each stakeholder implement their part of the plan.

A expert media company needs to be hired to find a 'catchy message' such like the 'Race Against Waste Campaign and the Road Safety Authority campaign on tyre tread depth safety 'when tyres loose grip – you loose everything- http://www.rsa.ie/RSA/Road-Safety/Campaigns/Current-road-safety-campaigns/Tyre-Safety1/

Impactful advertising as part of the *Race Against Waste* campaign.

Cré developed the national brown bin education plan scope (see below) in 2018 as part of the Cré submission on the 'Draft European Union (Household Food Waste and Biowaste (Amendment) Regulation 2018'. To date the committee was established and currently we are step 3 in the chart below.

NATIONAL BROWN BIN EDUCATION PLAN SCOPE

7.8 Waste Management Infrastructure

Long Term Target

- **The waste sector to develop more indigenous waste facilities to recycle waste in the State and capture resource potential here.**

Short Term Measures 2020

- **Assessment of Critical Waste Infrastructure to be completed in 2020 by the Regional Waste Management Planning Offices in line with the Strategic Emergency Management Guideline Document no. 3 on Critical Infrastructure Resilience (SEM3).**
- **Reserve capacity to manage waste to be put in place in 2020, in line with the on- going work of the local authority sector to develop a roadmap for the delivery of contingent capacity in case of a short term emergency.**
- **Complete overview of current status for all sites under the landfill remediation programme.**

Other Policy Options and Measures

- **New Waste Management Plan(s) to be in place by January, 2022.**
- **Measures to incentivise/facilitate the development of facilities which can process recyclable materials in the State to be introduced.**
- **Legislation and procedures regulating the development of waste infrastructure to be examined to see if processes and timelines can be streamlined.**
- **Legislation/procedures to strengthen the provision of contingent capacity to be introduced.**
- **Legislation to strengthen the powers of the regulatory authorities to ensure that collectors have contingent capacity in place and that waste can be directed by the regulatory authorities to be introduced.**

Consultation Questions – Waste Management Infrastructure

- **Should one national waste management plan be produced in place of the 3 current plans?**

Cré Comment:
Ireland is a small country and should have one waste management plan instead of three.

- **Should the regional offices be set up on a statutory basis?**

Cré Comment:
Clarification needs to be provided by DCCAE to explain the pros and cons of the regional office being set up on a statutory basis.

- **Should the State assist in funding the development of indigenous waste recycling facilities? If so, how should this be funded?**

Cré Comment:
Yes the state should fund capital grant aid for equipment to remove contamination. Over the next five years, the investment requirements for existing facilities in the RoI need to take place using a high-level assessment. Overall, it is estimated that approximately in the region of €50 million of capital and operational expenditure is required to maintain the existing infrastructure and to remove contamination at facilities over the next five years.

- **Have you any other comments or suggestions on how you would like to see Ireland transition to a more resource efficient and circular economy by improving our waste management practices?**

Cré Comment:
There are composting and biogas facilities that have underutilised capacity. It would be good to see local waste management infrastructure supported.

7.9 End of Waste

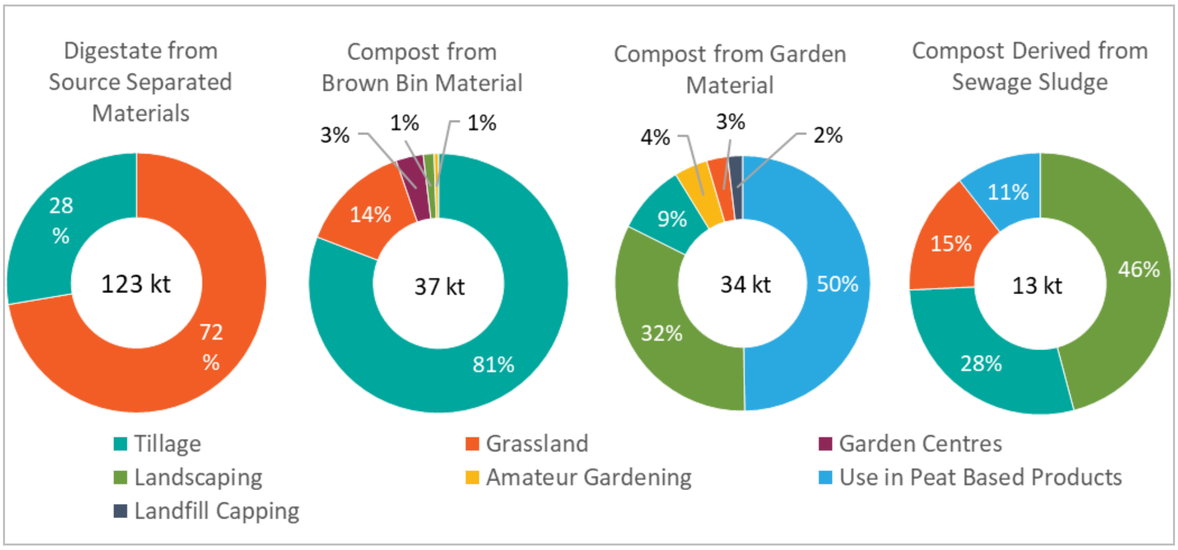
While NI certifies digestate and compost under the PAS100 and PAS110 accreditation schemes, the RoI currently has no equivalent standard in place. The PAS 100/110 accreditation allows producers to demonstrate that they have met the end of waste criteria as defined in the Waste Framework Directive (WFD) and as such products can be managed outside of waste regulations.

It was reported by operators in Ireland that a standard might assist with the overall valuing of compost and digestates in end markets, for it to be recognised as a product with significant environmental benefits.

Benefits of digestate and compost should be promoted by the industry, and this material should be viewed as a product with value as opposed to a by-product/waste from treatment.

To further develop the market for compost and digestate in Ireland and maximise the value gained through the use of these products, an End-of-Waste Criteria should be developed, based on best practice in other European nations, for compost and digestate in Ireland.

Compost and Digestate
A recent survey was conducted by Cré on markets for compost and digestate in 2018. The results are shown in the charts below.



To further develop the market for compost and digestate in Ireland and maximise the value gained through the use of these products, an End-of-Waste Criteria should be developed, based on best practice in other European nations, for compost and digestate in Ireland.

National End of Waste Standards for Quality Compost and Digestate
Cré is conducting a research project on end of waste standards for quality compost and digestate in Ireland. This project is funded under the EPA Research Programme 2014-2020. The EPA Research Programme is a Government of Ireland initiative funded by the Department of Communications, Climate Action and Environment.

The project findings would inform regulators and policy makers of any changes required to implement changes to quality standards in waste licences and waste permits and also what approach should be taken to develop national End-of-Waste Criteria for compost and digestate in Ireland. Recommendations of this research should be implemented to help develop markets for compost and digestate from food and garden waste.

Boldrin *et al.,* (2010)[13] concluded in a Danish study that using compost instead of peat leads to the reduction of greenhouse gases. It was assumed that compost replaced peat on the basis of volume. Carbon Storage Effects and avoided the use of mineral fertilisers were included in the greenhouse gas inventory. Use of compost could allow an amount of carbon bound in the soil. This amount will depend on where and how compost is used and is very challenging to quantify.

13 Boldrin, A., Hartling, K.R., Laugen, M. Christensen, T.H. (2010) Environmental inventory modelling of the use of compost and peat in growth media preparation. Resrouce. Conserv. Recycl. 54, 1250 -1260

7.10 Waste Enforcement

- **What, in your view, are the factors leading to waste crime (please tick one box)**

• **Ineffective enforcement by the authorities**	**Yes**
• **Ineffective penalties**	**Yes**
• **Waste Market Factors**	
• **Lack of awareness**	
• **Other (please specify)**	

- **What measures are required to respond to the links between waste crime and other forms of serious criminal offences, such as organised crime?**

Cré Comment:
A dedicated unit within the single waste regulator offices (see section 7.1) which liaise with CAB and other enforcement stakeholder such as Gardai Siochana.

- **What changes could make the regulatory or industry response to serious and organised waste crime more effective?**

Cré Comment:
Higher financial penalty and longer prison sentencing upon conviction.

- **Are the penalties available under the Waste Management Act appropriate?**

Cré Comment:

- The financial penalties under the waste management needs to be increased to levels that act as a deterrent.
- A single waste regulator would with powers of 'administrative sanctions' that if you break part of your waste collection licence you could be fined a percentage of your revenue.

- **What other penalties could be considered for illegal dumping by households/members of the public?**
  The current penalty for littering or illegal dumping is an on the spot fine of €150 or a maximum fine of €3000 if convicted in a district court. These levels are too low and need to be increased to act as a deterent.

- **Are there examples of existing good practice to prevent illegal dumping?**
  "US EPA illegal Dumping Prevention Guide".

- **What contribution to the cost of the enforcement system should the waste industry make?**
  The waste collectors could contribute to the enforcement system especially on specific enforcement activities such as making sure households are on a waste collection service which includes the provision of a brown bin.

- **Should financial provision be a requirement for permitted waste facilities?**

Cré Comment:
Yes, but it have to reflect the type and scale of the activity. The methodology to calculate the financial provision should be consistent with EPA approach. The Local Authorities and the EPA should work together to ensure a uniform approach is taken that is fair for all.

- **Have you any other comments or suggestions on how you would like to see Ireland transition to a more resource efficient and circular economy by improving our waste management practices?**

Cré Comment:

Enforcement Grant Aid
Enforcement is very important, without appropriate enforcement by the authorities it is very difficult for waste collectors to meet their targets for the roll out of the brown bin.

The enforcement grant aid provided to local authorities in 2014 was linked to their performance in the enforcement of food waste regulations.

It is considered that the linkage of grant aid to performance should be continued and the percentage of grant aid linked to performance.

It is recommended that this enforcement performance should be evaluated on the tonnage of household and non-household (EWC code 20 01 08) waste collected.

Single Waste Regulator

In August 2006, the Department of the Environment, Heritage and Local Government initiated a public consultation process, aimed at examining the possible regulation of the waste management sector. The Department's consultation paper posed the following issues for discussion:

- Is another regulator needed for the waste management sector?
- What model of regulation is most appropriate?
- Who will be responsible for the regulation of the waste sector?
- What services should fall within the remit of a regulator?
- What functions should a regulator have?

In recent years, the suggestion of a single waste regulator was raised during the discussion on the household waste charging.

The concept of a single waste regulator deserves merit for further investigation as there are many regulators involved in regulating the waste sector. Streamlining the responsibility to a single entity would results in efficiencies and development of staff with focused legal expertise.

Currently, there is need for greater enforcement of the commercial and household food waste regulation.

A variation on this concept could be 'a single waste regulator for the commercial and household food waste regulations'. This could be tendered out. For example, Dublin City Council tendered out the enforcement of the fats, oil and grease regulations and the commercial food waste regulations.

The idea and scope of a single regulator need more consultation with all stakeholders.

Cré acknowledges that there are issues within the currently market such as there are good waste collectors making an effort to promote the brown bin and in the same area competitors are not providing the service. The good collector is in effect put at a commercial disadvantage for complying with the law.

As a regulator there are a number of existing examples of this already in Ireland. There can be a suite of regulators tools given to a single waste regulator.

One possible option is:
Waste collection permits are taken back from all the waste collectors and instead given a licence from the single waste regulator to operate. The National Waste Permit Collection Office (NWPCO) power is limited such as revoking a permit. NWPCO don't have the power of 'administrative sanctions'.

A single waste regulator would have the powers of 'administrative sanctions' the administration sanction range from low end of – we will publish a report if you are doing something wrong and order you to pay back your customers – to gold standard that if you break part of your licence you could be fined a percentage of your revenue.

Enforcement of Food Waste Regulations
The Household Food Waste and Bio-Waste Regulations impose obligations on both waste collectors and householders. Waste collectors are obliged to provide a separate collection service for household organic waste.[14] Householders are required to segregate organic waste and have it separately collected by an authorised waste collector, they must not dispose of it in the residual waste collection, (or alternatively must compost at home; or take to an authorised treatment centre for recover).

Historically, there has been limited effective enforcement of the regulations. With a lack of effective enforcement, there is a reduced disincentive to ignore the requirements of the regulations. Effective enforcement of the regulations would increase the organic material captured.

[14] *Food Waste Regulations - Cork City Council*, accessed 12 November 2019, https://www.corkcity.ie/en/council-services/services/environment/waste-enforcement/food-waste-regulations.html

7.11 Waste Data and Waste Flows

- **Do you believe it would be beneficial to have all/most waste data available on at least a quarterly basis?**

Cré Comment:
Yes, this would be beneficial to have regular data. Waste data is published quarterly in Northern Ireland. The data collected should be used by regulators to have targeted enforcement of the commercial and household food waste regulations.

- **What resources are needed to validate this data more quickly and what are the barriers?**

Cré Comment: No comment.

- **How would you balance the need for validated reporting data for EU reporting against the desire for more up to date statistics?**

Cré Comment:
The current system is in line with the EU Requirements But perhaps interim reporting could help provide advance warning if targets are not going to be met.

- **Do you believe that all waste should and could be tracked from site of creation to final destination?**

Cré Comment:
Yes everything, especially food and garden waste should be tracked from generation to the final processing destination.

- **Are there confidentiality or other issues for industry in reporting on waste flows?**

Cré Comment: There are confidentially issues for the industry to be consider, however information on waste flows may be provided in a format which allows opportunity to develop markets from by products from secondary sources without prejudice to the original producer.

- **What changes need to be put in place to facilitate better reporting?**

Cré Comment: Real time systems.

- **What uses can be made of having more detailed, accurate, timely data?**

Cré Comment:
Immediate response and proactive approach to intervention.
The data should be used for targeted enforcement. It is important that the effort made to provide the data that it is used.

- **What penalties should be in place for the non-provision of data?**

Cré Comment:
Financial penalty and prison time.

- **Should there be voluntarily reporting on particular waste streams and its treatment destination prior to legislative changes being put in place?**

Cré Comment:
Yes, this will enable lessons to be learnt on how to improve and streamline reporting. There should be a template provided for voluntary reporting.

- **Have you any other comments or suggestions on how you would like to see Ireland transition to a more resource efficient and circular economy by improving our waste management practices?**

Cré Comment: Yes. The reporting of all waste streams without exception and including Article 27 streams, will provide a baseline on the production of by-products or secondary raw materials required to facilitate a truly circular economy, would be advantageous.

7.12 Research and Innovation

- **What are the research areas you would consider to be important in developing a circular economy?**

Cré Comment:

Developing the AD and composting sector further will enable organic materials to be managed in a more environmentally sound manner, in line with circular economy principles. The AD and composting sectors, if adequately supported, can play an important role in helping the Ireland meet carbon targets. Carbon sequestration in soils is increasingly recognised as a relevant measure to combat climate change. One way to increase carbon uptake in soils is the application of compost, as it contains a high percentage of stable organic matter.

In 2018, a Dutch government funded research program was set up to study the potential for carbon storage in mineral agricultural soils and to propose practical measures. The consortium is led by Wageningen University and supported by CLM and Louis Bolk research & consultancy. An annual budget has been made available by the Dutch Ministry of Economic Affairs & Climate Change. A study in Ireland that matches the current work funded by the Government in the Netherlands is likely to be beneficial.

- **What new research programmes/initiatives do you think could be put in place?**

Cré Comment:

A research programme using field trials using compost and digestate to examine carbon sequestration should be conducted.

- **What do you see as the main barriers/enablers to fostering a positive research culture around the circular economy?**

Cré Comment: Value of secondary raw materials, commercial sensitivity, lack of understanding of the concept of circular economy.

- **Do you think research on waste, resource efficiency and the circular economy could be better publicised and more readily accessible? How?**

Cré Comment:

The research done by the EPA in this area is well publicised, however it should be more accessible and promoted to the producers of the waste resources.

- **What further incentives could be put in place to encourage research?**

Cré Comment: For students working in Dublin on research projects, there should be funding provided for their accommodation. Currently Trinity College has reported to Cré that the housing crisis in Dublin it making it very difficult to recruit research students.

- **Have you any other comments or suggestions on how you would like to see Ireland transition to a more resource efficient and circular economy by improving our waste management practices?**

Cré Comment: No.

7.13 Consumer Protection and Market Monitoring

The CCPC recommended the establishment of an economic regulator for household waste collection.

- **In your opinion, should an economic regulator be established? In considering your reply it is recommended you consider the detailed rationale set out in the CCPC report, available here.**

Cré Comment: No it should not be established.

Cré acknowledges that there are issues within the currently market such as there are good waste collectors making an effort to promote the brown bin and in the same area competitors are not providing the service. The good collector is in effect put at a commercial disadvantage for complying with the law.

The solution to this is to focus on the existing market structure with improved enforcement. This approach will lead to the quickest way to improving the market.

- **If a regulator was to be introduced what powers should the office have? Should they be confined to economic powers?**

Cré Comment: see section 7.10 on single waste regulator.

- **Should a new office be set up or should the powers of existing regulator be broadened?**

Cré Comment:
n/a

- **What alternatives are there to setting up a regulator, for example, improved regulatory oversight for customer's complaints?**

Cré Comment:
Whilst we see the value of a single waste regulators (see section 7.10) we believe this question is confusing.

- **Do you believe the information currently available on kerbside waste collection pricing could be improved, and if yes, how?**

Cré Comment:
A central website in which the public can search and compare waste collector charges should be develop similar to bonkers.ie (which is accredited by the Commission for Regulation of Utilities as an impartial, accurate and independent supplier of energy price comparisons).

- **Do you believe that the information prepared by the Price Monitoring Group is useful? If No, what changes would you like to see?**

Cré Comment: No, because it has not picked up all market price increases.

- **Given that the last time flat rates fees were identified was July 2018, do you believe the work of the Group should continue?**

Cré Comment: Yes.

- **Would you support the Group undertaking whole of market monitoring including publishing prices for household waste collection for all collectors in all areas?**

Cré Comment: Yes.

- **Do you believe there needs to be further oversight of the waste sector from a consumer rights perspective?**

Cré Comment: No comment

- **Do you believe that a consumer complaints body should be put in place?**

Cré Comment: No comment

- **If yes, what powers would such a body have?**

Cré Comment: No comment

- **Should it be included within an existing body e.g. CCPC or the National Waste Collection Permit Office?**

Cré Comment: No comment

- **Is further regulation from a consumer perspective of the sector needed?**

Cré Comment: No comment

- **If yes, what measures do you see as necessary for further regulation or what legislation needs to be strengthened?**

Cré Comment: No comment

7.14 Green Public Procurement

- **What are the barriers to public authorities using GPP?**

Cré Comment:
There is a lack of knowledge of the properties of compost and digestate. National compost and digestate standards would help market acceptance.

- **How can business support more widespread use of GPP?**

Cré Comment: Mandatory green procurement policy.

- **What % target should apply to the use of GPP in Ireland?**

Cré Comment: GPP should not have a mandatory target but should be the primary decider when purchasing products and services.

- **Have you any other comments or suggestions on how you would like to see Ireland transition to a more resource efficient and circular economy by improving our green public procurement practices?**

Cré Comment:
There should be mandatory specification for the use of compost and digestate in public projects.

7.15 Bioeconomy

- **What kinds of activities to increase the financial support for bioeconomy development in Ireland?**

Cré Comment:
There should be provision for a green bank and financial incentives to promote the development of the bioeconomy e.g. lower rate of vat.

The industries in Ireland should be provided research funding on bioeconomy topics, particularly in the SME sector. Through this research support, facilities may be able to develop higher value biobased by-products in addition to the traditional end products.

- **Are current policy options in relation to innovation & enterprise policy instruments suitable or sufficient to address the development of systemic and cross-cutting bioeconomy approaches, business models and new value chains?**

Cré Comment: No comment.

- **How best to develop a value chain approach to link bio-based actors, value chains and territories?**

Cré Comment: A facilitated fora to engage producers, products and regions in the bioeconomy.

- **Have you any other comments or suggestions on how you would like to see Ireland transition to a more resource efficient and circular economy by improving our waste management practices?**

Cré Comment:

Potential of the Bio Based Bioeconomy Sector in Ireland

The European bio-economy employs some 21.5 million people and presents an annual market worth over €2 trillion, with significant potential for further growth, as EU member states supplement food production with sustainable technologies for production of biofuels, bio-fertilisers, bio-chemicals and bio-plastics.

A recent study of the potential of biorefining in Scotland alone found it could be a 1 billion turnover sector by 2025. If Ireland had a vision to set up a similar biorefining sector, we could have similar results.

Ireland has a long and strong history of bio-based production and processing. There is great scope beyond the current production and processing scenarios in place in the bio-processing industries to increase production, add value, and generate additional employment.

Benefits for Ireland

- Develop the potential of organic waste;
- Diversify and grow farmers' incomes;
- Replace at least 30% of oil-based chemicals and materials with bio-based ones by 2030.
- Create a competitive bio-based infrastructure in Ireland, boosting job creation, 80% of which will be in rural and underdeveloped areas.
- Deliver bio-based products that are comparable and/or superior to fossil-based products in terms of price, performance, availability and environmental benefits.
- The new bio-based products will on average reduce CO_2 emissions by at least 50% compared to their fossil alternatives.

The Irish bioeconomy strategy needs to enable a swift transition from fossil to bio-based resources.

Cré is primarily focused on the development of the bio-based industries within the bioeconomy. The terms bioeconomy and bio-based economy are often used interchangeably, but for the purposes of clarity our view is the use of 'bio-based' is reserved for products derived wholly or in part from biological resources. Long term, Cré believes that our sector needs to reposition the sector as key components of bioeconomy sector in Ireland.

Cré aims to:

- promote and develop the production and use of bio-based products in Ireland;
- to unite people working in these industries and to develop partnerships with those who shared synergies:
- Have the bioeconomy agenda at the centre of political debate on sustainability and economic growth in Ireland.

The bio-based products sector needs is for policies which help create markets, and history shows that these can function well in drawing inward investment.

Action

Encourage the sector to be active actors in the bioeconomy as envisaged above, the Government needs to:

- Ensure security of feedstock supply of food waste to existing reprocessing infrastructure
- Provide supports to develop the anaerobic digestion sector

Once this is stabilised these organisations can invest in research and development in the bioeconomy area.

7.16 Construction and Demolition Waste

Cré has no comments on this subject.

7.17 By Products

Cré has no comments on this subject.

7.18 Exemptions

Cré has no comments on this subject.

7.19 Extended Producer Responsibility (EPR)

Cré has no comments on this subject.

7.20 Household Bulky Waste

Cré has no comments on this subject.

7.21 Textile – Waste and Recycling

Cré notes that textiles are put into the brown bin by the public and Cré would encourage any initiative which would help stop the public from putting textiles in the brown bin.

One of the short terms measures to ban textiles from residual is proposed by DCCAE and this should be extended to also include a ban in brown bins.

8. Appendices

Appendix 1

Food and Agriculture Organization
of the United Nations

Food wastage footprint & Climate Change

Global food loss and waste

The 2011 FAO assessment of global food losses and waste (1) estimated that each year, one-third of all food produced in the world for human consumption never reached the consumer's table. This not only means a missed opportunity for the economy and food security, but also a waste of all the natural resources used for growing, processing, packaging, transporting and marketing food.

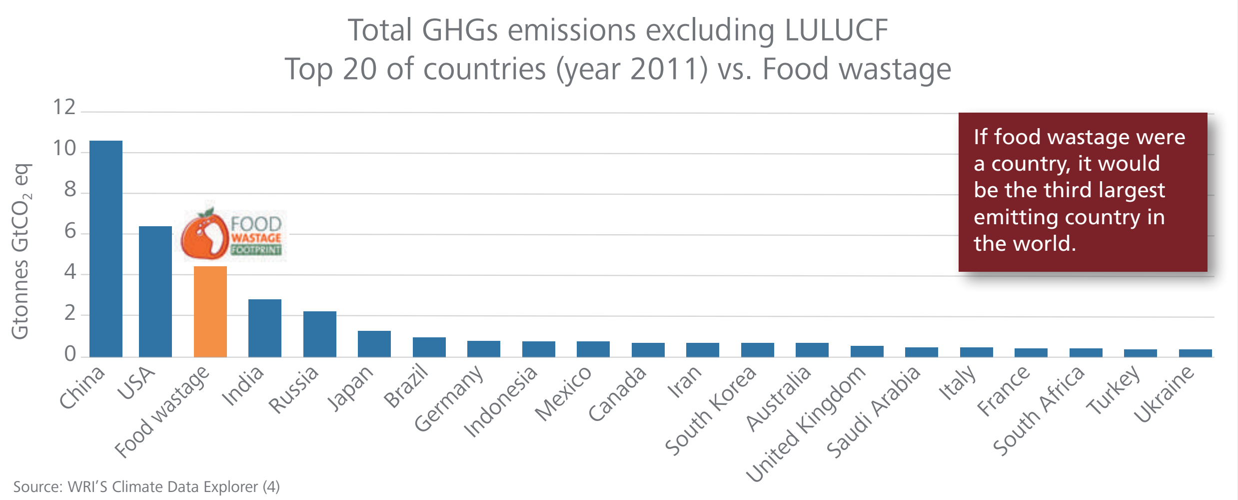
Through an extensive literature search, the 2011 assessment of food wastage volumes gathered weight ratios of food losses and waste for different regions of the world, different commodity groups and different steps of the supply chain. These ratios were applied to regional food mass flows of FAO's Food Balance Sheets for the year 2007.

Food wastage arises at all stages of the food supply chains for a variety of reasons that are very much dependent on the local conditions within each country. At a global level, a pattern is clearly visible; in high income regions, volumes of wasted food are higher in the processing, distribution and consumption stages, whereas in low-income countries, food losses occur in the production and post-harvesting phases.

In low income countries, the lack of infrastructure and lack of knowledge on proper storage and food handling, combined with unfavourable climatic conditions, favour food spoilage. In higher income countries, aesthetic preferences and arbitrary sell-by dates are factors that contribute to food waste.

Carbon footprint of global food wastage

FAO quantified the food wastage footprint on natural resources (2), most notably its carbon footprint. Carbon footprint calculations – based on the 2011 assessment of food wastage volumes (1) and emissions factors taken from Life Cycle Assessment studies – were estimated at 3.3 GtCO_2 eq for 2007 (excluding land use change). Using the most recent Food Balance Sheets (2011), this figure is updated to 3.6 GtCO_2 eq, plus 0.8 GtCO_2 eq from food wastage emissions from deforestation and managed organic soils (3). Thus, the total carbon footprint of food wastage is around 4.4 GtCO_2 eq per year.



Source: WRI'S Climate Data Explorer (4)

Global food loss and waste generate annually 4.4 GtCO_2 eq, or about 8% of total anthropogenic GHG emissions (5). This means that the contribution of food wastage emissions to global warming is almost equivalent (87%) to global road transport emissions (6).

The 2012 market value of food products lost or wasted was USD 936 billion; that is in the range of the GDP of countries such as Indonesia or the Netherlands. According to the methodology of the FAO report on full-cost accounting (3) and using the estimate of the social cost of carbon that mainly considers damage costs or defensive expenditures, the cost of GHG emissions from global food wastage is USD 411 billion.

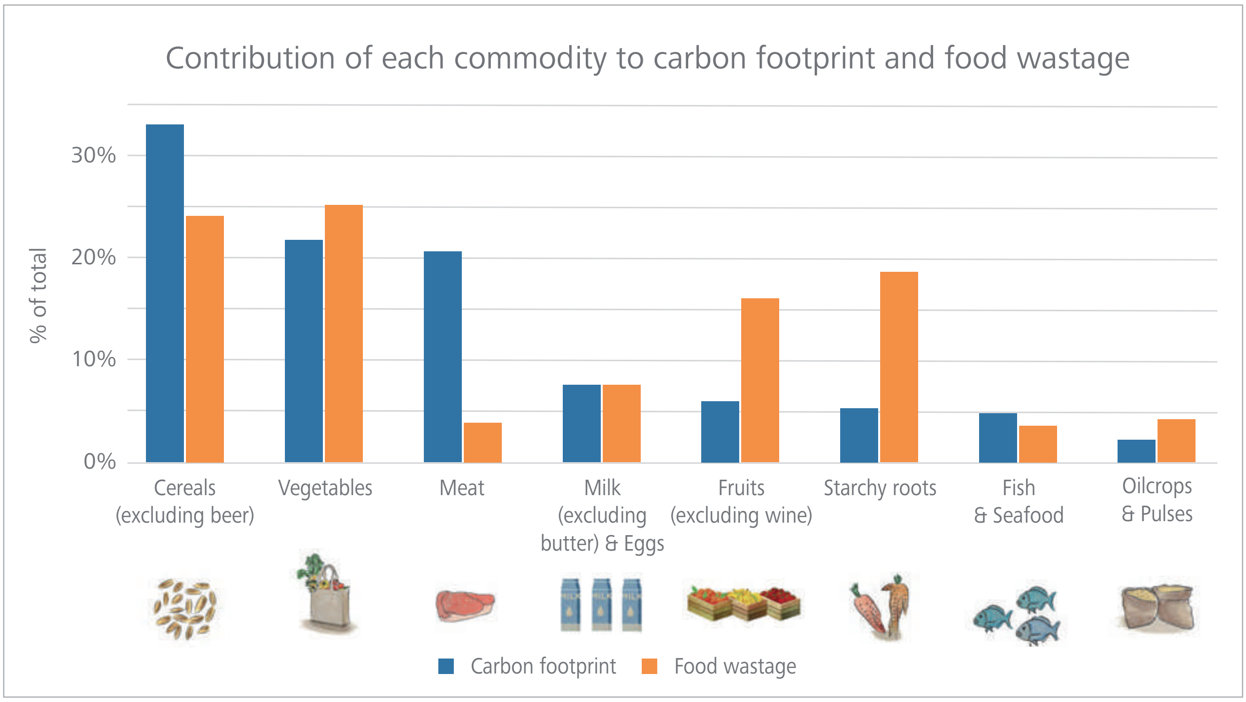
Carbon footprint intensities

The carbon footprint of a food product is the total amount of GHG emitted throughout its lifecycle, expressed in kilograms of CO_2-equivalents.

GHG emissions of the production phase (including all agricultural inputs, machinery, livestock, soils) and successive phases (such as processing, transportation, preparation of food, waste disposal) are all included in this calculation.

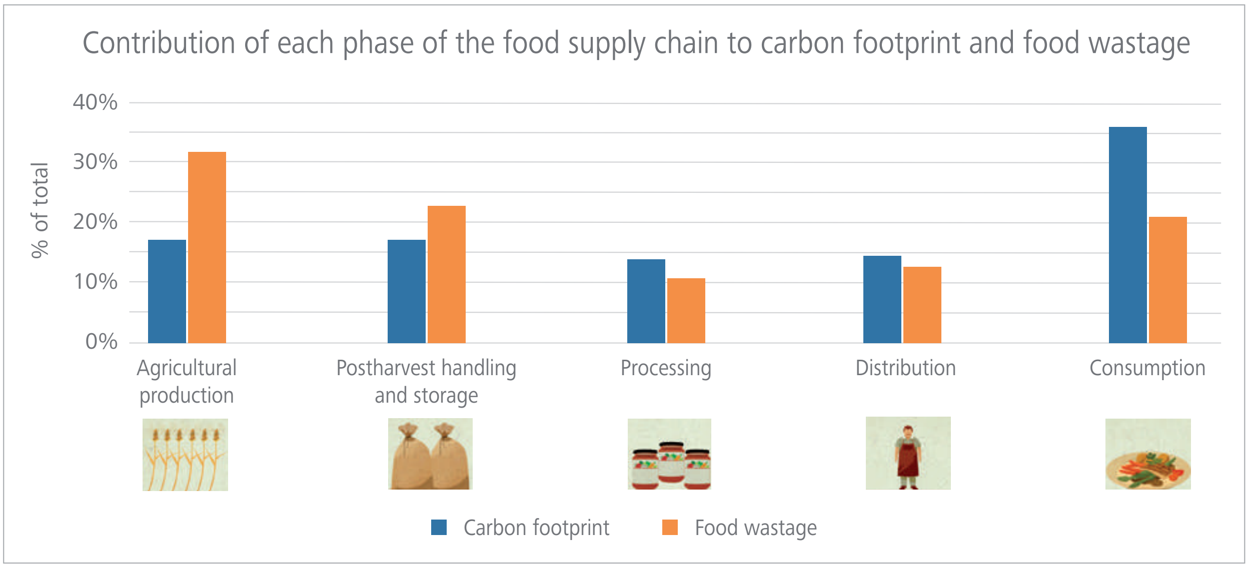
Thus, one kg of wheat, or one kg of beef, have different carbon footprints, since their life cycles are different, emitting specific types and varying amount of greenhouse gases.

Products hold different carbon intensities. For example, vegetable production in Europe is more carbon-intensive than vegetable production in Industrialized and Southeast Asia, as Europe uses more carbon-intensive means of production, such as artificially heated greenhouses. Inversely, cereal production in Asia is more carbon intensive than cereal production in Europe due to the difference in the type of cereal grown: rice on average has higher impact factors than wheat. Rice is a CH_4 emitting crop because of the decomposition of organic matter in paddy fields (1 kg of CH_4 is the equivalent of 25 kg of CO_2).



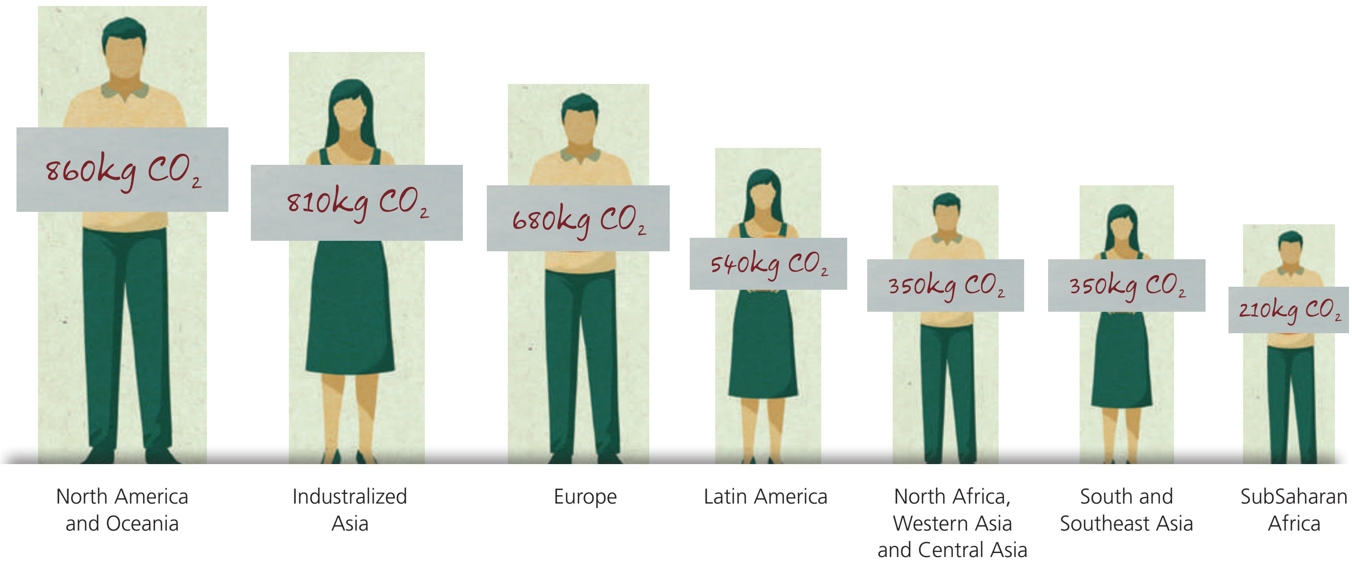
Despite meat being a relatively low contributor to global food wastage in terms of volumes (less than 5% of total food wastage) it has a significant impact on climate change, contributing to over 20% of the carbon footprint of total food waste (see chart above). This is because meat carbon footprint includes the emissions from producing a kilogram of meat (e.g. the methane emitted by ruminants), the emissions related to feed provision (e.g. the fertilizer used for the production of feed) and emissions from manure management. Thus, efforts to reduce GHG related to food wastage should focus on major climate hotspots commodities, such as meat and cereals.

The highest carbon footprint of wastage occurs at the consumption phase (37% of total), whereas consumption only accounts for 22% of total food wastage. This is because one kilogram of food that is wasted further along the supply chain will have a higher carbon intensity than at earlier stages.



The further along the chain the food loss occurs, the more carbon intensive is the wastage. For example, a single tomato spoiled at the harvesting stage will have a lower carbon footprint than tomato sauce wasted at the retail store, since the harvesting, transportation and processing accumulates additional greenhouse gases along the supply chain.

On a global average, per capita food wastage footprint on climate in high income countries is more than double that of low income countries, due to wasteful food distribution and consumption patterns in high income countries.



Food wastage reduction scenario and climate change mitigation

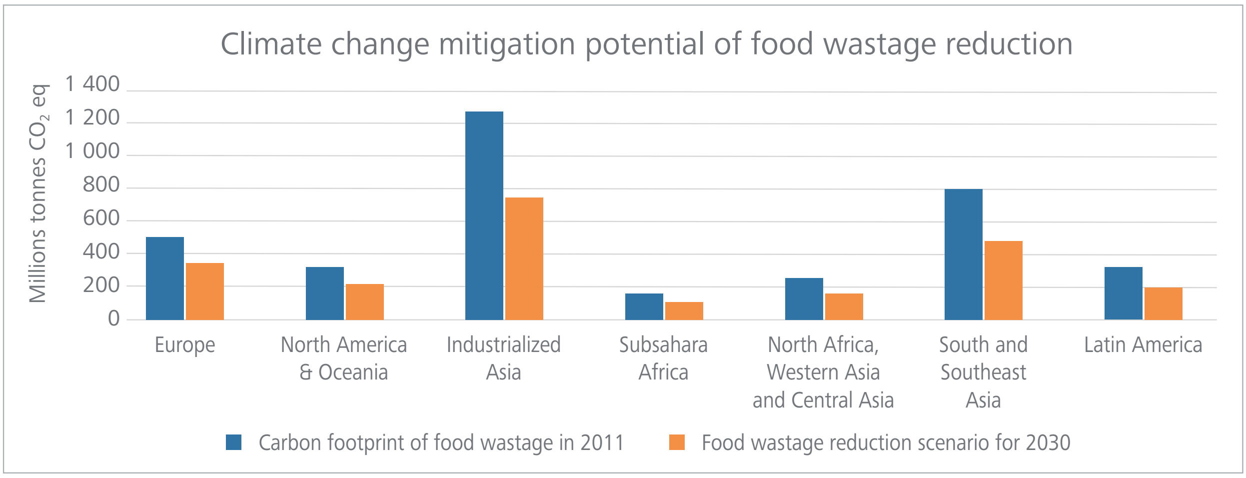
United Nations Sustainable Development Goal 12 (SDG 12) on "Ensuring sustainable consumption and production patterns" includes a specific food waste reduction target: "by 2030, to halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses".

The SDG 12 target of 50% food waste reduction is hereby combined with assumptions on feasible food loss reduction ratios, for each commodity group, in order to calculate a possible scenario.

Assumptions for food wastage reduction ratios achievable by 2030
Phases "Agricultural production" and "Processing"
• 5% reduction of 2011 food wastage in developed countries • 15% reduction of 2011 food wastage in developing countries (a larger progress margin is assumed for developing countries)
Phase "Post-harvest handling and storage"
• 5% reduction of 2011 of food wastage in developed countries • 54% reduction of 2011 food wastage in developing countries (reduction estimated to be needed to reach the average percentage of wastage observed in developed countries for most commodity groups)
Phases "Distribution" and "Consumption"
• 50% reduction of 2011 food wastage amounts in all regions

The proposed scenario would lead to a reduction of the carbon footprint of food wastage by 38%, or 1.4 $GtCO_2$ eq per year (see chart below); this would be equivalent to the GHG emissions of the Japanese economy. Considering that post-harvest handling reductions are feasible in developing countries through improvements in their food systems (e.g. adopting improved technologies, better handling practices, efficient markets), investment in reducing post-harvest losses represent an important climate mitigation strategy.

Despite data and modelling uncertainties, the magnitude of the figures above suggest that a reduction of food losses and waste at global, regional and national levels would have a substantial positive effect on societal resources and in particular, climate change.



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http://www.fao.org/nr/sustainability/food-loss-and-waste

bb144e/1/11.15

Appendix 2

Table of Tonnes per County per year (2012-2017) from Waste Collectors Annual Environmental Reports for Non- Household (Commercial) and Household Brown Bin Materials – EWC 20 01 08

County	2012		2013		2014		2015		2016		2017	
	Non-Household	Household	Non-Household	Household	Non-Household	Household	Non-Household	Household	Non-Household	Household	Non-Household	Household
Carlow	244	798	301	1,362	883	902	318	884	350	1,030	472	1,186
Cavan	0	187	147	148	2	40	14	50	48	169	541	134
Clare	1,741	1,882	1,214	2,091	1,641	2,545	1,531	2,213	1,787	2,372	1,879	2,459
Cork	4,218	1	5,932	583	6,739	2,046	9,191	4,573	9,860	7,799	7,573	9,776
Donegal	245	0	246	0	410	4	425	77	526	123	731	135
Dublin	21,323	44,747	20,668	45,826	26,797	51,850	19,140	52,370	26,424	50,867	19,961	56,509
Galway	0	7,693	3,959	7,374	5,217	7,194	5,073	7,159	4,798	7,500	5,190	8,640
Kerry	220	603	1,102	563	1,229	964	1,538	1,789	1,470	1,845	1,424	2,123
Kildare	1,995	5,963	2,421	6,558	5,750	7,549	1,932	6,574	2,351	7,591	2,970	8,067
Kilkenny	1,278	243	654	265	1,795	329	946	792	683	815	481	425
Laois	548	942	282	884	1,003	795	568	1,700	556	1,569	2,896	2,201
Leitrim	307	1	359	19	393	174	419	356	473	357	478	435
Limerick	1,657	2,844	1,863	3,132	2,069	3,612	2,121	4,832	6,268	5,807	3,981	6,021
Longford	0	338	0	333	0	396	0	374	8	447	42	453
Louth	1,312	1,921	202	1,597	266	1,391	780	1,405	1,890	3,092	1,562	3,473
Mayo	1,384	1,064	1,041	644	1,077	633	1,115	695	1,153	672	2,393	966
Meath	576	119	638	509	19,942	1,403	979	2,211	1,640	4,124	1,716	3,180
Monaghan	418	668	387	304	265	318	1,088	291	1,783	390	1,044	339
Offaly	492	333	53	775	219	670	52	1,007	468	1,010	89	1,231
Roscommon	114	427	50	435	5	361	134	926	170	990	166	1,067
Sligo	206	109	198	56	215	170	692	291	909	454	695	475
Tipperary	698	1,755	489	2,032	997	2,478	625	3,030	878	3,658	760	4,022
Waterford	2,101	5,467	3,377	5,462	157	5,618	822	4,737	941	5,156	245	5,989
WestMeath	358	176	233	692	427	282	1,903	458	2,141	69	1,923	253

Wexford	737	1,384	1,323	1,104	1,727	1,261	1,306	1,240	1,268	2,040	706	2,192
Wicklow	891	109	2,364	130	3,151	648	1,416	1,969	1,451	2,555	2,078	2,776
Total Tonnes	**43,063**	**79,774**	**49,500**	**82,877**	**82,375**	**93,631**	**54,129**	**102,003**	**70,291**	**112,502**	**61,995**	**124,527**
	Non-Household	**Household**	**Non-Household**	**Household**	**Non-Household**	**Household**	**Non-Household**	**Household**	**Non-Household**	**Household**	**Non-Household**	**Household**
	2012		**2013**		**2014**		**2015**		**2016**		**2017**	

Note:

- Please note this summary table was collated by Cré from the AER data provided by the NWPCO
- Please note, whilst every effort is made to ensure the accuracy of the information of this Annual Return data, it is not possible to guarantee that it is accurate in all cases. Information compiled by third parties is not necessarily correct, and is provided as is. The fact that we (NWPCO) are providing you with this information does not mean that the National Waste Collection Permit Office (NWCPO) accepts or agrees with it. Electronic data may also be modified or corrupted. Please note that the 2017 data is also incomplete.
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Appendix 3

Final Report
National Brown Bin Awareness Pilot Scheme in Sligo City

Sligo County Council

Roinn Cumarsáide, Gníomhaithe ar son na hAeráide & Comhshaoil
Department of Communications, Climate Action & Environment

NOVAMONT

cré
Composting & Anaerobic Digestion Association of Ireland

CONTENTS

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Disclaimer

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1. Executive summary

Sligo County Council coordinated the national Pilot Scheme of the Brown Bin programme in Sligo City between July 2014 and March 2015. The Project was jointly funded by Sligo County Council, the Department of Communications, Climate Action and the Environment, Cré – Composting and Anaerobic Digestion Association of Ireland, and Novamont.

The aim of the Project was to see how a range of educational and collection tools, such as the use of Brown Bin Waste Management Advisors and the provision of kitchen caddies to householders, could improve the capture and quality of food waste in the Brown Bin. The goal was to demonstrate the positive impact, which relatively low-cost measures can have on the performance of the system.

On foot of the findings of this Project, it is anticipated that the best practices identified in Sligo City will form a model which other towns could adopt.

The Pilot Scheme involved the following elements:

- The hiring of three interns under the JobBridge Internship Scheme. The interns went door-to-door to some 6,000 householders in Sligo City, providing Information on how to use the Brown Bin;
- The national Information leaflet developed by www.brownbin.ie was tailored to the local situation in Sligo City.
- A launch event was conducted at Institute of Technology Sligo's car park on a Saturday when the farmers market was in progress. The launch event included free compost give-away to the public.
- A waste characterisation study was conducted before the interns started the education programme and again at the end of the programme. This helped determine the impact of the programme.
- The waste collection routes in Sligo City were divided into three Areas. Two Areas given different types of kitchen caddies and compostable liners, and a group which would not have a kitchen caddy or compostable liner. This was used to assess the impact on the provision of a kitchen caddy and compostable liners to improve the capture rate of food waste.

Main Findings

There were a significant number of households without Brown Bins in Sligo City and prior to the awareness work their use was very low among those households which had Brown Bins.

The provision of an education programme of door-to-door education, a kitchen caddy and compostable bags to households resulted in:

- The participation and capture of organic waste at least doubling on average in Areas which received awareness Information compared with those which did not;
- A reduction in the level of contamination in Brown Bins from 18% to 1%; and
- Prior to awareness, the residual waste contained on average 39% organic waste, which was reduced to an average of 29% after the awareness programme.

Table 1: Summary of key findings

Parameter	Sligo City	Area A Awareness + solid caddies + 52 compostable liners	Area B Awareness	Area C Awareness + vented caddies + 52 compostable liners
Households which do not have a Brown Bin collection but should	24%	17%	26%	27%
Change in participation	+25%	+51%	+8%	+16%
Capture of organic waste from participating households Kg/ household/week	3.01	2.93	2.44	3.25
Overall capture of organic waste after awareness from all households	+0.95 Kg/ household/ week +59%	+1.6 Kg/ household/ week +76%	+0.36 Kg/ household/ week +45%	+0.77 Kg/ household/ week +47%
% contamination in Brown Bin before	18%	23%	20%	14%
% contamination in Brown Bin after	2.5%	1%	6%	3%
% change of contamination	-86%	-96%	-70%	-79%
Reduction of organics in residual bin After Trial		-6%	-11%	-10%

Bin presentation/participation

On average, participation at least doubled in Areas which received awareness information compared with those which did not.

All Sligo households which claimed to be signed up to a Brown Bin service and actually using their bin before the awareness work was just 37%. After the awareness initiative, the recorded presentation for the whole of Sligo City increased to 70% with the greatest increase (25% to 87%) being recorded in Area A.

Comparing those households which received awareness and tools for separating food waste in the kitchen with those which received some limited awareness (Area B) further demonstrates the impact of the work. Combined, recorded participation in Areas A and C increased from 38% to 77% whereas in Area B there was little change with participation changing from 33% to 43%. There was some uplift in Area B due to the communication work.

Capture of organic waste

On average, prior to the awareness programme Sligo was collecting 2.86 kg /household/week waste in the Brown Bins of which 17% was contamination. Thus, the quantity of organic waste suitable for organic recycling was 2.37 kg /household/week.

On average per week, prior to the awareness programme, every Brown Bin presented in Sligo contained 0.49 kg of contamination.

There was a marked difference in performance between those Areas which received awareness and tools to separate food waste in the kitchen.

Considering the households which were signed up to a Brown Bin, prior to the awareness programme, Area C, which had the highest user rate, had the highest capture of organic waste at 1.19 Kg. This increased significantly to 2.24 Kg post-awareness. In Area B, which had the lowest rates of participation, the rate of capture of organic waste also increased but to a lesser extent, rising from 0.57 Kg to 1.06 Kg. Area A showed the greatest increase in use of Brown Bins. This was reflected in the significant improvement in performance in the Area, with the level of organic waste in the Brown Bins of those signed up increasing greatly from 0.62 Kg to 2.55 Kg.

On average, participation and capture at least doubled in Areas which received awareness compared with those which did not.

Level of contamination

The level of contamination in the Brown Bin at the start of the Project was high in each Area, ranging from 14% to 23% with plastic being the main contaminant.

After the awareness programme, Area B has the highest level of contamination of 6%, compared with the Areas A+C (which got caddies and compostable bags) which were at 1% and 3% respectively.

A year later after this Project was finished; Area A was investigated and it was determined that the contamination level was still at a low level of just 3%.

Overall awareness had significantly positive effect on contamination.

Recommendations

- The provision of a door-to-door education programme might not be feasible for some waste collectors. However, the study has shown that the provision alone of just a kitchen caddy, compostable bags and Information leaflets will result in dramatic increases in the quantity and quality of Brown Bin material collected.
- To continue to monitor presentation and tonnage trends continually. Therefore, it is proposed that the collectors be requested to submit monthly reports on the tonnages collected and number of bins lifted for each waste stream.
- The Pilot Scheme in Sligo to act as a model for Brown Bin education schemes which can be adopted by other towns.
- It is recommended that if a Local Authority were going to do an education programme, this should be conducted in partnership with all the local waste collectors. It is important that all the waste collectors give a full commitment to the programme as without it, the programme will not be successful.
- The recommendations should be followed in the publication *Best practice guide of door-to-door Brown Bin Education in Ireland,* on which this Project was also based.

2. Background

The European Union (Household Food Waste and Bio-waste) Regulations 2015, (initial legislation introduced in April 2013) build on the commercial food waste regulations introduced in 2009 and are designed to promote the segregation and recovery of household food waste, in line with the national policy and the Waste Framework Directive objectives of maximising the resource which can be extracted from waste and minimising the disposal of waste.

The Regulations impose obligations on both householders and waste collectors. Householders are obliged to segregate their food waste, and make it available for separate collection. Alternatively householders may compost the food waste at home; or bring it themselves to authorised treatment facilities (such as civic amenity sites, composting or anaerobic digestion sites).

National statistics and Cré membership feedback have not reported expected increases in tonnage collected of Brown Bin material since the implementation of the household food and bio-waste Regulations. Additionally all Cré members processing Brown Bin material have reported increasing contamination of Brown Bin material with non-compostable material, of plastics in particular. It is vital that contamination is kept to a minimum in order for composting to meet the requirements of the National Compost Standard IS441.

The successful implementation of the new Household Food Waste Regulations is integral to the future stability of the biological treatment industry.

A report was conducted in 2013 entitled *Review of Best International Practice on How to Educate Households on Using the Brown Bin Correctly.*

The report found that focused education of households to use the Brown Bin properly will lead to its success and also control contamination. One of the key recommendations of the report was for a national Pilot Scheme programme of 'Brown Bin Waste Management Advisors' which would educate householders on how to use the Brown Bin system.

This report also highlighted the importance of CCC – *Clean Comfortable Compact* – to the success of a Brown Bin Scheme. The report states that *'Clean means the use of paper or compostable bags in the kitchen caddy.'* This is convenient, because only the bags were presented for kerbside collection. Little kitchen caddies/buckets do not need a lot of space in the kitchen which meets the requirement for a compact system.

The sector and the Government wanted to Pilot Scheme a Brown Bin Waste Management Advisors programme in Ireland. Such a programme would educate households on how to use the Brown Bin correctly and avoid Brown Bin contamination.

The key objective of the trial conducted in Sligo is to assess if households are given the correct education tools (leaflets, kitchen caddy and compostable bags) if the participation rate, quantity and quality of brown bin material improves.

2.1 Sligo

In order to improve the way in which waste was managed in Sligo, as well as addressing the requirements of the European Union Household Food Waste and Bio-Waste Regulations and the Landfill Directive, Sligo County Council put forward a number of changes so as to comply with this legislation and tighten up on waste management efficiency in the County of Sligo.

The Sligo County Council Waste Management Bye-Laws 2013 were adopted at the November 2013 Sligo County Council meeting and involved a three-month phasing-in period to allow waste collectors and members of the public, time to put the necessary measures in place.

There were a number of issues which needed to be addressed in regard to the way waste was managed in Sligo. Prior to the adoption of these Bye-Laws, households were able to purchase pre-paid bags/tags from their local shops for recyclable and general waste collection. This practice meant that it was very difficult to ascertain what percentage of household waste was actually going into the correct disposal stream versus what may have been illegally disposed of or even burned.

Based on quarterly returns from all waste collectors operating in the County of Sligo, up to 53% of households were unaccounted for. Therefore, strict measures were needed to be put in place to tighten up on the way in which waste was managed and to ensure all households were accounted for.

Sligo County Council Waste Management Bye-Laws 2013 designated 18 Areas in Sligo as third-bin Areas which supported the Household Food Waste Regulations in achieving its objectives.

Sligo County Council's involvement in the Project helped householders manage their waste in Sligo in accordance with the Waste Management Bye-Laws 2013.

2.2 Educational concept overview

When initially developing the education Project concept, it had been assumed that the householders had already been provided with kitchen caddies and had access to compostable bags. However, following investigations by Cré, it was found that despite their relatively low capital cost (approximately €2) and importance in achieving high performance of the Scheme, there are only two waste collection companies of approximately 70 in Ireland which provided kitchen caddies or compostable bags. The two collector firms which provided caddies and compostable bags did not operate in Sligo.

In the United Kingdom, the Waste and Resources Action Programme (WRAP) has published a number of reports on introducing food waste collections and they consider that the provision of suitable tools such as kitchen caddies and compostable liners is a prerequisite for success.

There are two waste collectors, Barna Recycling and Greenstar, operating in Sligo City. One collector provides a 120-litre wheeled bin the other collector provides a 25-litre caddy.

The main aim of the National Brown Bin Pilot Scheme was to provide households with different educational packages and tools and evaluating how effective each was.

The National Brown Bin Pilot Scheme in Sligo involved providing some householders with the following education and tools:

- A teaser leaflet delivered by a leaflet dropping company a few weeks before the door-to-door education commenced.
- A 7-litre kitchen caddy with a sticker on it on what types of food wastes can go into the caddy.
- A roll of compostable bags was provided as well as an instruction leaflet on how to use the Brown Bin service.
- Door-to-door education by the Waste Management Advisors who would provide additional leaflets and in some cases another roll of compostable bags.

3. Methodology

Methodology Overview

The following is a summary of the key steps and components of the Project:

1. Discussion and planning with local waste collectors, Local Authority officers and local composting plant.
2. Establishment of a steering committee.
3. Establishment of data for the amount of organics in the residual bin, recycling bin and in the Brown Bin together with levels of contamination in the Brown Bin. This analysis was conducted before and after the awareness campaign.
4. Establishment of data on the number of bins presented by householders and the corresponding weight. This analysis was conducted before and after the awareness campaign.
5. A teaser leaflet on how to use the Brown Bin was distributed by a leaflet distribution company prior to the start of the awareness campaign.
6. A detailed Information leaflet was given to each household in Sligo City. This leaflet was developed by the national programme www.brownbin.ie and was tailored for local contact details in Sligo.
7. Procuring solid-sided and vented-sided kitchen caddies.
8. Putting a sticker on what goes into a Brown Bin on the lids of the kitchen caddies and then distributing them to the relevant households.
9. Hiring three interns to undertake the operational roles in the Project which included:
   - Developing communication tools;
   - Providing door-to-door Brown Bin advice;
10. Organising a launch/compost give-away event in the car park of the Sligo Institute of Technology during a Saturday Farmers' Market.
11. Publications in local newspapers.
12. Radio interviews.
13. Participation in the Tidy Towns waste expo event.

Pilot Scheme Design

In Sligo City, there are approximately 8,000 households. These households were the focus of the Pilot Scheme. Households in Sligo City were divided roughly into three Areas (A, B and C) based on waste collection routes (See **Figure 1**).

Table 1 gives an overview of the Pilot Scheme.

- **Area A** was provided with solid side kitchen caddies, roll of compostable bags, teaser leaflet and Information leaflet and an awareness talk.
- **Area B** received awareness work only. Due to time constraints, just half of this Area received an awareness talk while the remainder received only a teaser leaflet.
- **Area C** was provided with vented-side kitchen caddies, roll of compostable bags, teaser leaflet, anInformation leaflet, and an awareness talk.

Before the education programme began, a waste characterisation survey and bin presentation survey was conducted.

At the end of the trial, the waste characterisation study and bin presentation survey was conducted to determine the impact of the trial.

Figure 1 – Overview of the three areas

Table 2 – Overview of the main pilot scheme design

City area	Number of households	Educational tools provided	Bin presentation number	Bin presentation weight	Waste
A	2,300	• Solid-sided kitchen caddy • Compostable bags • Instruction leaflet • Teaser leaflet • Door-to-door education	Before and after Pilot Scheme	Before and after Pilot Scheme	Before and After Pilot Scheme
B	1,720	• Teaser leaflet • Door-to-door education	Before and after Pilot Scheme	Before and after Pilot Scheme	Before and After Pilot Scheme
C	3,480	• Vented-sided kitchen caddy • Compostable bags • Instruction leaflet • Teaser leaflet • Door-to-door education	Before and after Pilot Scheme	Before and after Pilot Scheme	Before and After Pilot Scheme

Figure 2: Solid Sided Caddy

Figure 3: Vented Caddy

Figure 4: Roll of Compostable Bags

3.1 Communication and education

The three interns, named below, were employed for nine months as Waste Management Advisors, under the JobBridge Internship Scheme:

Margaret Dunleavy

David McGovern

Rachel Finan

The interns undertook the operational roles in the Project including:

- Developing communication tools;
- Providing door-to-door Brown Bin advice;
- Survey of householders; and
- Bin presentation and waste characterisation

Further to the *Review of best International Practice on How to Educate Households on Using the Brown Bin* report, it was noted that '*The key to the success of a Brown Bin system is the use of Brown Bin Advisors. They help encourage participation and motivate people to use the Brown Bin system. They achieve this through face-to-face contact with householders, explaining how to use the system and answering any questions, problems or complaints which the householder may have.*'

In-house training was delivered by Cré, Novamont and Sligo County Council to ensure that all interns were fully educated on waste management practice and in order to provide the required awareness work to all households in the Pilot Scheme Project Area.

During the employment of these interns, in-house meetings took place on a fortnightly basis. Door-to-door work completed in the fortnight prior to the meeting was highlighted and discussed with the Pilot Scheme Project Team. Waste Management Advisors were given a target of reaching 70% of 100 households assigned over a weekly period. A weekly reporting template was completed and submitted on a weekly basis (see Appendix). Following the completion of each estate, Waste Management Advisors were required to complete an 'Estate Completion Report' (see Appendix). Both of these reports were submitted to the Project Manager in order to track the progress made and to ensure that the Project stayed on schedule.

Waste Management Advisors were given work mobile phones (under Health and Safety Regulations). The interns were required to text their Supervisor before and after door-to-door work to ensure the safety of each Advisor while on site. Waste Management Advisors were also furnished with tablets in order to carry out surveys of each household. The Information Technology Department of Sligo County Council developed a software package for these tablets to allow for the input of data while on site which will upload to an internal database. Unfortunately, this particular form of taking surveys was unsuccessful. These tablets proved to be extremely time consuming, not user-friendly and highly temperamental with regard to Wi-Fi connection.

Following a short spell of trying this out, it was agreed to revert to paper surveys and to manually upload the Information received on a central database at the office. By using the paper surveys, it also allowed additional Information to be recorded and notes to be taken. It was quicker and allowed the Waste Management Advisors more time to reach their weekly targets. The paper-survey used is outlined in the Appendix. Calling cards were left at households when nobody was at home. Details are outlined in the Appendix.

3.2 Bin presentation/waste characterisation

Bin presentation

As part of the Project, Waste Presentation Surveys were carried out on all Areas before and after the provision of educational tools/awareness campaign. This was a six-week survey in each Area counting the number and type of waste bins presented for collection.

The procedure in carrying out these surveys was to drive around all estates within the relevant Area being surveyed, on the designated kerbside collection days for each waste collector. While doing so, the number of bins presented for kerbside collection were recorded for each waste stream presented.

Waste characterisation

The draft and published Environmental Protection Agency *Household Waste Characterisation Manuals and the Association for Organic Recycling 2012 protocol to measure contamination in bio wastes* were considered in preparing the procedures below. In addition, personnel communication took place with the steering committee for the National Brown Bin Pilot Scheme Programme and Colm Gibson of the Clean Technology Centre.

The following was carried out to determine a sample for waste characterisation:

1. Some nine samples from Greenstar's collection routes (Area A, B and C) were collected over a two-week period. Waste from the nine different loads was stockpiled at the collector's facility – recyclables for nine days, landfill and organic for two days. Greenstar collect landfill and organics on same week and recycling on the alternate week.
2. Some fifteen samples from Barna's collection routes (Area A, B and C) were collected over a two-week period. Waste from fifteen different loads was stockpiled at Greenstar's facility. Barna collected recycling and organic on the same week and landfill on the alternate week.
3. Samples of at least 150 kg were obtained for each waste receptacle type, for each Area for each collector.

4. Results and discussion

4.1 Communication and education

Sligo City was divided into three Areas. **Table 3** below outlines the communication and education work done in the three Areas.

Table 3: Overview of education/ communications done in the three Areas.

Education/ Tools	Area A	Area B	Area C
Door-to-door	Spoke with 70% of occupied households	Spoke with 33% of occupied households	Spoke with 70% of occupied households
Leaflets	100% mail drop of educational material	100% mail drop of educational material	100% mail drop of educational material
Tools	Solid 7 litre caddies plus compostable bags provided	No caddies No compostable bags provided	Vented 7 Litre caddies plus compostable bags provided

4.2 Household waste management

During the door-to-door education, Sligo County Council used it as an opportunity to survey householders on how they were managing their waste. The results of the survey are outlined below in **Table 4.**

Table 4: Survey responses: Household management of waste

Disposal System	Area A % of households surveyed	Area B % of households surveyed	Area C % of households surveyed
1. Bin kerbside (residual) collection	1%	3%	2%
2. Bin kerbside (residual + dry-recycling) collection	26%	24%	25%
3. Bin kerbside (residual + dry-recycling + organic recycling) collection	62%	47%	55%
Bring facility users	6%	14%	8%
Bin-sharing customers	2%	5%	6%
Other	3%	7%	4%
Total	100%	100%	100%
Home composters	17	16	11

The 'Other' section refers to householders which did not know which service they had, refused to say or had an alternative method. The numbers for households with home-composters are given separately as they were reported additionally to the standard services.

4.3 Bin presentation – residual bin, dry-recycling bin and Brown Bin

The surveys were carried out on all Areas prior to the door-to-door awareness campaign in order to determine the number of bins presented for kerbside collection before any awareness Information was provided. As expected, all Areas had quite a high level of use of residual waste bins, recycling bins were used less than they should have been and use of the Brown Bins was extremely low.

Following the completion of door-to-door awareness campaign on each Area, a further six-week Waste Presentation Survey was carried out in order to determine whether or not the awareness campaign was successful.

The results of the main bin presentation surveys are given below in **Table 5**. The numbers presented in this **Table** are the absolute values recorded over the two six-week presentation surveys and do not take into account the collective or individual results of those obtained through the face-to-face surveys.

Table 5: Number of Bins presented before and after

Area A	Number of Households	Before	After
		Number of bins	
Residual	2,300	1,549	1,684
Dry-recyclables		1,328	1,799
Brown Bin		359	1,235
Area B			
Residual	1,720	743	945
Dry-recyclables		810	991
Brown Bin		267	353
Area C			
Residual	3,480	2,617	2,361
Dry-recyclables		2,582	2,423
Brown Bin		884	1,293

Following the awareness campaign, there was a significant increase in the presentation of Brown Bins in all Areas. The highest Areas were A and C. The lowest increase was in Area B.

The same trends for the dry-recyclables bins and residual bins in terms of bin presentation.

The number of dry-recyclables bins presented for collection increased by 35.5 % in Area A, by 22% in Area B and decreased marginally by 6% in Area C.

The number of residual bins in Area A increased by 8.7% and in Area B by 27.2% and decreased by 9.8% in Area C.

It was expected that the Project would show a decrease in the number of residual bins presented and weight of bin. However, the increases were attributed to the fact the contamination which was previously in the Brown Bin was now being put in the residual bins or dry-recyclable bins. The awareness of the Council doing this Project and asking people how they managed their waste also contributed to people using a waste collection service instead of possibly burning waste illegally.

4.4 Brown Bin presentation

The data shown in **Table 5** above gives a general overview of the presentation rates in Sligo City. However, it does not take into account the results of the householder survey. The householder survey identified a number of factors which should be taken into account and in turn enable a critical review of **Table 5's** data. Combining the two sets of data enables the reporting of the performance according to different categories of households:

- Households which have signed up to a Brown Bin service
- Total households which should be signed up to a Brown Bin service, *i.e.* all those which were not home-composting, delivery waste to a recycling centre or were legitimately bin-sharing as well as those signed up.

Householders signed up to Brown Bin service

Figure 5 below shows that for all Sligo households which claimed to be signed up to a Brown Bin service. Those actually using their bin before the awareness work accounted for just 37%. After the awareness initiative, the recorded presentation for the whole of Sligo City increased to 70% with the greatest increase (25% to 87%) being recorded in Area A.

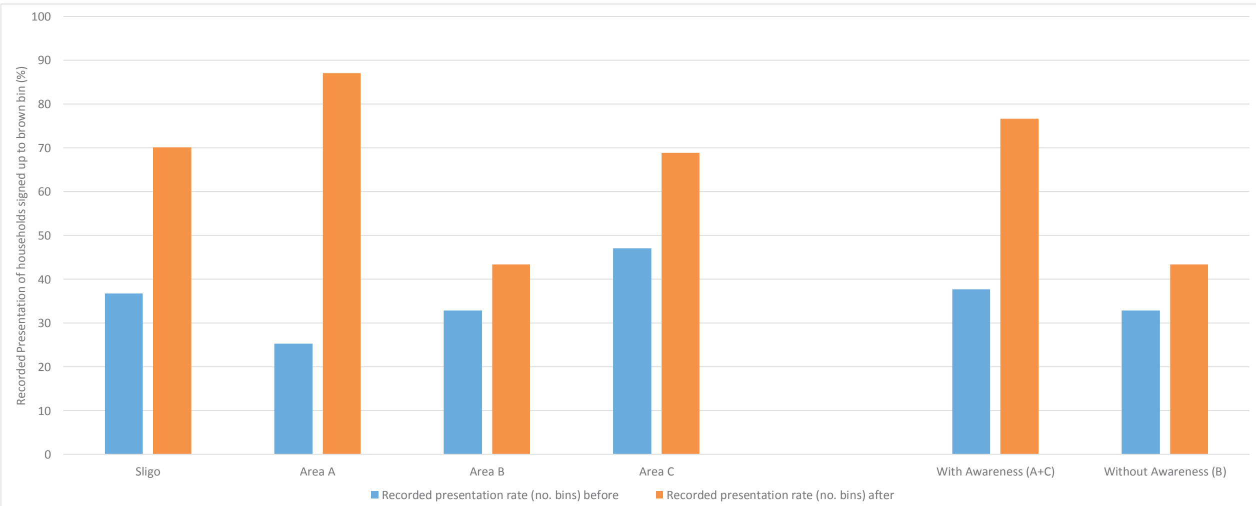


Figure 5: Brown Bin Presentation Rate of Households Signed up for the Service

Comparing those households which received awareness and tools for separating food waste in the kitchen to those which received some limited awareness further demonstrates the impact of the work. Combined, recorded participation in Areas A and C increased from 38% to 77% whereas in Area B there was little change with participation changing from 33% to 43% – probably due to the limited awareness conducted in the Area.

In order to understand better householder awareness and the use of the Brown Bin, the absolute figures shown in **Table 5** above should be considered in terms of the data from the face-to-face surveys, the total number of households in each Area and the situation with regard to the Food Waste Regulations. Households may comply with the Regulations through means other than the Brown Bin, *e.g.* home composting, bin-sharing, taking food waste directly to the recycling centre.

Figure 6 data below has been derived from the **Figure 5** data minus those which were home-composting or bin-sharing. **Figure 6** below also shows the bin presentation rates for Sligo in relation to the number of households which should be receiving and using a Brown Bin service before and after the awareness work.

In addition, it shows the breakdown between those Areas which received higher levels of awareness raising and the free support tools (A and C) and that with a lower level of awareness and no support tools (B).

Households which should be signed up to Brown Bin service

Households which should be signed up to Brown Bin service

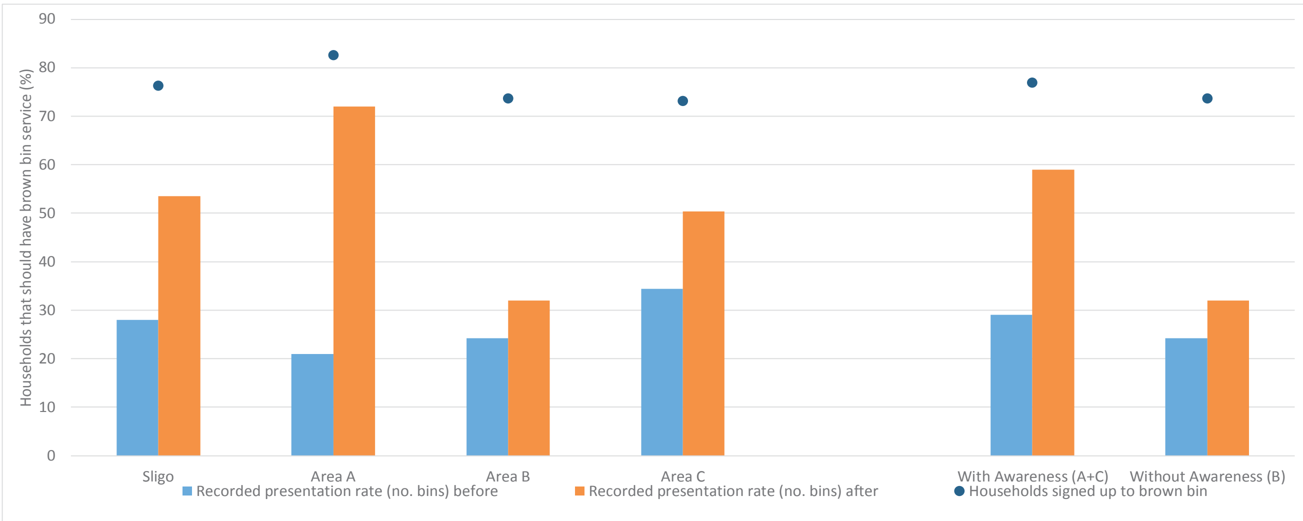


Figure 6: Brown Bin presentation rate of households which should be signed up for the service

Overall, **Figure 6** shows that in Sligo, of the households which should have a Brown Bin (*i.e.* all those were not home composting, bin-sharing or taking organic waste to a central point), 76% reported to be signed up for one and there were no significant differences in take up rates between the three Areas (blue spots).

Figure 6 also shows that prior to the awareness programme, overall presentation of Brown Bins was low at just 28% (blue bars). Following the awareness work, the use of the Brown Bin across all households in Sligo increased to 53% (orange bars). Of the three Areas, Area A showed the greatest increase with participation increasing by 51%, Area C by 16% and Area B by 8%. Comparing the Areas which received the full awareness programme with those which received less Information and no kitchen caddies or liners, the chart shows that on average where the full awareness programme was delivered, 59% of households which used their Brown Bins (up 30% points) compared with 32% of households in the Area which received the lower level, up just 8%

4.5 Organic waste analysis

4.5.1 Brown Bin organic waste analysis

Prior to the awareness work, samples and analyses were undertaken to ascertain the quantity of organic waste in the three bins as well as the level of contamination in the Brown Bins. The process was repeated after the awareness work was completed in each Area. **Table 6** below give the results of this intensive work in regards to the three categories of households identified: those using (presenting) their Brown Bins, those signed up for a Brown Bin service and those households which should have had a Brown Bin.

Weight data is presented as kilogrammes per household per week as this enables a better strategic understanding and future planning of targeted actions in other Areas of the country. It also enables comparison with data from other countries particularly from the United Kingdom where significant research has been undertaken.

In addition, by presenting the difference between total weight and weight of just organics (organic waste plus contamination) **Table 6** shows the level of contamination before the Pilot Scheme and the impact of addressing contamination during the awareness programme.

The difference between the three categories (presenting, signed up and should have Brown Bins) of households shows the potential for improvement in the use of Brown Bins. The data for those presenting their Brown Bins reflects those which were already using their Brown Bins and the data post-awareness is the 'best case' for organic waste diversion.

Table 6: Capture of organic waste in Brown Bins before and after awareness programme

	Before awareness					
		Sligo	A	B	C	Average A+C
	Households presenting their Brown Bin	Kg / household / week				
Before	Capture (organics + contamination)	2.86	**3.16**	2.18	2.94	3.00
	Capture organics (minus contamination)	2.37	2.43	1.75	**2.53**	2.50
After	Capture (organics + contamination)	3.09	2.96	2.60	**3.35**	3.16
	Capture organics (minus contamination)	3.01	2.93	2.44	**3.25**	3.09
	Households with Brown Bin service					
Before	Capture (organics + contamination)	1.05	0.80	0.72	**1.38**	1.13
	Capture organics (minus contamination)	0.87	0.62	0.57	**1.19**	0.94
After	Capture (organics + contamination)	2.17	**2.57**	1.13	2.31	2.37
	Capture organics (minus contamination)	2.11	**2.55**	1.06	2.24	2.37
	Households which should have a Brown Bin					
Before	Capture (organics + contamination)	0.80	0.66	0.53	**1.01**	0.87
	Capture organics (minus contamination)	0.66	0.51	0.42	**0.87**	0.73
After	Capture (organics + contamination)	1.65	**2.13**	0.83	1.69	1.86
	Capture organics (minus contamination)	1.61	**2.11**	0.78	1.64	1.82

* - highest value in **bold**

On average, prior to the awareness programme Sligo was collecting 2.86 kg /household/week of waste in the Brown Bins of which 17% was contamination. Thus, the quantity of organic waste suitable for organic recycling was 2.37 kg /household/week. Households in Areas A and C were presenting similar amounts of total waste (3.16, 2.94) with those in Area B presenting significantly less (2.18) in their Brown Bins. Contamination was very high and ranged from 23% in Area A to 20% in B to 14% in Area C (for more details see section 4.6 below). On average per week, prior to the awareness programme, every Brown Bin presented in Sligo contained 0.49 kg of contamination.

When the weight data was applied to the households which were signed up to a Brown Bin and those which should have had a Brown Bin, the impact of the low levels of participation became very clear. As expected, in all three Areas there was a reduction in the capture of waste in the Brown Bin when those which had a Brown Bin and those which should have had a Brown Bin were considered. The average amount of total waste captured in household Brown Bins fell from 2.86 kg /household/week to 0.80 kg /household/week across the City.

After the awareness programme, the total quantity of waste presented by households in Sligo increased to 3.09 kg /household/week. Again, the difference between households presenting their Brown Bins and households which should have had a Brown Bin, and be using it, was significant at -1.44 kg /household/week.

This **Table 6** also shows the marked difference in performance between those Areas which received awareness and tools to separate food waste in the kitchen.

Households in Area A, which received solid kitchen caddies, Mater-Bi® compostable liners and education showed a significant change in behaviour. Prior to the initiative, households presenting their Brown Bins in Area A had the highest level of waste at 3.16 Kg. However, this included 0.73 Kg of contamination. After the awareness programme, the level of total waste in the Brown Bins of those presenting fell to 2.96 Kg but there was a significant fall in contamination to just 0.03 Kg. This meant that the organic waste suitable for recycling increased from 2.43 to 2.93 Kg.

Households in Area B which received relatively little awareness showed a slight change in behaviour in Brown Bin usage. Total waste presented in Area B increased from 2.18 Kg to 2.60 Kg which contained 0.16 Kg of contamination.

Households in Area C which received vented caddies, Mater-Bi® compostable liners and education and presented their Brown Bins, initially placed 2.96 Kg of waste in their Brown Bins per week containing 0.41 Kg of contamination after the awareness the total waste increased to 3.35 Kg of which 0.1 Kg was contamination which was the highest level of organic waste presented by users of the three systems across Sligo.

Considering the households which were signed up to a Brown Bin, prior to the awareness programme Area C, which had the highest user rate, these had the highest capture of organic waste at 1.19 Kg. This weight increased significantly to 2.24 Kg post-awareness. Area B, which had the lowest rates of participation the rate of capture of organic waste, also increased but to a lesser extent, going from 0.57 Kg to 1.06 Kg. Area A showed the greatest increase in use of Brown Bins. This was reflected in the significant improvement in performance in the Area, with the level of organic waste in the Brown Bins of those signed up increasing greatly from 0.62 Kg to 2.55 Kg.

A similar trend was shown when the data was applied to all households which should have a brown in, with Area B being the lowest performing resulting in 0.78 Kg of organic waste compared with 1.64 Kg in Area C and 2.11 Kg in Area A.

4.5.2 Impact of awareness

Figure 7 below shows the overall impact of the awareness work on participation and capture of organic waste for all households which should be signed up to a Brown Bin service. It clearly shows that the awareness had the greatest impact in Area A with both participation and capture increasing significantly. Area B, which had a similar baseline to Area A, showed a much lower level of upward change, and in Area C the increase was between that seen in A and C albeit from a higher starting point. On average, participation and capture doubled at least in Areas which received awareness compared with those which did not.

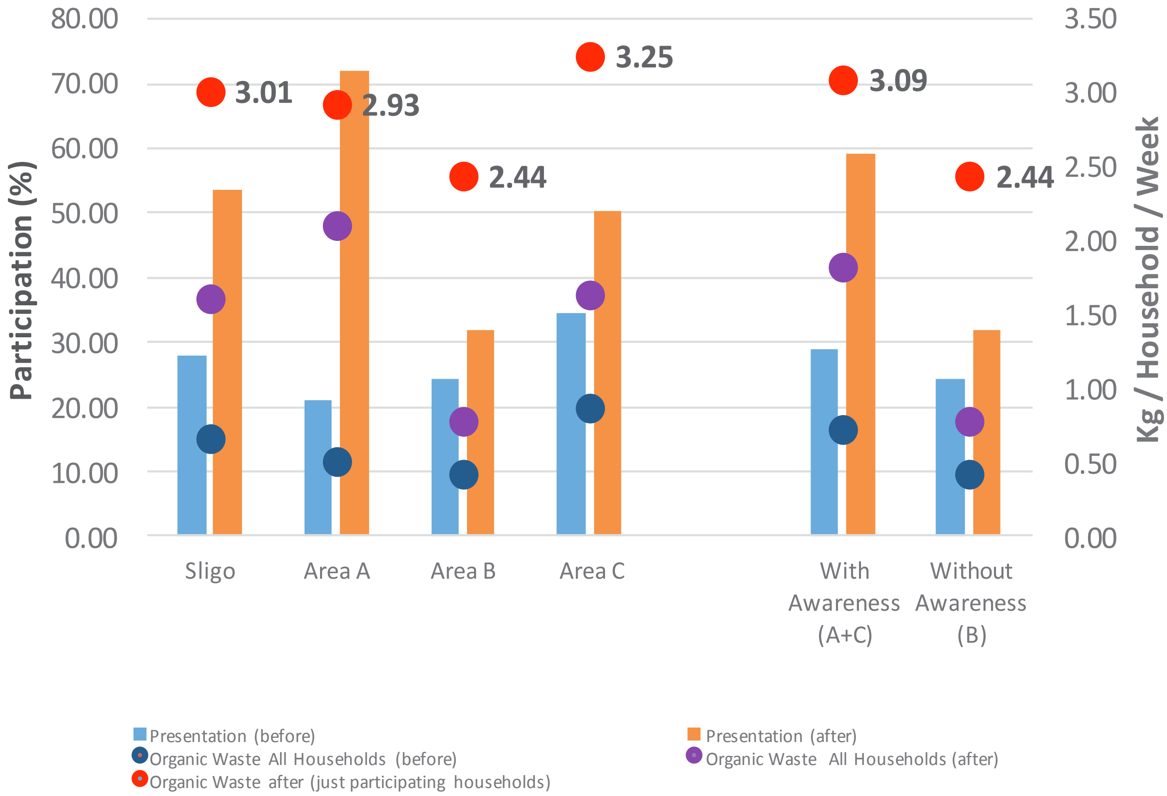


Figure 7: Overall impact of awareness in Sligo, by Area and awareness type

4.6 Contamination

The contamination of the Brown Bins by plastics, metals and other packaging was investigated during the Project. **Table 8** gives the contamination levels found in Sligo City Areas A, B and C and A + C.

Table 8: Contamination found in Brown Bins

	Area A	Area B	Area C	Sligo	A+C
% Contamination in Brown Bin – before	23	20	14	18	17
% Contamination in Brown Bin – after	1	6	3	2.5	2
Contamination in Brown Bin – % change	**-96**	**-70**	**-79**	**-86**	**-88**

At the start of the Project, Area A had the highest level of contamination at 23%, while Area C had the lowest at 14%. After the awareness programme and distribution of kitchen caddies and compostable liners was completed, overall contamination had fallen by 86% to 2.5% with the greatest level of contamination (6%) being found in Area B which itself had seen a drop of 70%. Further details on the contamination can be found in section 4.6.

A year later after this Project was finished, one of the interns, Rachel Finan, completed her degree thesis on a similar Project. She went back to Area A to investigate contamination levels a year later, during which period there had been no further education. She determined that the contamination level was still at a low level of just 3%.

4.7 Waste characterisation

In order to investigate fully the impact of the awareness work and provision of kitchen sorting equipment, significant effort was placed into undertaking the waste characterisation of the three Areas before and after the interaction with the householders. **Table 9** below shows the level of contamination (non-target material) in each bin with a specific focus on organic waste.

Table 9: Levels of contamination and organic waste in the three bins in each Area

	Area A		Area B		Area C	
Brown Bin	**Before**	**After**	**Before**	**After**	**Before**	**After**
Plastics contamination	8	1	7	4	8	2
Total contamination	23	1	20	6	14	3
Dry-recycling Bin						
Organic waste	4	4	3	7	5	5
Total contamination	17	24	28	32	28	20
Residual Bin						
Organic waste	41	35	39	28	36	26

The level of contamination in the Brown Bin at the start of the Project was high in each Area, ranging from 14% to 23% with plastics being the main contaminant. After the awareness work, contamination dropped to negligible levels in Areas A and C but was still at 6% in Area B.

Contamination of the dry-recycling bin was surprisingly high (17%-28%) across the Areas and Project and the level of organic waste stayed static in Areas A (4%) and C (5%) but increased in Area B to 7%. Organic waste fell in the residual bin in each Area, namely, by 6% in Area A, by 11% in Area B and by 10% in Area C.

Further details of the contamination found in the Brown Bins are given in **Figure 8** below.

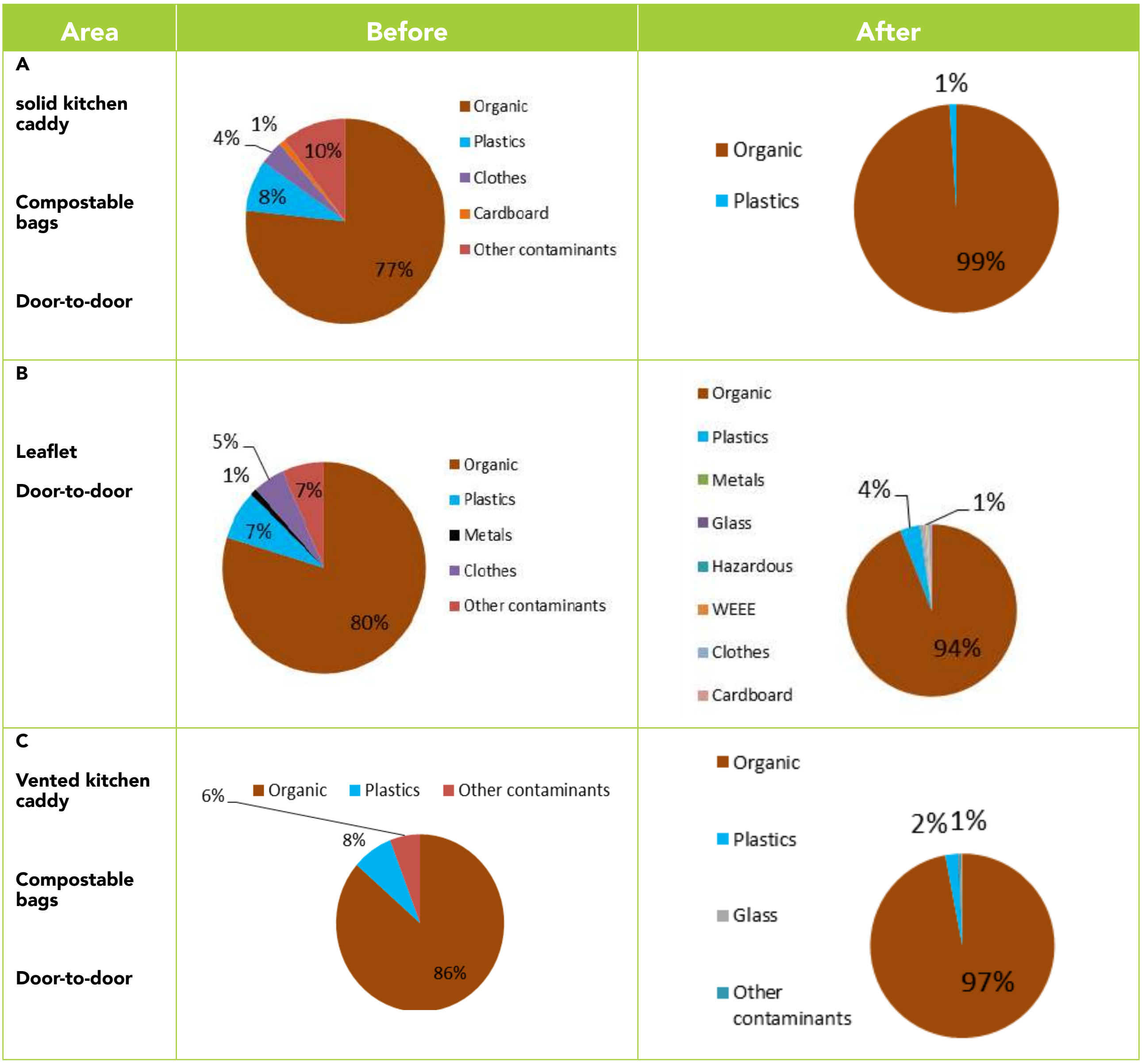


Figure 8: Detailed waste characterisation of Brown Bin

4.8 Feedback from householders

Key points in discussion with the residents

During the face-to-face awareness-raising discussions and the survey a number of points were raised by householders which may be considered as barrier or limitations to the success of the local Brown Bin Schemes. The following bullet-points are the direct feedback provided by the survey team:

- Householders say they had no food waste or they fed it to the dogs or pigs (which is a banned activity) or even burn it. Prior to the delivery of Information on food waste, some householders said they did not know what they could put in the food waste bin, in particular plate scrapings and raw meat.
- Some people, in particular the elderly, noted that the 25-litre food waste bin was too heavy when filled. It was suggested these might have wheels in the future.
- Regarding the size of food waste bin, some of those using a 120-litre bin stated that it was too big and those using the 25-litre that it was too small.
- A number of householders said they were facing delays in their delivery of new bins or that they were being told they did not need to have a Brown Bin due to their location.
- The cost of the waste collection service was perceived to be too high and, due to the pay by lift system, there was a lack of incentivisation to separate organic waste into the Brown Bin.
- A few householders stated they thought the waste collectors were mixing the wastes they had segregated which had reduced their confidence in the system.

Feedback from householders on educational tools

Of the households surveyed and which had used the caddy, some 76%-80% found the kitchen caddy beneficial.

Caddy type	Beneficial	Not beneficial
7-litre solid-sided kitchen caddy	80%	20%
7 litre vented-sided kitchen caddy	76%	24%

Online survey

One waste collector emailed an online survey to their customers. **Figures 8 to 10** are the results of the survey. **Figures 8 and 9** shows that people found the Brown Bin system easy to use, that compostable bags made it easier to use and that they should be provided by the waste collector.

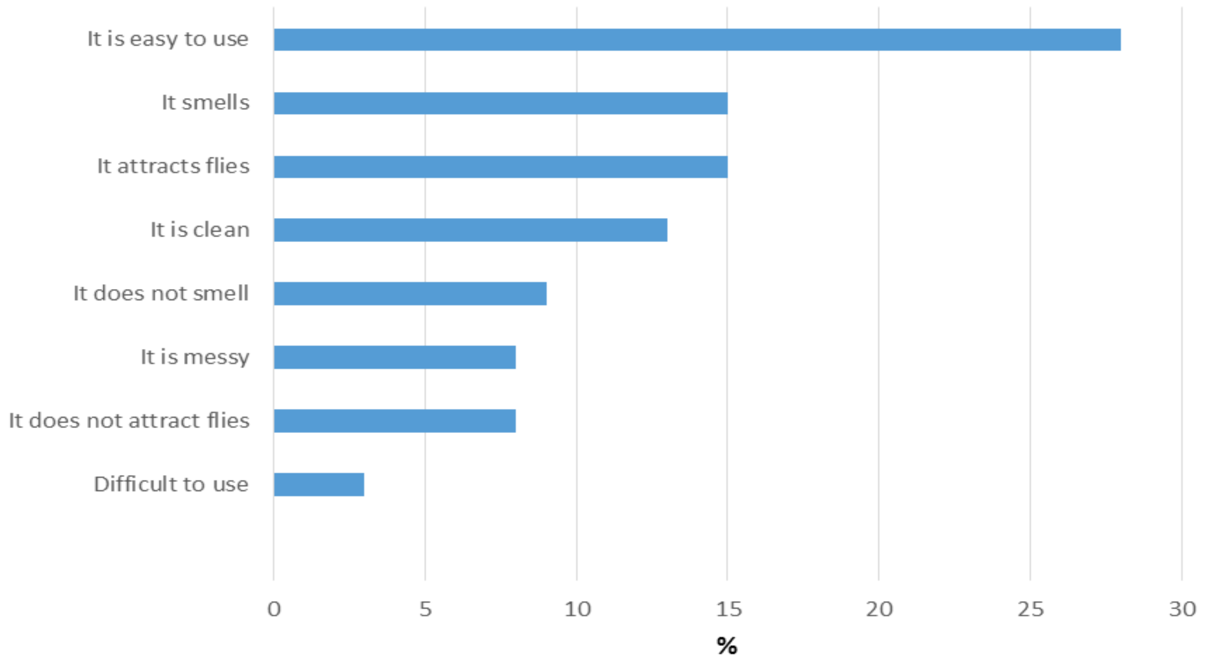


Figure 8: *My experiences using a Brown Bin are...*

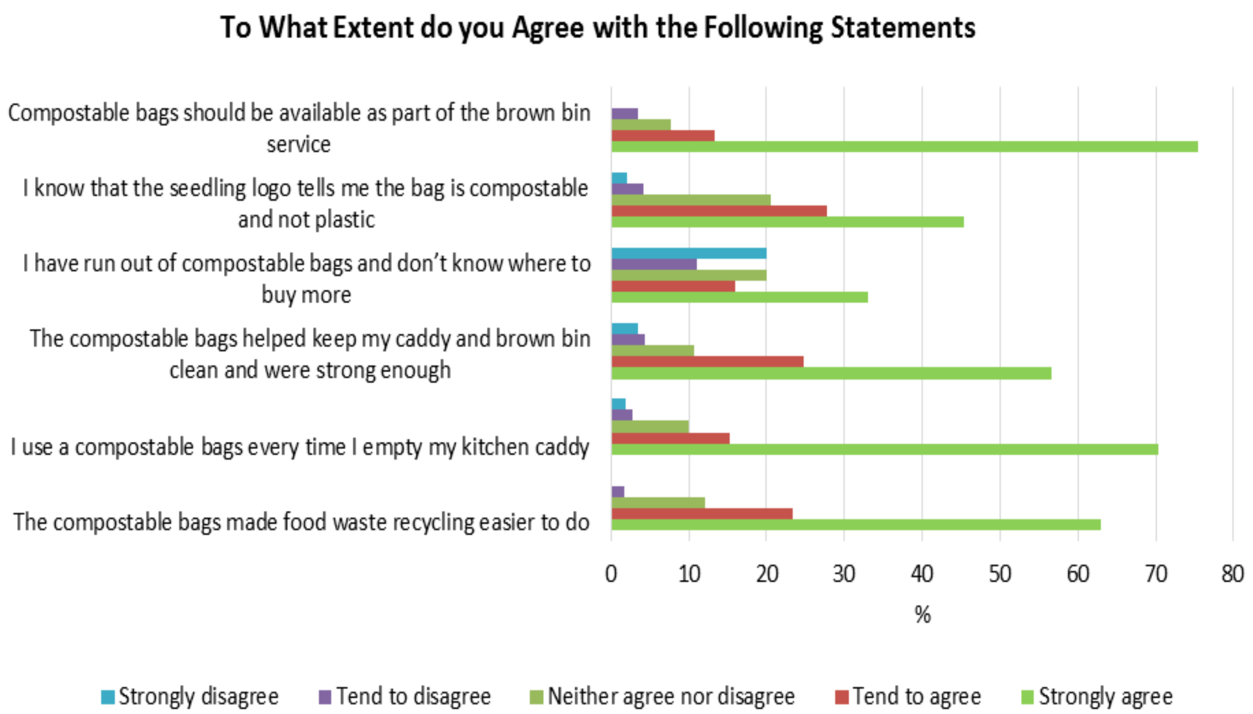


Figure 9: To what extent do you agree with the following statements?

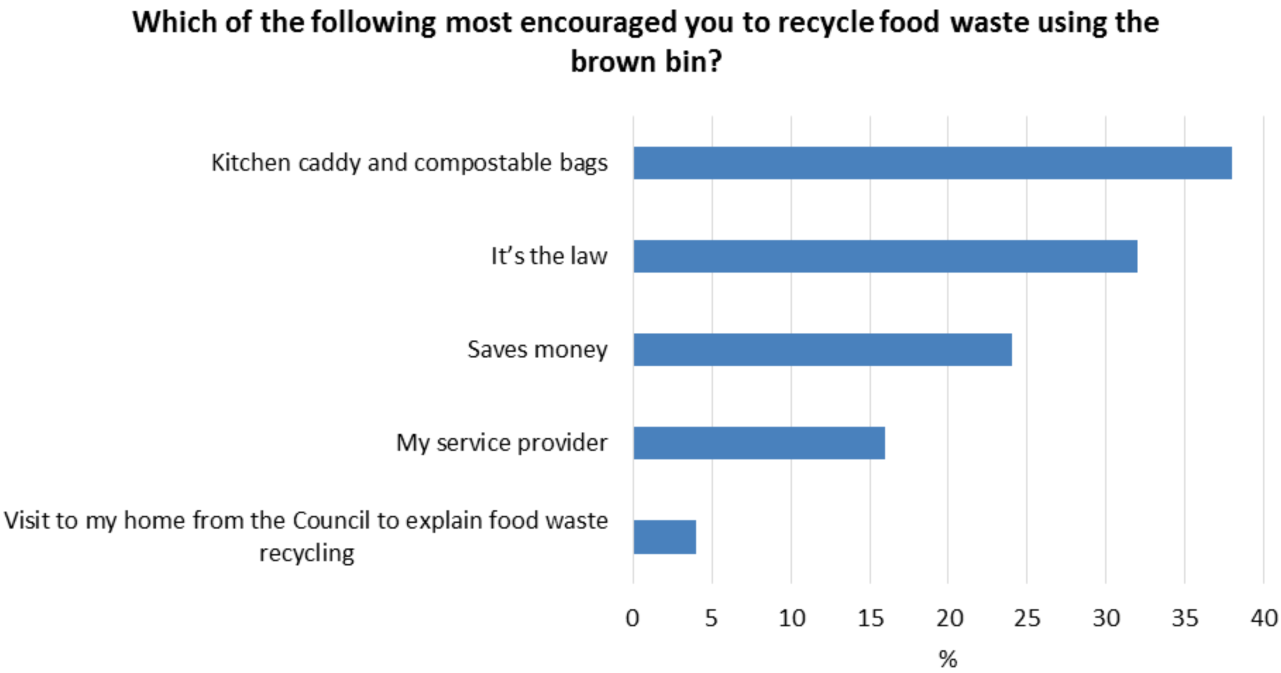


Figure 10: Which of the following most encouraged you to recycle food waste using the Brown Bin?

Figure 10 above shows an interesting trend that the provision of a kitchen caddy and compostable would encourage people the most to recycling food waste using a Brown Bin and the door-to-door visit to their home would be the least favoured option.

General comments trends from the online survey feedback:

- *I did not receive a caller but I think the caddies and bags might encourage me to use the Brown Bin.*
- *I think it would be much better if collected weekly rather than fortnightly. It would encourage me to use it more.*
- *If the Scheme were to continue, I believe the bags should be provided as part of the service, free of charge. This would encourage more people to use them, including myself. I do not know where to get more and if I run out, the kitchen caddy becomes useless because of the vented/ slit design meaning food and juices will run out of the caddy. Can the bags be provided as part of the service, without any additional cost?*

4.9 Comparison of contamination in Brown Bin collection systems

Each of the waste collectors operated different Brown Bin systems. One collects food waste only using 25-litre containers and the other collects food and garden waste in a 120-litre bin.

From the results of this Project, the following observations were below:

- The collection system with the 120-litre bin has the highest amount of contamination and garden waste
- The 25-litre outside-caddy had low contamination levels but some householders needed a second caddy or an increase frequency of collection.
- The 25-litre caddy had a higher capture of organic waste compared with the other collection system.
- On average across the three Areas in Sligo City, the 25-litre collection system resulted in a higher decrease of organics left in the residual bins after the awareness campaign of -18%, compared with 1.6% in the other collection system.

Table 10: The % of contamination in Brown Bin system before and after awareness

	Before	After	Before	After	Before	After
	A		C		B	
Type of Collection	%					
25-litre food waste only	6%	1%	6%	2%	7%	3%
120-litre food and garden waste	45%	1%	24%	3%	37%	9%

Figure 11: Left refers to food waste from 20-litre collection system. Right refers to a co-mingled food and garden Brown Bin system.

4.10 General feedback

The main challenge encountered by the Waste Management Advisors in the Pilot Scheme programme in Sligo City was with the waste collectors. The issues encountered in the household replies were:

- Brown Bins often not collected on collection day;
- Continuous price increases;
- Cost of bins does not encourage segregation;
- Fortnightly collection of the Brown Bin not frequent enough
- No food waste collection at the Civic Amenity site for those which do not want to avail of kerbside collection;
- Poor customer service for both waste collectors;
- Size of bin a problem (Too Big v Too Small); and
- Very long waiting period to receive the Brown Bin.

5. Conclusions

Main conclusions:

There were a significant number of households without a Brown Bin in Sligo City and of those households which have a Brown Bin, prior to the awareness work, their use was very low.

The provision of the door-to-door education programme providing a kitchen caddy and compostable bags to households resulted in:

- On average, participation and capture of organic waste at least doubled in Areas which received awareness and Information compared with those which did not.
- A reduction in the level of contamination in Brown Bins from 18% to 1%
- Prior to awareness residual waste contained on average 39% organic waste this reduced to an average of 29% after the awareness programme.

Table 11: Summary of key findings

Parameter	Sligo	Area A Awareness + solid caddies + 52 compostable liners	Area B Awareness	Area C Awareness + vented caddies + 52 compostable liners
Households which do not have a Brown Bin collection but should	24%	17%	26%	27%
Change in participation	+25%	+51%	+8%	+16%
Capture of organic waste from participating households Kg/household/week	3.01	2.93	2.44	3.25
Overall capture of organic waste after awareness from all households	+0.95 Kg/household/week +59%	+1.6 Kg/household/week +76%	+0.36 Kg/household/week +45%	+0.77 Kg/household/week +47%
% Contamination in Brown Bin	18%	23%	20%	14%
% Contamination in Brown Bin After	2.5%	1%	6%	3%
% Change of Contamination	-86	-96	-70	-79
Reduction of organics in residual bin After Trial		-6%	-11%	-10%

Bin presentation/ participation

On average, participation at least doubled in Areas which received awareness compared with those which did not.

All Sligo households which claimed to be signed up to a Brown Bin service and actually used their bin before the awareness work was just 37%. After the awareness initiative, the recorded presentation for the whole of Sligo City increased to 70% with the greatest increase (25% to 87%) being recorded in Area A.

Comparing those households, which received awareness and tools for separating food waste in the kitchen with those which received some limited awareness (Area B), further demonstrates the impact of the work. The combined, recorded participation in Areas A and C increased from 38% to 77% whereas in Area B there was little change with participation changing from 33% to 43%. There was some uplift in Area B due to the communication work.

Capture of organic material

On average, prior to the awareness programme Sligo was collecting 2.86 kg /household/week of waste in the Brown Bins of which 17% was contamination. Thus, the quantity of organic waste suitable for organic recycling was 2.37 kg /household/week.

On average per week, prior to the awareness programme, every Brown Bin presented in Sligo contained 0.49 kg of contamination.

There was a marked difference in performance between those Areas which received awareness and tools to separate food waste in the kitchen.

Considering the households which were signed up to a Brown Bin, prior to the awareness programme Area C, which had the highest user rate, had the highest capture of organic waste at 1.19 Kg. This increased significantly to 2.24 Kg post-awareness. In Area B, which had the lowest rates of participation the rate of capture of organic waste also increased but to a lesser extent, going from 0.57 Kg to 1.06 Kg. Area A showed the greatest increase in use of Brown Bins. This was reflected in the significant improvement in performance in the Area, with the level of organic waste in the Brown Bins of those signed up increasing greatly from 0.62 Kg to 2.55 Kg.

On average, participation and capture at least doubled in Areas which received awareness compared with those which did not.

Level of contamination

The level of contamination in the Brown Bin at the start of the Project was high in each Area, ranging from 23% to 14% with plastic being the main contaminant.

After the awareness programme, Area B had the highest level of contamination of 6%, compared with the Areas A+C (which got caddies and compostable bags) which were at 1% and 3% respectively.

A year later after this Project was finished; Area A was investigated and it was determined that the contamination level was still at a low level of just 3%.

Overall awareness had significantly positive effect on contamination

Other observations:

Leaflets

The provision of teaser leaflets and the printing of what should go into a Brown Bin or a compostable bag appeared to be of little benefit in raising awareness with householders.

Survey

The feedback of an online survey showed an interesting trend in that the provision of a kitchen caddy and compostable would encourage people the most to recycling food waste using a Brown Bin and the door-to-door visit to their home would be the least favoured option to encourage them.

Dry-recyclable and residual bin

The number of dry-recyclables bins presented for collection increased by 35.5 % in Area A, by 22% in Area B and decreased marginally by 6% in Area C.

The number of residual bins in Area A increased by 8.7% and in Area B by 27.2% and decreased by 9.8% in Area C.

It had been expected the Project would show a decrease in the number of residual bins presented and in the weight of bin. However, the increases were attributed to the fact that the contamination, which had been in the Brown Bin, was now being put in the residual bins or dry-recyclable bins. The awareness of the Council doing this Project and asking people how they managed their waste also contributed to people using a waste collection service instead of their possible burning waste illegally.

Waste collection

Negative impact on the collection companies

- Because of the low number of households using the Brown Bin, it makes waste collection more expensive. If there were more people using the Brown Bin, it would offer greater efficiencies for waste collection companies.

Negative impact on householders

- The large numbers of households not signed-up drives up price by increasing collection inefficiencies;
- The low use of the Brown Bins by those which have signed up to the service means a high percentage of households were paying for something they were not using.

6. Recommendations

- The provision of a door-to-door education programme might not be feasible for some waste collectors. However, the study has shown that the provision alone of just a kitchen caddy, compostable bags and an Information leaflets will result in dramatic increases the quantity and quality of Brown Bin material collected.
- To continue to monitor presentation and tonnage trends continually. It is therefore proposed that the collectors be requested to submit monthly reports on the tonnages collected and number of bins lifted for each waste stream.
- The Pilot Scheme in Sligo City to act as a model for a Brown Bin education Schemes which can be adopted by other towns.
- It is recommended that if a Local Authority were to do an education programme, this should be conducted in partnership with all the local waste collectors. It is important that all the waste collectors give a full commitment to the programme as without it, the programme will not be successful.
- The recommendations should be followed in the publication which was also done based on this *Best practice guide of door-to-door Brown Bin education in Ireland* Project.

Advice for waste collectors

A Brown Bin collection service needs a 100% commitment from the waste collector in order for any awareness programme to be successful.

If education were to be conducted by a Local Authority, there should be regular meetings with the waste collection companies operating in the Area to ensure the education provided reflects the service which will be provided by the waste collector.

To facilitate better uptake of the Brown Bin service, the following points should be born in mind by the waste collector when establishing and maintaining a Brown Bin collection service:

- To use good labels for the three bins. Do not label the Brown Bin the ‘Compost bin’ as this was confusing. Householders think the bin was for home-composting and hold onto it for months. Furthermore, they will not put uncooked meats into it.
- The sticker on the caddy is vital as it tells people what the caddy is for and what to put into it. Some people were confusing the 7-litre indoor kitchen caddy as the bin which should be presented for collection. The sticker on the kitchen caddy should also state that it is not the one for collection.
- To ensure that people on a food-waste-only collection have the option of getting an additional bin for food waste if their existing Brown Bin were not sufficient. All waste collection staff should be consistent with the message they give to their customers otherwise, confusion and complaints arise.

- The size, location and occupancy of a dwelling can influence the amount of food waste presented. A fortnightly collection of a 25-litre caddy may not be the solution for all households. Collectors should consider other options such as increased frequency of collection, provision of additional bins, bags for garden waste, *etc.* Collectors providing a food waste only collection should also provide a separate garden waste collection. The Brown Bin should not be the same colour as the general waste bin as this confuses the householder, particularly when the bins were collected on the same day.
- To ensure prompt delivery of bins, especially if running a promotional or awareness event. In order to be efficient and reduce the number of complaints, collectors should aim to provide a Brown Bin to all their customers in an Area at the same time via a blanket drop of Brown Bins as opposed to delivering bins as requested on an individual basis.
- To use the www.brownbin.ie resources in order to deliver a consistent message.
- To introduce a regime for inspecting and rejecting contaminated bins. Rejection stickers/tags should be placed on contaminated bins and the reason for rejecting the bin identified on the label/tag.

1. Appendix

Compostable Bags

Novamont, a bio-plastics company based in the UK are worked closely with Sligo County Council in the delivery of this Project. Tony Breton, is the contact person and is also a member of the Pilot Programme Steering Committee. Tony has worked closely with Sligo County Council during the training phase with the Waste Management Advisors in the preparation of the awareness campaign. Novamont greatly contributed to the project by providing a 9 month supply (72) of certified compostable caddy bags for 6,000 households to Sligo County Council.

The compostable bags for inclusion with each of the caddies for households in Areas A & C.

The image below is the print screen of what appeared on the compostable bags.

Brown Bin Stickers

Information leaflets and brown bin stickers have been developed by brownbin.ie, but tailored by Sligo County Council and Cré, in order to suit the situation in Sligo City. Turners Printing Company in Longford printed the stickers, information and teaser leaflets.

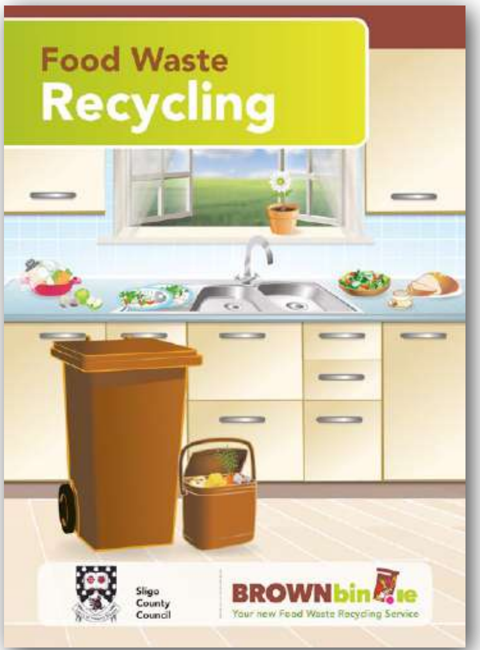
All caddies had a brown bin sticker attached to the front outlining the do's and don'ts of items allowed in the brown bin. The following is a print screen of the agreed sticker used:

Information Leaflet

Also included in the caddies was a six page information leaflet outlining:

- Changes in legislation
- How to use the outside brown bin, kitchen caddy and compostable bags
- An itemised list (including picture images) of what can be placed in the brown bin
- An itemised list (including picture images) of what cannot go in the brown bin
- A detailed picture image outlining each step involved in the disposal of food waste

This information leaflet was distributed to households in Areas A & C only (Areas provided with a kitchen caddy). The following is a print screen image of how this information leaflet appeared:



Teaser leaflets

Teaser leaflets were distributed to all households in the selected areas two weeks prior to the delivery of kitchen caddies and contents. This teaser leaflet were a condensed information leaflet on the brown bin system in Sligo.

The company chosen for the distribution of teaser leaflets was 'All Homes, Unit 8, The Enterprise Centre, Park West, Dublin 12

Teaser leaflet used in **Areas A & C:**

Teaser leaflet used for Area B:

Photos

Launch Event

The launch of the Pilot Project was held at I.T. Sligo on Saturday 19th July 2014 during the Farmers Market from 10am until 1pm.

Envirogrind, (members of the Pilot Project Steering Committee), delivered 10cubic metres of compost for this free compost giveaway event.

The event proved to be a great success with well in excess of 150 people availing of free compost to bring home to their gardens.

There were plenty of questions from members of the public mainly in regard to the food waste bin, the new waste management system and also some questions on garden composting. It was a great opportunity to be able to showcase to people, the advantage of ensuring food waste is segregated properly rather than disposing to landfill.


EGGIE MIX


E MIX


ONAL BROWN BIN PILOT
GRAMME SLIGO CITY
LAUNCH
EVENT
REE COMPOST
OWN BAG
10am to 1pm
turday 19th

Common Questions asked during door-to-door interviews

Q. Do I have to put my food waste into a brown bin?
A. Yes.

Q. Tinfoil contaminated with food – which bin does it go into?
A. Tinfoil contaminated with food should go into the general refuse bin and not the dry recyclables bin.

Q. Which bin can clothes go into?
A. A clothes bank at a civic amenity centre

Q. Can you put raw food into the brown bin?
A. Yes.

Q. I only produce a small amount of food waste; can I put it in the general waste bin?
A. No, as food waste to landfill is banned. By putting it in the brown bin, it will be composted and a useful product will be produced.

Q. Where can more compostable bags be purchased and what price?
A. You can get them in your local supermarket.

Q. We don't have any food waste, I don't need a brown bin.
A. You will need a brown bin, as you will generate food waste when you have dinner parties/kid parties and other functions.

Q. How much will the brown bin cost?
A. Contact your waste collector. But pay by weight is coming and your brown bin and recycling bin will be cheaper than the general waste bin.

Sligo County Council Calling Card Example

Sligo County Council	Waste Management Bye-Laws 2013

I called to you again today to provide you with an opportunity to discuss the changeover from the old waste collection system to the new 3 bin system as contained in the Sligo County Council Waste Management Bye-Laws 2013.

URGENT - Action Required

Under the new Bye Laws you are obligated to manage your household waste as follows:-

a) Register with a permitted waste collector for the provision of 3 waste receptacles to ensure waste is segregated into the following 3 types:-
(i) Foodwaste (ii) Recycling (iii) General Waste

b) Alternatively you can bring your household waste to a Civic Amenity site/Transfer Station for disposal. Receipts must be maintained for a minimum of 3 years for this option of waste disposal.

Please contact me on mobile 087 2077979 or landline (071) 9111465 to confirm if you are already operating in compliance with the above or alternatively to highlight any difficulty you may be having in trying to do so.

Name -- Date ----------

Generic Calling Card Template

INSERT LOGO AND NAME	Household Food Waste and Biowaste Regulations 2015

I called to you today to provide you an opportunity to discuss the changeover from the old waste collection system to the new three bin system as required by the European Union (Household Food Waste and Bio-waste) Regulations 2015.

URGENT ACTION REQUIRED

Under the Regulations you are obligated to segregate food waste and use a brown bin collection service by your waste collector.
You are required to manage your household waste as follows;
Segregate your waste into at least,
(i) Foodwaste and biowaste, (ii) recyclables (iii) residual

Ensure that these three waste streams are dealt with by any combination of the following three methods:

a. Collected by an authorised waste collector.
b. Brought, by you, to an authorised facility (Civic Amenity Site, Transfer Station, landfill, composting or anaerobic digestion facility (you must retain receipts provided to you from these facilities)
c. Deal with the waste on the site on which it was produced by home composting

Please contact me on my mobile xxxxxxxxxx to confirm if you are already operating in compliance with the above or alternatively to highlight any difficulty you may be having in trying to do so.

Name & Date

Door to Door Interview Form

Name: ______________________________

Address: ______________________________

____

Contact No: ______________________________

No. Occupants in Household: ☐

How are you disposing of your waste?

☐	☐	☐	☐
WASTE COLLECTOR 1	WASTE COLECTOR 2	TRANSFER STATION/CIVIC AMENITY SITE	OTHER

	Yes	No	N/A
Are you availing of a 3-bin kerbside collection system	☐	☐	☐

If 'NO' then are they awaiting brown bin delivery or have yet to order?

____

____

Are you a Bin-Sharing Customer?	☐	☐	☐
Do you use a home composter?	☐	☐	☐

	Yes	No
Awareness Talk provided to householder	☐	☐

Completion of Estate Form Template

Waste Advisor: ____

Date: ______________________

Item:	Comment:
Name of Estate:	
Number of HH assigned (from office)	
Number of actual HH on estate/road:	
Number of vacant properties:	
Number of HH spoken to:	
Number of HH awaiting Brown bin (if householder has ordered)	Waste Collector Name: ____________________ Waste Collector Name ____________________
Number of HH actually using the brown bin:	
Total Number of Occupants in Estate:	
Number of households availing of kerbside collection:	
Number of households not availing of kerbside collection but disposing of waste at Civic Amenity Sites/ Transfer Station:	
Number of Bin Sharing Households:	
Details of Bin Sharing Households (i.e. House No's):	
Number of Holiday Homes:	
Details of Holiday Home Occupants:	
General Feedback & Types of Questions being asked:	
Number of Awkward/Negative Households and Feedback on Same:	
AOB that you feel necessary to highlight	

Summary Report of 7 Day Activities

Report to be submitted at weekly in-house meetings

Description	Formula	Result
Start date to finish date (these will usually be meeting dates)		
Number of houses in your area that you examined (including vacant) in last 7 days	X	
Number of vacant houses	Y	
Number of occupied houses (min target of 100)	X-Y	
Number of houses where you spoke with occupants (min target of 70)	Z	
Percentage of occupied houses that you spoke with	(Z/X-Y *100) %	

What goes into the three bins – example literature

DO YOU KNOW HOW TO RECYCLE?

Tips for your Organic Waste Collection Bin

All food and garden waste can be collected in this new waste collection stream for organic waste. To reduce odour problems, biodegradable bags are available or you can simply wrap organic items in old newspapers before placing them in the brown bin. Further tips on food waste prevention can be viewed on **www.foodwaste.ie** Items for placing in the organic waste bin include:

- ✔ Garden waste i.e. grass cuttings, hedge clippings etc
- ✔ Food scraps (including cooked/uncooked meat, fish & poultry)
- ✔ Shellfish & bones
- ✔ Eggs, Egg Shells & Egg Boxes,
- ✔ Dairy Products (Cheese, Yoghurt, etc)
- ✔ Soups & Sauces
- ✔ Table & Plate Scrapings
- ✔ Fruit, Vegetables, Breads, Cereals, Pasta, Dough & Rice
- ✔ Teabags, Coffee Grinds & Paper Filters
- ✔ Cakes, Biscuits, Food Soiled Napkins & Paper Towels
- ✔ Food Soiled Paper
- ✔ Wet Cardboard & Paper (No Plastic)

In rural areas, where people have bigger gardens and areas where compost can be used, the incorporation of a garden composting unit is an excellent way to get rid of garden waste, eggs, egg shells/boxes, fruit, vegetables, teabags & coffee grinds.

Note: No plastic, dairy or meat products should go into a garden composter.

Tips for your Dry Recyclable Collection Bin

Keep all recyclables clean. Remember to wash and squash before popping them into your recycle bin. This helps you get more into your recycle bin giving you value for money while also helping the contractors to recycle more. Items for your recycling bin include:

Aluminium:
- ✔ Food Tins
- ✔ Aluminium Drink Cans
- ✔ Lids from glass sauce jars
- ✔ Biscuit tins
- ✔ Clean tin foil and clean takeaway food trays

Tetra Pak:
- ✔ Milk Cartons
- ✔ Juice Cartons
- ✔ Soup Cartons

Paper & Cardboard:
- ✔ Phone Books
- ✔ Catalogues
- ✔ Tissue Boxes
- ✔ Labels & Tags from new clothes
- ✔ Envelopes
- ✔ Printing paper

Plastic:
- ✔ Shampoo & Shower Gel Bottles
- ✔ Window Cleaner Bottles
- ✔ Washing up Liquid Bottles
- ✔ Detergent & Fabric Softener Bottles
- ✔ Yoghurt Drink Bottles
- ✔ Clean Plastic Wrap, like that found around toilet paper & kitchen towels.
- ✔ Lids removed from plastic & glass bottles
- ✔ Plastic Bags
- ✔ Clean Plastic Food Containers

Tips for your Landfill Bin:

Recycling may seem like a tedious hassle, but it is in all our interests to reduce, reuse and recycle where possible and avoid placing incorrect items in the landfill bin. Putting these new habits in place now will reduce your costs of waste disposal as the charges placed on landfill of waste are rising substantially each year. With population growth on the increase, so too is the need for landfill space, therefore, costs are inevitably going to keep rising for disposal of this type of waste.

The only waste to be placed in this segregation stream is what cannot be placed in the other streams so think twice before you throw out!

This bin should only contain:
- ✔ Non-Recyclable waste
- ✔ Non-Compostable waste
- ✔ Non-Hazardous waste
- ✔ Exclude construction or demolition waste

Examples:
- ✔ Ashes, Nappies, Dirty Plastic
- ✔ Dirty Tin Foil, Sanitary Items,
- ✔ Blades, Toothpaste Tubes,
- ✔ Non-CFL Light Bulbs
- ✔ Crisp Packets,
- ✔ Biscuit Wrappers
- ✔ Wax-Paper Wrappings

Green Composting

Ballisodare Composting Facility accepts all bio degradable garden waste (grass clippings, hedge trimmings, trees, leaves etc) – small fees apply. Peat free compost and home composters are also available for purchase.

Bring Banks / Bottle Banks

FREE recycling of:
- ✔ Glass Jars
- ✔ Aluminium Cans
- ✔ Unwanted Clothes
- ✔ Textiles & Shoes
- ✔ Bottles

Bulky Waste/Unwanted Items

Old toys and unwanted furniture items could be given away to charity if they are in good condition or given away online through sites such as **www.freetradeireland.ie**

sligo.ie

Civic Amenity Sites

Segregate waste at home and transport when full to your local Civic Amenity Centre at a reduced rate to kerbside waste collection and for many items even free of charge i.e. old electrical equipment. Household Hazardous Waste is also accepted at Tubbercurry Civic Amenity Site.

Visit **www.sligococo.ie**, Environmental Services for further details.

Environmental Services, Sligo County Council, Unit 9, Cleveragh Business Park, Sligo www.sligococo.ie

PROHIBITION OF WASTE DISPOSAL BY BURNING

The term 'Backyard Burning' is applied to the uncontrolled burning of waste. Unfortunately this type of waste disposal is frequently being carried out in backyards and in gardens. The term also refers to the burning of any waste in open fires, ranges and other solid fuel appliances or in the open. This form of waste disposal is expressly prohibited and if prosecuted carries high fines and/or imprisonment.

Much of the dioxins created and released into the air through backyard burning settle on plants. This form of waste disposal is quite common in rural farming areas where dioxin emissions can more easily be deposited on animal feed crops and grazing lands. These dioxins then accumulate in the fats of dairy cows, beef, poultry and swine, making human consumption of these harmful chemicals difficult to avoid.

Dioxins are classified as persistent, bioaccumulative and toxic pollutants otherwise known as PBTs. PBTs are highly toxic, long-lasting substances that can build up in the food chain in levels that are harmful to human and ecosystem life. Persistent means they remain in the environment for extended periods of time. Bioaccumulative means their concentration levels increase as they move up the food chain. As a consequence, the top of the food chain tends to have the highest dioxin concentrations in their bodies i.e. humans. Dioxins are not the only pollutants released from this form of waste disposal, other pollutants such as particle pollution, polycyclic aromatic hydrocarbons, volatile organic compounds, carbon monoxide and hexachlorobenzene are all released from backyard burning. Many dangerous health conditions can be caused by inhaling or ingesting even small amounts of these pollutants. Small children, the elderly, or people with pre-existing respiratory conditions can be especially vulnerable to some of these pollutants.

Backyard burners are clearly unaware of the harm they are causing themselves, their neighbours and the wider community. Anyone who witnesses backyard burning in their locality is asked to contact and report this activity to the Environment Section of Sligo County Council immediately.

It may be considered to be a free and easy way to get rid of waste, but in the long run, the number of harmful dioxins and toxic pollutants being released into the air we breath are highly increasing cases of asthma, bronchitis, various cancers and cardiac arrhythmia.

sligo.ie

Environmental Services, Sligo County Council, Unit 9, Cleveragh Business Park, Sligo   www.sligococo.ie

Brown Bin Instruction leaflet

Based on the Feedback from the Pilot the Brownbin.ie instruction leaflet was redesigned

What food waste can I recycle?

You can put any of the following materials into your brown bin:

- ✓ **RAW OR COOKED FOOD**
- ✓ **MEAT, POULTRY & FISH, INCLUDING BONES**
- ✓ Leftover food from your plates and dishes
- ✓ Fruit & vegetables
- ✓ Tea bags, coffee grinds & paper filters
- ✓ Breads, cakes & biscuits
- ✓ Rice, pasta & cereals
- ✓ Dairy products (cheese, butter, yoghurt)
- ✓ Soups & sauces
- ✓ Eggs, egg shells & cardboard egg boxes
- ✓ Food soiled paper napkins, paper towels
- ✓ Newspaper (when used for wrapping food waste)
- ✓ Out of date food with packaging removed (no glass/plastic)

Grass clippings and small twigs can also be added to your large brown bin.

NO THANKS!

Please DO NOT put any of the following materials into your brown bin

- ✗ **Plastic bags/bottles**
- ✗ **Packaging of any sort**
- ✗ Nappies
- ✗ Glass
- ✗ Stones/soil
- ✗ Metal cans/wire
- ✗ Cardboard
- ✗ Ashes, coal or cinders
- ✗ Pet faeces or litter
- ✗ Cooking oils

IF IN DOUBT PHONE AND FIND OUT
contact your waste collection company

How do I use my kitchen caddy?

Compostable Bags / Paper Bags

Step 1.

ONLY use compostable bags with the seedling logo / paper bags.

Kitchen Caddy

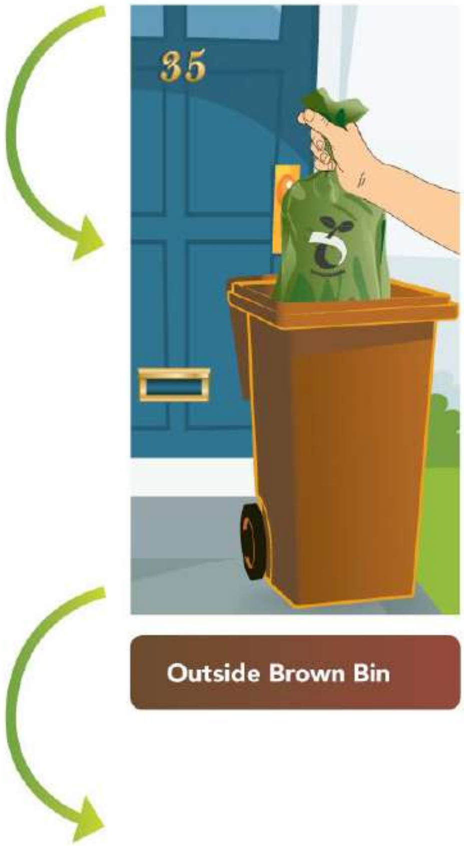
Step 2.

The kitchen caddy is for use in the kitchen.

Not for collection at kerbside

Step 3.

Line your caddy with compostable bags and fill it with food waste



Step 4.

When the kitchen caddy is full, tie the bag and put it into your outside brown bin

Step 5.

Leave you brown bin out every fortnight for collection by your waste collector

Frequently asked questions

I already compost food waste at home, can I still do this?

Yes you can. Your home composting bin can still be used for uncooked vegetables and fruit peelings. However you cannot place raw meat/cooked meats into your home composter.

You can use your brown bin for all types of food waste, **INCLUDING RAW/COOKED FOODS OR MEATS.**

But remember, you cannot place food waste into your general waste bin.

Why should you use the brown bin?

- **It saves money** because you become more aware of the food you waste and is cheaper to use than your waste bin.
- **Recycling food waste is the Law.**
- **It's better for the environment** because you are avoiding sending food waste to a landfill where it produces harmful greenhouse gases.
- **It produces a high quality compost.**

Can I use plastic bin bags in my brown bin?

No. Plastic bags are made from petrochemical plastics that do not break down during composting and contaminate the process. Please remember that if plastic is found in your brown bin, your bin will not be emptied and a contamination tag will be placed on your bin to inform you of this.You may also be liable to an on the spot fine from your local authority.

Will the brown bin cost me more money?

The new brown bin system should not cost more money providing correct segregation of waste is taking place. Under By-laws and National Waste Policy, your waste collector must encourage recycling by offering a lesser charge for collecting your brown bin than your general waste bin.

The most expensive waste stream of all is general waste (landfill waste). There is a Government levy on waste going to landfill, therefore by putting food waste instead into your brown bin, you are avoiding this levy and saving money.

Can I put my food waste into my general waste bin?

You are no longer allowed by Irish law to put food waste into your general waste bin.

If you have any queries contact your waste collector or visit the national information website for more details:

BROWNbin.ie

Your new Food Waste Recycling Service

Tips For Recycling Food Waste

- Only use the special compostable bags that have the seedling logo to line your caddy.
- Keep your kitchen caddy where it's easily accessible or under your kitchen bench.
- Keep you caddy clean by rinsing with water and wiping with kitchen towel.
- Empty your kitchen caddy every 2-3 days to avoid odours.
- Your food waste is collected and brought to a large composting site where high quality compost is produced which is used in landscaping, in gardens and on agricultural land. It is important that you do not put any glass, metal or plastic into your brown bin as it will make the material more difficult to compost and will lower the quality of the compost produced.
- If you have any queries about the scheme contact your waste collector.

BROWNbin.ie

Your new Food Waste Recycling Service

Appendix 4

Sligo County Council

Roinn Cumarsáide, Gníomhaithe ar son na hAeráide & Comhshaoil
Department of Communications, Climate Action & Environment

NOVAMONT

cré
Composting & Anaerobic Digestion Association of Ireland

BROWN BIN IN APARTMENTS - SLIGO TRIAL

As part of the National Brown Bin Awareness Pilot in Sligo a separate project was done in June 2015 with apartments. The trial determined best practice to promote the segregation of food waste using a brown bin system in an apartment complex setting.

Design of the Trial:

- Two apartment complexes were selected for the trial, which are serviced by two waste collectors.
- The apartments selected for the trial were Kevinsfort (comprises of 20 apartments) and Millbrook (3 blocks – total 85 apartments).
- Meetings were arranged with the Management Company of both apartment complexes and also the waste collectors servicing each of these apartment complexes.
- Following the initial meetings, correspondence was prepared and the provision of kitchen caddies, bags, info etc, was provided to the management companies for further circulation to all apartments (Example of letter to each apartment on next page).
- The tenant used a compostable bag in a 7 litre kitchen caddy and then carried it down to a 140 litre brown bin which was located in the communal waste area for the entire apartment complex.

Results

- Monitoring of progress was carried out for up to two months after the circulation of material.
- During the trial, there was a notable improvement in the quantity & quality of brown bin material generated from the tenants.
- However towards the end of the trial there was a lack of interest/buy in from both the management companies and waste collectors meant that old practices crept back in.
- Within the second month of monitoring, the compostable bags provided to tenants ran out and quite a lot of contamination in the brown bin was noted from there on as tenants did not buy more compostable bags and instead started to use normal plastic bags.

Recommendations

- Continued provision of compostable bags by the waste collectors or Apartment Management Company to tenants for continued correct use of the brown bin.
- Obligation to be placed on management companies to ensure correct waste management practice at apartment complexes.
- Information to be provided to tenants on how to correctly segregate and recycle waste.

Further Information

- You Tube on food waste recycling in apartments in Milan - https://www.youtube.com/watch?v=zSjBbp-Q3lU
- Best Practice Guide for Door to Door Brown Bin Education in Ireland

Author: S. Gillen. January 2018

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Sligo County Council, Riverside, Sligo, Ireland
Cré – Composting & Anaerobic Digestion Association of Ireland, Po Box 135, Enfield, Co. Meath Ireland
Novamont, Via Fauser 8, Novara, Italy
Department of Communications, Climate Action and the Environment, Newtown Road, Wexford, Ireland

EXAMPLE OF LETTER TO TENANTS

IMPORTANT NOTICE
LEGAL OBLIGATIONS – WASTE MANAGEMENT

June 2015

Tenant/Householder,
Millbrook Apartment Complex,
Sligo

RE: Sligo County Council Waste Management Bye-Laws 2013

Dear Tenant,

Sligo County Council's Waste Management Bye Laws 2013 require all households in Sligo Town to segregate their waste into three separate waste streams: General, Recyclable and Organic/Food Waste.

In order to assist you with your household waste management and to ensure that you are compliant with the Bye Laws, the following items have been provided to you and you are obliged to start using them from receipt of this notice:

- 7L Solid Kitchen caddy for use within your apartment
- Compostable bags to be used in the kitchen caddy, then transferred, when full, to your outside Food Waste Bin located in the communal waste area.
- White bin liners for your recyclable waste ONLY.
- Black bin liners for your general waste ONLY.
- Laminated publication '*Do you know how to Recycle*?' which is an itemised list of what is allowed in each waste stream. You should place this on the wall of your kitchen which you can refer to if in doubt over what item should be placed in the correct waste stream.
- Information leaflet on how to correctly use your brown bin (food waste collection).

A separate receptacle for all glass items is also located in the communal waste area. It is prohibited to place any glass item in any of the three waste streams outlined above.

Your landlord/management company are obliged to inform you about correct waste management practice in accordance with the above legislation. Monitoring of correct waste segregation in Millbrook will be carried out on a regular basis following receipt of this Notice. As a tenant, non compliance with any condition of these Bye-Laws may result in inspections and a Fixed Penalty Notice of €75.

If you have any queries on the content of this letter or the new waste management requirements, please do not hesitate to contact Waste Enforcement Officer on xxxxxxxxxx or by email to xxxxxx

Yours sincerely

Environmental Services Dept.
Sligo County Council

Appendix 5

Cré
Composting & Anaerobic Digestion Association of Ireland

CRÉ COMPOSTABLE CERTIFICATION SCHEME

"Giving confidence to Irish users that the product is compostable and is accepted in food waste bins"

The Cré Compostable Certification Scheme takes packaging[1]/products[2] certified to European standards and tests them in an Irish composting plant to ensure they are compostable under Irish conditions. If the packaging[1]/products[2] are compostable, they then are awarded a certification from Cré that it is compostable in Ireland.

The Cré Compostable Certification Scheme certificate gives confidence to Irish users that the packaging[1]/products[2] are compostable and is accepted in food waste bins.

CONSUMERS NEED FOR THE SCHEME

Compostable packaging looks similar to disposable packaging and is easily confused. Clearly marked packaging indicating it is compostable is required so people know the correct bin to put it in.

COMPOSTERS NEED FOR THE SCHEME

Collected food waste is contaminated with non-compostable packaging. This results in contaminated compost which cannot be sold.

Cleary distinguishable compostable packaging[1]/products[2] in food waste bins is welcomed by the Irish composting industry.

PACKAGING COMPANIES NEED FOR THE SCHEME

There is a growing consumer demand for compostable packaging[1]/products[2]. However there is great confusion as to what is compostable.

A transparent certification scheme will develop and expand the packaging supply chain.

It has been demonstrated in other EU Countries that certification to European Standards (EN 13432/14995) does not give packaging/product carte blanche to self-declare as compostable in a country. Certification to EN13432 enables producers of products to demonstrate compliance with the Essential Requirements of the standard. When it comes to local market acceptance, EN13432 certification certainly is important but it does not lead automatically to a market, a local certification scheme boosts consumers' confidence and product acceptability.

BENEFITS OF THE CRÉ SCHEME

- Provides independent Irish certification to packaging[1]/products[2] manufacturers that their packaging is compostable in Ireland.
- Provides independent endorsement to packaging manufacturers' customers that their products are compostable.
- Gives confidence to the the public that products are legitimate and compostable in Ireland.

1. Packaging certified to EN13432
2. Non packaging products certified to EN 14995

1. Pre-Qualification	Products must first be certified by TÜV Austria*/Din Certco or equivalent to I.S. EN 13432 / I.S. EN 14995. **TÜV Austria (formerly Vincotte)*
2. Application Process	A completed application form, product testing fee and a sample of the product are sent to Cré Certification Ireland. The scheme manager assesses suitability to progress to the testing phase.
3. Testing in Composting Plant	A trial using the product will be set up by the scheme inspector at an Irish industrial composting plant. Once the trial is completed, the scheme inspector completes a report on the results in an industrial composting plant including a recommendation on certification.
4. Validation of Results	The results of the testing are reviewed and validated by the Certification Committee to determine the final certification result.
5. Certificate & Logo	Successful applicants are required to sign the 'Cré Certification Scheme Logo Use Rules' and pay the annual licence fee. On completion of this, the certificate and logo are issued.

FEES

- **Stage 1:** Testing Phase of the Product in a Irish Composting Plant
- **Stage 2:** Annual License Fee for Scheme Logo

For details on prices contact the scheme manager – certification@cre.ie

WEB:

Please visit www.compostable.ie for information on the scheme.

ABOUT

Cré Certification Ireland is the certification body for the Cré Compostable Certification Scheme. It is a wholly owned subsidiary of Cré - the Composting and Anaerobic Digestion Association of Ireland, which is the national trade body for the sector.

The Cré Compostable Certification Scheme is the only Irish scheme providing third party independent assessment that packaging/products are compostable in Ireland and is accepted in food waste bins (brown bins).

cré
Composting & Anaerobic Digestion Association of Ireland

cré certification IRELAND

Appendix 6

Commercial Food Waste Survey

Date: September 2019

Job Reference: 375319

Co-funded by:

southern waste region

eastern - midlands waste region

connacht-ulster waste region

cré Composting & Anaerobic Digestion Association of Ireland

epa Environmental Protection Agency

An Ghníomhaireacht um Chaomhnú Comhshaoil

Roinn Cumarsáide, Gníomhaithe ar son na hAeráide & Comhshaoil

Department of Communications, Climate Action & Environment

REDC

Research Details

What?

- Research was needed to assess attitudes & behaviours among businesses in relation to food waste disposal to feed into discussions around food waste legislation.
- RED C Research was commissioned to carry out the survey, funded by the below organisation.

How?

- Participants were sent a link to an online survey.
- A sample of members of the Restaurant Association of Ireland, the Vintners Federation of Ireland, Small Firms Association and IBEC took part in the survey.

How many?

- A sample size of 151 was achieved.

When?

- 15th - 30th August 2019.

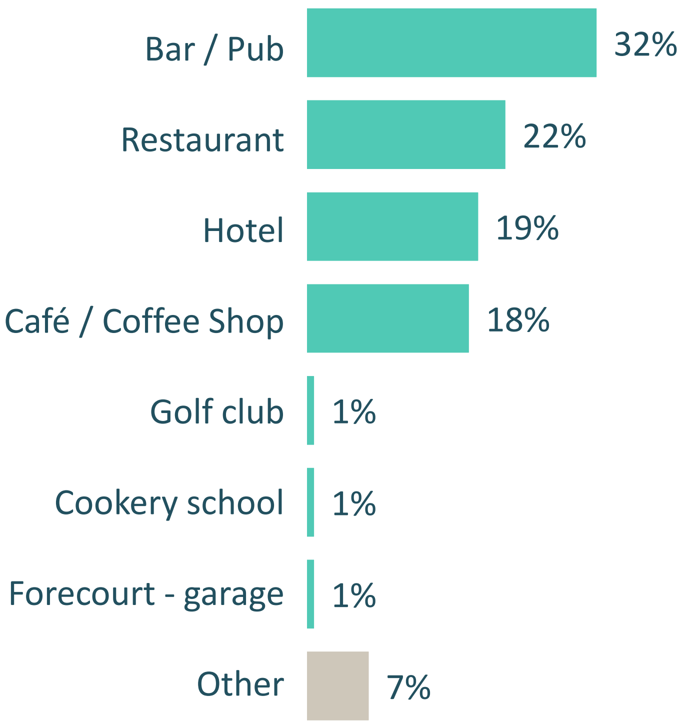
southern waste region
eastern - midlands waste region
connacht-ulster waste region
cré Composting & Anaerobic Digestion Association of Ireland
epa Environmental Protection Agency
Roinn Cumarsáide, Gníomhaithe ar son na hAeráide & Comhshaoil
Department of Communications, Climate Action & Environment

REDC

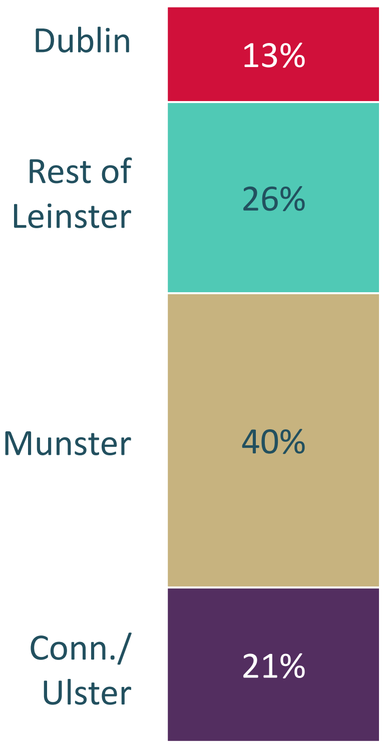
Profile Of The Sample

(Base: All Businesses; n= 151)

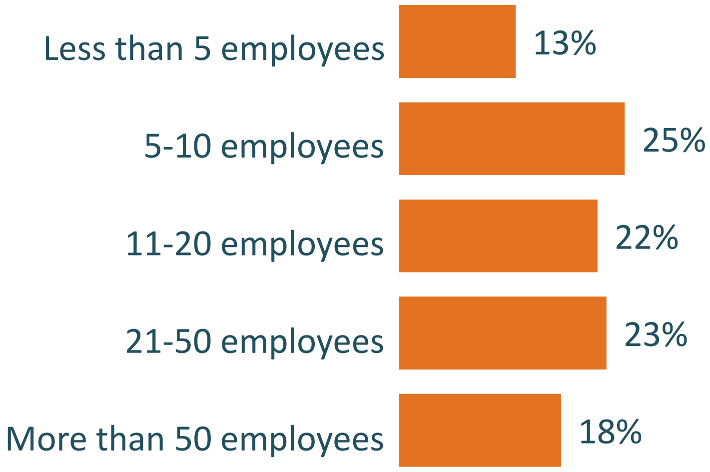
Type of Business



Region



No of Employees

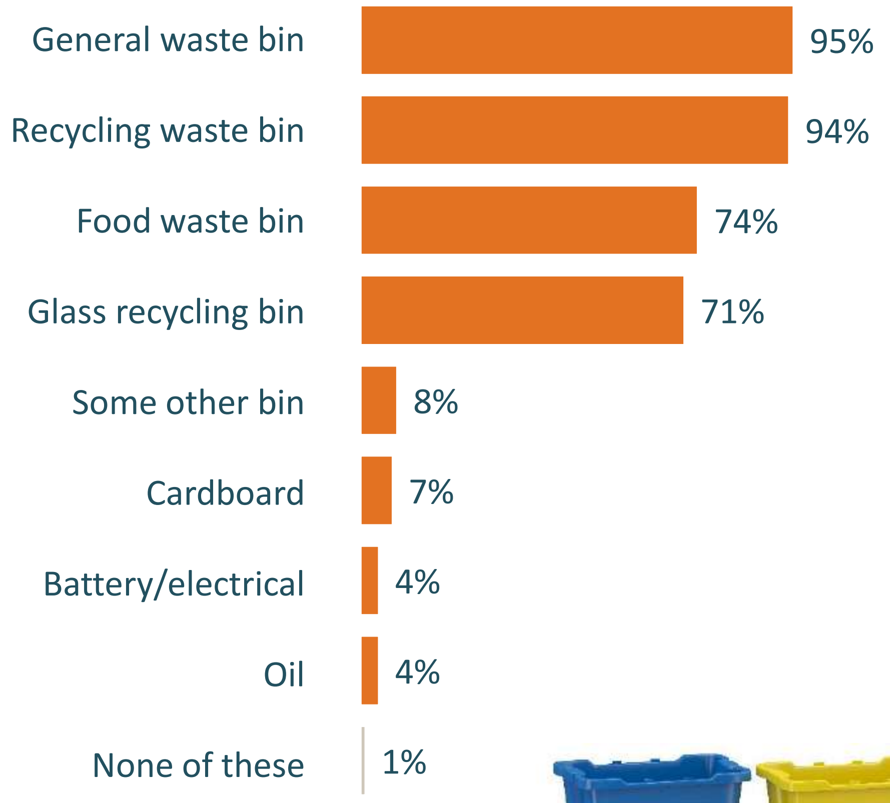


A mix of business types and sizes with a wide geographical spread was included in the survey.

Waste Bin Usage & Collection

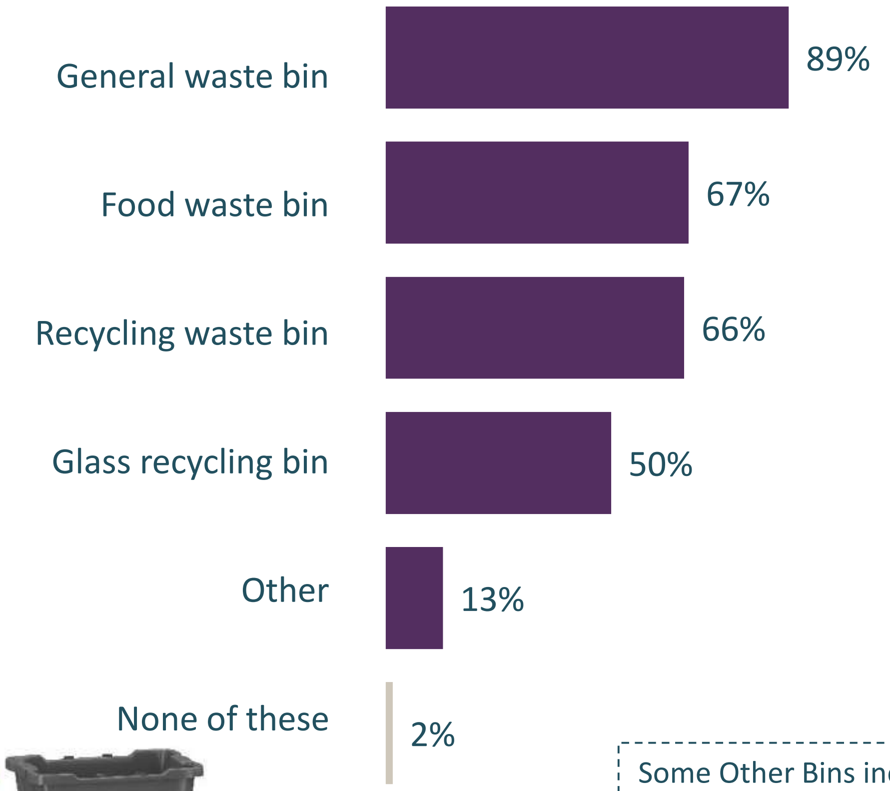
Types Of Bins On Premises

(Base: All Businesses; n= 151)



Types Of Bins Used For Waste

(Base: All Those With Each Bin Type; N= 150)



Some Other Bins include:
- compost bin
- bringing waste to a recycling centre

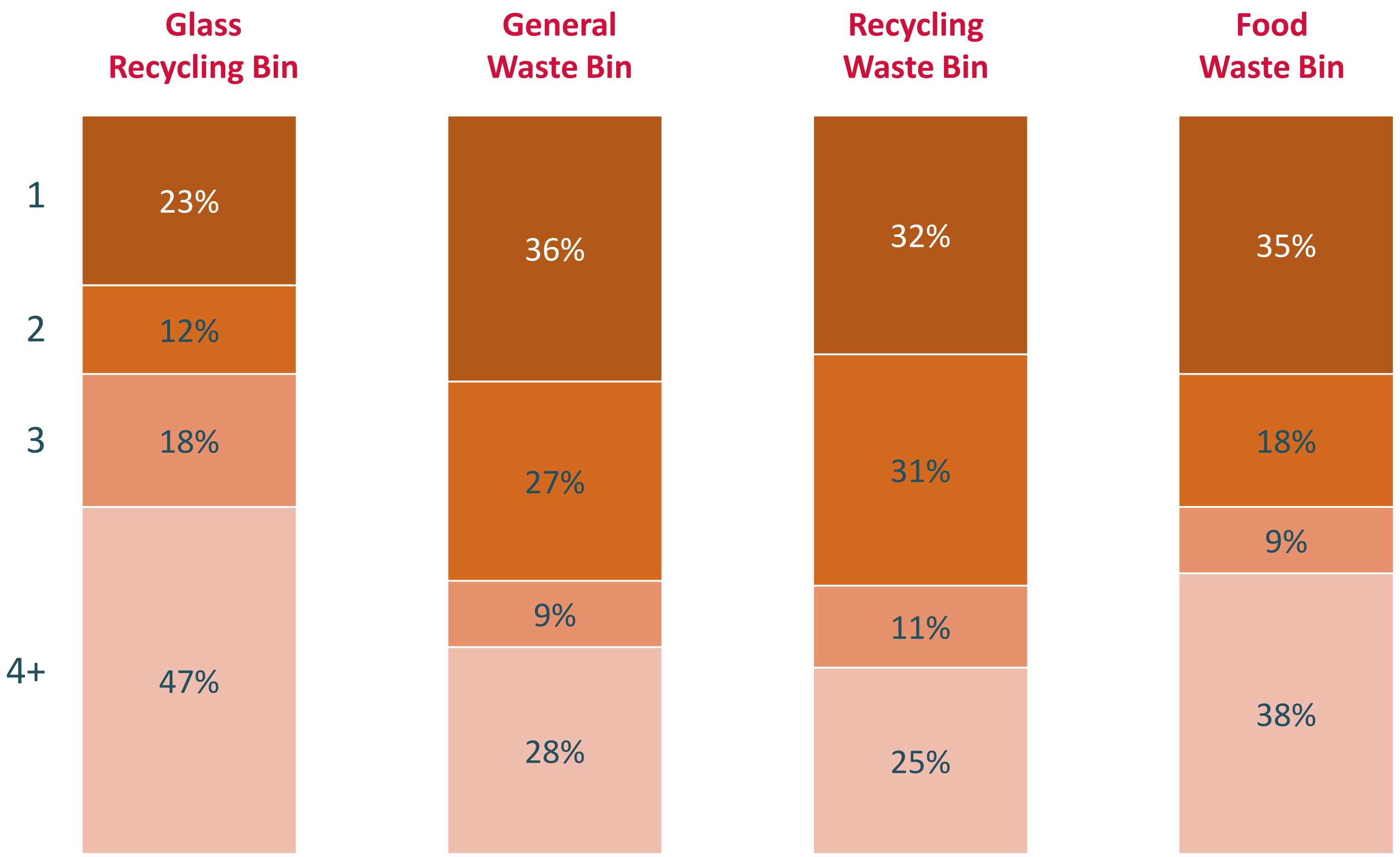
More than 9 in 10 businesses reported having a general and a recycling waste bin, however, only 89% and 66% of these said they use these bins for their waste respectively. Despite legislation requiring businesses to have a food waste bin, only 3 in 4 said they have a food waste bin and only 67% of these said they use these bins.

REDC

(Q.3/4)

How Many Of Each Bin Types Do You They Have?

(Base: All These With Each Bin Type; n = 151)



Those with 4+ bins are more likely to be:

- Larger establishments (20+ employees)

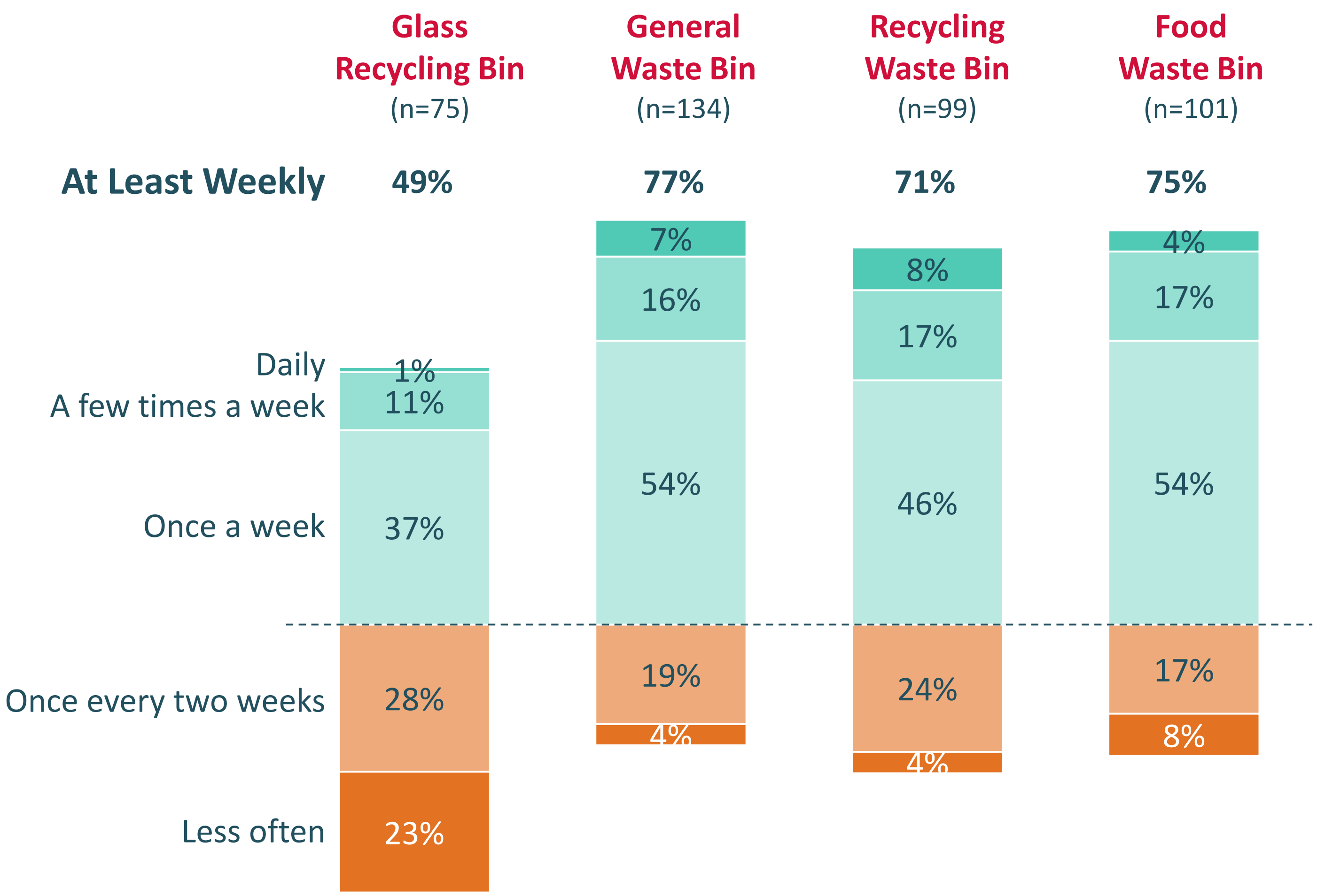
Businesses tend to be more likely to say they have 1-2 general, food and recycling waste bins as opposed to close to half that say they have more than 4 glass recycling bin. This may be linked to frequency of collections, as general, food and recycling waste tends to be collected more frequently and as such doesn't accumulate as much as glass recycling might.

REDC

(Q.3b)

How Often Is Each Bin Collected?

(Base: All These With Each Bin Type; n = 151)

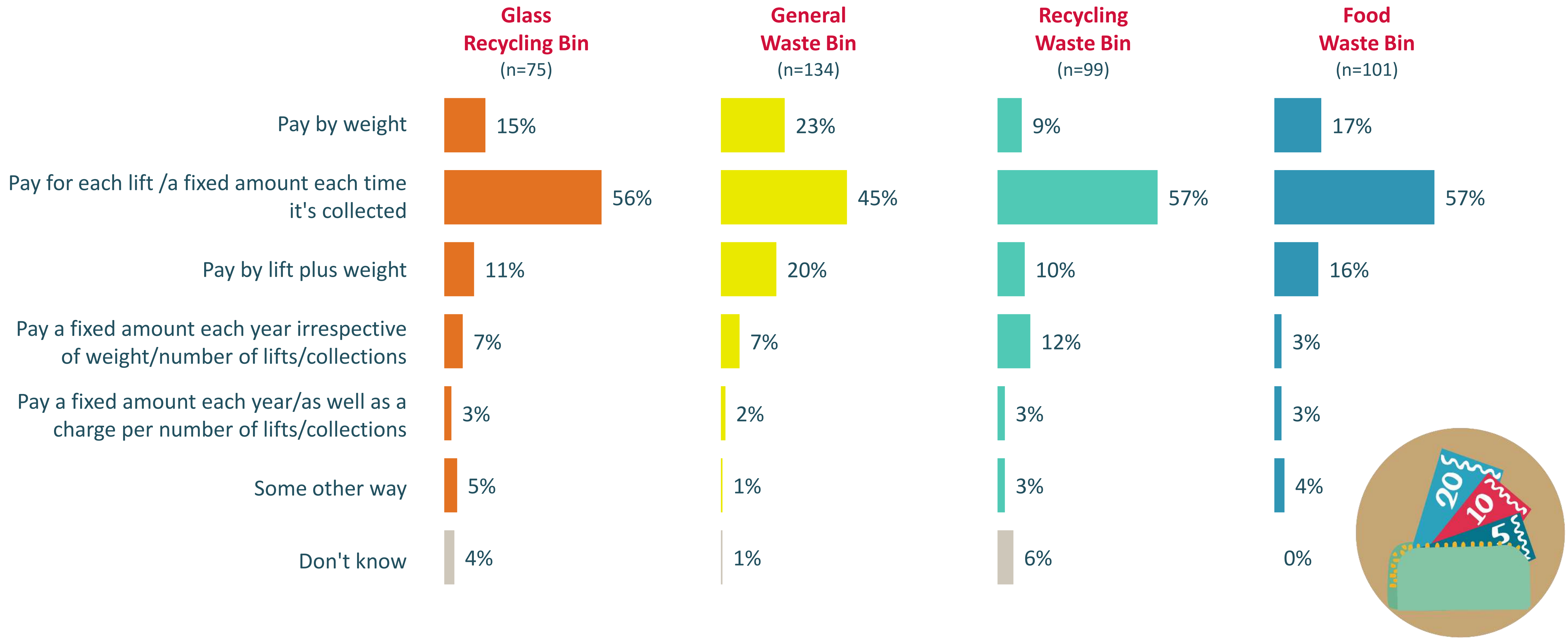


Majority of the businesses have their bins collected at least weekly, with over 3 in 4 saying their general waste, recycling and their food waste bin are collected once a week or more often. Only half the businesses with a glass recycling bin have these collected on a weekly basis.

(Q.5)

How Are They Charged For Bin Collections?

(Base: All Who Use Each Bin Type)



Paying per lift or per collection is the most popular mode of payment for waste collection among these businesses regardless of the type of waste.

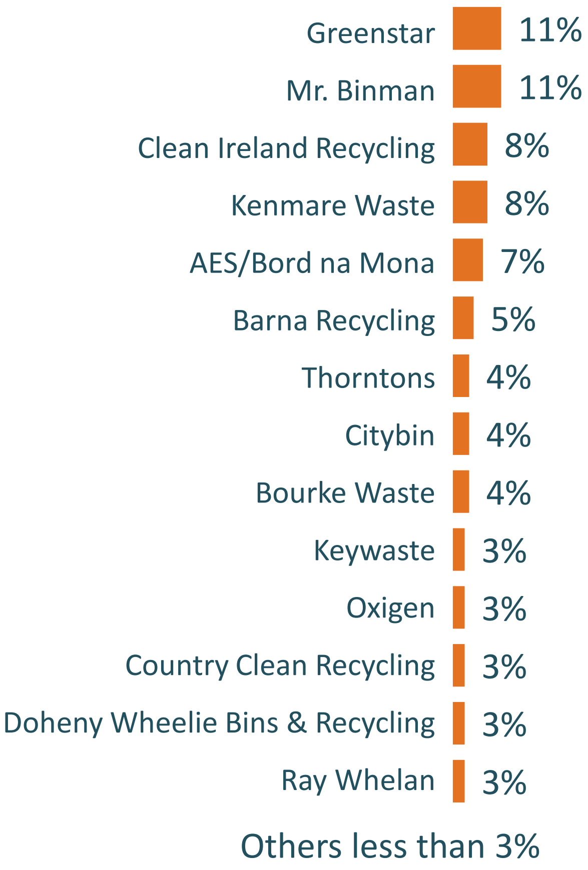
REDC

(Q.6)

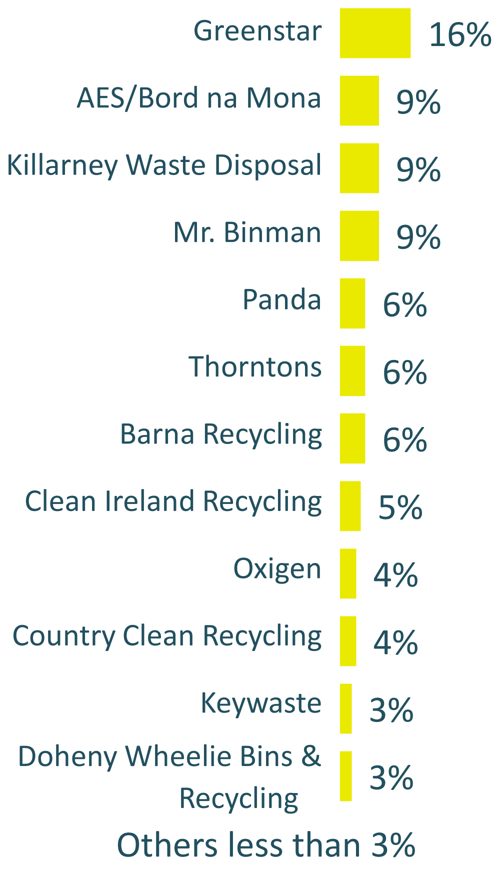
Who Have They Employed To Collect Their Bins?

(Base: All Who Use Each Bin Type)

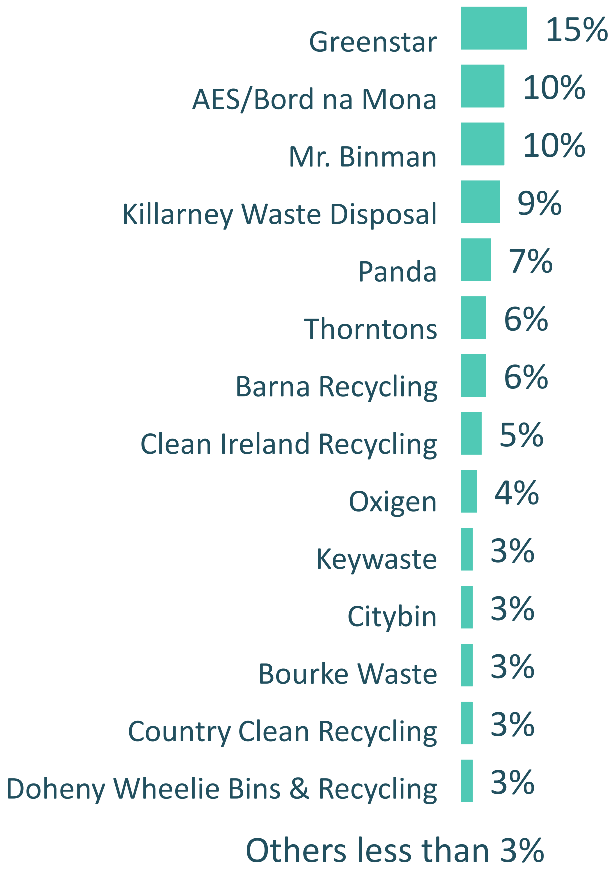
Glass Recycling Bin (n=75)



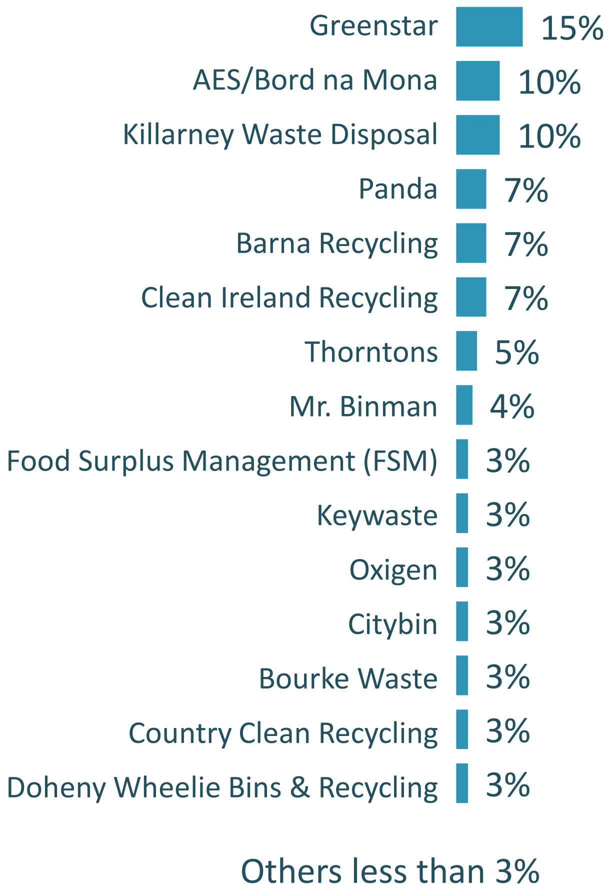
General Waste Bin (n=134)



Recycling Waste Bin (n=99)



Food Waste Bin (n=101)



While Greenstar is the top mentioned waste collector across the different bin types, a wide mix of companies are employed to collect various bin types.

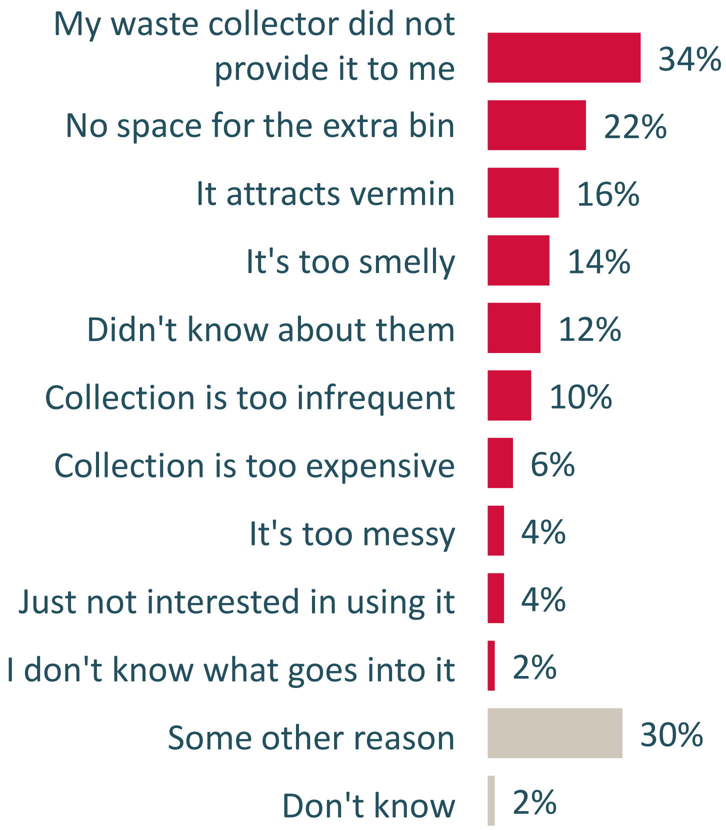
(Q.7)

Attitudes Towards Food Waste Bin Usage

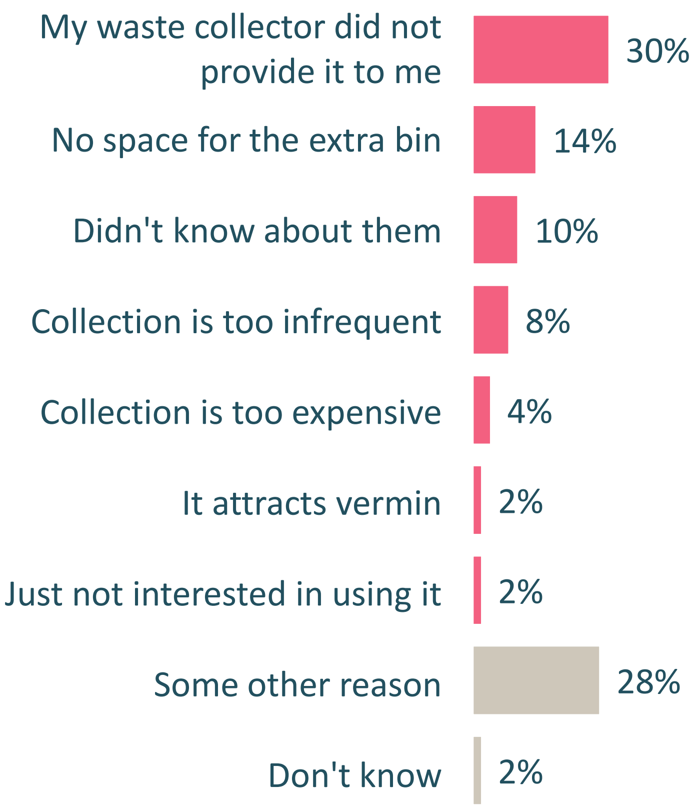
Reasons They Don't Have/Use A Food Waste Bin

(Base: All Who Don't Have/Use A Food Waste Bin; n= 50)

Any Reason



Main Reason



Other reasons included:

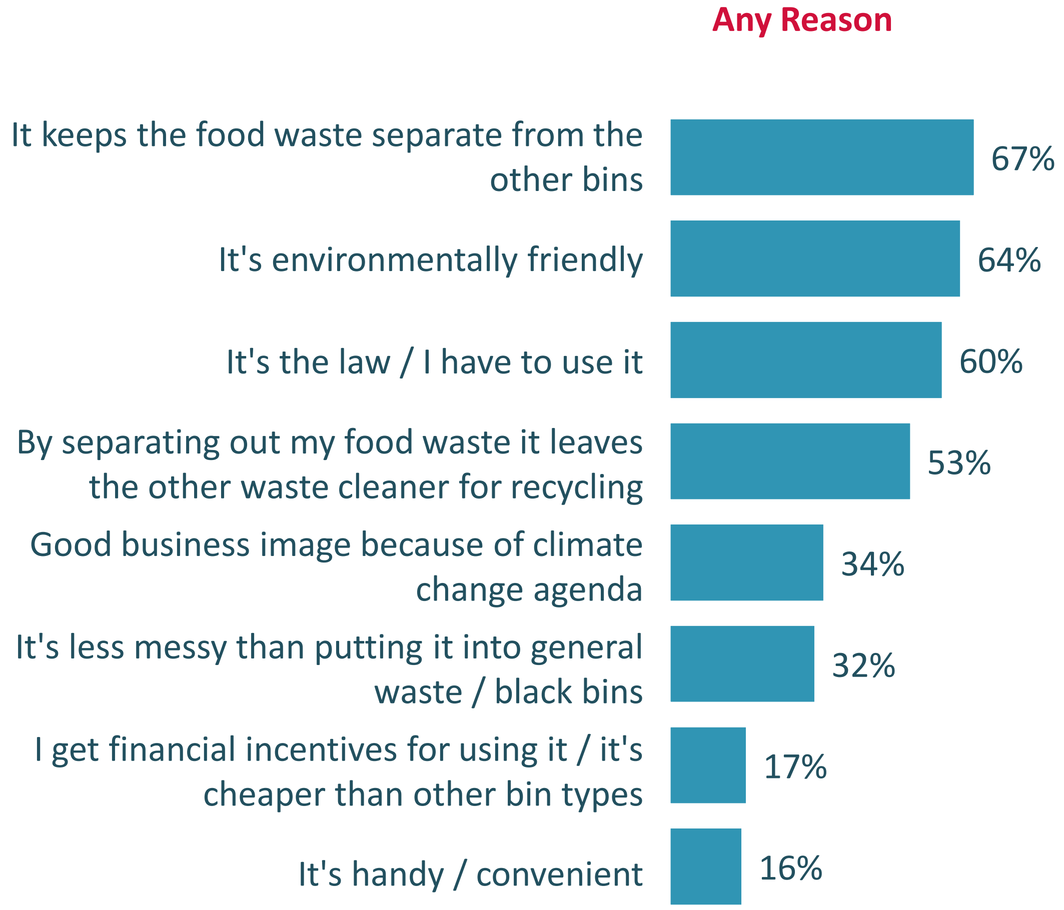
- Composting food waste
- Produce very little food waste
- Take food waste home/to farm
- Food waste collected by dog owners/ pig farmers

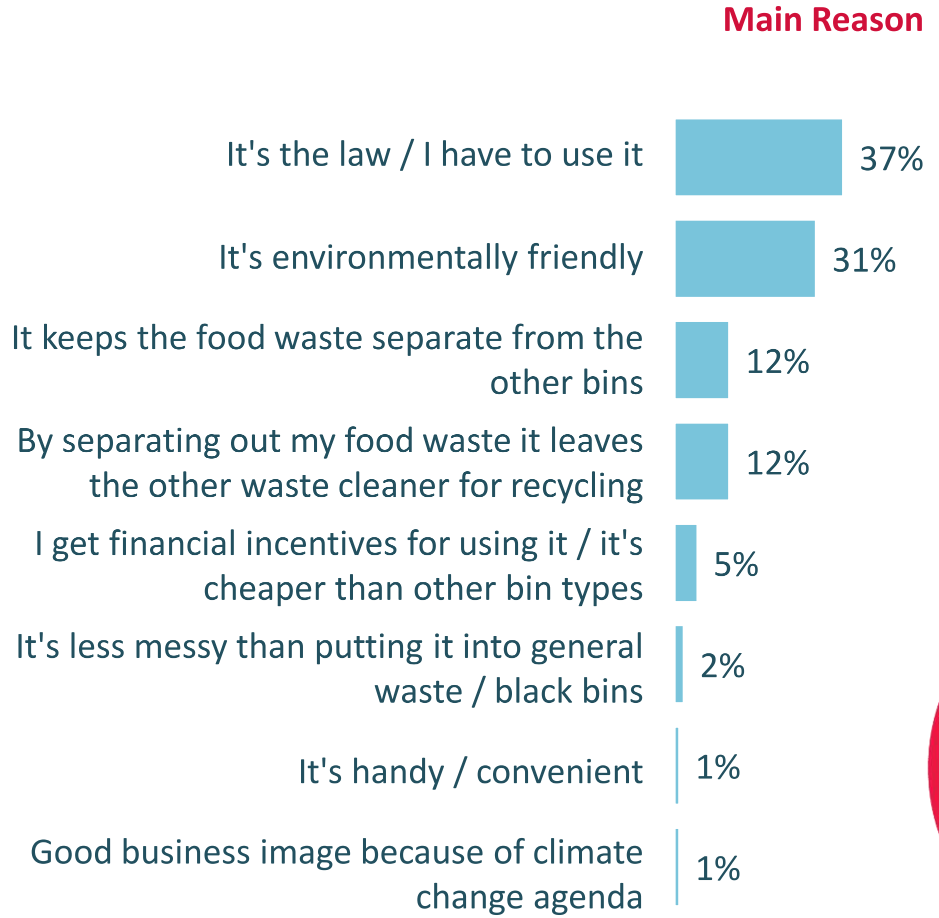
According to businesses, the main reason why they don't have or use a food waste bin is because it was not provided by their waste collector – this is despite the fact that legislation requires collectors and businesses to have and use a food waste bin. Not having the space needed for an extra bin and not knowing about food waste bins were also among the reasons cited.

(Q.8/8a)

Reasons For Using A Food Waste Bin

(Base: All Those Who Use A Food Waste Bin; n= 101)



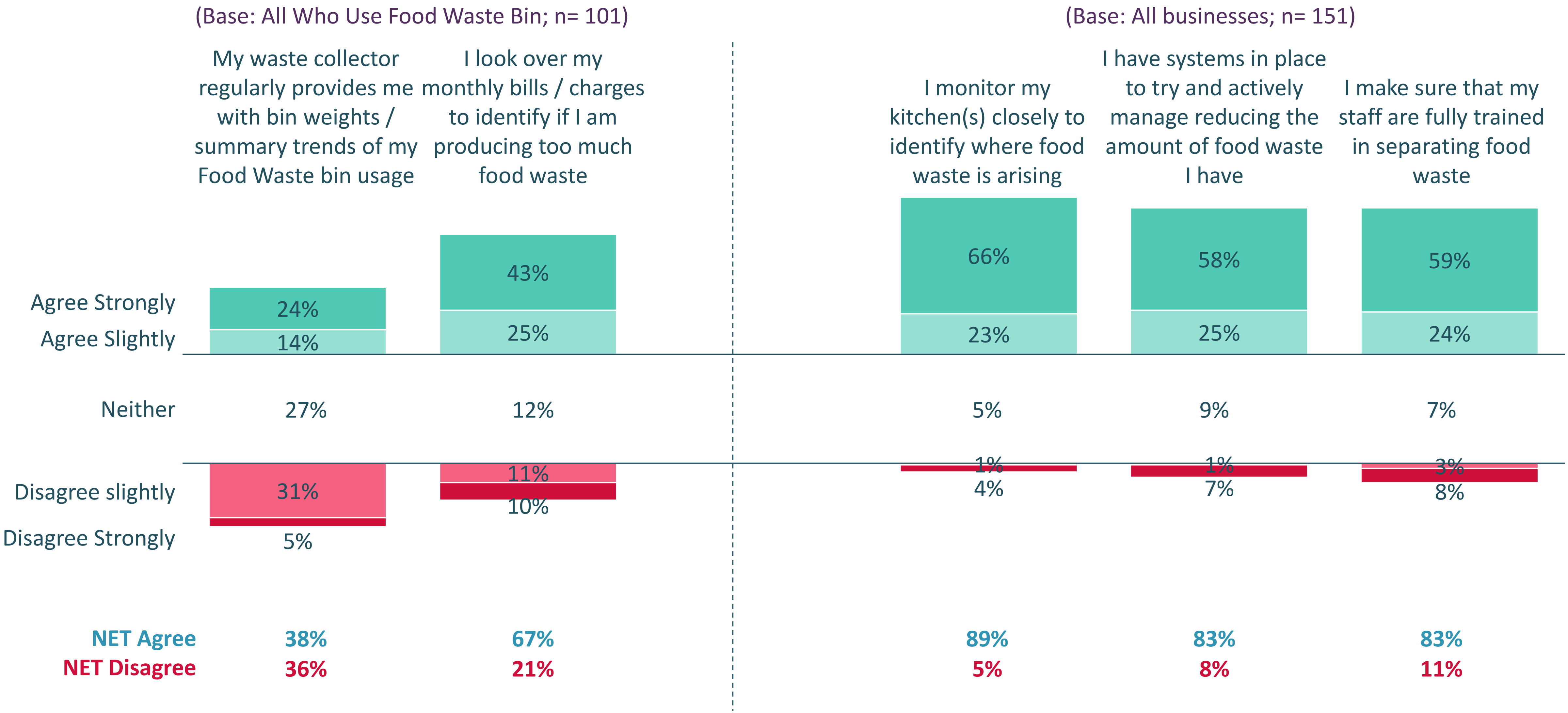


On the other hand, over a third of those who use a food waste bin say they do so because it's the law. A slightly lower proportion use a food waste bin because it's environmentally friendly, while a quarter of businesses say using a food waste bin keeps the food waste separate from other types of waste and leaves other waste cleaner for recycling.

REDC

(Q.9/9a)

Attitudes Towards Food Waste Management



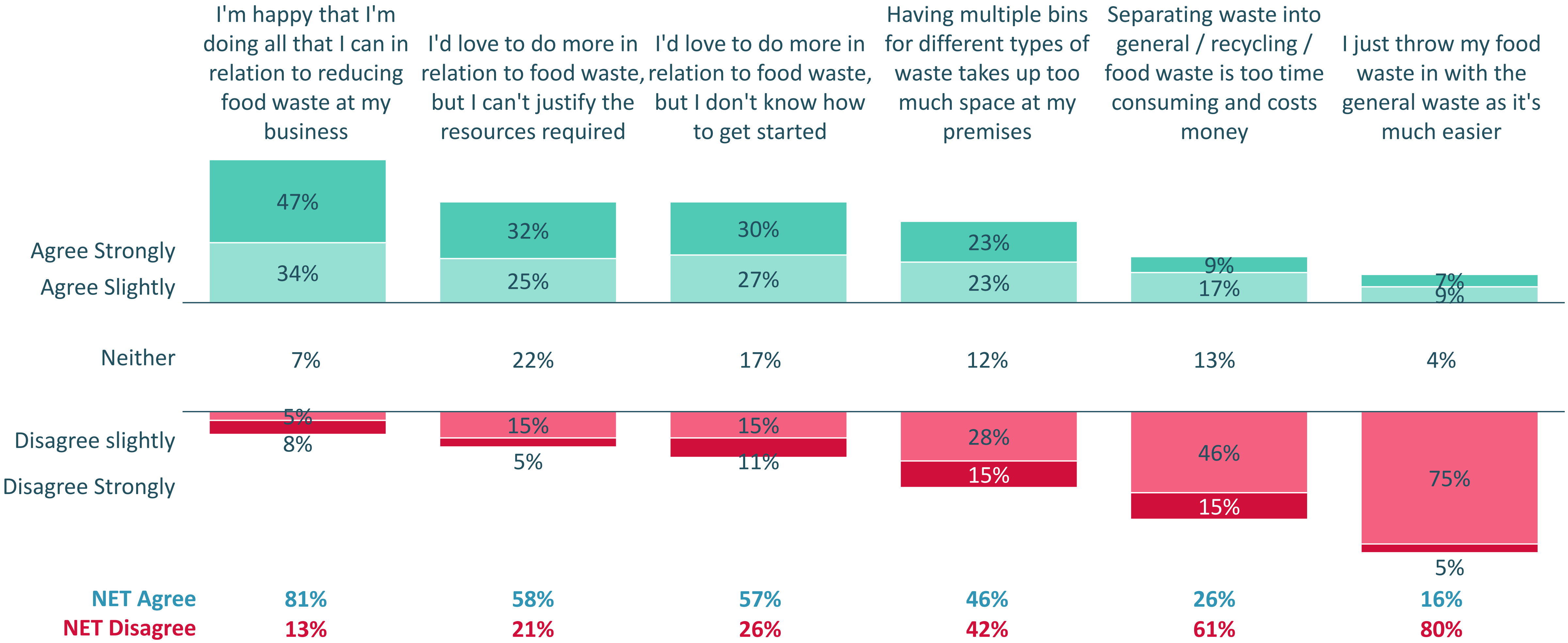
Just under 2 in 5 say they receive summary trends in relation to their food waste bin usage and 2 in 3 say they look over bills and charges to see if they're producing too much food waste. Over 8 in 10 report monitoring kitchens, having systems in place to reduce food waste produced and train their staff in relation to separating food waste.

REDC

(Q.10)

Attitudes Towards Food Waste Management

(Base: All Businesses; n= 151)



While 8 in 10 say they're happy they're doing all they can in relation to reducing food waste, just under 3 in 5 would still like to do more but say they either can't justify the resources required or don't know where to begin. Only 1 in 4 believe that separating waste is too time consuming and cost money, while only 1 in 6 report throwing their food waste with the general waste as it's easier.

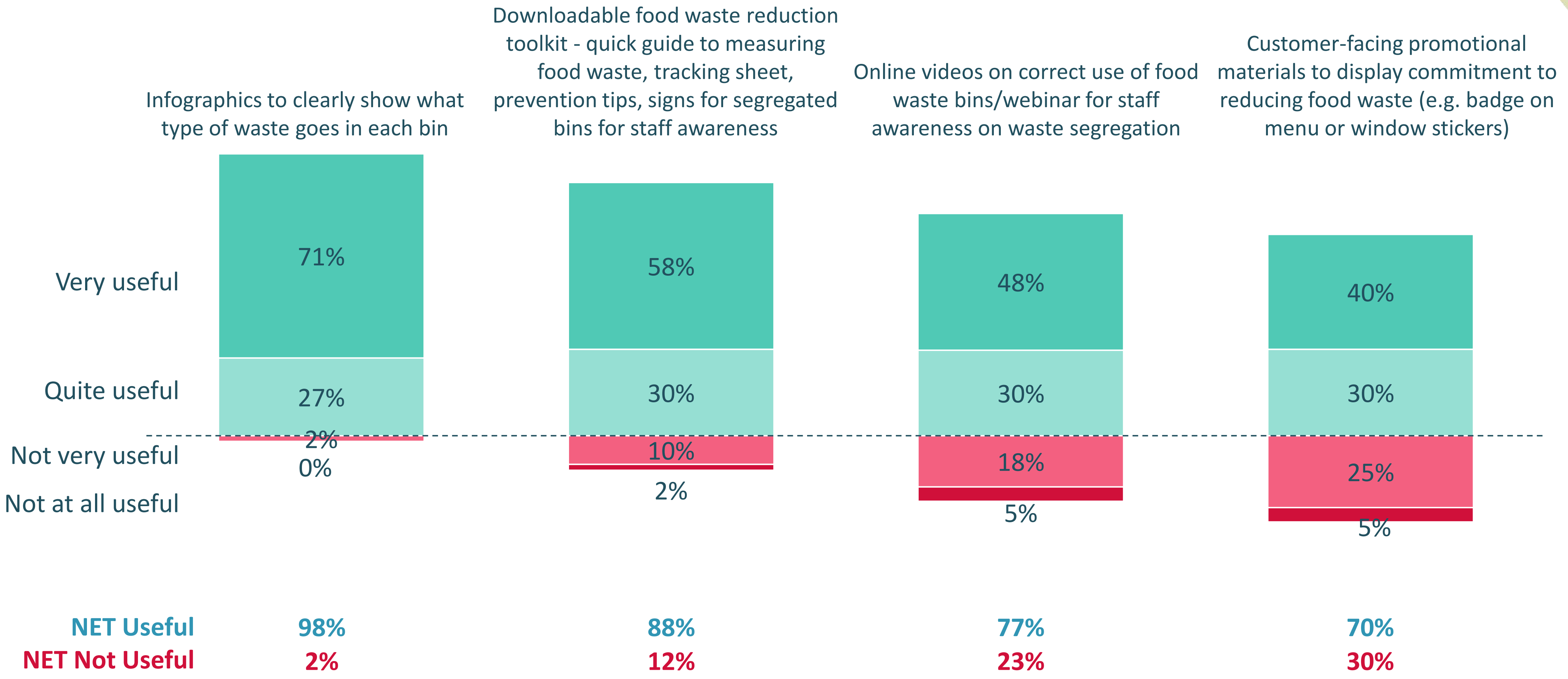
REDC

(Q.10)

Encouraging Food Waste Bin Usage

Useful Initiatives To Encourage Food Waste Bin Usage

(Base: All Respondents; n = 151)

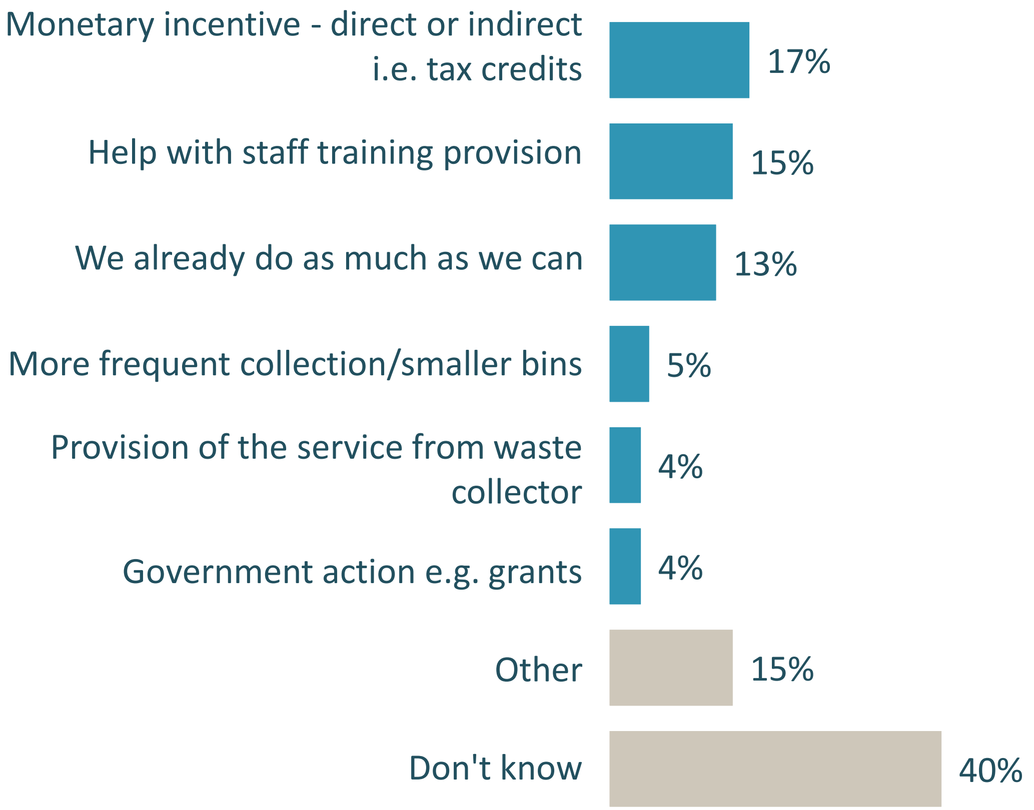


Infographics to show what type of waste goes into each bin proves to have universal appeal among businesses to help encourage them to use their food waste bin, while nearly 9 in 10 believe a downloadable food waste reduction toolkit is also useful. Over 70% would also think online videos and customer facing promotional material would be helpful in getting businesses to use a food waste bin.

(Q.11)

What Can Be Done To Encourage Them To Use Food Waste Bins More Frequently

(Base: All Respondents; n= 151)



Food waste is expensive to dispose of as it's so heavy.

Education that food waste and biodegradable products such as paper napkins, paper towels can go together in food bins. Big education required in some premises to segregate waste.

Supply the Bin and have a low cost pick up service that incorporates a bin cleaning system

Not much more we can do. We're very proactive.

Incentivize the use of it. Make it free or very cheap relative to other bins to dispose of.

I believe we currently use the bin to a good degree but as is the case in a lot of circumstances staff may, in busy time need to be reminded.

Introduction of smaller bins which can be emptied in to large bins easily. So they are more convenient for all the team.

It would be more beneficial to have food waste collected more often. The summers bring a challenge with flies and other animals

Daily pick up of the waste. We do not have a space to store any bins so food waste bags will need to be pick up every day.

In order to justify the use of a separate Food waste bin it would need to be very competitively priced, as in our case we have very little food waste.

The cost of a small 100L bin is over €14 per bin And a 1000L bin is €70 Food waste collection should be in line or free, Compostable Ware is cups plates etc will fill a small bin with 2 bags!!! They end up in the general bin, Give a grant for onsite composting!

It would be nice if it was cheaper to have bins lifted. Information on where food waste ends up, how its processed, and what the benefits are might be motivating for staff

A standard training package available for all management and staff highlighting the advantages of minimizing and handling food waste correctly.

When asked to suggest what else can be done to encourage more frequent usage of food waste bins, businesses mention monetary incentives and help with staff training. In addition, 13% feel that they already do as much as they can regarding food waste.

REDC

(Q.12)

Key Findings

Key Findings

1. The survey represents a good spread of business establishments and business sizes, spread across geographical locations around Republic of Ireland.

2. Overwhelming majority of businesses have general and recycling waste bins and use these. However, only 3 in 4 have food waste or glass recycling bins and there are gaps in whether or not these bins are used.

3. A good spread of waste collectors across businesses, with majority of waste being collected at least weekly. Most pay a fee per lift or per collection for their waste disposal, regardless of the type of bin.

4. Those businesses who don't have or use food waste bins say not being provided the bins by their collector or lack of space for an additional bin as the main reasons. While those who do use these bins cite the law and environmental concerns as the main reasons.

5. Businesses report analysing their bills in order to assess their food waste production and actively looking at ways to reduce this type of waste. They express an openness to initiatives that can help encourage food waste bin usage through toolkits and staff training aids.

THANK YOU

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Appendix 7

Flanders
State of the Art

Implementation plan for household waste and comparable industrial waste - summary

TOGETHER WE
MAKE TOMORROW
MORE BEAUTIFUL

OVAM

WWW.OVAM.BE

IMPLEMENTATION PLAN FOR HOUSEHOLD WASTE AND COMPARABLE INDUSTRIAL WASTE

TABLE OF CONTENTS

1 WHAT IS THIS DOCUMENT ABOUT?

Trying out innovative collection systems, efficiently tackling litter, sharing best practices with other local authorities on how to tackle waste and materials? The new implementation plan for household waste and comparable industrial waste offers you inspiration to start working on waste and materials in your municipality as well. What you have in your hands is a brief summary of the aforesaid implementation plan.

The implementation plan is the successor of the "Implementation Plan for Environmentally Responsible Household Waste Management" (UMBHA) and the plan "Separate Collection of Industrial Waste from Small Enterprises". From 2008 to 2015, UMBHA laid down the general guidelines for the prevention, separate collection, and treatment of household waste. Meanwhile, the social context has changed: e.g., the composition of the Flemish population is rapidly changing, an increasing number of Flemish people now live in cities, and compact living is gaining in popularity.

According to this changing context the new implementation plan for household waste and comparable industrial waste intends to customise. It translates the Flemish waste- and materials policy for the coming years into detailed actions on the field, with a local-level focus. With the implementation plan, you as a local authority can more customise your approach and work out pilot projects to test new collection schemes.

As a local authority, you play a key role in the waste- and materials policy. After all, you are the first point of contact for the residents in your municipality. The implementation plan for household waste and comparable industrial waste will provide you with ideas and tools to collaborate with the residents, associations, and companies from your municipality, to achieve more waste prevention and re-use, a better source-separated collection and recycling, and less litter. In this manner, we will jointly work together towards a beautiful and material-conscious Flanders showing in Europe at the top regarding its waste policy.

The implementation plan is aimed at the following types of waste:

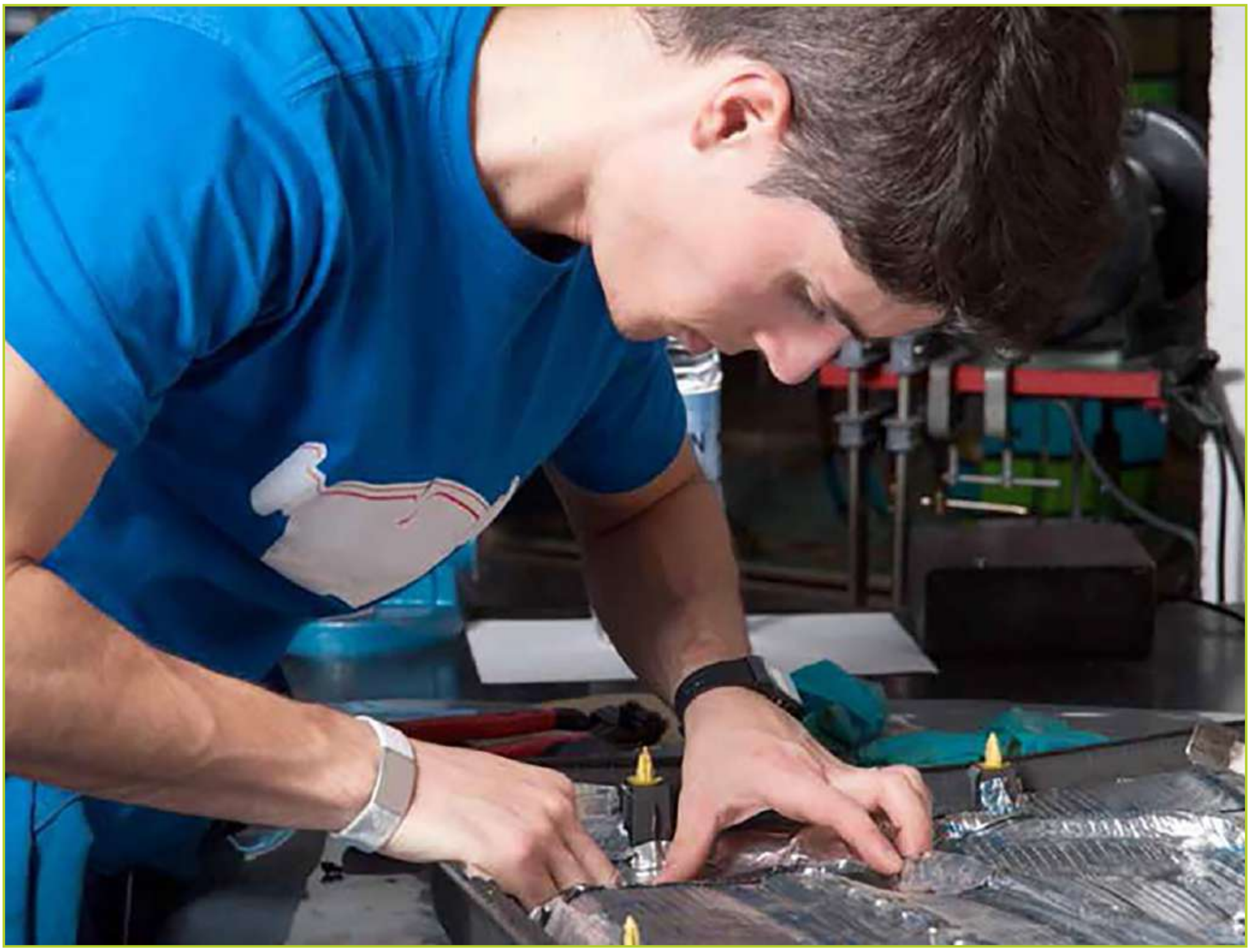
Household waste:

- source-separated collected waste;
- residual waste;
- bulky waste;
- street and sweeping waste, litter and waste from street dustbins.

Industrial waste:

- industrial waste similar to household waste: this refers to waste from businesses that is of a nature, composition, and quantity similar to household waste. It is mainly collected by municipalities.
- comparable industrial waste: this refers to waste from businesses that is of a nature and composition, similar to household waste. This involves quantities larger than those of household waste, and such waste is mainly collected by private waste collectors.


Papier



2 SOCIETY IS CHANGING

Since the launch of the previous implementation plan in 2008, the social context in Flanders has changed. This also has implications for the waste- and materials policy. The new implementation plan for household waste and comparable industrial waste is a response to this changed context.

2.1 Three social trends

The implementation plan takes into account **three social trends**. Your municipality is also involved in this to a certain extent:

1. **Compact living is gaining in importance.** In recent years, the construction of high-rise buildings and the number of smaller homes is increasing again. Residents there have less space to store their waste for a long period of time.
2. **Mobility** is increasingly becoming a bottleneck. Waste collection also places a burden on local traffic and on the liveability. In addition, it is not evident for urban dwellers to visit a recycling yard, since they often don't have a car.
3. **The composition of the Flemish population** is changing. "The citizen" does not exist. The Flemish citizen sorts waste in various ways and generates various quantities and types of waste, depending on their income, age, family structure, socio-cultural background, education, ... He also responds differently to initiatives to prevent and sort waste.

2.2 More customisation

With the new implementation plan, the OVAM aims to respond to those social trends and offers local authorities more customisation. We take into account the changed local context and the differences between municipalities. The plan therefore provides the outlines, but the municipalities will have **more autonomy** in implementation. For example, the implementation plan determines the waste fractions that each local authoroty is mandatory to collect, but you will keep control on the waste management: raising awareness among families, ensuring that they collect their waste source-separated in a correct way, ensuring cleanliness in your municipality, ...

2.3 Innovative collection systems

In the next seven years, you as a local administration will be able to utilise new collection systems. In concrete terms, this concerns the following:

- **bring system at short distances:** residents carry their waste to a nearby collection point;
- **mini recycling yard:** you may set up temporary or permanent mini recycling yard. Residents may dispose of their waste on foot or by bicycle;
- **try out new methods of collection in a pilot project.**

3 GOALS TO ACHIEVE BY 2022?

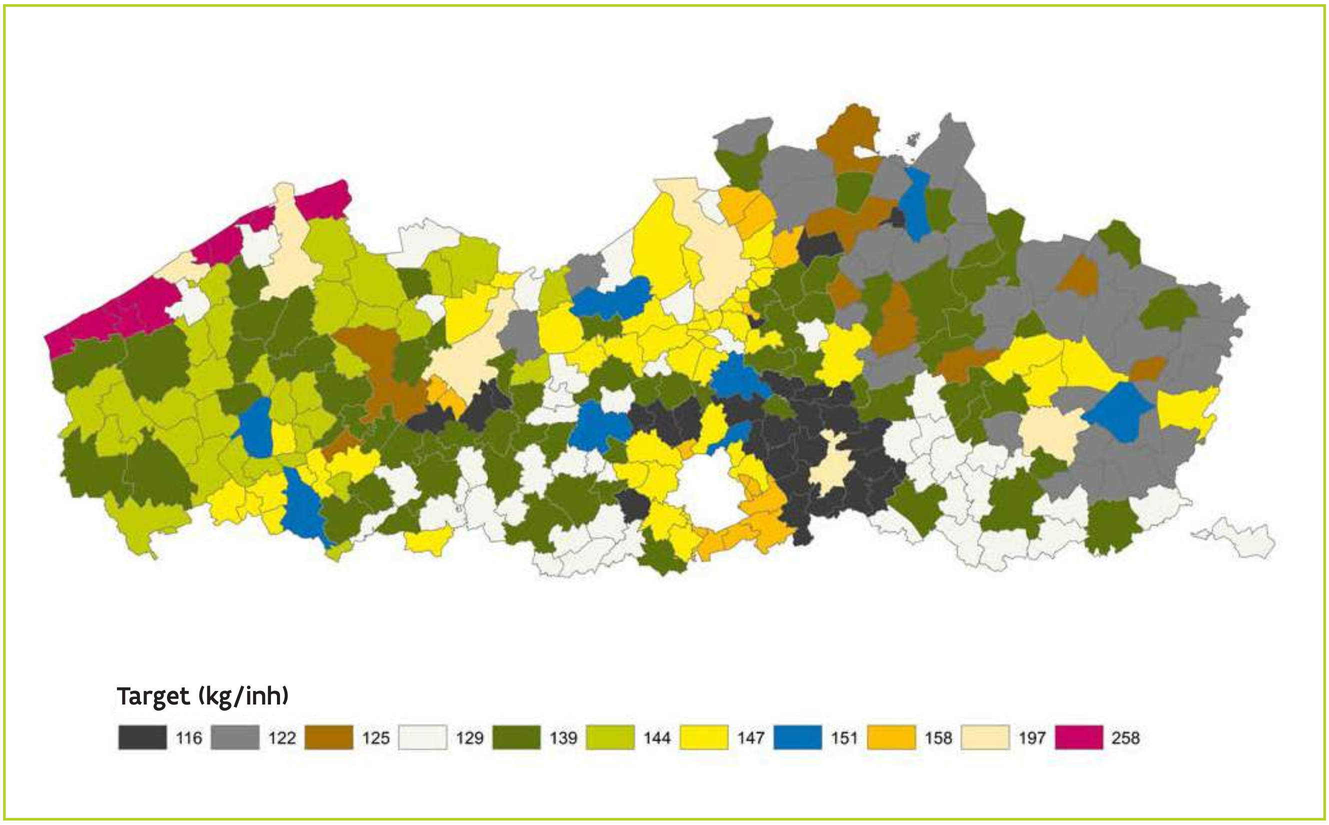
With the implementation plan for household waste and comparable industrial waste, Flanders wants to drastically reduce the total quantity of residual waste from households, companies, and organisations during the 2016-2022 period. It will do this by imposing various targets of residual waste for each cluster of municipalities. The implementation plan imposes new targets for waste prevention, re-use, litter, illegal dumping, and industrial waste in Flanders.

3.1 Tailor-made targets

The implementation plan abandons the idea of one single residual waste target for the entirety of Flanders; instead, it adopts a tailor-made approach to the local authorities. The plan aims to achieve eleven targets, distributed over sixteen clusters of municipalities that are similar in a socio-economic point of view. For example, coastal municipalities are assigned a less stringent target since they produce more residual waste due to tourism than rural municipalities, for instance.

Depending on the cluster to which your municipality belongs, you will be assigned a different target for the quantity of maximum residual waste that you may produce. Each municipality must achieve its objective by 2022. Did your municipality achieve its target? In that case, you will be required to maintain your result over the coming years or to improve it if possible. Until the classification of clusters is evaluated, the targets are indicative. The targets will only become binding in case of a positive evaluation of the new classification.

Those are the targets for each cluster of municipalities for household residual waste and industrial waste similar to household waste in 2022:



Denomination	Target
In the suburbs	116kg/inh
Rural or urbanized rural municipalities with strong economic growth	122 kg/inh
Urbanized rural municipalities with industrial activity and demographic growth	125 kg/inh
Less urbanized municipalities with demographic decline Small agricultural municipalities	129 kg/inh
In rural areas Rural and agricultural municipalities with industrial activity Medium sized cities	139 kg/inh
Significantly rural municipalities with high ageing in the population	144 kg/inh
Highly urbanized municipalities with low incomes Cities and metropolitan municipalities with industrial activity Metropolitan municipalities with tertiary activity	147 kg/inh
Residential suburbia with high income	158 kg/inh
Regional cities	151 kg/inh
Large and regional cities	197 kg/inh
Coastal municipalities	258 kg/inh

In order to help the municipalities to achieve their targets by 2022, a target has also been formulated at the intermunicipal organization level, as an aid. These intermunicipal organization targets are indicative.

INTERMUNICIPAL ORGANIZATION/ MUNICIPALITY	target per IO (kg/inh) by 2022
AARSCHOT	102
LIMBURG.NET	126
ECOWERF	110
HAVILAND	141
I.VL.A.	133
IBOGEM	143
IDM	127
IGEAN M&V	125
ILVA	121
IMOG	144
INCOVO	136
INTERRAND	158
INTERZA	124
IOK-AFVALBEHEER	96

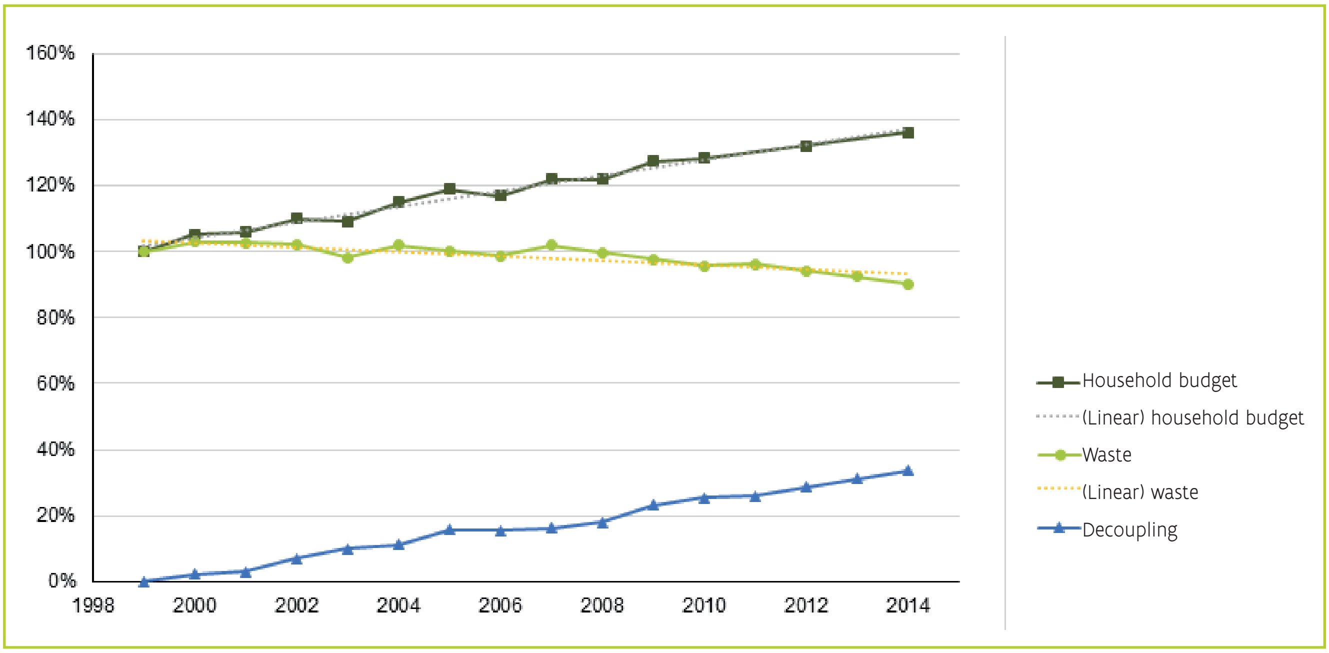
INTERMUNICIPAL ORGANIZATION/ MUNICIPALITY	target per IO (kg/inh) by 2022
ISVAG	197
IVAGO	193
IVAREM	136
IVBO	184
IVIO	142
IVM	136
IVOO	190
IVVO	164
KNOKKE-HEIST	258
MIROM MENEN	147
MIROM ROESELARE	144
MIWA	143
VERKO	134

3.2 More prevention

Source-separated collection, recycling, and treatment of waste is important. But it is even better to prevent waste generation and to re-use goods. With the implementation plan, Flanders wishes to decouple consumption from waste generation. In other words: more consumption may not necessarily lead to more waste.

In addition, the total quantity of waste produced must remain the same even if the population grows. **While Flanders produced an average of around 522 kg of household waste per capita in 2012, 2013 and 2014, this cannot be over 502 kg in 2022.**

Evolution decoupling waste generation from consumption pattern from households



3.3 More re-use

In the years to come, we want to provide larger amounts of furniture and belongings with a second life. The previous implementation plan assumed a minimum of 5 kg of re-use per resident. That target has already been achieved. By 2022, the accredited re-use centres have to ensure that each Flemish person reuses 7 kg of goods.

3.4 Less litter

People also produce waste out of home. That waste must be collected (source-separated) insofar as is possible. Whatever still is thrown on the ground must be cleaned up as soon as possible.

There is still far too much litter in evidence. That is not good for the environment ánd for the cleanliness of your municipality. The quantity of litter must therefore be lowered by 2022. We will map this reduction with the following level indicators:

- Litter is found in particular at motorway car parks, public transport stops, and waste collection points. By 2022, the Cleanliness Index at those places must improve by 10% in comparison to 2014. The cleanliness of other locations must also not deteriorate. The Cleanliness Index, or cleanliness barometer, is a practical tool that you can use to measure the cleanliness of your municipality.
- By 2022, the litter will be decreased by 20% (in terms of weight) in comparison to 2013. This means that in 2022, a maximum of 14,000 tonnes of litter will be generated (in comparison to 17,500 tonnes in 2013).

3.5 Less illegal dumping

In 2016, the OVAM will conduct a study to map the quantity, cost price, composition, locations, and perpetrators of illegal dumping in Flanders in 2015. These figures will form the basis for an action plan to reduce illegal dumping in Flanders.

3.6 Less comparable industrial waste

Idem the industrial residual waste still contains far too much materials that can be collected source-separated. In 2013, the industrial residual waste still contained at least 20% of materials that could have been recycled. The objective: by 2022 there will be **15% less industrial residual waste** in comparison to 2013, taking into account the employment rate.

Purchaser: pivot in the circular economy

A key player in the sustainable materials policy is the purchaser within a municipality or a company. His purchase policy has the power to place products back into the material cycle after use. By opting for re-use and recycled materials, purchasers will implement circular economy in practice.

Choose recycled materials
The OVAM wants to give greater impetus to the market for products produced from recycled materials. For this purpose, it is developing materials criteria for public procurement contract specifications of Flemish and local authorities in order to maximise the possibility of opting for recycled materials. Furthermore, it shares its expertise concerning the materials aspects of products or services for public contracts.

Streams	Door-to-door or bring method-system*	Large recycling yard
household waste	every two weeks, or bring method	
paper and cardboard waste	monthly, or bring method	mandatory
plastic bottles and flasks, metal packaging, and drink cartons (PMD)	every three weeks, or bring method	
glass waste	monthly, or set of bottle banks for transparant/ coloured glass (2 single or 1 double bottle bank, aboveground or underground) (minimum one per 1,000 residents)	
prunings	on demand, minimum four times a year (in green region)	mandatory
vegetable, Fruit and Garden waste VFG) - kitchen waste (organic waste)	every two weeks or bring method (in VFG region)	
bulky waste		mandatory
textile	on demand, minimum twice a year four times a year, or containers (minimum one container per 1,000 residents)	mandatory
waste Electrical and Electronic Equipment (WEEE)		mandatory
metals		mandatory
wood (type A and B)		mandatory
re-usable goods	on demand	
flat glass		mandatory
hard plastics		mandatory
small hazardous waste		mandatory
frying fats and oils		mandatory
stone debris		mandatory
other construction and demolition waste		mandatory
bounded asbestos cement		mandatory
tree trunks		mandatory
fine garden waste		mandatory

* bring system: source-separated collection at a short distance via underground or aboveground collection systems

4 COLLECTION OF HOUSEHOLD WASTE: YOU CHOOSE HOW

As a local authority, you are responsible for the collection of household waste. That makes you an important link in the Flemish waste- and materials policy. The implementation plan for household waste and comparable industrial waste defines which types of waste streams you are required to collect, but from now on, it also gives you more room to choose how you approach the task.

4.1 What is mandatory to collect?

The table alongside shows which waste streams you as a municipality are obliged to collect at least source-separated, the way how, and the frequency this must at least be done. You may always collect more waste streams than the streams listed here. After all, the more waste that is collected source-separated, the less has to be incinerated. Consequently, more materials will remain in the material cycle and you will make a significant contribution to the circular economy. Through this, less new raw materials will be required. The extraction of raw materials requires considerably more energy than re-use or the use of recycled materials.

4.2 How do you collect the waste?

The implementation plan has abandoned the mandatory door-to-door collection for residual waste, paper and cardboard, plastic bottles and flasks, metal packaging and drink cartons (PMD), and vegetable, fruit and garden waste (VFG). For those streams, you have a choice between a door-to-door collection, a nearby bring system, or a combination of both systems.

Nearby bring system: advantages and disadvantages

In a bring system, residents bring their waste to a waste container in their neighbourhood. The opening times are extensive: residents can dispose of their source-separated collected waste whenever it suits them. This is particularly advantageous for people who live in small houses and have little storage space.

Sometimes a bring system leads to loss of quality of the collected waste streams, and a higher pollution. In addition, collection points attract more illegal dumping. Aboveground systems score lower than underground systems.

Recycling yards

Besides a population standard, also a distance standard will be applied from now on.

90% of the population lives within a **maximum radius of 5 kilometres from a recycling yard site that is accessible to them.** The waste fractions that you are required to collect in a recycling yard site can be found in the table above.

or

One recycling yard in a municipality with **more than 10,000 residents.**

4.3 Learning networks

In order to help you as a municipality in the source-separated collection of waste streams, the OVAM offers you customised support. The basic principle is that municipalities within the same cluster can learn from each other. For this reason, the OVAM will start up 'learning networks' in collaboration with the Association of Flemish Cities and Municipalities (VVSG) and Interafval (Intermunicipal Waste Agency) . Within such a network, you can share best practices with other municipalities in your cluster.

Municipalities with the largest amount of residual waste will receive extra support. There may be various causes for high residual waste figures. For example, a municipality with high quantities of bulky waste will already have high residual waste figures. The introduction of VFG waste collection can also reduce the amount of residual waste.

5 COMPARABLE INDUSTRIAL WASTE

Comparable industrial waste is waste from companies that is of a nature and composition similar to household waste: paper and cardboard, PMD, bio-organic waste, ... It involves quantities larger than those of household waste, and such waste is mainly collected by private waste collectors.

The OVAM supports companies to better manage their materials streams, so that they consume less and recycle more. The OVAM does the same in various ways:

5.1 Handy OVAM-tools

Companies can rely on some tools in order to efficiently manage their resources and materials:

- The **e-resources** tool helps to make a distinction between waste materials and raw materials.
- Via the **feedback tool,** companies receive feedback and tips about their materials management in relation to other similar companies in Flanders.

5.2 Targeted communication about the sorting obligation

The past years, the OVAM organised regular awareness-raising and information campaigns on the sorting obligations of companies. Such communication actions will be continued in the years to come. The OVAM chooses two tracks: a general approach and an approach per sector for the source-separated collection in SMEs.

5.3 Quality assurance for waste collectors?

The collection of industrial waste has to be further professionalised. For this reason, the OVAM is investigating whether a quality management system (QMS) would be useful to collectors of industrial waste. The introduction of such a QMS is intended to encourage companies to deliver source-separated waste, so that the quality of the collected streams is ensured.

5.4 Collective collection on industrial premises

Local authorities and companies can set up pilot projects for the collective collection of source-separated fractions on industrial premises. This is better for the environment and cheaper in view of the more efficient logistics. A smoothly operating service prevents individual companies from dumping small quantities of source-separated streams into the residual waste.

6 ACTIONS FOR SIX WASTE STREAMS

Bio-organic waste, packaging, hard plastics, paper and cardboard, textiles and bulky waste: the implementation plan describes specific actions for these six waste streams. With these actions, Flanders wishes to significantly reduce the total quantity of residual waste and to increase recycling.

6.1 Bio-organic waste

Too much food is still throwing away into our waste. The Flemish Government and the actors in the entire food chain are committed to reducing food waste by 15% by 2020. In the implementation plan, we focus on how local authorities can prevent food losses. The OVAM continues to stimulate closing the material cycle at home (including home composting).

The collection vegetable, fruit and garden (VFG) waste will be further optimised and enhanced in municipalities collecting separately VFG waste (VFG regions). In addition, the OVAM is examining the feasibility of expending the VFG with kitchen waste that contains animal by-products. This will provide a clearer sorting message to the citizens.

In the green regions, a combination of home composting and a more intensive source-separated collection of green waste will be strengthened.

For companies that produce a lot of bio-organic waste, the source-separated collection of bio-organic waste will become mandatory starting from 2021. For smaller producers, first a pilot project will be carried out.

6.2 More collection and recycling of packaging

In the coming years, VAL-I-PAC and Fost Plus will have to collect and recycle more packaging waste. VAL-I-PAC promotes the recycling of industrial packaging waste; Fost Plus is responsible for the promotion and financing of source-separated collection, sorting, and recycling of household packaging waste in Belgium.

In order to collect more packaging waste, the Interregional Cooperation Agreement (ICA) shall be made more stringent. This cooperation agreement imposes a number of obligations on companies that put packaging on the market, for example for the recycling targets.

By making the ICA more stringent, VAL-I-PAC and Fost Plus will have to focus more on the smaller streams of packaging waste that, until now, are not source-separated collected. The amendment to the ICA relates to:

- higher targets, so that packaging companies will recycle even more;
- extra targets for other plastic streams, so that streams like EPS (polystyrene foam), films, and hard plastics are source-separated collected.

New accreditation for VAL-I-PAC and Fost Plus

The current accreditation of VAL-I-PAC expires on 31 December 2016, while that of Fost Plus will continue until the end of 2018. Both are therefore due to be reviewed in the next few years. The Flemish Government is proposing a number of guiding lines for both accreditations. For example, it wishes to ensure mandatory source-separated collection of all the remaining plastics that still is disposed of into our residual waste.

6.3 Source-separated collection of hard plastics

From now, citizens have to bring non re-usable hard plastics such as buckets, toys, tubes, source-separated to the recycling yard. Thus, this hard plastic waste fraction will be recycled and no longer incinerated. Also, companies will also be obliged to collect source-separated used plastics insofar as is possible. This relates to hard plastics, foils, and polystyrene.

6.4 Communication about paper and cardboard packaging

The OVAM is starting a new communication campaign together with Fost Plus and Paper Chain Forum. This will make it clear to citizens that paper and cardboard packaging waste is also part of the paper and cardboard.

6.5 Worn-out textiles are also textiles

Until today, textile collection includes the collection of mainly re-usable clothing and shoes, while also worn-out clothing, shoes, towels, and sheets have to be collected source-separated. A clear and correct sorting message is therefore important. For this reason, the OVAM is investigating the sorting messages that is mentioned on textile containers and will modify the message, if necessary. In 2017 the OVAM will also bring together actors from the textile sector to check how they can jointly tackle the challenges of closing the textile chain.

6.6 Bulky waste: no furniture and mattresses any more

The OVAM will provide support to municipalities that generate large amounts of bulky waste. In addition, there will be a specific policy for furniture and mattresses, with incentives for eco-design, more (local) re-use, and source-separated collection. Moreover, the extended producer responsibility (EPR) for mattresses will also be introduced by 1 January 2018. For furniture, the OVAM will seek out the most appropriate tool to collect this stream source-separated.


Girteka
KEEP IT
CLEAN


7 LESS LITTER

Litter is defacing our public space and is an eyesore for everyone. In addition, clearing the same is costing Flanders millions of euros. To get rid of all the litter, everyone must make an effort The new plan describes the broad strategic lines. Concrete implementation is given to this in the form of an annual action plan.

The progress of the litter policy will be evaluated for the first time in 2018. If it is found that the quantity of litter does not drop sufficiently, the policy will be suitably amended.

7.1 What does Flanders do?

A first step is prevention: preventing that waste becomes litter. The most commonly occurring litter fractions are cigarette butts, chewing gum, and food packaging (e.g., coffee cups, beverage containers, wrappers, etc.). Flanders wishes to tackle these specific fractions at the source. How? By encouraging producers and distributors to develop solutions that will help consumers to not generate any litter.

In addition, extra attention will be paid to the places with the largest amount of litter. A tailor-made approach will be worked out for these target sites. This will enable you as a municipality to get started.

7.2 What can you do?

A lasting change in behaviour is required in order to keep the public space clean in your municipality as well. Each link in the chain will be called on to fulfil its responsibility: producers, distributors, consumers and citizens, companies, local authorities, domain administrators, and enforcement agencies.

A good litter policy is based on five fundamental pillars:

Infrastructure: a well-thought-out set-up of public spaces will encourage citizens to throw waste in dustbins and to avoid illegal dumping. This happens through well-placed and efficiently managed dustbins and an efficient public sweeping policy.

Participation: support the network of volunteers and partners, and expand it. Make their efforts visible and ensure in this way recognition. In this manner, you will increase the commitment to public cleanliness and also create effective social control.

Communication: use communication campaigns that raise awareness to make it clear that leaving behind waste is socially unacceptable. Communication at the time at which litter is generated, is the most effective (target site-specific communication). You can make use of the annual Indevuilbak-campaign on litter, a partnership between VVSG, Fost Plus, and the OVAM. By adapting the message of this campaign according to the situation in your municipality, you can be certain that this will have an impact on your residents.

Environment: an abandoned or dilapidated neighbourhood can provoke littering behaviour due to anonymity and neglect. The OVAM is investigating which best practices could reverse the situation.

Enforcement: this is the cornerstone of any policy. It must be visibly clear out in the field that no form of litter and illegal dumping will be accepted anymore. Enforcement will be interpreted in broad terms: not only fines can be imposed; you can also challenge violators concerning their behaviour and increasing social control.

8 MINIMISING INCINERATION AND LANDFILLING AS MUCH AS POSSIBLE

Incinerators or landfill sites are the last resort for the treatment of waste. Valuable resources are lost in these treatment methods.

Flanders stands by the principle of “self-sufficiency”: waste that is generated here has to be incinerated or disposed of on the landfill site only here.

8.1 Incineration: capacity must be adjusted according to the supply

The incineration capacity in Flanders is adjusted according to the quantity of waste that has to be incinerated. The OVAM maps out the supply of combustible waste as well as the incinerators in a transparent way. If the quantity of waste remains the same, incineration capacity can only be added if capacity elsewhere is reduced. Waste treatment facilities shall also be expected to take efforts to ensure greater effectiveness and energy efficiency.

In the next few years, Flanders wishes to further reduce the quantity of residual waste. For this reason, the OVAM is developing a tool to stimulate the reduction of waste treatment facilities over the next few years.

8.2 Landfill: last option

Waste landfilling is and remains the last treatment option. In order to limit landfilling, the Flemish Government imposes landfill levies, landfill bans, and a ban on new landfill sites for non-hazardous waste.

Landfilling must continue to remain more expensive than incineration. Also in the future the environmental levies will be based on this principle. Since there is sufficient landfill capacity at present, no additional landfill capacity will be permitted at new locations.

9 CONCLUSION

From innovative collection methods to targets for recycling and the collection of plastics, this brief summary of the new implementation plan has hopefully provided you with a lot of new ideas about how you can approach waste and litter also in your municipality.

More inspiration and comprehensive details can be found in the complete version of the implementation plan at www.ovam.be/uitvoeringsplan.

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MAKE TOMORROW
MORE BEAUTIFUL

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Appendix 8

cré

Composting & Anaerobic Digestion Association of Ireland

Research Report:

The Collectable Source Separated Food and Garden Waste Arising from Households in Ireland

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Table of Contents

Executive Summary

The latest Environment Protection Agency (EPA) Waste Report 2008 has shown that Ireland is 280,000t of Biodegradable Municipal Waste (BMW) short of the first Landfill Directive target due by July 2010. This report reviewed some of the best biowaste collection systems in the European Union (EU) and then they were applied to the Irish situation. This research report estimates the collectable source-separated food and garden waste for each county in Ireland.

Proper management of organic waste needs to be implemented in Ireland. Ireland should follow best practice system in Europe. For example, the Province of Lower Austria has a population of 1.5 million people, comprising 625,000 households, and 573 local districts. The majority of local districts have less than 5,000 people each. Biowaste is managed by home composting, brown bin collection and the collection of garden waste at the kerbside in paper bags, or by people dropping it off at the local civic amenity centre. The collected biowaste is then composted in on-farm composting plants and the farmers use the compost primarily on their own land. With 95% of the organic waste fraction managed in this way, this leaves only 5% organics in the black bin.

The Department of Environment, Heritage and Local Government (DoEHLG) recently published the *International Review of Waste Management Policy* which recommended national legislation in which waste collectors would have to provide a food waste only brown bin collection service to households in Ireland.

The key findings of the report are:

- Source separation schemes can be categorised into two main types of collection schemes:
    a. commingled collection of food and garden waste using a wheelie bin (80 to 240 litres) which is collected either weekly or fortnightly and
    b. bespoke collection of food waste only (excluding garden waste) with small bin/caddies (bins up to around 35 litres or compostable bags of 10 to 20 litres) being collected weekly. In addition, garden waste can be delivered to civic amenity sites or small amounts of garden waste can be collected at the kerbside together with the brown bin in a garden waste paper bag which is additionally charged by the waste collector.
- Based on a number of case studies from European countries with advanced source separation schemes, the collectable food and garden waste from householders in Ireland is estimated to be 642,761 tonnes of BMW per year. The European case studies do not have identical conditions to Ireland. However, they provide good examples of the potential tonnes which could be collected.
- In urban areas (cities with a population of more than 20,000) a reduced capture of around 75kg/Inhabitant of waste could be expected. This would reduce the collectable biowaste from 642,761t to 520,967t.
- Barth *et al.,* (2008) estimated 150 kilogram/inhabitant/year (kg/inh*y) as a realistic mean result. The data determined in this report 152kg/inh*y with a reduced capture in urban areas (123 kg/inh*y) is similar to this reported figure. This supports the findings of this report.

Results and benefits of food waste only small bin schemes are:

- specific collection of food waste keeps bulk density higher, and volume smaller;
- no compaction is needed because the food waste is wet and dense;
- hand picking is possible, implying a much reduced pick-up time and saving money;
- vehicles for food waste may be of a cheaper type (usually small-sized open lorries), since compaction is not needed;
- the foregoing implies a significantly lower cost of the single collection round, which in turn makes it possible to increase its frequency;
- this increases capture of food and garden waste to a significant extent, which in turn reduces the percentage of organics in residual waste;
- consequently, collection of residual waste may be performed at reduced frequency;
- collection of garden waste may be made cheaper, either through a 'green round' at the kerb, but with much reduced frequency (*e.g.* monthly) or with direct delivery at local authority recycling centres, and
- little or no contamination as people cannot hide contamination in the small containers.

This study recommends:

1. Immediate preparation of the national legislation requiring that all collectors who collect household waste to provide a food waste collection service to households.
2. Immediate preparation of the national legislation to ensure that all household waste recycling centres are equipped with facilities for the separate collection of garden waste.
3. Food waste prevention/home composting should be promoted first, and then a brown bin service should be provided to householders, if required.
4. The continuation and development of the EPA's national home composting and food waste prevention programme called *www.stopfoodwaste.ie*
5. Future household brown bin schemes should be provided for food waste only. Garden waste should be home composted or delivered to civic amenity sites. Small amounts of garden waste may be collected at the kerbside together in a separate garden waste paper bag during the summer months. This may be additionally charged by the waste collector. Simultaneous collection with the brown bin will avoid separate transport.
6. A national awareness campaign on the proper use of brown bin should be provided in Ireland. This campaign should provide promotional brochures on how to use the brown bin, and also be available on a national website.
7. Consideration should be given to hiring of "brown bin advisors" who could visit homes and explain the proper use of brown bin. This was conducted in Germany for a period of 1-2 years when source separation was first introduced. Alternatively, a private company could provide this service during the initial period of the roll out of brown bins.

1. Introduction

Based on a number of case studies from European countries with advanced source separation schemes, the collectable food waste and garden waste from householders in Ireland was assessed. The performance of food waste 'small bin up to 35 litres' food waste collection schemes was examined as well.

1.1 Background

The Comptroller and Auditor General[1] noted in his annual report for 2005 that *"there is a significant risk that Ireland will fail to meet the targets set down in the Landfill Directive."* He also highlighted the *"possibility of EU financial penalties arising from any such failure."* It is of the greatest urgency that the DoEHLG implement measures in order to meet the targets.

The DoEHLG published on 19 November 2009 the *International Review of Waste Management Policy* for Ireland. The report commissioned by the Minister for the Environment, Heritage and Local Government examines all aspects of waste management policy, from prevention and minimisation to the management of residual waste.

Key recommendations of the report are:

- Legislation requiring that all collectors who collect household waste provide a food waste collection service to households (either themselves, or through collaborating with other providers), and
- Legislation to ensure that all household waste recycling centres are equipped with facilities for the separate collection of garden waste.

Presently the main instruments in place to achieve Ireland's targets under the EU Landfill Directive are:

- The Minister[2] announced increases to the landfill levy to drive waste from landfills in order to meet challenging EU targets, the first of which occurs in 2010. The levy will increase from €30 per tonne to €50 in 2011, and to €75 in 2012. "*Earlier this year the Government also decided to introduce an incineration levy. While the actual rate of the levy will need to relate to the rates of landfill levy which I have just announced I do envisage that the incineration levy will be in the range of €20 to €38 per tonne,"* the Minister stated.
- Conditions in waste collection permits introduced by some local authorities (*e.g.* Limerick, Clare, Kerry), which mandate that domestic and commercial premises must be provided with a brown-bin service by a certain date.
- Conditions set out in the EPA Technical Guidance document *Municipal Solid Waste: Pre-treatment and Residuals Management,* which will require operators of landfill and incineration facilities to demonstrate, via their waste acceptance policy, that waste accepted at these facilities has been subjected to appropriate pre-treatment. The guidance document will also impose restrictions on the amount of biodegradable waste which can be landfilled.

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1 www.audgen.gov.ie [28/11/2008]

2 Press Release DoEHLG *Gormley Publishes International Review of Waste Management Policy* 19/11/09

- The Food Waste Regulations Statutory Instrument (SI) 508 of 2009[3] aims of ensuring that, as a significant source of food waste arises in the commercial sector; it will be segregated at source for collection. This source-separated material will then be suitable for downstream processing in composting and anaerobic digestion facilities. The SI has not been extended to householders, but is intended to apply to other non-household sources of significant quantities of food waste.

It is timely, with the increased emphasis on incentives and legislation to divert organic waste from landfills, to examine best practice on how to set up a robust source separation collection scheme for food and garden waste.

1.2 Objective of the study

The objectives of the study are to:

- Estimate realistic scenarios for food and garden waste arising from households, and
- Examine the performance of food waste collection schemes.

1.3 Methodology

Overall, the summary of the methodologies used in the report are as follows:

- The report examined the best practice approaches of six source separation collection schemes from Italy, Austria and the United Kingdom (UK).
- The capture rate data (kg of waste per inhabitant per year), from these schemes, was then used and with Census 2006 Irish population data.
- The estimated potential food and garden waste from households, which could be collected, was determined for Ireland.

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3 Waste Management (Food Waste) Regulations SI 508 of 2009.

2. Estimated Potential Source Separated Food and Garden Waste in Ireland

2.1 Estimation of potential food and garden waste by population; data for Ireland multiplied by average waste arising from best practice collection schemes in other EU Countries

One option to estimate the amount of food waste and garden waste in Ireland, which could be collected by source-separation schemes, is by using data from countries which already have well-established source-separation collection schemes. This can be done by using the average waste-arising figures from those established collection schemes and then multiplying the result with the population data for Ireland. This is a method using best available information in order to determine the potential waste arising were collection schemes to be established in Ireland using best-practice experiences already established abroad.

This method was used by Barth *et al.,* (2008) in a European study as part of the *End of Waste Project* for the European Commission. The authors established 150 kg per inhabitant per year as a reliable estimate for the collectable organic fraction of biodegradable municipal waste (OFBMW). Using this baseline figure as the *per capita* waste arising, and multiplied by the CSO population data of 2006, would result in a total biowaste collection potential of approximately 600,000 t/a in Ireland.

Best Practice Collection Schemes

This section shows case studies/scenarios of some well-established source-separation collection schemes for Austria, Italy and the UK. The schemes can be categorised into two main types of collection schemes:

- commingled collection of food and garden waste using a wheelie bin — 80 to 240 litres — which is collected weekly or fortnightly, and
- bespoke collection of food waste only with small weekly-collected receptacles — bins up to ca 35 litres or compostable bags of 10 to 20 litres — in combination with an additional garden waste collection regime involving less frequent collection, kerbside tipping on garden waste campaign dates, shredder service, delivery to civic amenity sites*, etc.*

For this report, six schemes which are representative of best-practice collection schemes for households have been studied. They are as follows:

- **Scenario (1) – Austria/Brown-Bin**: Weekly brown-bin collection scheme for commingled collection of food and garden waste from households and similar institutions. In addition, garden waste can be delivered to civic amenity sites or small amounts of garden waste can be collected at the kerbside together with the brown-bin in a garden waste paper bag which incurs an extra charge from the operator.

- **Scenario (2) – Austria/Small Bin up to 35 Litre**: A 10 to 49 litre bin collection scheme involves a; weekly collection of food only. In addition, garden waste can be delivered to civic amenity sites or small amounts of garden waste can be collected at the kerbside together with the brown-bin in a garden waste paper bag which incurs an extra charge from the operator.

- **Scenario (3) – Italy/low** *i.e.* low capture of garden waste: A small bin up to 35 litre collection scheme with compostable bags as a liner at minimum weekly bespoke collection of food waste only and a separate garden waste collection regime. There are lower captures than in the scenario *(4)–Italy/high* due to a higher proportion of home composting of garden waste and own-composting by some professional gardeners.

- **Scenario (4) – Italy/high***, i.e.* high-capture of garden waste: A small bin up to 35 litre collection scheme with compostable bags as a liner in which there is, at minimum, a weekly bespoke collection of food waste only and a separate system for garden waste.

- **Scenario (5) – UK/ Small Bin up to 35 Litre**: This is a small bin up to 35 litre or bag collection scheme involving a weekly bespoke collection of food waste only. In addition, garden waste can be delivered to civic amenity sites or small amounts of garden waste can be collected at the kerbside together with the brown-bin in a garden waste paper bag which incurs an extra charge from the operator.

- **Scenario (6) – UK/Brown-Bin**: This is a fortnightly brown-bin collection scheme for commingled collection of food and garden waste from households and similar institutions. In addition, garden waste can be delivered to civic amenity sites or small amounts of garden waste can be collected at the kerbside together with the brown-bin in a garden waste paper bag which incurs an extra charge from the operator.

Table 1 summarises organic waste quantities resulting from the case studies/scenarios in Austria, Italy and the UK. It is important to note that these figures always relate to the entire population in the covered collection area. Examples of best performances show captures of 250kg/household with a Local Authority area of mixed rural and urban housing. However, in densely-populated urban zones total capture rates may decrease to 70 kg/inh*a (kilogram per inhabitant *per year*).

Figure 1. Paper bag used to collect garden waste at the kerbside in Bath, UK

Table 1: Summary of the Case Studies/Scenarios in Austria, Italy & UK of Capture Rates [kg/Inh*a] Food and Garden Waste

Compostable Bag / Small Bin up to 35 Litre scheme kg/inh*a bespoke collection of food waste						
	Food Waste		Garden waste		Food Waste + Garden waste	
Example 'Freistadt'						
urban	114		134		248	
rural	26		111		136	
Example 'Italy-low' [1]	with garden	without garden	with garden	without garden	with garden	without garden
urban	80	80	120	20	200	100
rural	70	80	90	15	160	95
Example 'Italy-high' [2]						
urban	80	80	175	75	255	155
rural	70	80	110	30	180	110
Example 'UK-Bio-Bag'						
urban	50		50		100	
rural	50		65		115	
The average kg/inh*a for urban area is	**80.7**[4]		**95.7**		**176.4**	
The average kg/inh*a for rural area is	**62.7**		**70.2**		**132.9**	
Brown-Bin scheme Commingled collection of Food and Garden waste						
	Brown-Bin		Garden waste		Brown-Bin + Garden waste	
Example 'Gaenserndorf'	with garden	without garden	with garden	without garden	with garden	without garden
urban	180	45	150	50	330	95
rural	120	45	75	75	195	120
Example 'UK-Brown-Bin'						
urban	100		[3] 0		100	
rural	130		[3] 0		130	
Example Linz						
urban	60		10		70	
The average kg/inh*a for urban area is	**96.25**		**52.5**		**148.75**	
The average kg/inh*a for rural area is	**98.33**		**50**		**148.33**	

1) 'Italy-low': example with low garden waste captures

2) 'Italy-high': example with high garden waste captures

3) Additional garden and landscaping waste collection to the brown-bin is not provided

4) Example of a calculation is 114+80+80+50+80+80 / 6= 80.7

For all scenarios, it is possible to deliver garden waste to civic amenity sites and composting plants. Also in the Austrian scenarios, small amounts of garden waste can be delivered at the kerbside together with the brown-bin in a garden waste paper bag, which incurs an extra charge from the operator. In the Italian scenarios, kerbside collection of garden waste is provided at reduced collection frequencies, *e.g.,* once a month during the summer) and often under a *pay-as-you-throw* regime.

It is assumed in all six scenarios that material collected also includes some commercial waste, because typically small shops such as greengroceries or food markets, small canteens, and small restaurants are also included in the domestic brown-bin collection scheme.

Table 2 shows the population for Ireland based on the rural/urban divide. These population figures will be used in the calculations, in the following Tables 3-6, in which they will be multiplied by the data from the case studies/scenarios, in order to provide an accurate estimation of the potential food and garden waste arising.

Table 2: Urban and Rural Population of Ireland

County/Region	Urban	Rural	Total
Leinster	**1,724,936**	**570,187**	**2,295,123**
Carlow	24,306	26,043	50,349
Dublin	1,160,501	26,675	1,187,176
Kildare	122,016	64,319	186,335
Kilkenny	30,942	56,616	87,558
Laois	27,165	39,894	67,059
Longford	8,836	25,555	34,391
Louth	71,640	39,627	111,267
Meath	85,705	77,126	162,831
Offaly	30,114	40,754	70,868
Westmeath	37,604	41,742	79,346
Wexford	45,612	86,137	131,749
Wicklow	80,495	45,699	126,194
Munster	**608,126**	**565,214**	**1,173,340**
Clare	43,391	67,559	110,950
Cork	295,686	185,609	481,295
Kerry	49,233	90,602	139,835
Limerick	95,613	88,442	184,055
North Tipperary	24,616	41,407	66,023
South Tipperary	33,512	49,709	83,221
Waterford	66,075	41,886	107,961
Connacht	**171,765**	**332,356**	**504,121**
Galway	99,756	131,914	231,670
Leitrim	2,595	26,355	28,950
Mayo	35,678	88,161	123,839
Roscommon	14,334	44,434	58,768
Sligo	19,402	41,492	60,894
Ulster	**69,486**	**197,778**	**267,264**
Cavan	16,913	47,090	64,003
Donegal	36,585	110,679	147,264
Monaghan	15,988	40,009	55,997
State total	**2,574,313**	**1,665,535**	**4,239,848**

Source: Census 2006; Central Statistics Office Ireland, CSO www.cso.ie/Census [9/10/2009]

According to the Central Statistics Office, population in the Aggregate Town/Urban Area[4] is defined as those persons living within population clusters of 1,500 or more inhabitants. The population residing in all areas outside clusters of 1,500 or more inhabitants is classified as belonging to the Aggregate Rural Area.

The following Table 3 shows the extrapolation of the six scenarios to the Irish situation.

The Table 3 shows that:

- From the six scenarios, the mean kg/inhabitant/year for food waste is 84.5kg
- From the six scenarios, the mean kg/inhabitant/year for garden waste is 67.1kg
- From the six scenarios, the mean kg/inhabitant/year for food and garden waste is 152kg. This last figure will be used in the calculations in the following Tables 4, 5 & 6.

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4 Appendix 2, CSO Census 2006

Table 3 Extrapolation of the Food and Garden Waste Data from the Six Case Studies/Scenarios to the Irish Situation

Scenario	kg/inh for the scenario	Total potential tonnes for the Irish situation
Small Bin up to 35 Litre/Compostable Bag scheme Bespoke collection of Food Waste		
Rural Food Waste	62.7	
Urban Food Waste	80.7	
Rural Garden Waste	70.2	
Urban Garden Waste	95.7	
Total Urban	176.4	454,109
Total Rural	132.9	221,350
Total (Urban + Rural)		**675,458**
BROWN-BIN scheme Commingled collection of Food and Garden Waste		
Rural Food Waste	98.33	
Urban Food Waste	96.25	
Rural Garden Waste	50	
Urban Garden Waste	52.5	
Total Urban	148.75	382,929
Total Rural	148.33	247,049
Total (Urban + Rural)		**629,978**
MEAN of Brown Bin + Small Bin up to 35 Litre/Compostable Bag scheme		
Food Waste Mean kg/inh/year	84.50[1]	
Garden waste Mean kg/inh/year	67.1	
Mean kg/inh/year	**152**	

1 Calculated by 62.7+80.7+98.33+96.25=337.98/4 = 84.5

Table 3 indicates a considerable difference in organic waste arising, between 629,978 and 675,458 t/a, depending upon the system of collection in use.

In this report's assessment, the authors have assumed a complete countrywide implementation of domestic source-separation scheme for both food and garden waste. The organic waste capture of 152 kg, *cf.* Table 3, is the average result from the presented six scenarios in Table 1 relative to the whole population of Ireland and includes the typical proportion of home composting.

For source-separated brown-bin collection schemes, well-documented statistics exist. In contrast, garden waste estimates include far more uncertainties. The reasons are:

- Exact figures for the rate of home composting are hardly available;
- The capture rate from private gardens depends greatly upon the education and commitment to home composting and gardening;

- Where garden waste is delivered to civic amenity sites it cannot be distinguished between private, commercial and municipal sources;
- The extent to which Local Authority parks/garden divisions compost their own garden waste within their own department, and
- In many cases, a certain amount of potential garden wastes are disposed off elsewhere, such as with dumping, direct agricultural use as mulch, and/or by biomass power plants.

Table 4 **The Potential Tonnage of Food Waste in Ireland, if We Were to Extrapolate the Mean of 84.5 kg/inhabitant from the Six Case Studies Schemes from Austria, Italy and the UK and Multiply by the Respective Populations, Urban and Rural, in Ireland.**

	tonnes/inh/year		
County Region	Urban	Rural	Total
Leinster	**145,757**	**48,181**	**193,938**
Carlow	2,054	2,201	4,254
Dublin	98,062	2,254	100,316
Kildare	10,310	5,435	15,745
Kilkenny	2,615	4,784	7,399
Laois	2,295	3,371	5,666
Longford	747	2,159	2,906
Louth	6,054	3,348	9,402
Meath	7,242	6,517	13,759
Offaly	2,545	3,444	5,988
Westmeath	3,178	3,527	6,705
Wexford	3,854	7,279	11,133
Wicklow	6,802	3,862	10,663
Munster	**51,387**	**47,761**	**99,147**
Clare	3,667	5,709	9,375
Cork	24,985	15,684	40,669
Kerry	4,160	7,656	11,816
Limerick	8,079	7,473	15,553
North Tipperary	2,080	3,499	5,579
South Tipperary	2,832	4,200	7,032
Waterford	5,583	3,539	9,123
Connacht	**14,514**	**28,084**	**42,598**
Galway	8,429	11,147	19,576
Leitrim	219	2,227	2,446
Mayo	3,015	7,450	10,464
Roscommon	1,211	3,755	4,966
Sligo	1,639	3,506	5,146
Ulster	**5,872**	**16,712**	**22,584**
Cavan	1,429	3,979	5,408
Donegal	3,091	9,352	12,444
Monaghan	1,351	3,381	4,732
State total	**217,529**	**140,738**	**358,267**

Specific waste captures (t/inh*a) x CSO 2006 population figures

Table 5 **The Potential Tonnage of Garden Waste in Ireland if We Were to Extrapolate the Mean Results from the Six Reference Schemes from Austria, Italy and the UK and Multiply by the Respective Populations, Urban and Rural, in Ireland.**

County / Region	tonnes/inh/year Urban	Rural	Total
Leinster	**115,743**	**38,260**	**154,003**
Carlow	1,631	1,747	3,378
Dublin	77,870	1,790	79,660
Kildare	8,187	4,316	12,503
Kilkenny	2,076	3,799	5,875
Laois	1,823	2,677	4,500
Longford	593	1,715	2,308
Louth	4,807	2,659	7,466
Meath	5,751	5,175	10,926
Offaly	2,021	2,735	4,755
Westmeath	2,523	2,801	5,324
Wexford	3,061	5,780	8,840
Wicklow	5,401	3,066	8,468
Munster	**40,805**	**37,926**	**78,731**
Clare	2,912	4,533	7,445
Cork	19,841	12,454	32,295
Kerry	3,304	6,079	9,383
Limerick	6,416	5,934	12,350
North Tipperary	1,652	2,778	4,430
South Tipperary	2,249	3,335	5,584
Waterford	4,434	2,811	7,244
Connacht	**11,525**	**22,301**	**33,827**
Galway	6,694	8,851	15,545
Leitrim	174	1,768	1,943
Mayo	2,394	5,916	8,310
Roscommon	962	2,982	3,943
Sligo	1,302	2,784	4,086
Ulster	**4,663**	**13,271**	**17,933**
Cavan	1,135	3,160	4,295
Donegal	2,455	7,427	9,881
Monaghan	1,073	2,685	3,757
State total	**172,736**	**111,757**	**284,494**

Specific waste captures (t/inh*a) x CSO 2006 population figures]

Table 6 Summary of Potential Organic Waste Estimated in Tables 4 and 5: (1) Food Waste (2) Garden Waste and (3) Total Amounts from Households and Similar Institutions for each County and Region [tonnes]*

County Region	Food Waste	Garden Waste	Total
Leinster	**193,938**	**154,003**	**347,941**
Carlow	4,254	3,378	7,633
Dublin	100,316	79,660	179,976
Kildare	15,745	12,503	28,248
Kilkenny	7,399	5,875	13,274
Laois	5,666	4,500	10,166
Longford	2,906	2,308	5,214
Louth	9,402	7,466	16,868
Meath	13,759	10,926	24,685
Offaly	5,988	4,755	10,744
Westmeath	6,705	5,324	12,029
Wexford	11,133	8,840	19,973
Wicklow	10,663	8,468	19,131
Munster	**99,147**	**78,731**	**177,878**
Clare	9,375	7,445	16,820
Cork	40,669	32,295	72,964
Kerry	11,816	9,383	21,199
Limerick	15,553	12,350	27,903
North Tipperary	5,579	4,430	10,009
South Tipperary	7,032	5,584	12,616
Waterford	9,123	7,244	16,367
Connacht	**42,598**	**33,827**	**76,425**
Galway	19,576	15,545	35,121
Leitrim	2,446	1,943	4,389
Mayo	10,464	8,310	18,774
Roscommon	4,966	3,943	8,909
Sligo	5,146	4,086	9,232
Ulster	**22,584**	**17,933**	**40,517**
Cavan	5,408	4,295	9,703
Donegal	12,444	9,881	22,325
Monaghan	4,732	3,757	8,489
State totals	**358,267**	**284,494**	**642,761**

* Please note that the presented data models include:

a) Participation level in home composting

b) A categorisation of counties according to CSO statistics and not by regional Waste Management Plans.

Table 6 is the total amount of the estimates of organic waste collected first via food waste and secondly via garden waste in tonnes from households for each county and region. This shows that a possible 642,761t of food and garden waste could be collected. From the six scenarios examined, the mean kg/inhabitant/year for food and garden waste is 152kg.

Reduced Capture Rates in Urban Areas

When examining domestic biowaste captures in densely-populated urban areas, the average collection rates are often lower. Examples of this can be found is two Austrian cities Graz and Linz, with ca 70 to 80 kg/inh*a . Data on waste arising may vary with specific settlement structures and socio-economic backgrounds. Since these figures represent a specific urban and partly industrialised situation, they cannot be taken as reference for the whole country.

Nevertheless, it is justified to apply this experience to urbanised areas in Ireland. Therefore, assuming an urban reduction collection rate of 75 kg/inh*a instead of a mean of 152 kg/inh*a, the nationwide result is reduced from 642,761t to 520,967t per year. Table 9 explains how this was calculated, with a lower weighting of 75 kg/inh only applied to 'urban' populations, and takes account the fact that in urban areas with population densities of greater than 20,000 inhabitants a reduced capture rate of 75 kg/inh*a was applied.

Table 7 shows the following:

- Irish cities with a population of more than 20,000;
- Population of the individual cities multiplied by the average potential waste arising per inhabitant;
- The mean weight of 152 kg/inh*a is based on the mean of the six case studies/scenarios outlined in Table 8;
- Reduction of potential waste for each individual city using a collection capture of 75kg/inh*a, and
- Total estimated organic waste arising for each city.

Table 7 Estimated Reduction of Organic Waste Captures in Densely-Populated Areas with an Assumed Collection Rate of 75 kg/inh*a

County	City/Town	Population	Waste arising based on 152kg/inh [1)]	Waste arising based on 75kg/inh
Dublin	Dublin area	1,187,176	179,976	89,038
Louth	Dundalk	29,037	4,402	2,178
Meath	Navan	21,141	3,205	1,586
Meath	Drogheda	28,973	4,392	2,173
Wicklow	Bray	27,041	4,099	2,028
Clare	Ennis	20,142	3,054	1,511
Cork	Cork City	119,418	18,104	8,956
Kerry	Tralee	20,288	3,076	1,522
Limerick	Limerick City	52,539	7,965	3,940
Waterford	Waterford City	45,748	6,935	3,431
Galway	Galway City	72,414	10,978	5,431
Totals		**1,623,917**	**246,186**	**121,794**

Tables 4, 5 and 6 show the potential tonnes of food and garden waste respectively in Ireland were we to extrapolate the mean results from the six brown-bin case study schemes in Austria, Italy and the UK.

The ranges of collectable organic waste resulting from all scenarios extrapolated from the six brown-bin case study schemes from Austria, Italy and the UK are summarised in Table 8.

Table 8 **Summary of the Estimation of Organic Waste from Households in Ireland**

Scenario for Ireland	Tonnes
Mean scenario for Ireland	642,761t
Reduced scenario for cities > 20,000 inhabitants	121,794t
Adjusted Scenario for Ireland after adjusting for the reduced capture for cities > 20,000 inhabitants	520,967t
The mean kg per inhabitant from the six reference schemes is 152 kg.	
The mean kg per inhabitant from the six scenarios after adjustment for reduced capture for cities > 20,000 inhabitants is 123kg.	

2.2 Summary of total potential food and garden waste in Ireland

Table 9: Summary List with the Collectable Part of Source Separated Food and Garden Waste from all Relevant Origins

County Region	Food waste	Garden waste	Total organic BMW waste	
	Full implementation: mean specific capture rate = 152 kg/Inh*a			*Reduced capture in urban zones [75 kg/Inh*a]*[1]
Leinster	**193,938**	**154,003**	**347,941**	**248,869**
Carlow	4,254	3,378	7,633	7,633
Dublin	100,316	79,660	179,976	89,038
Kildare	15,745	12,503	28,248	28,248
Kilkenny	7,399	5,875	13,274	13,274
Laois	5,666	4,500	10,166	10,166
Longford	2,906	2,308	5,214	5,214
Louth	9,402	7,466	16,868	14,644
Meath	13,759	10,926	24,685	20,846
Offaly	5,988	4,755	10,744	10,744
Westmeath	6,705	5,324	12,029	12,029
Wexford	11,133	8,840	19,973	19,973
Wicklow	10,663	8,468	19,131	17,060
Munster	**99,147**	**78,731**	**177,878**	**158,105**
Clare	9,375	7,445	16,820	15,277
Cork	40,669	32,295	72,964	63,817
Kerry	11,816	9,383	21,199	19,645
Limerick	15,553	12,350	27,903	23,878
North Tipperary	5,579	4,430	10,009	10,009
South Tipperary	7,032	5,584	12,616	12,616
Waterford	9,123	7,244	16,367	12,863
Connacht	**42,598**	**33,827**	**76,425**	**70,878**
Galway	19,576	15,545	35,121	29,574
Leitrim	2,446	1,943	4,389	4,389
Mayo	10,464	8,310	18,774	18,774
Roscommon	4,966	3,943	8,909	8,909
Sligo	5,146	4,086	9,232	9,232
Ulster	**22,584**	**17,933**	**40,517**	**40,517**
Cavan	5,408	4,295	9,703	9,703
Donegal	12,444	9,881	22,325	22,325
Monaghan	4,732	3,757	8,489	8,489
State total	**358,267**	**284,494**	**642,761**	**518,369**
kg/Inh*a	84.5	67.1	152	**123**

1. Reduced captures for town >20,000 people in Table 14 are subtracted from relevant figures.

Table 9 is a summary of the collectable part of source separated food and garden waste from household sources.

Table 9 shows the total amount of potential food and garden waste from:

- The amount of food waste from households,
- The amount of garden waste provided separately from brown-bin collection from households and similar institutions, public greens and material delivered to civic amenity sites or composting facilities,
- Taking into consideration a reduced capture rate for organic waste in urban areas and

In total nationally there is a potential 518, 369 tonnes of source separated organic waste available.

This national figure only represents an accurate estimation if source separation is offered throughout the country, including consistent treatment of garden waste originating from publicly and commercially maintained garden and park estates. On a local basis and for a more detailed evaluation three factors may considerably influence the effective collection results. These are

- The proportion of households participating in home composting,
- The settlement and housing structure or the private garden area respectively and
- The type of collection scheme offered for food waste and garden waste from private households (size of collection bins, collection frequency, etc.).

Barth *et al.,* (2008) reported as a realistic mean result on national scale which has been estimated with 150kg/Inh*y. The data determined in this report 152g kg/Inh*y with a reduced capture in urban areas (123 kg/Inh*y) is similar to this reported figure.

Figures 2 to 3 show photographs of the typical methods of the collection of organic waste in Austria. Figure 4 shows the small food waste bins used in the UK.

Figure 2: Food waste containers and paper bags to collect garden/landscaping waste

Figure 3: Garden waste dropped off at a recycling centre

Figure 4: Small bin up to 35 litre food waste containers awaiting collection in Calderdale UK (Source WRAP)

3. Typical Performance of Food Waste Collection Schemes

There is increasing appreciation of the collection model of food waste only small bins up to 35 litre schemes with garden/landscaping waste collected less frequently on a different collection round. This model was originally designed in Southern Europe.

This approach addresses operational problems caused by commingled collection food and garden brown bins, which in principle would require:

- a high frequency (to tackle nuisance caused by long-lasting retention of food waste by households), and
- larger size receptacles — to tackle the bulky nature of garden waste — which in turn implies mechanical loading into packer trucks (Figure 5).

Figure 5: Collection of brown bin using mechanical loading into a packer truck in Armagh

All of this implies a remarkably higher cost of the single collection round. This may and typically does cause a comparatively low frequency for collection, which is typically run on alternate weeks (AWC = alternate week collection). In turn, reduced frequencies tend to keep a high capture of garden waste, which is promoted by large volumes available at the kerb with wheelie bins, but which impair captures of food waste to a great extent, since food waste tends to be disposed of "*in the next bin to be emptied*" (and this is mixed garbage, every other time). Consequently, collection of mixed garbage (residual waste) itself must be kept comparatively expensive (frequencies of collection) because of high percentages of food waste it still contains.

The foregoing operational issues have been addressed by means of a separate, 'bespoke' collection of food waste by means of small-sized receptacles (small bins, normally ranging from 10 to 35 litres).

Results and benefits of food waste only small bins up to 35-litre scheme are:

- specific collection of food waste keeps bulk density higher, and volume smaller
- hand-picking is possible, implying a much reduced pick-up time and saving money,

- vehicles for food waste may be of a cheaper type (usually small-sized open lorries), since compaction is not needed (see Appendix 1),
- the foregoing implies a significantly lower cost of the single collection round, which in turn makes it possible to increase its frequency,
- this increases capture of food and garden waste to a significant extent, which in turn reduces the percentage of organics in residual waste,
- consequently, collection of residual waste may be performed at reduced frequency,
- collection of garden waste may be made cheaper, either through a ‘green round’ at the kerb, but with much reduced frequency (*e.g.* monthly) or with direct delivery to local authority recycling centres, and
- little or no contamination as people cannot hide contamination in the small containers.

Figure 6: Food waste collection in Kingston upon Thames, UK using a small vehicle (Source: WRAP)

Remarkably, the less convenient and thus decreased collection of garden waste results into enhanced participation in home composting and reduces total deliveries of garden waste at the kerbside brown bin. Garden waste has been blamed for the sharp increase in waste arising in many districts across Europe, when a frequent wheelie bin collection is provided. The general result tends to be a reduced cost for collection of biowaste on the whole, higher diversion from residual waste, and an achievement of high recycling rates with no concurrent increase in waste arising — which is often a hidden benefit of such systems (Hogg *et al*., 2007).

As Ireland is at an early stage of introducing brown bins, the possible implementation of a ‘small bin up to 35 litre’ system for the collection of food waste is possible. There are pilot schemes currently in use in the UK, where a specific funding and a research programme was promoted by the Waste and Resources Action Programme (WRAP), and rolled out to 18 Local Authorities (WRAP, 2008). In recent times, the number of food waste only collection has increased. In the UK alone, there are 78 local authorities providing food waste only collection and 70 combined food and garden waste. In Ireland, Belfast City Council has provided 9,000 households with a food waste only collection using small bins.

The UK schemes are still in operation and are affected by many local conditions and operational/regulatory constraints, which may need to be overcome in the near future. These constraints in the UK include factors such as the collection frequencies for residual waste, not using compostable bags as liners in the bins. These constraints should be considered for the Ireland situation. Thus, the data used reflect the more ‘mature’ schemes and ongoing trends. The authors have also reported on typical/average performances in Italian schemes, where already some 2,000 local authorities (or so) out of 8,000 have implemented such schemes which gives consistent statistical grounds to build on. Table 11 reports on summary performances. For UK conditions, the following factors are assumed (albeit not generally used in pilot schemes). These represent the 'ongoing trend' for optimisation of performances and costs, *i.e.*

- collection of food waste with small bins up to 35 litres, and compostable bags as a lining system, once a week,
- collection of garden waste with reduced frequency at the kerb and/or delivery at recycling centres, and
- collection of residual waste on alternate weeks, which increases diversion of food waste into the proper 'collection stream'.

Table 11: Typical / Average Performance Data of Segregated Collection of Food Waste, Garden Waste in Italy and the UK

	Italy	UK
Local authorities	ca. 2,000	18
Inhabitants	18 million	92,000 households
Collection scheme	door-to-door bucket collection of food waste garden waste collected through wheelie bins or delivered to civic amenity sites	door-to-door bucket collection of food waste garden waste collected at the kerb though bins or sacks, additional delivery to civic amenity sites
Specific food waste collection [kg/inh*a]	70-80 kg	50 kg
Specific garden waste collection (includes deliveries by professional gardeners) [kg/inh*a]	High-rises: 20-80 kg Houses with gardens: 85-175 kg	50-65 kg
Total food and garden waste collection [kg/inh*a]	110-255 kg	100-115 kg

At a glance, performance of UK schemes, albeit 'filtered/upgraded' in light of ongoing trends, still show comparatively low captures which may be decreased, relative to Italy, due to some or all of:

- still unconsolidated systems/behaviours (which impairs above all captures of food waste),
- lower percentages of biowaste due to a higher reliance on 'convenience food' (again, impairing captures of food waste),
- more diffused tradition for home composting (markedly decreasing captures of garden waste), and
- own management of garden waste — delivering directly to compost sites. This aspects escapes capture statistics, although it does enter the 'composting system' again afterwards.

3.1 Factors Which Affect Separate Collection Schemes

A successful separate collection system for biowaste depends upon various factors. An important aspect is the understanding and acceptance of the system by all parties involved. For instance, for the general public, separate collections must be convenient to handle, clean and avoids any odours. In order to achieve this, they must follow best practice in collection schemes procedures. This includes for example:

- Collection frequency,
- Type and size / volume of collection bins and receptacles (*e.g.* small bins up to 35 litres and compostable bags for food waste collection),
- ca. 100 litre paper/wax bags for fine garden waste, and
- Collection of bulky garden waste or access to local civic amenity sites to drop off the garden waste.

There has to be a clear message defining the type of collection system and what it is it trying to achieve. Besides the diversion of organic waste from landfills, a key objective is the production of a high quality compost product. This will only be achieved if the composting process is managed by a compost quality assurance scheme.

Lessons can be learnt from examples in many European countries where composting began solely with a view to managing waste and not to the production of quality compost products. Very often, this has resulted in large amounts of compost with no developed markets.

From the authors' own experience in advanced biowaste management, factors which effect the waste capture rate for biowaste include;

1. Collection scheme operation:

a. Whether it includes segregated collection of food waste in small bins or not,
b. Whether supplementary garden waste collection is available and rate of supplementary collection (weekly, monthly, on demand),
c. Whether kerbside offer collection for bulky garden waste (*e.g.* 4 times per year),
d. Whether garden waste is delivered by operators to collection points,
e. Whether garden waste is delivered to civic amenity sites,
f. Whether brown bin allows co-mingled collection of food waste and garden waste,
g. The volume of bins, frequency of collection, density of housing and gardens,
h. The 'decentralisation' or individual management of garden waste by public parks and local authority areas, and
i. Waste charge system for residual waste and organic waste collection and treatment.

2. Awareness

A secondary — but important — effect is the awareness of the population, which results in a developed commitment and discipline in all aspects of home composting and separate collection behaviour.

A national awareness campaign on the proper use of brown bin should be provided in Ireland. This campaign should provide promotional brochures on how to use the brown bin, a national website. Consideration should be given to hiring of ‘brown-bin advisors’ who could visit homes and explain the proper use of brown bin. This was conducted in Germany for a period of 1-2 years when source separation was first introduced. Alternatively, a private company could provide this service during the start of the provision of brown bin service.

Figure 7: Contamination tag, Waveney trial (Source: WRAP)

Good Practice Tip: Nipping contamination in the bud

One of the WRAP trials found high rates of contamination (up to 40% of containers) in the less affluent areas during the first week of the food waste collection trial. Effective and increased levels of communication – use of contamination tags explaining why containers had not been collected backed up with door-to-door canvassing, reduced contamination to a negligible level almost immediately (WRAP, 2009).

Table 12 provide a summary on factors influencing the acceptance of source separation and composting of biowaste.

Table 12: Factors Influencing the Sustainability and Acceptance when Introducing Source Separation and Composting of Biowaste

Point of event	Activity / Feature	Remarks
Collection	Type of materials collected	• Differentiated collection schemes for food waste and garden waste brown bin systems • A differentiated collection for food waste comprises some important advantages: specific adaptation of volume and collection frequency to the relative constant food waste production and the high seasonal variation of garden waste per household
	Frequency	• Depends on the season (summer/winter), size of collection volume relative to settlement structure (with or without garden?) and type of material collected (food waste only?)
	Type of collection bins	• The higher the volume the more bulky garden waste • Small receptacles designed for *e.g.* the weekly collection of food waste can be collected by hand-picking and open lorries which saves incremental collection time and costs as compared to wheel bin/compaction truck schemes
	Locality of collection	• Door-to-door collection best performance (high purity; high recycling rates) for food waste and commingled kitchen/garden collection systems • Road container collection; increases impurities for food waste and mixed collection systems; reduces overall captures of organic household waste
	Type of trucks	• Rotopress less suitable for food waste (hindrance of pre-sorting of impurities; increased press water) • Bulk trucks with/without compaction • Open lorries or trailers for hand-picking or with hydraulic emptying systems
	Information, support of the public	• Regular encouragement for home composting (leaflets, seminars, articles, compost parties, information centre, *etc.*) • Regular information to inhabitants about what and how they should do the source separation in the household • Support with collection logistics (*'bio buckets'* for households, compostable bags (paper or compostable bags) • Regular information about the environmental and economic value of source separation
Treatment	Location of composting plant	• Principle: There is little or no nuisance caused by the plant to neighbours (e.g. odour, bioaerosols, 'flying plastics'); minimum distance from permanent residential areas and permanent working places
	Technology	• 'Best practice' for all systems of composting in the frame of a Quality Management system: • Complete and documented receipt control • Immediate treatment of fresh, easily biodegradable source materials • Flexible and controlled moisture, temperature (sanitation) and odour management • Ligneous structure material storage for flexible mixing to the best carbon to nitrogen (C/N) level • Standards for quality orientated production • Controlled collection, treatment and use of drainage water • External control system by a Quality Assurance System (QAS)
Marketing and use		• Third-party certification of compost products within QAS (quality label) • Differentiated product lines and information of customer groups (private gardens, landscaping, land reclamation, agriculture, horticulture (non-food/food)) • Offering compost blends and compost based substrates for the end use (potting soil, greens, sports ground, golf course*, etc.)*

4. Conclusions

The key findings of the report are:

- Source separation schemes can be categorised into two main types of collection schemes:
  a. commingled collection of food and garden waste using a wheelie bin (80 to 240 litres) which is collected either weekly or fortnightly and
  b. bespoke collection of food waste only (excluding garden waste) with small bin/caddies (bins up to around 35 litres or compostable bags of 10 to 20 litres) being collected weekly. In addition, garden/landscaping waste can be delivered to civic amenity sites or small amounts of garden/landscaping waste can be collected at the kerbside together with the brown bin in a garden/landscaping waste paper bag which is additionally charged by the waste collector.
- Based on a number of case studies from European countries with advanced source separation schemes, the collectable food waste and garden waste from householders in Ireland is estimated to be 642,761 tonnes of BMW per year. The European case studies do not have identical conditions to Ireland. However, they provide good examples of the potential tonnes which could be collected.
- In urban areas (cities with a population of more than 20,000) a reduced capture of around 75kg/Inhabitant of waste could be expected. This would reduce the collectable biowaste from 642,761t to 520,967t.
- Barth *et al.,* (2008) estimated 150 kilogram/inhabitant/year (kg/inh*y) as a realistic mean result. The data determined in this report 152kg/inh*y with a reduced capture in urban areas (123 kg/inh*y) is similar to this reported figure. This supports the findings of this report.

Results and benefits of food waste only small bin schemes are:

- specific collection of food waste keeps bulk density higher, and volume smaller,
- no compaction is needed because the food waste is wet and dense
- hand picking is possible, implying a much reduced pick-up time and saving money,
- vehicles for food waste may be of a cheaper type (usually small-sized open lorries), since compaction is not needed,
- the foregoing implies a significantly lower cost of the single collection round, which in turn makes it possible to increase its frequency,
- this increases capture of food and garden waste to a significant extent, which in turn reduces the percentage of organics in residual waste,
- consequently, collection of residual waste may be performed at reduced frequency,
- collection of garden waste may be made cheaper, either through a ‘green round’ at the kerb, but with much reduced frequency (*e.g.* monthly) or with direct delivery at local authority recycling centres, and
- little or no contamination as people cannot hide contamination in the small containers.

5. Recommendations

This study recommends:

1. Immediate preparation of the national legislation requiring that all collectors who collect household waste to provide a food waste collection service to households.
2. Immediate preparation of the national legislation to ensure that all household waste recycling centres are equipped with facilities for the separate collection of garden waste.
3. Food waste prevention/home composting should be promoted first, and then a brown bin service should be provided to householders, if required.
4. The continuation and development of the EPA's national home composting and food waste prevention programme called *www.stopfoodwaste.ie*
5. Future household brown bin schemes should be provided for food waste only. Garden waste should be home composted or delivered to civic amenity sites. Small amounts of garden waste may be collected at the kerbside together in a separate garden waste paper bag during the summer months. This may be additionally charged by the waste collector. Simultaneous collection with the brown bin will avoid separate transport.
6. A national awareness campaign on the proper use of brown bin should be provided in Ireland. This campaign should provide promotional brochures on how to use the brown bin, and also be available on a national website.
7. Consideration should be given to hiring of "brown bin advisors" who could visit homes and explain the proper use of brown bin. This was conducted in Germany for a period of 1-2 years when source separation was first introduced. Alternatively, a private company could provide this service during the initial period of the roll out of brown bins.

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http://www.wrap.org.uk/local_authorities/research_guidance/food_waste/separate_food_waste.html

This WRAP website contained interesting reports on their food waste collection trials such as:

Evaluation report - food waste collection trials
Case study alternate weekly collections
Case study high density housing areas
Case study low and medium density housing areas
Case study use of liners
Case study multi-occupancy housing
Case study communications

8. Acronyms and Annotation

All acronyms refer to Ireland unless otherwise indicated.

a	year (*L.*) annum
ABP	Animal By-Products
ABPR	Animal By-Products Regulation (European Commission Nº 1774/2002)
AD	Anaerobic Digestion
BMW	Biodegradable Municipal Waste
C	Carbon
℃	Celsius/centigrade
CA	Civic Amenity [recycling centre]
ca.	about, approximately, (*L.*) *circa*
Cd	Cadmium
CO_2	carbon dioxide
Cr	Chromium
CSO	Central Statistics Office
Cu	Copper, (*L.*) *cuprum*
DAFF	Department of Agriculture, Fisheries, and Food
d.m.	dry matter
DoEHLG	Department of the Environment, Heritage and Local Government
e.g.	for example, (*L.*) *exempli gratia*
EC	European Communities
EPA	Environmental Protection Agency
equ	equivalent
et al.	and others, (*L.*) *et alii*
etc.	and so on, in similar respects, *(L.) et cetera*
EU	European Union
EWC	European Waste Catalogue
EWP	European Waste Programme
f.m.	fresh matter
GWC	Green waste compost
h	hour(s)
H_2S	Hydrogen sulphide
Hg	Mercury, (*L*) *hydrargyrum*
HH	Households
i.e.	that is [to say], *(L.) id est*
IPTS	Institute for Prospective Technological Studies
K	Potassium, *(L.) kalium*

km	kilometre
kg	kilo
kg/Inh*a	kilo per inhabitant per annum
m^2	square metre
m^3	cubic metre
Mg	Magnesium
mg/l	milligrams per litre
MS	Member State(s) [of the European Union]
Mt	Mega tonnes [million tonnes]
N	Nitrogen
n.a.	not available
Ni	Nickel
NI	Northern Ireland
NSBW	National Strategy on Biodegradable Waste
NWR	National Waste Report
OC	Organic Carbon
OF	organic fraction
OFBMW	Organic Fraction of Biodegradable Municipal Waste
OM	Organic Matter
PAS	Public Amenity Sites
Pb	Lead, (*L.*) *plumbum*
pH	Quantitative unit of measure of acidity or alkalinity, (*L. pondus Hydrogeni*)
QAO	Quality Assurance Organisation
QAS	Quality Assurance System
QM	Quality Management
R&D	Research and Development
SI /S.I.	Statutory Instrument
STRIVE	Science, Technology, Research and Innovation for the Environment
t	tonne (metric 1,000 kgs) / ton (imperial)
t/a	tonnes per annum
tpa	tonnes per annum
UK	United Kingdom
Zn	Zinc

9. Basic Definitions

ABP / ABPR	Animal By-Products / Regulation. ABP as defined by the Animal By-Products Regulation (EC) no. 1774/2002
Anaerobic digestion (AD)	Fermentation process of organic feedstocks under anaerobic conditions with the objective to produce a methane-rich gas as renewable energy resource, liquid or solid digestion residues (digestate) can be used as organic soil amendment. Solid digestate can be composted together with structure material or other organic feedstocks and used like compost.
Biowaste	Source-segregated biodegradable waste of an organic or putrescible character. It is used in line with the term *'organic waste'* which represents the source separated fraction of municipal waste collected from households and similar premises.
Compost classes	Compost classified according to quality levels. In many cases, the classification refers to heavy metal concentration classes, which are related to specific use restrictions.
Compost types	Composts made from specified categories of source materials
Food waste	For this report we use the term food waste synonym to organic kitchen waste or catering waste from domestic origin and restaurants.
Garden waste (Green waste)	Vegetation waste from private gardens, landscape maintenance including tree cuttings, branches, grass, leaves, prunings, old plants and flowers.
Heavy metals	Even if chemically not fully correct we use heavy metals for the potential toxic elements Cd, Cr, Cu, Hg, Ni, Pb and Zn
Home composting	Composting of organic kitchen and garden residues treated on the property of its origin, the private garden. The compost is recycled to the own garden property.
OFBMW	Organic fraction of biodegradable municipal waste. As defined by the National Strategy for Biodegradable Waste this comprises mainly food and garden waste from the household and commercial sector
QAO (Quality Assurance Organisation)	Organisation carrying out the external independent quality assurance scheme for composting plants. In most of the cases this includes the awarding of a quality label for the certified compost products
QAS (Quality Assurance System)	External independent quality assurance scheme for composting plants. This includes the approval of plant operation (process management) as well as product certification according to existing compost standards.
QM (quality management)	Management required for the entire process of compost production. It starts from the receipt control of delivered feedstock materials and ends with final product storage and dispatch of compost to the customer. QM systems comprise a traceable documentation system to be checked by external QSO or the competent authority if it is part of the licensing and compost related legislation.
Residual waste	This is waste collected from households, commerce, and industry, which has not been separated at source.

10. Appendix 1: Collection Vehicles for Food Waste

Source of photos are from the WRAP Publication “Evaluation of the WRAP Separate Food Waste Collection Trials” June 2009 **ISBN:** 1-84405-416-0

Bespoke design used in Preston

Farid Minimatic on Iveco Chassis

Vehicle used in Mid-Bedfordshire

Food waste collection in Newcastle upon Tyne

Farid Micro used by Elmbridge

Localised bulking in Elmbridge – from vehicle directly into roll on off skip

Lifting the slave bins in Elmbridge

Food waste collection in Hackney

Food waste collected in Guildford

Food waste collection in Kingston upon Thames

Electric powered vehicle in Shropshire

Appendix 9

WORLD BIOGAS ASSOCIATION

C40 CITIES C40 NETWORKS FOOD, WATER AND WASTE PROGRAMME

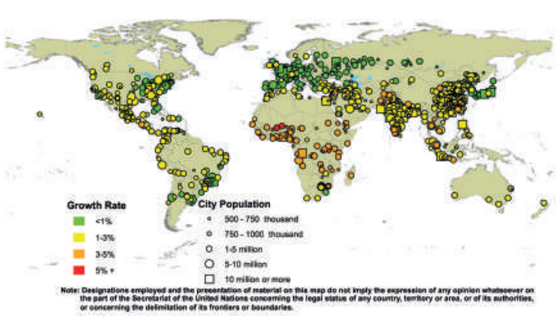
GLOBAL FOOD WASTE MANAGEMENT:
AN IMPLEMENTATION GUIDE FOR CITIES

Full Report

GLOBAL FOOD WASTE MANAGEMENT: AN IMPLEMENTATION GUIDE FOR CITIES

FOREWORD

Globally, food waste has become an increasingly recognised environmental issue over the last decade. Not only has the issue of wasted food become an ethical one in a world where approximately 800 million people suffer from hunger, but the environmental impacts of producing food that is then discarded can no longer be overlooked. As population and urbanisation grows, more food is being produced and more food is being wasted. Moreover, food wasted in an urban context creates severe environmental and public health consequences that have a negative impact upon human well-being and the environment. For the first time in Human history, over 50% of the global population lives in cities and by 2050, this will rise to over 70%. This concentration of people is putting cities' infrastructure under tremendous pressure – the need to provide clean water, sewage treatment, public transport, maintain urban hygiene, build waste treatment facilities, provide education and health services, in cities growing constantly, is an enormous task; however, cities also provide unique opportunities for energy, resources and services efficiency, health services, technological innovation and sustainable development.



UN WORLD URBANIZATION PROSPECTS REPORT, 2014 UPDATE, ANNUAL PREDICTED GROWTH RATE 2014-2030

Food management is also a major source of greenhouse gas emissions and cities are key actors in the global mission to reduce the impact of climate change. The Paris Agreement commits signatories to "holding the increase in the global average temperature to well below 2 degrees above pre-industrial levels, and to pursue efforts to limit the temperature increase to 1.5 degrees above pre-industrial levels." Without the involvement of cities in this process, the goals become impossible to achieve.

Solid waste management is one of the key services every city government must provide with widely variable service levels, costs and environmental impacts. Solid waste generation is also increasing faster than any other environmental pollutant, including CO_2. As the world population becomes more urbanized and affluent, the increase of waste generation is putting enormous pressure on local governments, primarily in the rapidly growing cities of Africa, Latin America, Southeast Asia, China and India.

GHG emissions from solid waste management have also emerged as a major point of debate as, under current UNFCCC accounting methodologies, they are estimated to account for 3% of the overall global GHG emissions, primarily from methane from landfills.[1] However, recent studies demonstrate that current methodologies reflect only a limited recognition of the extent to which improved waste management systems can play in GHG reductions,[2] since most of the beneficial impacts from those actions are recorded in other parts of the overall inventory, or lost. Yet calculations undertaken by, for example, the International Solid Waste Association and presented to the Climate and Clean Air Coalition secretariat in 2009[3], show that the waste sector can contribute reductions of some 15% to 20% of a city's emissions if all actions regarding waste management are fully considered. However, because the IPCC emissions accounting is undertaken by sectors, policy makers often overlook the contribution biodegradable waste can make to emission reductions.

[1] *IPCC, 2007b*

[2] *Resource Savings and CO2 Reduction Potential in waste management; Prognos, 2008. Climate Protection Potential in the Waste management sector; Umweltbundesamt, 2010.*

[3] ***http://www.waste.ccacoalition.org/document/white-paper-waste-and-climate-change-iswa-key-issue-paper***

This renders implementation of policies a difficult task and this report sets itself the task of ensuring those contributions are widely understood and recognised.

Cities have a responsibility to create solutions to climate change. Fortunately, they also have a real capacity – and will – to do so. Acting both locally and collaboratively, cities are making a meaningful global impact by implementing sustainable development practices. Each city is unique in its infrastructure, scope of control over municipal services, technical savvy and even progress in addressing climate change.

Competitive advantages allow individual cities to pursue a subset of strategies that will lead to meaningful emissions reductions at the local level. Cities can be nimble in implementing policy changes, but are also readily accountable to their citizens, local businesses, schools, and institutions for the success or failure of their actions. To this extent, cities are a test-bed for larger action: policies and programs that work - environmentally, economically and politically - have powerful potential to enact change globally. Cities with common profiles can network, collaborate on solutions and disseminate best practices that bring actions to scale in other similar cities.

When cities decide to undertake policies together, they can have the impact of nation states. The 90+ cities that are members of the C40 Cities Climate Leadership Group are witness to this willingness to act upon these global challenges.

This report intends to be a guide to assist the decision-makers in cities that recognise the challenges of food waste management and wish to find sustainable and effective solutions.

Cities and nations are acting in various ways to reduce and treat food waste. These include actions focused on donating schemes for food that would otherwise go to waste- especially left-over food from points of sale to consumers that are now collected at the end of the day and given to collection centres where charities redistribute them to the needy. Nations, like France and Italy, have made the donation by supermarkets of left-over food a legal obligation and have reduced taxes to stimulate this. Private and public initiatives have multiplied in major cities, like London, where charities such as FareShare have become major distributors of edible food left-overs.

A significant fraction of food waste is considered unavoidable, which include peelings and skins, bones and fats, oils and fresh food mistakenly left to rot. Separate collection of food waste makes treatment much more efficient whilst promoting reduction too. Several cases are quoted in chapter 4 of cities that have decided to separately collect these residues and send them to treatment. From major cities like Milan to smaller towns, the movement to separately collect food waste is growing. New York, Paris, Oslo, Copenhagen, Auckland, San Francisco, Mexico City, and many others, separately and regularly collect their food waste from millions of citizens, either on a voluntary or obligatory basis. These are usually the result of decisions taken at a city level but often due to an enabling national legislation which has stimulated this action. The recent European Union agreement revising the Waste Framework Directive, in which separate food waste collections will be obligatory from 2023, is an example of how a wider policy framework will impact decisions at a local level.

This report will look at how these cities have implemented these policies and to what degree they have succeeded, what policies need to be enacted and how best results are achieved-learning from experience and understanding best practices. Food waste treatment can create a series of positive outcomes including renewable energy production; natural soil improvers that can store carbon and increase soil humidity; reduced methane and other GHG emissions; air quality improvement; reduced reliance on landfills; job creation; economic development; sustainable infrastructure investments; and reduced reliance on fossil fuels.

In chapters 5, 6 and 7 we will look at these solutions and their relative suitability in different urban scenarios. Whilst anaerobic digestion technologies are mature and well-tested, they are relatively complex and require careful management to ensure they achieve their targets in terms of outputs and performance. Training, maintenance, health and safety considerations, upgrading, are continually needed to ensure that a plant performs well over its programmed life span.

This report is also a call to action. It is published in Spring of 2018 and recognises that time to implement policies and investments to combat climate change is running out. It is vital to remember that the impacts of climate change are already underway, and already being experienced around the world. Global temperatures have already increased by 1 ºC from pre-industrial levels. Atmospheric CO2 levels are already above 400 parts per million (ppm), far exceeding the 350 ppm deemed to be "safe" for human civilization. These facts emphasise the incredible urgency with which we need to act if the ambitions agreed in Paris are to be met. Recent C40 research shows that, based on current trends of consumption and infrastructure development, within five years the world will have "locked-in" sufficient future emissions to exceed 2 degrees. A third of these emissions will be determined by cities, making them pivotal actors in any solution.

The overriding and deeply significant finding of the C40 Deadline 2020 report is that the next 10 years will determine whether or not the world's megacities can deliver their part of the ambition of the Paris Agreement. Without action by cities, the Paris Agreement cannot realistically be delivered. To remain within a 1.5 degree temperature rise, average per capita emissions across C40 cities need to drop from over 5 tCO_2e per capita today to around 2.9 tCO_2e per capita by 2030. For wealthier, high emitting cities that means an immediate and steep decline. Some developing cities can maintain their current levels for up to a decade, and in a small number of cases there is some scope for emissions per person to rise slightly before they eventually fall to zero. But every city needs to diverge considerably from its current business as usual pathway.

The business-as-usual path of C40 cities' emissions needs to 'bend' from an increase of 35% by 2020, to peak at only a further 5% higher than current emissions. This "bending of the curve" is required now to ensure that in the coming decades the necessary reductions remain feasible, given that actions can take many years to mature and reach full scale.

The reduction and treatment of urban food waste is one of the most significant methods cities can use to reduce their carbon footprint. The interesting aspects of food waste treatment technologies are that they can be implemented within a short timeframe and that cities have most of the powers to do so.

National and city authorities can take action immediately to reduce and capture the resources available in food waste and turn these into compost, biogas, transport fuel, soil improvers, power and heating and cooling. By quantifying the local availability of food waste feedstocks, the intrinsic energy and carbon value in these, the opportunities to reduce food waste, and the technologies available to treat the wastes that are left, cities can initiate the process for turning a major pollutant into a useful resource. Access to finance, the adoption of policies and the consequential actions follow from the decision to collect and treat food waste. Continuous communication activities involving the local population are needed to ensure the population understands, participates in and actively promotes the new system. Stakeholder involvement is required throughout the process and even more so once it is implemented to ensure continuity and successful running of the programmes. As some cities have shown, punitive measures may also be needed to ensure compliance.

The C40 Cities Food, Water and Waste Programmeand the World Biogas Association offer their collective assistance to cities coming to terms with food waste, its reduction and treatment. By making our expertise in this sector available to those willing to embrace the food waste challenge, we hope to speed up the process of change and to help cities achieve their climate change and urban sustainability goals.

The report intends to give the reader a wide ranging overview of how cities can deal with food waste. As such the report wants to help policy makers and their relative stakeholders in cities adopt best practices to reduce the negative impacts of untreated food waste and create positive impacts related to energy, soil quality and human health.

Divided into 7 chapters, the report looks at the impacts of food waste on the global commons; how to prevent and reduce food waste; experiences of cities that have implemented source segregated collection of food waste; treatment options for food waste ranging from low to high investment solutions; the products derived from food waste treatment and how to use them; we enter into some detail about anaerobic digestion and its role in sustainable management of food waste; finally, we look at the policies required to overcome economic and social barriers to implementing food waste treatment.

This is a comprehensive report, one designed to be a point of reference to policy makers and stakeholders for time to come. It is also a dynamic report- through the website archive linked to the report itself, new resources are continuously uploaded bringing vast amounts of information about the issues discussed here.

You, the reader, are invited to contribute to this archive with your experiences and knowledge.

The report is a collaborative effort led by the C40 Cities Food, Water & Waste Programme and the World Biogas Association, with inputs and information provided by a host of expert writers from the world over. We are particularly grateful for the help received from the Global Methane Initiative of the Environmental Protection Agency of the United States of America and the Eastern Resource Group consultancy, for decades a leader in ensuring methane from landfills is captured and used for energy production. Some input has been received from the United Nations Food and Agricultural Organisation. We thank also the Editorial Board of the report who have dedicated free time to give their views, comments and inputs over the six months of drafting. Finally we thank the countless numbers of friends, colleagues and parties that have contributed experiences to the study without which it would have been poorer. They are cited in the annex and quoted where relevant in the report itself. Above all, our thanks go to Dr. Sarika Jain of WBA and Kathrin Zeller of C40 who have been the key contributors for this report and to their respective contributing colleagues. Sponsorship to pay for this report has been received from numerous sources and we thank each of the sponsors for their precious support

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GLOBAL FOOD WASTE MANAGEMENT:
AN IMPLEMENTATION GUIDE FOR CITIES

WORLD BIOGAS ASSOCIATION

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GLOBAL FOOD WASTE MANAGEMENT:
AN IMPLEMENTATION GUIDE FOR CITIES

INDEX

CHAPTER 1. IMPACT AND SOURCES OF FOOD WASTE

CHAPTER 2. FOOD WASTE PREVENTION

CHAPTER 3. FOOD WASTE COLLECTION

CHAPTER 4. FOOD WASTE TREATMENT TECHNOLOGIES

CHAPTER 5. ANAEROBIC DIGESTION

CHAPTER 6. PRODUCTS OF ANAEROBIC DIGESTION

CHAPTER 7. POLICY RECOMMENDATIONS, BARRIERS AND IMPLEMENTATION

1. SOURCES AND IMPACT OF FOOD WASTE

1.1. Introduction

This chapter explores the sources of food waste and the extent to which the environment, global economy and society are bearing the burden of food wasted and lost.
The lifecycle of the food we eat begins in the farms where it is grown and harvested or the sea, rivers and lakes it is fished from. It continues through handling and storage stages and, often, processing prior to distribution and consumption. Throughout the food cycle, losses and wastage occurs, at farms, processing plants, distribution centres, storage houses, supermarkets, restaurants and households.

The magnitude of the problem and lost opportunity is highlighted by the following three facts:

- **A third of the food produced for human consumption globally, about 1.6 billion tonnes per year, is lost or wasted [1].**
- **The cost of food waste globally is estimated at around USD 2.6 trillion – of which USD 1 trillion is incurred from greenhouse gas (GHG) emissions, water scarcity, biodiversity loss, increased conflicts and loss of livelihood due to issues such as soil erosion, nutrient loss, reduced yields, wind erosion and pesticide exposure [2].**
- **Food waste accounts for 4.4 giga-tonnes (Gt) of CO_2 eq. per year, which represents 8% of global anthropogenic GHG emissions [3] . In comparison, the overall emissions from China, USA and India are 12.45, 6.34 and 3.00 Gt of CO_2 eq. per year [4].**

Avoiding food waste along its lifecycle is therefore imperative for all those managing food production, distribution and sales. However, as set out below, a significant fraction of food waste, especially at the household stage, still occurs. The correct management of these materials at the end of their lifecycle is essential in order to avoid the environmental and societal impacts caused by untreated, decomposing food.

By shifting from a linear to a circular management system, utilising food 'waste' as a 'resource', for example via composting or anaerobic digestion (AD), a multitude of benefits can be delivered; renewable energy generation, reduced GHG emissions, reduced dependence on fossil fuels, improved soil fertility, food security, energy security, better health and sanitation, protection of water bodies, more self-sufficient and resilient communities and sustainable industrialisation, in addition to potential economic benefits from reduced expenditure and additional revenue streams from sale of electricity, heat, biomethane, vehicle fuel, digestate/compost or other high value products [5].

These benefits are described in greater detail in Chapter 5 and touched on in this chapter.

1.2. Definition of food waste

The terms food, inedible food, food loss and food waste need to be contextualised both geographically and within the food chain. For the purpose of this report, 'food' is defined as any substance, whether processed, semi processed or raw, that is intended for human consumption as well as the 'inedible parts' associated with food that are not intended to be consumed by humans [6]. For example, pineapple is a food; its skin is inedible.

'Food loss' refers to food that unintentionally undergoes deterioration in quality or quantity as a result of food spills, spoils, bruising, wilting or other such damage as a result of infrastructure limitations at the production, storage, processing and distribution stages of the food lifecycle. In this report, 'food waste' means any food and inedible parts of food, removed from the food supply chain that can be recovered or disposed. This includes food waste that is to be composted, spread to land, treated through anaerobic digestion, combusted for bio-energy production, incinerated, disposed to sewer, sent to landfill, dumped in open dumps, or discarded to sea [7]. The rationale behind this choice of food waste definition is that from a resource efficiency perspective, any parts of food that are not consumed are still rich in carbon, water and nutrients. By collecting and recycling this food waste, nutrients and water can be recovered and recirculated, and renewable energy from the carbon harvested to substitute fossil fuels. It may be noted that by using this definition, inedible parts of food, such as fruit and vegetable skins, egg shells, are a part of food waste. 'Avoidable food waste' is defined as food or drink that was, at some point prior to disposal, edible (e.g. slices of bread, apples, meat) while 'unavoidable food waste' is waste arising from food and drink preparation that is not, and has not been, edible under normal circumstances (e.g. meat bones, egg shells, pineapple skin) [8]. Within the context of cities, food waste will primarily be characterised by where it is produced – not on the farm or in the fishery, but in households, catering facilities, processing plants (e.g. canneries, abattoirs, and bakeries), storage and distribution operations, markets and shops, restaurants, bars and cafés.

[1] *Food and Agriculture Organisation of the United Nations (2011) Global Food Losses and Food Waste – Extent, Causes and Prevention* **http://www.fao.org/docrep/014/mb060e/mb060e00.pdf**

[2] *Food and Agriculture Organisation of the United Nations (2015) Food Wastage Footprint & Climate Change* **http://www.fao.org/3/a-bb144e.pdf**

[3] *Food and Agriculture Organisation of the United Nations (2015) Food Wastage Footprint & Climate Change* **http://www.fao.org/3/a-bb144e.pdf**

[4] *The World Bank Data Bank based on European Commission, Joint Research Centre (JRC)/Netherlands Environmental Assessment Agency (PBL). Emission Database for Global Atmospheric Research (EDGAR), EDGARv4.2 FT2012* **https://data.worldbank.org/indicator/EN.ATM.GHGT.KT.CE**

[5] *Ellen MacArthur Foundation (2013) Towards the Circular Economy Vol 2* **https://www.ellenmacarthurfoundation.org/assets/downloads/publications/TCE_Report-2013.pdf**

[6] *The Food Loss and Waste Accounting and Reporting Standard* **http://flwprotocol.org/wp-content/uploads/2017/05/FLW_Standard_Exec_Summary_final_2016.pdf**

[7] *EU FUSIONS (2016) Food waste definition* **https://www.eu-fusions.org/index.php/about-food-waste/280-food-waste-definition**

[8] *WRAP (2009) Household food and drink waste in the* **UK http://www.wrap.org.uk/sites/files/wrap/Household_food_and_drink_waste_in_the_UK_-_report.pdf**

1.3. Impacts of food waste

In addition to the squandering of resources (including energy, carbon, water and nutrients) needed to produce food that is not consumed, poorly managed food waste adversely affects our climate due to the GHGs that are emitted upon its decomposition, contaminates watercourses from nutrient and leachate runoff and can be a vector for diseases and a health hazard.

This section gives an overview of the breadth and scale of the impacts that food waste inflicts upon society and the environment and how its collection and recycling can mitigate some of these. It describes the impacts, identifies the relevant international commitments in place to address these impacts, and explains some of the potential mitigation measures needed to achieve this, with particular regards to:

- GHG emissions and climate change;
- Water footprint;
- Nutrient loss;
- Sanitation;
- Ecological impacts; and
- Economic impacts.

1.3.1. GHG emissions and Climate Change

Background to impact

Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are greenhouse gases that contribute to global warming and climate change, and are emitted at all stages of the food life cycle, including:

- **Change in land use from forests (for example) to agriculture causing release of carbon that was stored in the cleared biomass;**
- **Emissions from livestock and from manures and slurries;**
- **From burning fossil fuels to produce energy for:**
- **Operating farm machinery;**
- **Producing and using of mineral fertilisers;**
- **Heating farm buildings and greenhouses;**
- **Processing food (e.g. pasteurisation); and**
- **Refrigerating and transporting of food.**
- **When wasted food is disposed of in landfill sites or dumpsites, it decomposes and releases further emissions to the atmosphere.**

CO_2, CH_4 AND N_2O ARE GREENHOUSE GASES THAT CONTRIBUTE TO GLOBAL WARMING

International Commitments

In December 2015, 195 parties signed and 171 nations have ratified at the date of writing (so the Agreement is in force), the United Nations Framework Convention on Climate Change (UNFCC) “Paris Agreement”, aiming to limit global warming to 1.5 – 2 degrees Celsius above pre-industrial levels by 2100, committing to collective action towards a low carbon economy. At the heart of this agreement are the publicly available plans of each signatory’s post-2020 climate actions known as their Intended Nationally Determined Contributions (INDCs) [9] . Each of the signatories is now working on their INDCs. Food waste accounts for 4.4 Gt of CO_2 eq. GHG emissions on an annual basis - 8% of all anthropogenic GHG emissions [10]. By identifying and delivering actions on reducing and treating food waste, countries can achieve and increase their INDCs.

Mitigation

As explained further in Chapter 2, the prevention of waste along the food chain brings the greatest benefits to society and the environment through the reduced cost and impacts of food produced. Measures for the prevention of food waste can be implemented to prevent avoidable losses within urban contexts, whilst several climate change mitigation benefits will occur by managing unavoidable food waste once it is discarded, i.e. in collecting and treating it correctly.

Food waste treatment through composting or Anaerobic Digestion (AD) can prevent:

- **Methane emissions from rotting food in landfills and open dumps. 50% of all waste is still not collected in low income countries and up to 60% of these volumes are made up of food and organic waste .**
- **Carbon dioxide emissions from substituting fossil fuels traditionally used for energy production with biogas-based energy from AD which is renewable and produced from recovering food waste [11].**
- **Emissions of black carbon and carbon dioxide from substituting traditional solid domestic fuel in households such as firewood, charcoal, dung cakes, etc. with biogas. This mitigates climate change and also improves indoor air quality.**
- **Carbon dioxide emissions from the energy used in the production of mineral fertilisers by substituting it with biofertiliser (compost or digestate) produced after treatment of food waste.**

It is estimated that 580 kg CO_2 eq. can be saved per each tonne of food waste diverted from landfill to an anaerobic digester when the resulting biogas is used to replace natural gas [12] .

Given the GHG emissions mitigation benefits of food waste collection and treatment, it is one of the few steps that every country and city should include in their INDCs and plan for their future.

[9] United Nations Framework Convention on Climate Change ***http://unfccc.int/paris_agreement/items/9485.php***

[10] FAO (2015) Food Wastage Footprint and Climate Change ***http://www.fao.org/3/a-bb144e.pdf***

[11] The World Bank (2012) What a waste – A Global review of solid waste management ***https://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/What_a_Waste2012_Final.pdf***

[12] Ellen MacArthur Foundation (2013) Towards the Circular Economy ***https://www.ellenmacarthurfoundation.org/assets/downloads/publications/TCE_Report-2013.pdf***

1.3.2. Water footprint

Background to impact

Water is essential to plant and animal life and therefore for the production of food for human consumption. In places where rainfall is not adequate or seasonal, water is extracted from groundwater aquifers and surface water bodies for irrigation.The production of food that is wasted and the uncontrolled disposal of food waste has an impact on surface water as well as groundwater bodies.

Impacts on water supply and quality can arise as follows:

- **Wastage of food results in the waste of water extracted from the ground or surface water bodies for irrigation. It is estimated that the blue water footprint for the agricultural production of food that ends up being wasted is approximately 250 km^3 which is three times the volume of Lake Geneva [13] .**
- **Use and subsequent runoff of fertilisers and pesticides has an adverse impact on the water quality of ground and surface water bodies.**
- **Leachate from dumpsites and landfills pollutes the groundwater as well as surface water.**
- **Where poorly regulated, untreated wastewater from food processing industries pollutes the surface water bodies.**

International Commitments

The United Nations (UN) Sustainable Development Goal (SDG) 6 aims to substantially increase water-use efficiency across all sectors and ensure sustainable withdrawal and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity, by 2030. Also, by 2030, the international community is committed to improve water quality by reducing pollution, eliminating dumping and minimizing the release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse of water globally [14].

Mitigation

Preventing food waste can reduce the pressure on water bodies while collecting and treating the food waste that still occurs can reduce its impact on the quality of surface and groundwater.

FOR MILLENNIA HUMANS HAVE LIVED IN RURAL ENVIRONMENTS WHERE THE RECYCLING OF FOOD AND HUMAN WASTE TO SOIL HAS BEEN A CONTINUAL PRACTICE.

[13] *FAO (2013) Food wastage footprint – Impacts on natural resources* ***http://www.fao.org/docrep/018/i3347e/i3347e.pdf***

[14] *United Nations Sustainable Development Goal 6* ***https://sustainabledevelopment.un.org/sdg6***

- When wastewater from sources such as food processing industries is collected and anaerobically digested, carbon is captured in the form of biogas. This reduces the biological and chemical oxygen demand of the wastewater and also reduces the pathogens in it, thus, reducing the impact on water bodies.
- Proper collection and management of food waste reduces instances of leachate formation, accumulation and free flow such as in landfills and open dumps. This prevents contamination of ground water.
- With correct application of digestate to soil in the form of biofertiliser, farmers can manage their soil and reduce contamination of water bodies from leaching of synthetic fertilisers.

GROWING POPULATION AND CONSUMPTION ARE PUTTING INCREASING PRESSURE ON THE ALREADY LIMITED AGRICULTURAL LAND SUPPLIES TO PRODUCE EVEN MORE FOOD.

1.3.3. Nutrient loss

Background to impact

Plants are primarily made of carbon and water, and need nitrogen (N), phosphorus (P) and potassium (K), amongst other nutrients, for their growth. Plants photosynthesize carbon from the atmosphere while the NPK are obtained from soil, and from organic and inorganic fertilisers applied by farmers. Decades of unsustainable agricultural practices have resulted in depletion of these nutrients, as well as of organic matter in the soil.

With a growing population and its increasing wealth and consumption, there is increasing pressure on the already limited agricultural land supplies to produce even more food. Waste of food further exacerbates the problem of food security. For millennia human beings have lived in generally rural environments where the recycling of food and agricultural waste and human excreta to soil has been a continual practice. Further, only in the last century have soils been subjected globally to intensive agricultural practices and use of synthetic fertilisers. As humanity has urbanised (in year 2014 54% of humans lived in urban areas and this will increase to at least 66% by 2050 [15]) the natural recycling of food and agricultural waste and human excreta on farmland has declined, as these wastes are produced increasingly in cities, and not returned to farmlands. The breakdown in this cycle can be partially addressed by recycling these wastes from urban contexts back to farmland, through the use of digestate and compost. Cities therefore have a role to play in promoting sustainable food production through better food waste management.

[15] *United Nations (2014) World urbanization prospects* ***https://esa.un.org/unpd/wup/publications/files/wup2014-highlights.pdf***

A few key data give us an understanding of the value of soils.

- 95% of all food consumed by humans is grown in soil [16].
- 1.4 billion hectares (30% of all agricultural land) is used for the production of food that is never eaten as it is wasted [17] .
- 2.6 billion people depend directly on agriculture, but 52 per cent of the land used for agriculture is moderately or severely affected by soil degradation [18]
- Globally, up to 2 billion hectares of land is degraded, with agricultural activities and deforestation being one of the primary causes of land degradation [19].
- The world's soils have lost 133 billion tonnes of carbon since the dawn of agriculture [20]. A part of this carbon, which is lost from the soils, ends up in the atmosphere in the form of GHGs such as carbon dioxide and methane, reducing the quality of air we breathe and also causing our climate to change.
- Phosphorus, which is widely used in agriculture to promote growth and is essential for maturity of plants, is depleting and concentrated in only a few countries (most of the world's reserves are owned or controlled by Morocco, China and the US) [21] .

International Commitments

As a part of the UN SDGs 2 and 15, countries have committed to[22]:

- **By 2030, end world hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round.**
- **By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality[16].**
- **By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world.**

[16] *FAO (2015) Healthy soils are the basis for healthy food production* ***http://www.fao.org/soils-2015/news/news-detail/en/c/277682/***

[17] *FAO (2013) Food waste footprint: Impacts on natural resources* ***http://www.fao.org/docrep/018/i3347e/i3347e.pdf***

[18] *United Nations Sustainable Development Goal 15* ***http://www.un.org/sustainabledevelopment/biodiversity/***

[19] *United Nations Convention to Combat Desertification (2017)* ***http://www2.unccd.int/news-events/over-110-countries-join-global-campaign-save-productive-land***

[20] *EcoWatch (2017) World's soils have lost 133bn tonnes of carbon since the dawn of agriculture* ***https://www.ecowatch.com/soil-carbon-loss-2478725457.html***

[21] *Cordell D, Drangert J and White S (2009) The story of phosphorus: Global food security and food for thought, Global Environmental Change, 19, 292-305.*

[22] *United Nations Sustainable Development Goal 2* ***http://www.un.org/sustainabledevelopment/hunger/***

THROUGH THE SDG, COUNTRIES HAVE COMMITTED TO END WORLD HUNGER, ENSURE SUSTAINABLE FOOD PRODUCTION AND COMBAT DESERTIFICATION.

Mitigation

Prevention of food waste has the effect of reducing the pressure on land for higher yields. This in turn gives agricultural land a chance to replenish, reducing its degradation.

Collecting food waste, digesting it and applying the digestate or compost to agricultural land can have multiple benefits:

- **It slows down degradation of land by returning organic carbon to soil, increasing yields and reducing the need for inorganic fertilisers to grow crops and obtain higher yields.**
- **Returning the food waste to agricultural land in the form of digestate and compost prevents loss of nutrients (nitrogen, phosphorus and potassium) to landfills, keeping them in circulation for reuse. This is particularly important for phosphorus, the remaining reserves of which are geographically concentrated and in continual decline.**
- **Nutrient recycling also prevents run-off nutrients to surface water bodies, which causes eutrophication and growth of algal blooms, which in turn impact aquatic life and the livelihood of people who depend on it.**

1.3.4. Sanitation

Background to impact

Globally, about 50% of waste is sent to landfills while 13 to 33% of waste is still being openly dumped in lower and middle-income countries [23]. The food and other organic waste in the landfills and dump sites can lead to parasitic and gastrointestinal diseases in the populations living and working near the site, including women and children [24]. Organic waste in dumpsites attracts vermin, flies, birds and other carriers of communicable diseases and those that prey on them, further increasing the health risk via transfer to the food chain [25]. Grazing animals whose meat and milk are consumed by humans can be found in open dumps across the globe.

International Commitments

As a part of SDG 3, UN Member States have committed to substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination.

Mitigation

Source segregated collection and treatment of food waste prevents it from being available to disease spreading rodents, mitigating the spread of diseases. Anaerobically digesting the food waste also reduces the pathogens in the waste, further preventing spread of diseases and odours, and promoting sanitation and hygiene.

[23] *The World Bank (2012) What a waste – A Global review of solid waste management* **https://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/What_a_Waste2012_Final.pdf**

[24] *UNEP ISWA (2015) Global Waste Management Outlook Waste* **http://www.iswa.org/nc/home/news/news-detail/article/press-release-global-waste-management-outlook-gwmo/109/**

[25] *ISWA (2015) The Tragic Case of Dumpsites* **https://www.iswa.org/fileadmin/galleries/Task_Forces/THE_TRAGIC_CASE_OF_DUMPSITES.pdf**

1.3.5. Ecological impacts

Background to impact

Increased food production to support the growing global population has resulted in widespread ecological damage from:

- **Change of land use from forests, prairies, peat, marshes, etc., to agriculture;**
- **Loss of biodiversity of species, including mammals, birds, fish, and amphibians; and**
- **Over exploitation of marine life.**

The impacts of this damage from food production at the global scale have been felt in the form of loss of biodiversity, soil quality, marine population, and many other such indicators.

International Commitments

UN SDG 15 aims to protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and biodiversity loss. It aims to integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts by 2020.
In addition, SDG 14 aims to prevent and significantly reduce marine pollution of all kinds, in particular from land based activities, including marine debris and nutrient pollution by 2025.

Mitigation

Circumstantial evidence from areas where food waste is separately collected suggests that collection allows for the easier measurement of such waste and enables the development of more effective, targeted policies and prevention measures.

Ecological impacts of food waste can be mitigated in the following ways:

- Use of biogas as a domestic fuel in households dependent on solid fuels such as firewood, charcoal, dung cakes, etc., reduces the pressure on local woods and forests and other natural resources.
- Proper collection and management of food waste prevents free flowing leachate formation from untreated food waste openly dumped. The liquid and solid by products of composting and anaerobic digestion are applied to farmland as organic fertiliser preventing nutrient pollution: the contamination of ground water and surface water bodies, their eutrophication and formation of algal bloom.

1.3.6. Economic impacts

The total annual economic, environmental and social costs of food waste to the global economy are in the order of USD 2.6 trillion [26], the figures attributed to each of these aspects are shown in the table below.

TABLE 1 : GLOBAL COSTS OF FOOD WASTE

ASPECT	COST (US DOLLARS)
Economic	1 trillion
Environmental	700 billion
Social	900 billion
Total	2.6 trillion

Source: FAO (2014) Food wastage footprint (2014)

Further research is needed to understand how these macro estimates can be assessed at the local level of individual cities. For example, food waste which is not separately collected and disposed of in landfill, generates a cost to the city relative to transport and gate-fees, not including any environmental or social costs. This may vary from USD 150 per tonne in Europe to near zero in emerging economies where landfill or open dumping is not charged for.

Cities may account for the cost of GHG they emit. GHG accounting for untreated food waste sent to landfills, the impacts on health of the local population living near those sites, the cost of pollution to water bodies and soil, are possible to quantify with detailed analysis, but are very location specific - an analysis in emerging economies with poor quality landfill management practices will be completely different to cities where, for example, landfill gas is extracted from sites.

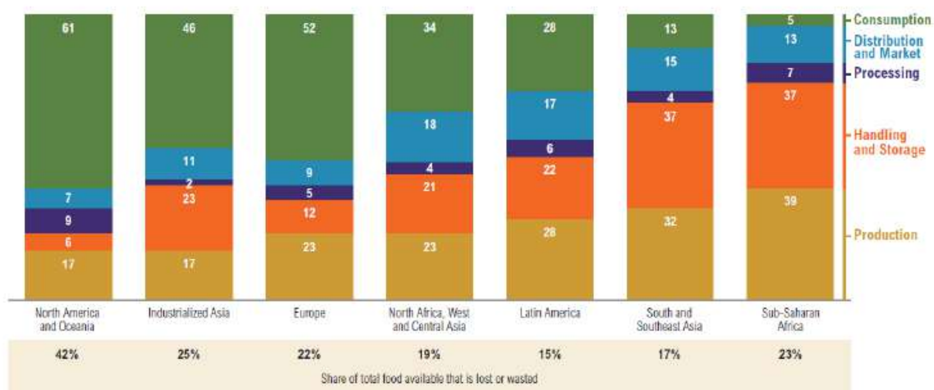
The separate collection and treatment of food waste from urban food cycles has a cost and, as we shall see in Chapters 3, 4 and 5, this represents a significant barrier to implementation of such practices. Only by correctly analysing the true cost of uncontrolled disposal is it possible to put the cost of separate collection and treatment into context and measure holistically. The environmental and economic costs of untreated food waste may be analysis cities would wish to undertake before evaluating the costs of collection and treatment, in order to have a comparison. Finally, it is necessary to understand the income generated from the treatment of food waste in urban contexts through the sale of compost, organic soil amendment or biogas to produce electricity, heat, transport fuel and soil nutrients.

[26] *FAO (2014) Food wastage footprint – Full-cost accounting* ***http://www.fao.org/3/a-i3991e.pdf***

1.4.Sources of food waste

In order to prevent food waste, understanding where, when and why it is being generated is absolutely essential. In this section, we briefly analyse the primary sources of avoidable food waste.

Food is lost and wasted at various stages of its life cycle: production, processing, distribution, retail and consumption. While in developing countries food loss takes place primarily in the production, processing and distribution stages, due to lack of infrastructure, food waste in developed countries primarily occurs in the retail and consumption stages due to consumption patterns and expectations. The average per capita food waste by consumers in Europe, North America and Oceania is 95-115 kg per year while that in Sub-Saharan Africa and South and South-Eastern Asia is only 6-11 kg per year. An extensive study commissioned by the FAO in 2011 can be seen in these graphics in abbreviated form.



Note: Numbers may not sum to 100 due to rounding.

Source: WRI analysis based on FAO. 2011. *Global Food Losses and Food Waste—Extent, Causes, and Prevention*. Rome: UN FAO.

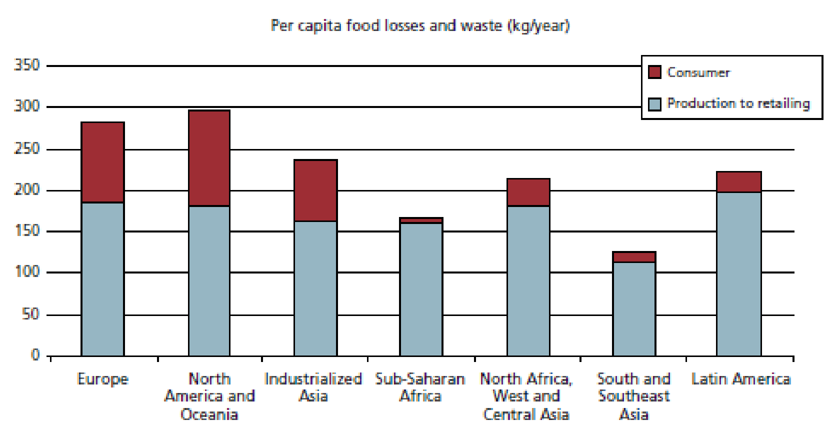


Figure 1: Food Loss in different regions

1.4.1. Developing countries

In developing countries, the proportion of food waste is much smaller than food loss. Food loss here primarily takes place in the agricultural production, post-harvest handling and storage and processing stages, for example, due to premature harvesting, poor storage facilities and lack of infrastructure, lack of processing facilities, inadequate market systems. Food waste, which is the focus of this report, in developing countries is composed primarily of the inedible parts of food, such as peels, shells, pulp, etc. These may be what is left over after consumption by people or a by- product or waste after processing by the food and drink industry.

1.4.2. Industrialised countries

In industrialised countries, there are increased wastes and losses in the distribution and consumption stages. On average, in the EU, around 180 kg of food is wasted per person per year. Food that may still be suitable for human consumption is discarded for various reasons.

The main drivers and sources of waste are shown below [27,28,29]:

Manufacturing:

- Over-production resulting from pressure to meet contractual requirements,
- Appearance quality standard for produce,
- Damaged products,
- Cheap disposal alternatives,
- Inedible parts of produce.

Wholesale and retail:

- Temperature changes leading to spoilage,
- Aesthetic standards expected by the consumers and retailers,
- Packaging defects making produce not fit for sale,
- Over supply due to consumer choices,
- Overstocking due to poor planning and excess surplus.

Food services:

- Lack of flexibility in portion sizes,
- Insufficient planning in forecasting and ordering ingredients,
- Consumer attitudes towards taking leftovers home,
- Refused food due not meeting customer preferences.

Households:

- Buying too much due to poor planning,
- Bad storage resulting from lack of awareness,
- Confusion over freshness and safety labels,
- Discarding edible parts of produce like bread crusts or apple peals,
- Discarding leftovers,
- Large portion sizes.

[27] FAO (2011) Global food losses and food waste – Extent, causes and prevention **http://www.fao.org/docrep/014/mb060e/mb060e00.pdf**

[28] European Environment Agency (2016) What are the sources of food waste in Europe h**ttps://www.eea.europa.eu/media/infographics/wasting-food-1/view**

[29] European Commission (2011) Preparatory Study on Food Waste Across EU 27 **http://ec.europa.eu/environment/eussd/pdf/bio_foodwaste_report.pdf**

SDG 12.3 AIMS TO CUT THE GLOBAL FOOD WASTE IN HALF AT THE RETAIL AND CONSUMER LEVELS BY 2030.

The primary focus of this report is the prevention, collection and treatment of this food waste within the context of cities.

Across the globe, food waste campaigners have brought the need to prevent food waste and treat unavoidable food waste correctly to the attention of the public and thus to policy makers.

As a result, there are a number of relevant initiatives underway on multiple fronts:

- **With the recent surge in decentralised renewable energy production in developing countries, significant research and innovations are being targeted towards better infrastructure to prevent food loss.**
- ***Not-for-profit* organizations like *'FeedBack'* are lobbying for transparency in the food supply chain [30].**
- **Software applications like *'Too Good To Go'* are targeted towards redistribution of cooked meals [31].**
- **There are a growing number of Food Banks now functioning in a number of countries and cities to redirect surplus food to those who need it most via community groups and not for profit organisations such as the Global Food Banking Network [32] and the Robin Hood Army [33].**
- **The Consumer Goods Forum has called upon all retailers and food producers to act on simplifying date labels to reduce food waste by 2020.**
- **Cities have initiated separate collection of food waste, mainly in the more developed countries. Milan, Copenhagen, Paris, New York, San Francisco, London, Stockholm, Oslo, Auckland, Minneapolis, Cajica, and many others, are examples of where separate food waste collections are successfully implemented.**
- **France and Italy have introduced legislation that obliges retailers to donate edible food that has reached its sell-by date to charities that then distribute the food to those in need.**
- **Anaerobic digestion of separately collected food waste is increasing in the developed economies. More countries are looking to capture the energy and environmental advantages of the technology.**

[30] *FeedBack* ***https://feedbackglobal.org/*** *Accessed on 02/01/2018*

[31] *Too Good To Go* ***http://toogoodtogo.co.uk/*** *Accessed on 02/01/2018*

[32] *The Global Food Banking Network* ***https://www.foodbanking.org/*** *Accessed on 02/01/2018*

[33] *The Robin Hood Army* ***http://robinhoodarmy.com/*** *Accessed on 02/01/2018*

While these trends are encouraging, there remains much to be done. Chapter 2 will elaborate upon the food waste prevention strategies, Chapter 3 on food waste collection while chapters 4, 5 and 6 will focus on the processes available for food waste treatment.

2. FOOD WASTE PREVENTION

2.1. Introduction

This chapter explores some of the ways in which cities and governments can facilitate a reduction in the generation of food waste in urban areas. The focus, both of this chapter and the report, is food that is wasted in manufacturing, the wholesale and retail sector, food services and households as a result of various causes, including lack of information, planning, coordination, awareness and not having accounted for the impacts of food waste.

The UN SDG 12 - "Ensuring sustainable consumption and production patterns" - includes a specific food waste reduction target: "by 2030, to halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses" [1].

The scale and impact of food waste calls for immediate action from governments, businesses and individuals. The first step in this direction is the prevention of food waste.

This chapter explores:

- The steps in food waste management;
- How governments can support the prevention of food waste generation by raising awareness amongst citizens and industries within its jurisdiction;
- How businesses can reduce the food waste generated and improve their bottom lines by implementing available technology and best practices;
- How governments and businesses can engage with and support community organisations;
- How governments can employ regulatory measures to prevent food waste; and
- Examples of best practices and initiatives in food waste prevention from all around the world.

SDG 12:

TO REDUCE GLOBAL FOOD WASTE AT THE RETAIL AND CONSUMER LEVELS IN HALF BY 2030

[1] United Nations Sustainable Development Goals **http://www.un.org/sustainabledevelopment/sustainable-consumption-production/**

2.2. Food and drink material hierarchy

The concept of a waste hierarchy, first proposed into legislation by the Netherlands MP Ad Lansink in 1979 and adopted into the *European Waste Framework* Directive in 2008, is often a reference point for nations in forming their own waste legislation. The hierarchy sets out the treatment and disposal preferences for waste, with the pinnacle being prevention. In the UK, for example, Government guidelines enshrine in law an obligation to apply the hierarchy to those who produce and deal with waste [2].

The diagram of the hierarchy shown below was produced by the United Nations Environment Programme (UNEP) and the FAO and shows an inverted pyramid with prevention of food and drink waste as the preferred action [3].

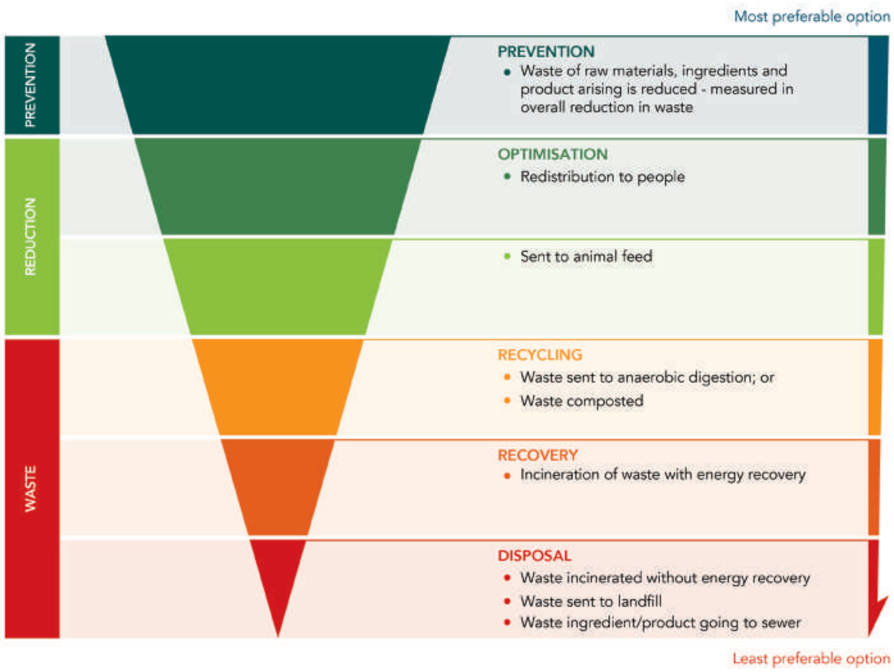


Figure 3: Food and Drink Material Hierarchy

The food and drink material hierarchy sets out guidance on the preferred methods of dealing with food waste so as to minimise its impact on the environment and the society. On the top of the hierarchy is prevention of waste. While every effort should be made to prevent the generation of food waste, any that is still generated should be redistributed to people if possible, if not then to animals. Once it has been deemed that the food cannot be consumed, then it should be treated through composting or anaerobic digestion (AD), as energy and nutrients can be recovered and available for reuse (see Chapter 4 and 5 for further information). Incineration with energy recovery is the least preferred recovery method for food waste. Methods of disposal by which all nutrients and energy is lost, including incineration without energy recovery, landfilling or disposal in sewers, are least preferred.

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[2] *Department for Environment Food and Rural Affairs (2011). Guidance on applying the Waste Hierarchy* ***https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69403/pb13530-waste-hierarchy-guidance.pdf***

[3] *UNEP (2014) Prevention and reduction of food and drink waste in businesses and households - Guidance for governments, local authorities, businesses and other organisations, Version 1.0. http://* ***www.fao.org/fileadmin/user_upload/save-food/PDF/Guidance-content.pdf***

Prevention

- FOOD WASTE PREVENTION: Prevention of food waste sits on the top of the material hierarchy. Any food or drink material wasted is a loss of the resources that have gone into producing it (nutrients, soil, energy, water, biodiversity, labour), a burden on the solid waste management system used to dispose of it or a burden on the environment, if it is not managed suitably. Hence, every effort should be made to prevent waste generation by optimising resource utilisation.

Optimisation

- REDISTRIBUTION TO PEOPLE: If there is food that has been produced but cannot be utilised or sold by the producer, then it should be redistributed to those who can use it. This step is possible for food and drink materials that are edible and still safe for human consumption and improves resource utilisation. There is some energy spent on transport and redistribution, but this is a small investment for a larger scale benefit from the prevention of wastage.
- SENT TO ANIMAL FEED: This step is applicable for the part of food waste that is inedible for humans, such as juice pulp, spent brewer's grains and whey permeate, but edible by livestock. The key to redistribution to livestock is food safety and animal health. Different countries have taken different views on this, for example recycled food waste in Japan is sold as a premium product, "eco-feed", for livestock consumption; there is a certification scheme in place to ensure safety standards are maintained and there are ambitious targets for its uptake [4]. In contrast, in the USA feeding food waste to animals is heavily regulated under federal law, with some states going further and banning the feeding of vegetable waste to pigs [5]. The EU also bans reusing food waste for animal feed, enshrined in the *Animal By-Products Regulations*, which first entered into force in 2002 (Reg. 1774/2002).

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[4] *Sugiura K, Yamatani S, Watahara M and Onodera T (2009) Ecofeed, animal feed produced from recycled food waste, Veterinaria Italiana, 45 (3), 397-404* ***http://www.izs.it/vet_italiana/2009/45_3/397.pdf***

[5] *Harvard Food Law and Policy Clinic and the Food recovery Project University of Arkansas, School of Law (2016) Leftovers for livestock: A legal guide for using food scraps as animal feed* ***https://www.chlpi.org//wp-content/uploads/2013/12/Leftovers-for-Livestock_A-Legal-Guide_August-2016.pdf***

Recycling

- ANAEROBIC DIGESTION: anaerobic digestion (AD) is a process in which food waste breaks down in a series of biological reactions, resulting in the release of biogas. Biogas is rich in methane and can be used in energy production, while the left-over organic material is rich in nutrients and can be used as a soil conditioner for further production of food and further refined by composting with garden waste. AD constitutes energy and nutrient recycling, contributes towards mitigating climate change by renewable energy generation and prevention of emissions gases and odours from landfills. The full benefits of AD are discussed in detail later in this report.
- COMPOSTING: Composting of food waste results in recovery of nutrients that have gone into its production. Often, the organic material left-over from anaerobic digestion is composted and then applied to land. Composting can provide a more easily managed soil improver.

Recovery

- INCINERATION WITH ENERGY RECOVERY: Incineration of food waste is suboptimal from both the nutrient and energy point of view. The nutrients in food waste are lost to the ashes. Some energy is recovered but due to the high water content of food waste, the proportion of recovery is quite low, which is why it is difficult to consider it a form of recycling.

Disposal

- LANDFILLS, INCINERATION WITHOUT ENERGY RECOVERY, DISPOSAL TO SEWER: These are the least favoured options as these forms of disposal results in complete loss of energy and nutrients and have a detrimental effect on the climate, water bodies and sanitation and hygiene, if not managed properly. There are good practices within these such as landfill gas capture, energy recovery through municipal waste water treatment plants and maintaining hygiene via incineration, however these measures are the last resort before the food waste is categorised as unmanaged.

The report reflects the structure of this hierarchy with this chapter, Chapter 2, exploring food waste prevention and redistribution to people. Chapter 3 looks at collection methods and best practices from around the world. Chapter 4 discusses the various options available for recycling and recovery of food waste, including AD, composting and incineration. The report then delves deeper into AD, with Chapter 5 as an overview of the technology. Chapter 6 looks at the products of AD and how they can be used, while; Chapter 7 looks at the barriers to implementation of AD and gives policy recommendations to enable adoption.

2.3. Quantification and characterisation of food waste

The first step in the prevention of food waste is to quantify it. Quantification not only gives an insight into the sources of food waste which can be used to implement targeted preventive measures but also provides a baseline to measure the effectiveness of any campaign.

Among examples of instruments to measure food waste is *The Food Waste and Loss Protocol*, which is a multi-stakeholder partnership that has developed the global *Food Loss and Waste Accounting and Reporting Standard* (FLW Standard). This gives a framework for quantification of food and associated inedible parts removed from the food supply chain [6]. The framework may be used by countries, cities, companies and others to develop food waste and loss inventories and management.

The FLW standard provides guidance on how to define food loss and waste for the context, system boundaries, units of measurement, types of data sources and, quantification methods as well as evaluation of trade-offs between accuracy, completeness, relevance and cost, evaluating accuracy of results and their reporting.

Countries, cities, sectors, industries, businesses and households may develop their own standards and methods that are customised to their context. Some of these could be direct measurements, mass energy balances, statistical analysis, questionnaires, food waste diaries, interviews or a combination of the above [7].

CITIES AND GOVERNMENTS MAY START WITH ASKING THESE VERY SIMPLE QUESTIONS:

✓ What do we know about household waste in our jurisdiction?
✓ What major industries are producing edible and inedible food waste in our jurisdiction?
✓ How are commercial and industrial establishments in our jurisdiction disposing of their food waste?
✓ What is the volume of food waste being generated in our jurisdiction? What proportion of this food waste is avoidable?
✓ What does it cost our government/authority to dispose of this waste?
✓ How much can we as policy-makers invest in waste prevention in order to ultimately avoid expenditure in disposal and related environmental and health costs?
✓ Are there any current food waste prevention programmes or policies in place in our jurisdiction? If yes, how can we make them stronger and more effective?
✓ Is our government aware of the global state-of-the-art practices and technologies available in this field? How can we modify and adopt those for our population and circumstances?

Having quantified the sources and volumes of food waste being generated in the jurisdiction, there are many regulatory and awareness initiatives that can be undertaken to prevent it.

[6] *Food Loss + Waste Protocol (2016) Food Loss and Waste Accounting and Reporting Standard* ***http://flwprotocol.org/wp-content/uploads/2017/05/FLW_Standard_final_2016.pdf***

[7] *EU Fusions (2014) Report on review of (food) waste reporting methodology and practice*

2.4. Raising awareness and communication policies

Cultural and geographical contexts require tailored communication instruments, which will change over time and respond to changes in consumption patterns and social behaviour. For example, the growth of pre-prepared, ready-to-eat food delivered to households, often managed through web apps, has led to a dramatic change in the ways people produce waste. The growth of households with one inhabitant in inner cities has accelerated this trend. Packaging waste increases whilst food waste falls as people cook less at home. Indeed, in advanced economies, the idea of building new dwellings without kitchens has been proposed [8].

Changes in how people live clearly impacts on the waste they produce and therefore the prevention and management techniques that will be effective or needed. Once a jurisdiction has identified food waste as being an issue which requires attention, has monitored food waste sources and volumes, has explored collection and treatment possibilities, and has decided upon an implementation strategy, raising awareness among its stakeholders (e.g. public, enterprises) is required. Educational campaigns may involve web-based instruments, the delivery of printed materials, public meetings with citizens, information seminars with local businesses and door-to-door interviews with citizens, as well as the requirement of reporting and constant monitoring. Indeed, by requiring reporting from businesses, there will be greater awareness of the amount and cost of the food waste produced and therefore they will be more willing and incentivised to respond to the challenge of prevention. Such is especially true for catering businesses, retailers and markets selling food. Wasted food is usually wasted money for these businesses, a waste they are often not fully aware of.

One example is the UK food chain Pizza Hut which has a zero landfill policy for food waste and has invested in monitoring and reducing its food waste [9].

Below are some examples of communication andeducational actions.

- **HOUSEHOLDS - Educational campaigns, such as *Love Food Hate Waste* [10] in the UK, *Stop Wasting Food Movement* [11] in Denmark, and *Think.Eat.Save* [12] a global partnership between UNEP, FAO and Messe Düsseldorf in support of the UN Secretary-General's Zero *Hunger Challenge*, are aimed at raising awareness about the problem of food waste. These campaigns offer practical advice and solutions to the public on how to reduce food waste through a variety of communication media such as guidelines, recipes, engaging with the community via events, radio adverts, articles on the web and newspapers, dedicated websites, etc. The UK *Love Food Hate Waste* campaign saw a reduction in avoidable food waste of 14% in the first 6 months of its launch, saving money for consumers on the cost of buying food, local authorities on disposal of food waste as well as being environmentally beneficial [13]. Similar campaigns have been undertaken in France - *Antigaspi* [14], Singapore – *Save Food Cut Waste* [15], and many others all around the world.**
- **SCHOOLS – Education and awareness are central to driving change in behaviour towards food waste. Educating children about food waste and its impacts can start in schools as a part of the science/environment/society curriculum. School lunches are a wonderful opportunity for schools to reinforce what the children learn in the curriculum.**
- **EDUCATION OF WOMEN – In cultures where women still play a central role in households and are for the most part responsible for cooking and planning the meals, it is important to specifically educate them in food and food waste management.**
- **ADVOCACY CAMPAIGNS – Campaigns such as 'Feeding the 5000' run by *FeedBack* [16] raise public awareness on the issue of food waste, while also advocating for better regulations and business practices to reduce generation of food waste.**

[8] *Tara Slade (2016). Could You Live In A Home Without A Kitchen?* ***http://popupcity.net/could-you-live-in-a-home-without-a-kitchen/***

[9] *Pizza Hut (2017) Corporate Social Responsibility* ***https://www.pizzahut.co.uk/restaurants/about/csr/***

[10] *Love Food Hate Waste* ***http://www.wrap.org.uk/content/love-food-hate-waste***

[11] *Stop Wasting Food* ***http://stopwastingfoodmovement.org/***

[12] *Think.Eat.Save Reduce your footprint* ***http://thinkeatsave.org/***

[13] *The impact of Love Food Hate Waste* ***http://www.wrap.org.uk/sites/files/wrap/West%20London%20LFHW%20Impact%20case%20study_0.pdf***

[14] *Ministry of Agriculture and Food* ***http://agriculture.gouv.fr/antigaspi***

[15] *Save Food Cut Waste* ***http://www.savefoodcutwaste.com/***

[16] *Feeding the 5000* ***https://feedbackglobal.org/campaigns/feeding-the-5000/***

2.5.Engagement and reporting

The management of food wastes is easier if the amounts and quality of food waste produced are regularly monitored and accounted for. Engagement to ensure the dissemination of best practices and experiences helps spread the understanding of how to prevent waste occurring.

- **LARGE FOOD WASTE GENERATORS - Businesses that generate large quantities of food waste, such as food processing facilities, wholesale, retailers, food services, etc., may be required to report the origin, volume and disposal methods of such waste. This informs policy-makers about the sources and volume of food waste, but also enables the business to calculate the cost of their waste, thus encouraging its reduction. Such legislation has been implemented in Japan resulting in a 17% decrease in generation of food waste from the food industry over a period of 5 years (2008-2012) [17].**

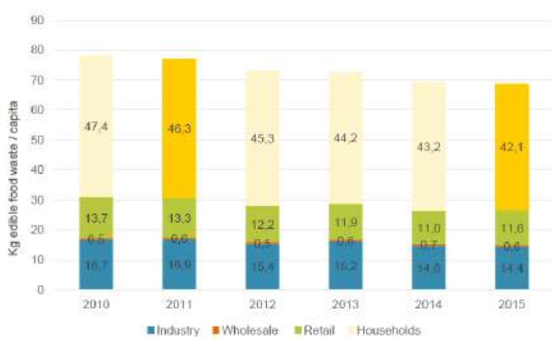

Figure 4: Edible food waste per capita (2010-2015)

- **FOOD SUPPLY CHAIN – Voluntary or mandatory reporting requirements on the food discarded by producers and warehouses, unsold food items in supermarkets, surveys from households can raise awareness amongst these sectors on their food waste. Such a program, ForMat was implemented in Norway for 6 years and resulted in a 12% decrease in edible food waste measured as kg per head of population [18].**

- **ENGAGEMENT – Engaging with trade associations, industry publications, conferences and tradeshows to disseminate sectoral knowledge, best practices and performance standards can help reduce generation of food waste by developing strategies that work for that specific sector, which may be food services like restaurants, food and drink industries like dairies and distilleries, institutions like schools, hospitals or any other sector generating food waste.**

- **RECOGNITION AND REWARD – Recognising the efforts of institutions and industries towards food waste prevention motivates and challenges them to reduce their food waste and build better public relations by recognising high achievers. Such a challenge and recognition programme *'The Food Recovery Challenge'* is run annually by the US Environmental Protection Agency [19] .**

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[17] *Organisation for Economic Cooperation and Development (2014) Preventing food waste: Case studies of Japan and the United Kingdom* ***http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=TAD/CA/APM/WP(2014)25/FINAL&docLanguage=En***

[18] *Ostfoldforskning (2016) Food Waste in Norway 2010 – 2015* ***https://ec.europa.eu/food/sites/food/files/safety/docs/fw_lib_format-rapport-2016-eng.pdf***

[19] *Food Recovery Challenge* ***https://www.epa.gov/sustainable-management-food/food-recovery-challenge-frc***

2.6. Organisation-level initiatives

For commercial establishments in the food industry, food waste can be prevented by implementing a range of voluntary or regulatory initiatives and using available technology. Some examples of successful initiatives are listed below.

- FOOD RETAILER COMMITMENT – Partnerships between supermarkets and food banks and other community organisations, such as that operated by Tesco via a UK based food redistribution charity *FareShare FoodCloud* [20], can not only prevent food waste but also provide nourishment to the vulnerable parts of the society. *FareShare FoodCloud* received and redistributed 13,552 tonnes of food from the food industry and stores supporting 6,723 charities and community groups, providing 28.6 million meals in 2016/17 in the UK [21].

- ENDING QUANTITY-BASED DISCOUNTS – Quantity-based discounts such as 'buy one get one free' encourage people to buy food in quantities larger than they immediately need, leading to food waste. In Denmark, supermarket chain *REMA 1000* has discontinued such quantity-based discounts, and has replaced them with offering the same price discount on each unit [22].

- COMMERCIAL KITCHEN SOLUTIONS – Software solutions designed specifically to manage food waste in commercial kitchens may be integrated into the operations of the enterprise to reduce wastage and save money. The implementation of *Winnow Solutions* at Sofitel Bangkok Sukhumvit has reported a reduction of food waste by 50% and a saving of $60,000 per year [23].

- ENCOURAGE DOGGY BAGS – While the concept of taking left-over food home from a restaurant or house party is common in countries like the USA, in others like Italy and France, it is still not widely culturally acceptable or adopted. Since the food services industry accounts for 14% of the food waste in Europe [24], changes in attitude towards packing left-overs can make a big contribution towards the prevention of food waste.

[20] *Tesco Community Food Connection* ***https://www.tesco.com/community-food-connection/***

[21] *FareShare (2017) FareShare report and financial statements* ***http://fareshare.org.uk/wp-content/uploads/2017/10/FareShare-annual-report-and-financial-statements-2016-2017.pdf***

[22] *EU Fusions (2016) Denmark – Country report on national food waste policy* ***https://www.eu-fusions.org/phocadownload/country-report/DENMARK%2023.02.16.pdf***

[23] *Winnow Solutions website http://info.winnowsolutions.com/sofitelfoodwaste-2*

[24] *European Environment Agency (2016) What are the sources of food waste in Europe* ***https://www.eea.europa.eu/media/infographics/wasting-food-1/view***

2.7. Regulatory initiatives

The EU (at the time of writing early in 2018) is in the process of adopting changes to the *Waste Framework Directive* in a series of policy revisions known as the *Circular Economy Package*. Included in the Directive are actions required of member nations to implement waste prevention policies and to report back to the European Commission on their efficacy. Further, an obligation to separately collect food waste by 2023 and an aspirational target to reduce food waste within the EU by 2030 by 50%, have been adopted.

Such regulatory changes indicate decisive action from governments to tackle food waste. Regulatory requirements can work either by enabling action or incentivising it or by streamlining current processes. Other regulatory options have been listed below.

- GOOD SAMARITAN LAW – In order to facilitate redistribution of surplus food, and to address the legal obstacle, governments can pass *"Good Samaritan"* laws which limit the liability of donors in case redistributed food unexpectedly turns out to be somehow harmful to the consumer unless there has been gross negligence [25]. The law enables donors and foodbanks to serve more people and reduce more food waste.

- TAX CREDITS AND TAX DEDUCTIONS FOR FOOD REDISTRIBUTION – Multiple European countries including France, Germany, Greece, Italy and Poland give tax and fiscal incentives for donation of food as a goodwill gesture and to encourage donations. For example, in Italy, value added tax (VAT) is not imposed on food that is donated. Similarly, in France and in Spain, a proportion (35-50%) of the value of donated food can be deducted from the taxable revenue of the donor enterprise [26].

- FOOD DATE LABELLING – While some date labels on food bought from grocery stores refer to food safety (for example, 'use by') others are targeted towards food quality (for example, 'best if used by' and 'display until'). The meanings of these labels are often unclear to the consumers and leads to wastage of food that is still edible and safe to consume. There has been a call for action by the Consumer Goods Forum to standardise food labels worldwide by 2020 [27]. This includes using only one date label on a product and educating the consumers on its meaning via in-store displays, web service and public service announcements. Should this happen, the standardisation of labels is likely to have a widespread impact of reduction of food waste generated by households, supermarkets, and any other establishment selling packaged food.

[25] *Bill Emerson Good Samaritan Food Donation Act* ***https://www.law.cornell.edu/uscode/text/42/1791***

[26] *European Economic and Social Committee (2014) Comparative study on EU Member States' legislation and practices on food donation* ***http://www.eesc.europa.eu/resources/docs/executive-summary_comparative-study-on-eu-member-states-legislation-and-practices-on-food-donation.pdf***

[27] *The Consumer Goods Forum (2017) Call to action to standardise food date labels worldwide by 2020* ***https://champs123blog.files.wordpress.com/2017/09/champions-123-call-to-action-to-standardize-food-date-labels-worldwide-by-2020.pdf***

- SUPERMARKET FOOD WASTE RECOVERY REQUIREMENT – Regulatory requirements, such as banning the destruction of edible food by addition of water or bleach unless it poses a real food safety risk, may be enacted to encourage redistribution and energy/ nutrient recovery from the food [28].

- BANNING OF ORGANIC WASTE TO LANDFILLS – the EU Landfill Directive obliges the member states to reduce the amount of biodegradable waste going to landfill to 35% of 1995 levels by 2020 [29]. Some EU member states have gone further and banned any food waste to landfill (such as Germany, Austria and Sweden). Along similar lines, commercial establishments generating organic waste in excess of a predetermined threshold may be required to recycle it, if such a facility exists within a certain distance. This encourages businesses to reduce their food waste in the first instance. Such laws have been enforced in some states in USA, such as Massachusetts and Connecticut, and also in the City of Vancouver, Canada.

- PAY-AS-YOU-THROW (PAYT) – 'Pay as you throw' (PAYT) schemes charge the producers of food waste for the disposal of the waste they generate based on the waste's weight/volume. Seoul (South Korea) [30] has reported a 10% reduction in food waste generation after implementation of such a collection method. PAYT schemes have a direct impact on the profit or expenditure of the business or household and are an effective tool for food waste prevention, as well as contributing towards the funding of collection/ treatment. This tool, however, needs strict monitoring to prevent illegal dumping or fly tipping. This policy mechanism will be explored in detail in Chapter 7.

2.8. Research

Finding new ways of reducing food waste is a topic that must be a priority for every government, business and individual and ongoing research is required. An example of the impact of research is provided by a project undertaken by the Japanese Ministry of Economy, Trade and Industry and the Japan Weather Association – the project utilised weather forecasting information, social media such as Twitter, and other data to reduce food loss and waste in the supply chain, and successfully prevented food waste by cutting food loss inventory of soup for cold noodles by 20% over the year before. The project is being widened to include more food groups [31].

THE EU LANDFILL DIRECTIVE OBLIGES MEMBER STATES TO REDUCE BIODEGRADABLE WASTE GOING TO LANDFILL TO 35% BY 2020, COMPARED TO 1995

[28] NRDC (2015) France moves toward a national policy against food waste **https://www.nrdc.org/sites/default/files/france-food-waste-policy-report.pdf**

[29] European Commission (2016) Biodegradable waste **http://ec.europa.eu/environment/waste/compost/index.htm**

[30] Waste Management World (2017) High Tech Bins Cut Food Waste in Seoul by 10%. **https://waste-management-world.com/a/video-high-tech-bins-cut-food-waste-in-seoul-by**

[31] Ministry of Economic, Trade and Industry (2017) Successful Achievement of Zero Food Loss by Forecasting Demand Based on Weather Information and Other Data **http://www.meti.go.jp/english/press/2017/0605_003.html**

Case Study: Rotterdam actions on Food Waste Prevention

Rotterdam is no exception with respect to the worldwide trends of foodwaste in cities. Roughly 14% of the food entering the city is wasted. That is slightly above the national average of 12%. In fact, recent research about material flows estimated that the city of Rotterdam currently wastes 38,400 tonnes of food annually. The vast majority of this waste comes from households (28,220 tonnes), and to a lesser extent from catering industry (7,520 tonnes) and retail (2,660 tonnes). As such, the foodwaste represents one of the largest residual flows of the city. However, most organic waste is not collected or disposed of separately and therefore ends up in the incinerator as residual waste. A small part is collected as organic waste and is processed to make biogas and compost.There are various solutions to close the leakages of the current linear system in the various flows of the agri-food sector in Rotterdam. The proposed measures aimed at reducing food waste can together reduce up to 50% of the current volumes of food waste. Rotterdam is home to a number of social initiatives and enterprises focused on preventing foodwaste. Some initiatives like 'voedselbanken' (or food banks) that distribute discarded food from larger supermarkets to Rotterdammers with a low income, or festivals where large amounts of discarded food is prepared and eaten by and for Rotterdamers, are listed below.

TABLE 2 : ROTTERDAM FOOD WASTE AVOIDANCE INITIATIVES

ROTTERDAM BASED INITIATIVES WORKING TO PREVENT FOOD WASTE	ROTTERDAM BASED ENTREPRE-NEURS & START-UPS WORKING WITH FOODWASTE	FOODWASTE FESTIVALS, PLATFORMS & NETWORKS
■ Isaac en de Schittering : One of many Rotterdam Food Banks ■ BroodNodig: campaigning against bread waste ■ ResQ: app in which restaurants offer leftover dishes at discount.	■ BEWA : composting & digestion of food waste ■ Eat Art Collective: foodwaste collective ■ Freggies: snacks from foodwaste ■ RotterZwam : grow mushrooms on coffee grounds ■ Coffeebased: make bioplastics from coffee grounds ■ FruitLEather: make leather from fruit waste ■ Ugly Food Rescuers Club: zero waste catering & foodwaste collective ■ GroenCollect – Logistic start up that collects (food)waste with EV's	■ ERGroeit, Rotterdam ■ Milieucentrum, Rotterdam ■ Zero Waste, Rotterdam ■ Food Cluster, Rotterdam ■ Youth Food Movement ■ Slow Food Movement ■ Blue Food Festival: recurring well visited festival in BlueCity ■ Zero Food Waste, Rotterdam: working on a food waste distribution centre ■ Damn Food Waste 2015: over 3,000 visitors ensured that more than 1,000 kilos of food was saved.

* *The case study is based on information provided by City of Rotterdam.*

2.9. Food waste prepared and treated to be used as animal feed

The food waste hierarchy suggests that the next best option for food waste, if it cannot be prevented and is not suitable for human consumption, is to use it as animal feed. Depending on the proximity of food waste generators to local farms or zoos, it may be viable to recover discarded food as feed for livestock, poultry, or other animals.

Food waste's high nutrient content makes it a good potential option for animal feed. Most analyses reveal food waste to have high protein and fat content, both in excess of 20%. The bulk of research completed with food waste has used wet waste for animal feed; however, recent projects have used various processes (with the food waste being extruded, dehydrated, pelleted, ensiled, etc.) and products in animal feeding experiments. The ability to further process and dewater food waste would allow preservation, storage, and easier use commercially [32].

There are numerous by- or co-products of industries currently fed to animals, examples being brewers and distillers grains, beet pulp, citrus pulp, soy hulls, and cottonseed, to name a few. These have been fed to animals for many years, are consistent in nutrient content, and are often available regionally, if not nationally.

Disposing of food waste to technologies such as incineration or landfill usually incurs a cost to the food waste producer. However, food surpluses sold for animal feed usually achieve an income. This is an added benefit of sending food waste to animal feed, when allowed.

The issues with animal feeding relate primarily to animal health concerns, moisture content, and nutrient variability. Food waste is relatively inconsistent in quality, is usually high in moisture content, and only available locally. Some food scraps, such as coffee or foods with high salt content, can be harmful to animals, and regulations pertaining to the types of food waste that can be used vary from place to place [33].

Below are some examples to show how the use of food waste in animal feed is variable between different locations.

[32] *Michael L. Westendorf, Iowa State University Press (2000) Food Waste to Animal Feed* **http://onlinelibrary.wiley.com/doi/10.1002/9780470290217.fmatter/pdf**

[33] *U.S. EPA (2014) Food Waste Management Scoping Study* **https://www.epa.gov/sites/production/files/2016-01/documents/msw_task11-2_foodwastemanagementscopingstudy_508_fnl_2.pdf**

UK

In the UK there are around 2.2 Mt of food or food by-products from food manufacturing used as animal feed [34] and there is regulation and standards in place to ensure food safety and animal health is protected.

Vietnam

The most popular method of reusing food waste in Vietnam is feeding it to livestock, particularly to pigs in smallholder farms in peri-urban areas. Household kitchens, restaurant kitchens, markets, hotels, food shops, and food processing plants produce a huge amount of avoidable uneaten food that contains cellulose, hemicellulose, lignin, protein compounds and nutrients that are beneficial to pigs. Pigs can therefore play an important role in food waste management, as they can eat and digest different food types and are considered food waste collectors [35].

Egypt

The same is true in Egypt where the *Zabaleen* community collects food waste from households to feed pigs. The Zabaleen are Coptic Christians and therefore eat pork, but this is at times a conflictual issue in a mainly Muslim nation [36]. This highlights that culture and religious beliefs and practices should be taken into account when considering food waste use in animal feed. The reluctance of farmers to feed these food wastes directly to their pigs for fear of transmission of disease can be overcome by cooking the food waste before feeding it to the animals, producing what is colloquially known as "swill" (cooked food waste fed to pigs) [37]. The application of heating and fermentation technologies rids the food waste of disease.

Treating and recycling food waste as animal feed can deliver a triple benefit of increasing pig farmers' incomes, managing food waste, and also reducing disease and environmental pollution [38].

Swill was banned in the EU in 2002 after the UK foot-and-mouth disease epidemic (which is thought to have been started by the illegal feeding of uncooked food waste to pigs), but it is actively promoted in nations such as Japan, South Korea, Taiwan, and Thailand. As mentioned, heat treatment deactivates viruses such as foot-and-mouth and classical swine fever, and renders food waste safe for animal feed.

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[34] *Parry, A., P. Bleazard and K. Okawa (2015), "Preventing Food Waste: Case Studies of Japan and the United Kingdom", OECD Food, Agriculture and Fisheries Papers, No. 76, OECD Publishing, Paris* ***http://www.oecd-ilibrary.org/docserver/download/5js4w29cf0f7-en.pdf?expires=1513935777&id=id&accname=guest&checksum=A97DF7C1E1C177225645278365FD8DE7-***

[35] *CIRAD, INRA (2015). Food Waste recycling into animal feeding in Vietnam.* ***https://umr-selmet.cirad.fr/content/download/4053/29641/version/2/file/NIAS_REPORT_FW2FEED_VN.pdf***

[36] *Layla Eplett (2013) Second Helpings: Recycling Cairo's Food Waste* ***https://blogs.scientificamerican.com/guest-blog/second-helpings-recycling-cairos-food-waste/***

[37] *Erasmus zu Ermgassen (2015). Regulate, rather than prohibit, the use of food waste as feed: learning from East Asian experiences.* ***https://www.feedipedia.org/sites/default/files/public/BH_024_food_waste.pdf***

[38] *CIRAD, INRA (2015). Food Waste recycling into animal feeding in Vietnam.* ***https://umr-selmet.cirad.fr/content/download/4053/29641/version/2/file/NIAS_REPORT_FW2FEED_VN.pdf***

Japan and South Korea

As of 2015, Japan and South Korea respectively recycled 35.9% and 42.5% of their food waste as animal feed. In these countries, the industry is tightly regulated: the heat treatment of food waste is carried out by registered "Ecofeed" manufacturers, who are required by food safety law to heat treat food waste containing meats for a minimum of 30 minutes at 70°C or 3 minutes at 80°C. In Japan and South Korea, swill is seen as a strategic resource: it is a cheap, domestic alternative to the more expensive, volatile international market for grain- and soybean-based feeds [39].

While food waste as animal feed has been historically used for pigs, it can, of course, be fed to other species. A number of studies have trialled food waste diets for poultry, fish, insects, and ruminants (cattle, goat and sheep)[40].

2.10. Conclusion

Governments, businesses and people have a gamut of awareness, reporting and regulatory options to encourage food waste prevention and avoid its harmful effects on the environment, economy and people. The chapter has listed a few select measures that can be implemented to avoid food waste.

Each country and city with its unique population, geography, economics and culture; each business with its unique feedstock, scale, logistics and financial model; and each person/family with their unique circumstances and preference; need to take action to make food waste prevention an integral part of their regulations, strategies, operations and lives.

While all efforts are being made to reduce food waste, the unavoidable fraction of food waste as well as the inedible fractions need to be collected and treated in order to contain their impact on the environment and people. These aspects will be discussed in the following chapters.

[39] *Erasmus zu Ermgassen (2015). Regulate, rather than prohibit, the use of food waste as feed: learning from East Asian experiences.* ***https://www.feedipedia.org/sites/default/files/public/BH_024_food_waste.pdf***

[40] *Erasmus zu Ermgassen (2015). Regulate, rather than prohibit, the use of food waste as feed: learning from East Asian experiences.* ***https://www.feedipedia.org/sites/default/files/public/BH_024_food_waste.pdf***

3. FOOD WASTE COLLECTION

3.1 Introduction

This chapter explores the methods used to bring food waste from households and businesses into treatment plants. We provide a series of examples of collection systems adopted in cities around the world and attempt to show how these have succeeded and where they have encountered difficulties. We also look at the policies that have enabled the implementation of collection systems and the barriers they overcame, including the experience of their citizens.

Separate collection of organic waste is important for the recovery of nutrients and energy. There are, however, differences in the collection schemes of cities: while some cities have separate collection of food waste, others collect a wider range of organic material, such as garden waste, together with food waste. While some cities collect food waste from businesses only, others collect from households as well. While some cities have made food waste collections mandatory, others have used differential waste management taxes to aid the collection. This is also reflected in the treatment of this material: while some cities treat the collected food waste via wet or dry anaerobic digestion, others compost it. While some cities use the biogas from collected food waste to produce electricity, others convert the biogas to biomethane to be used in waste collection and other vehicles. There are therefore a series of different models that can be studied with reference to the specific circumstances of a city wanting to implement food waste collections.

The collection systems, the frequency, the treatment process, the policies to support them, as well as the use of energy are all based on operational local conditions such as existing infrastructure, climate, demographics, population density, and type of housing, as well as the political landscape, existing regulatory processes, the consensus of the local population, the national commitments, and the available funding.

Following are some examples from cities that have implemented food waste collections.

3.2 Auckland, New Zealand [1]

The city of Auckland is highly urbanised, with food waste accounting for 40% of the waste stream. In 2012, Auckland Council established two goals:

- **Reducing kerbside non-recyclable waste collection by 30% by 2018 from 2012 baseline; and**
- **To achieve zero waste by 2040 by turning its waste into resources.**

In order to achieve these targets, separate kerbside collection of food waste was identified as a key step.

A pilot was rolled out to 2,000 households to get a good estimate of participation rates, volume of collection, contamination levels, resident behaviour, customer satisfaction, barriers, and benefits, and to identify best practices.

Before rolling out the trial, a postcard was sent out informing residents. This was followed by door-to-door visits by waste advisors.

The trial ran for four months in which a 23 litre (L) kerbside bin and a 6L caddy for kitchen, and compostable bags were delivered to the residents along with how-to information booklets, collections calendar and date of first collection.

Example Images: photographs of bins and educational information provided to residents (left) and door-to-door visits (Photographs courtesy of Auckland Council)

Example images: leaflet explaining what can and cannot be placed in the organics bin

[1] The case study is based on information provided by Auckland Council to C40 Cities.

Once the collections began, waste advisors undertook follow-up visits to resolve any issues such as undelivered bins and rubbish taken out on the wrong day. In addition, they conducted audits of the waste and left feedback tags on the bins explaining whether separation had been done correctly or if contamination had been found in the separated food waste (shown in the images below).

Example images: example feedback tags for bins

Periodic quantitative and qualitative surveys were also conducted during the trial period and it was found that residents were receptive to separate food waste collection with an approval rating of 93%.

Further trials in different areas and types of housing have been planned, leading to full service roll out to 490,000 citizens by 2021.

Feedstock collected

Only food waste is collected. The food waste collection volume is expected to go up to 50,000 tonnes per annum from 2,500 tonnes per annum in 2018.

Collection process

Food waste is collected on a weekly basis using dedicated vehicles for separate collections. These are side loading, semi-automatic vehicles that involve no interactions with the rear of the truck, a danger spot for the collectors.

Treatment process

The chosen method of treatment by Auckland Council is composting. It is currently a combination of aerated static pile and Gore-Tex cover system. A new in-vessel composting technology is expected to be in place by 2021.

Available financial information

The Council is in a procurement process but has estimated the cost per household receiving the service at approximately $67NZD per year by 2021.

Barriers

The main barrier for implementation of separate food waste collection is that Auckland has very low landfill disposal costs (including the waste levy and Emissions Trading Scheme), which are significantly less than food waste processing.

Conclusion

The separate food waste collection programme is a great example of gradually growing the collection infrastructure. The one-to-one interaction of waste advisors with the residents make the collections easy for them, while the residents indirectly gain from participating in a public good service like recycling or collection food waste.

3.3 Cajica, Colombia [2,3]

In Cajica, Colombia, Empresa de Servicios Públicos de Cajicá (EPC) and IBICOL have been running a door-to-door source-segregated organic waste collections programme since 2008. The collection programme now serves 25,000 houses and 88,000 inhabitants. This is one of the very few examples of food waste collection in Latin America that have endured over a long time period.

Feedstock collected

About 480 tonnes of organic matter is collected from homes and schools per month.

Collection process

Residents collect organic waste in a plastic bucket with holes at the bottom to drain liquid produced by accumulated waste. The collected liquid can be drained in the household drain. The bucket is pre-applied with Bokashi EM (Effective Microorganisms)[4], a rice/wheat bran based material which has been fermented with a mix of microbial cultures and then dried. Bokashi EM aids in the composting of the organic matter and reducing odours and is supplied to the residents free of charge. The waste is collected once a week and transported to a composting site.



Example images: photographs illustrating the collection process in Cajica (Courtesy of Cajica municipality)

Treatment process

The composting process takes place at an IBICOL facility. EM compost is made from the kitchen waste by crushing and spraying with Activated EM (AEM). The mixture is set in piles and kept for further fermentation. These piles are turned over according to the temperature (must be more than 60°C and less than 70°C) and after approximately 50 days, the compost is ready to use for growing vegetables. AEM must be applied every time the pile is turned over.

Citizen engagement

The successful implementation of segregated collection and composting can be attributed to the upfront emphasis placed on the education of students and the residents by the local officials. The students, as well as local officials, were involved in training residents on correct segregation, the composting process and the environmental pollution the system was addressing. The following measures were taken during the implementation process:

- **Involvement of educational sector as well as community;**
- **Call for active participation of residents;**
- **Setting up of infrastructure; and**
- **Application of biotechnology (EM technology).**

Some initial resistance was faced from the residents which was overcome by education and involvement.

Conclusion

Cajica is an example of a town in an economically developing country which has successfully implemented source segregated food waste collections for nearly 10 years now. The infrastructure and investment required is minimal. The education and involvement of residents has been identified as a key element. The project has been reported to have been carried out in 24 cities in Colombia. It has reduced illegal dumping, raised public awareness about recycling and encouraged home growing of food.

[2] Case study based on information provided by Mr Josue Frias Cruz, fomer Manager of the "Empresa de Servicios Publicos"/ ESP and Ibicol, and responsible of the development and implementation of the program.

[3] EMRO EM for Sustainable Society, Cajica City, Columbia ***https://emrojapan.com/case/detail/17 (No date, accessed on 20/02/2018)***

[4] EM was developed by Professor Teruo Higa.

3.4 Copenhagen, Denmark [5]

At the time of writing, Copenhagen is in the process of finalising the implementation of separate food waste collection. The city started implementing the collection of food waste from all households in September 2017 and will be fully implemented in spring 2018. It is a mandatory scheme, but villas (single family houses) have the opportunity to cancel their participation. Around 300,000 households are included in the scheme (280,000 in multi-family houses and 20,000 villas). This covers the population of around 600,000 inhabitants.

Private waste collection companies are hired by the municipality through a tender process for the different districts of the city. These companies collect waste from households and businesses. If businesses produce waste in amounts similar to the generation from a household then their waste can be included in municipal collection.

Feedstock collected

The volumes are expected to increase each month since the sorting and collection only started from September 2017. 10,000 tonnes are expected to be collected in 2018 when the collection is fully implemented.

Collected waste includes food waste, raw and cooked, rice, pasta and breakfast products, meat, fish, bones, bread and cakes, fruit and vegetables, gravy and fat, cold cuts, eggs and eggshells, nuts and nutshells, coffee grounds and coffee filters, tea leaves and tea filters, used paper towels, and cut flowers.

Collection process

Private collection companies hired by the municipality through a tender call collect the waste from multi-family houses as well as from villas. The biowaste is collected once per week from multi-family houses. From villas it is collected every second week, but during summer it is collected once per week to avoid smell and insects. Villas can share one bin for biowaste between two households.

BAGS OF BIOPLASTICS

KITCHEN BIN (15L)

Example Images: bags and kitchen bins for collection of biowaste in the City of Copenhagen

[5] The case study is based on information provided by Dr Line Kai-Sørensen Brogaard, City of Copenhagen

Treatment Process

The biowaste is treated via anaerobic digestion (AD). Larger items, misplaced waste and bags are separated from the waste during pre-treatment. The biowaste is pre-treated to create a bio pulp that can be pumped into a biogas reactor tank. The AD plant treats organic waste from several cities as well as industrial waste from food producing industries. The AD plant also receives waste from the fishing industry, slaughterhouses, breweries as well as manure from mink, cow and chicken farms. The biogas produced, 7,500,000 m^3 per year, is used for production of electricity sent to the grid and district heating for the local villageof 450 houses. In the future, when a new AD plant is built closer to Copenhagen, the gas will be used for heavy duty goods vehicles. Digestate is used by local farmers as fertiliser for the fields.

Example Images: AD plant provided by City of Copenhagen

Available financial information

Local farmers own the AD plant and therefore they financed the plant when it was built. The collection and treatment of biowaste is funded via the taxes paid for waste management. There were increased costs due to the investment in food waste collection bins and a revised collection programme. Copenhagen believed that their waste management tax would decrease over the coming years, but it has decreased by less than was foreseen. However, inhabitants will still benefit from a decrease in the waste tax in coming years. The cost of the collection and treatment of biowaste is lower than the cost of incineration.

Policies

The initiative to collect and recycle organic waste is part of the 'Resource and Waste Management Plan 2018' for the City of Copenhagen [6]. The recycling target of the City of Copenhagen is 45% by 2018 and introducing source separation of organic waste is an important step to meeting this target. It is not allowed to send biowaste to landfill since this was banned in 1997.

Barriers

The only barriers that have been experienced are operational, such as lack of space in back yards and kitchens in apartments for separate containers for biowaste (a 15L bin).

Citizen engagement

Most inhabitants reacted positively about sorting biowaste, but a few concerns were raised such as:

- **People were concerned about the distance of transportation of the waste. It was calculated and communicated that the CO_2 emission from the transportation equates to only 7% of the total CO_2 benefit from the production and use of the biogas.**
- **People were concerned about which is better; incineration or AD. Regarding CO_2 and the effect on climate change, the impact and savings of CO_2 is similar. However, nutrients can be recycled when sending the biowaste to AD, which is not possible if the waste is incinerated.**

Conclusion

Copenhagen is an example of a recently implemented food waste collection project. It has begun by integrating its food waste treatment into a treatment plant that already existed and was digesting manure and food waste from other cities and industries. The city plans to build a new AD facility that is closer, and utilise biogas as biomethane for heavy duty transportation.

[6] *Resource and Waste Management Plan 2018* ***http://kk.sites.itera.dk/apps/kk_pub2/index.asp?mode=detalje&id=1184***

3.5 Hartberg, Austria [7]

Hartberg is a countryside town in Austria. Food waste from Styria and Burgenland is collected. Catering and other businesses are served by a private waste management company, *Saubermacher*, as well as other waste collectors who deliver it to the biogas plant which is about 2km away from Hartberg's town centre.

Feedstock collected

On an annual basis, about 5,450 tonnes of food waste are collected from catering services, 530 tonnes from beverage production industry, as well variable waste from fruit and vegetable waste, waste from butchery and slaughterhouses, dairy farms, milk, grease removal separators, and grass and green waste.

Collection process

Food waste is collected in 120L brown bins which can be sealed and have a shutter on top of the lid. Weight of the collected food waste bin varies between 80 and 100kg. About 50,000 bins are collected annually and transported for treatment in trucks with a carrying capacity of 40 bins. The frequency of collections varies from once every two weeks for small generators to twice a week for large generators. The generators of food waste pay per collected bin. The bins are collected and transported to the biogas plant where they are emptied and washed with hot water from the inside and outside and then returned back to customers, usually once a week. It should be noted that a bin is not specific to a customer and may be returned to other customers when collecting full bins.

HARTBERG IS COLLECTING APPROXIMATELY 5,450 TONNES OF FOOD WASTE FROM CATERING SERVICES AND 530 TONNES FROM BEVERAGE PRODUCTION INDUSTRY PER YEAR

Treatment process

The collected food waste is treated via AD. The food waste is emptied from the bins into a storage tank from where it is transported to a metal separator and then shredded into particles of less than 1cm. Other impurities are then removed and the food waste is pasteurised according to Austrian regulations. The hot water from washing the bins is added during the digestion process. The food waste is then digested and the biogas is used for heat and electricity generation via a CHP unit. The digestate is used by farmers as soil amendment for their crops.

[7] *Case study based on information provided in Bin2Grid (2016) Good Practice on segregated collection of food waste* ***http://www.bin2grid.eu/documents/73603/136534/D2.1_Good+practice+on+segragated+collection+of+food+waste.pdf/***

Available financial information

The cost of bins is about €30 and they are designed for a lifetime of 10 years. The gate fee for treating waste being charged by the biogas plant is about €10 per tonne for beverage waste and €25-€60 per tonne for food waste. The cost of collection comes to €150-250 per tonne. The fee charged to customers and revenue generated from the sale or use of energy is not known. The biogas plant employs three people for discharging bins, logistics, maintenance and administration. In addition, farmers are paid €14 per tonne for accepting digestate to be applied to farmland.

An initial investment of about €2 million was made in the building of the biogas plant, with a few additional investments during subsequent upgrades. The annual operation and maintenance cost is about 2% of the investment cost.

Conclusion

The town of Hartberg is a fantastic example of the collection and digestion of food waste from commercial enterprises and industries on a small scale. It is different from most other kerbside collections which collect the waste in garbage trucks and leave the bin behind, as it is the property of the household or business. The collection of the bin, washing, delivery and circulation between customers is a unique process of implementation of food waste collection. The simplicity of implementation of this type of food waste collection and treatment enables quick deployment and reduced investment in infrastructure.

3.6 Milan, Italy [8,9,10]

The city of Milan was one of the pioneers in separate food waste collection from households. The city extended separate collection of residential food waste in 2012, which was previously available only to businesses and organisations such as restaurants, hotels, schools and supermarkets. After an initial period of 1.5 years, the service was extended to all households in the city. The collections are made by a Public Company – AMSA (A2A Group).

Feedstock collected

Food waste from 100% of households and commercial activities is collected, which equates to around 1.4 million residents. About 140,000 tonnes of food waste is collected annually from residents, businesses, industries and markets.

Collection process

Food waste is collected separately from green waste. Collection is at the kerbside for all waste (i.e. household and commercial). Households are equipped with a 10L vented kitchen-caddy plus a starter kit of compostable bioplastic liners. Multiple-occupancy buildings (i.e. high-rise) are equipped with one or more 240L wheely-bins depending on the number of households per building. Food waste is collected twice a week. Residual waste is collected twice a week in transparent bags. The waste is collected by AMSA with methane or biodiesel powered trucks.

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[8] *The case study is based on information provided by the Italian Composting and Biogas Association*

[9] *Bin2Grid (2016) Good Practice on segregated collection of food waste* **http://www.bin2grid.eu/documents/73603/136534/D2.1_Good+practice+on+segragated+collection+of+food+waste.pdf/**

[10] *Milano Recycle City (2015) Food waste recycling: the case study of Milan* **https://issuu.com/giorgioghiringhelli/docs/food_waste_recycling_the_case_study**

Commercial premises are equipped with 120/240L wheely-bins and collection frequencies rise from two per week up to six per week. Market booths producing biowaste are equipped with watertight, biodegradable plastic bags and a bag-holder; the biowaste is collected daily, at the end of the market. Figure 5 below shows the growth in the recycling rate of biowaste from 5.3% in 2011 to 18.1% 2014 [11].

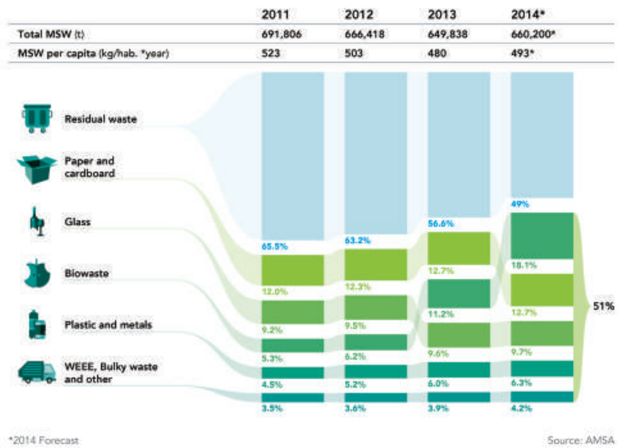

Figure 5: recycling rates of different waste fractions

Treatment process

Food waste is discharged in a transfer station and transported to an integrated AD and composting facility by large-capacity trucks of 30 tonnes. The facility is located in Montello near Bergamo and was built in 1997. The residual, non-recyclable waste is sent to incineration with energy recovery.

Every year, the plant processes under thermophilic conditions 285,000 tonnes of biowaste into biogas for the generation of electricity, for which the installed capacity of the plant is about 9 MW_{el}, and another 300,000 tonnes a year of biogas which is converted into biomethane that is fed into the national gas grid. During the pre-treatment process, bags are shredded, metallic contaminants are removed and recycled, while plastic contaminants are sent for energy recovery.

Available financial information

The project was financed by Municipality of Milan which spent about €4.5 million for the purchase of 45 vehicles and other equipment required for the collection process. Citizens were provided with delivery bins and baskets, 25 free certified compostable bin liners and instruction leaflet on how to recycle.

The payback was planned via a waste management fee, which comprises of a fixed component (~70%) based on the size of housing and a variable part (~30%) based on the number of inhabitants. Based on the size and location, the price of collection can vary between €150-300 per tonne of collected waste. The gate fee charged by the biogas plant varies between €50 and €80 per tonne of waste depending on the biogas potential of the waste. The produced compost/digestate is sold to farmers at €20-50 per tonne depending on its quality.

[11] *Milano Recycle City (2015) Food waste recycling: the case study of Milan* **https://issuu.com/giorgioghiringhelli/docs/food_waste_recycling_the_case_study**

It is worth noting that due to a considerable reduction in waste sent to incineration, at a higher price than the food waste being sent to AD, AMSA was able to reduce its disposal costs and this helped to cover much of the extra cost of the investment in new collection infrastructure.

Policies

The collection of food waste is driven by EU Waste Framework Directive and the EU Landfill Directive which have been transposed into legislative decrees targeting 65% municipal waste recycling by 2012 and landfilling of biowaste below 81kg per inhabitant per year by 27 March 2018.

In addition, several decrees over the last decade have set incentives for electricity produced from renewable sources and in December 2013 the first decree providing incentives for biomethane production came into effect to provide financial incentives for generation and utilisation of biogas. Separate food waste collection is mandatory in the City of Milan. To maximise the efficiency of separate food waste collection, a mechanism of fines has been implemented to help reduce contamination and maximize recycling. A dedicated crew of inspectors perform visual check on sample buildings an hour before collection, penalising households that put impurities into food waste collections, such as plastics. In areas with lower quality than average, additional awareness activities are implemented.

Barriers

One of the major challenges faced during the implementation of separate household food waste collection in Milan was the preparation, coordination and delivery of vented kitchen bins, compostable bags, and information, as well as wheely bins to over half a million households in a highly densely built city. This challenge was overcome by mapping the housing and planning procurement, delivery and contingency.

Citizen engagement

One of the mainstays of the separate food waste collection in Milan was the extensive communication with the residents, which started with raising awareness of property managers of multi-family buildings. It was followed up with a letter to inhabitants sharing details about the service. In addition, calendars, leaflets in multiple languages, a smartphone app, newspaper, radio and television advertisements and a toll-free phone line were used for engagement.

Face-to-face education and awareness raising was undertaken during the delivery of the free delivery of vented kitchen bins, compostable liners and communication materials. In addition, numerous compost giveaway events have been held to demonstrate the circular nature of food waste collection and recycling.

Whilst citizens undertaking food waste collection in Milan have adopted the system quickly and with overwhelming approval, some have voiced concerns around the development of the biogas installation at Montello. These are often politically motivated groups but also genuinely concerned citizens worried about emissions and increased frequency of traffic to the plant. The biogas plant works continuously with local citizen groups and organizes frequent visits to the plant to raise transparency and show the operation of the plant.

Conclusion

The case study of the city of Milan shows that it is possible to implement separate food waste collection and digestion in a large, densely populated city. The proportion of non-compostable waste contaminating the food waste is consistently under 5%, with a positive reduction trend. One of the primary reasons for its success has been the engagement of the community and its education.

3.7 Minneapolis, USA [12]

The City of Minneapolis initiated an organics collection pilot in 2008, then expanded coverage in 2009 and 2010. These initial pilots were critical to determining the level of participation in a free opt-in programme (e.g. sign up), assessing the effectiveness of the city's outreach methods (e.g. mailings, neighbourhood events), and developing efficient collection routes based on the number of stops and weight of the organics [13].

In 2012, the city requisitioned a study to evaluate options for moving the organics programme forward. In 2014 followed the establishment of several organics collection drop-off sites around the city to engage early adopters and educate the broader public. The low-cost drop-off sites comprised 96 gallon rolling carts in parking lots with combination locks; residents that signed up to use the carts received the lock code via e-mail [14]. That same year, the Hennepin County Board approved a measure for Minneapolis to begin collecting food scraps city-wide in 2015.

More than 45,000 households—equating to 43 percent of the eligible single-family households and small apartment buildings—have enrolled in the organics programme since its city-wide expansion [15].

Feedstock collected

Food scraps, food soiled and non-recyclable paper products, and certified compostable plastics are accepted. Other acceptable waste includes coffee grounds, filter and tea bags, tissues, cotton swabs and balls, wood chopsticks, popsicle sticks and tooth picks, floral trimmings and house plants, animal and human hair and nail clippings, small amounts of grease and oil. Yard waste is collected separately and is not accepted along with food waste [16].

Treatment process

The collected food waste is sent to a commercial composting facility where it is mixed with garden waste and composted for six to nine months and then applied in gardens, landscaping projects or erosion control projects [17].

Available financial information

Organics collection is free for residents that receive Minneapolis Solid Waste & Recycling services.

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[12] *This case study was authored by Brooke Robel, Brian Guzzone and John Carter at ERG (Eastern Research Group, Inc)*

[13] *Kish K (2017) Recycling coordinator of City of Minneapolis, Minnesota*

[14] *ibid*

[15] *Roper, E. (2017) Minneapolis curbside composting yields high interest, less organic waste than expected. Star Tribune. 14 July 2017.* ***www.startribune.com/minneapolis-curbside-composting-yields-high-interest-less-organic-waste-than-expected/434569713/***

[16] *Minneapolismn (2017) Organics* **http://www.ci.minneapolis.mn.us/solid-waste/organics/acceptable-organics Accessed on 09/02/2018**

[17] *Minneapolismn (2018) Residential organics recycling* **http://www.ci.minneapolis.mn.us/solid-waste/organics/organics-faq Accessed on 09/02/2018**

Policies

In 2015, the City Council approved goals calling for recycling and/or composting for 50% of city-wide commercial and residential waste by 2020, then increasing to 80% by 2030 [18].

Citizen engagement

Minneapolis has utilised many of the traditional outreach mechanisms (e.g. welcome kits, direct mail, websites, and social media) since the city-wide programme began in 2015, but more recent 2016-2017 efforts by interns going door-to-door and talking directly with residents yielded a 36% sign-up rate among residents reached via door-knocking [19].

> ### Conclusion
>
> The City of Minneapolis is a great example of gradual introduction of source segregated food waste collection. It started the process with a pilot programme which informed key decisions for the full scale implementation. The full scale implementation was started as drop offs to engage with public and then gradually as the public awareness increased, moved to kerbside collections. This gives ample time for raising public awareness and making investment required in infrastructure. Minneapolis does not recover energy from its food waste but is able to accept a wider range of organics in addition to food waste such as food soiled, non-recyclable paper, wooden 'popsicle' sticks and cotton balls by choosing composting as the treatment technology.

3.8 New York City, USA [20]

New York City (NYC) has been targeting organics since the late 1980s with its first law requiring the Department of Sanitation of New York (DSNY) to collect and compost leaves and seasonal yard waste. In 2006, DSNY released its 'Comprehensive Solid Waste Management Plan' that emphasised the need to address the organic portion of the city's waste stream and also created a Compost Facility Siting Task Force [21].

Subsequent laws sought to strengthen seasonal yard waste collection efforts and requisitioned a food waste composting study. In accordance with a 2013 NYC law to establish voluntary organics collection, DSNY initiated its organics pilot programme to collect yard waste and food scraps, then spent several years — from 2014 to 2016 — expanding the programme district-by district. By late 2017, 30 of 59 districts had this service. Households with one to nine units were auto-enrolled in the programme and larger multiple unit buildings completed online applications.

Feedstock collected

New York City collects food scraps such as fruit, vegetable, meat, bones, dairy and prepared food waste as well as food soiled paper such as napkins, tea bags, plates and coffee filters and leaf and yard waste such as plants, trimmings, twigs and grass [22].

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[18] *Minneapolismn (2015) City sets recycling goals. City of Minneapolis, MN. Published 19 June 2015.* **http://www.ci.minneapolis.mn.us/news/WCMS1P-143012**

[19] *Kish K (2017) Recycling coordinator of City of Minneapolis, Minnesota [20] This case study was authored by Brooke Robel, Brian Guzzone and John Carter at ERG (Eastern Research Group, Inc)*

[20] *This case study was authored by Brooke Robel, Brian Guzzone and John Carter at ERG (Eastern Research Group, Inc)*

[21] *Anderson, B. (2017) From Curb to Compost: How the City of New York is Building an Organics Collection Program to Serve 8.5 Million People. Waste 360 Webinar presentation. 16 November 2017.*

[22] *Department of Sanitation (2017) Organics curbside collection* **http://dsny.wpengine.com/wp-content/uploads/2018/01/organics-collection-brochure-OCB2017.pdf**

Collection process

More than 750,000 households (representing approximately 3.3 million residents) are currently served by the organics collection programme, as well as about 750 schools and more than 100 institutions [23]. There are also more than 100 food scrap drop-off sites throughout the city. NYC ultimately strives for city-wide access by the end of 2018, and earmarked nearly US$30 million to distribute bins, educate residents, and collect/transport materials for *composting* [24] . Some of the variables to consider when providing organics collection in the largest U.S. city include: housing and population density (single-family households and multi-family high-rise buildings) diversion/capture rates, day-to-day operations (e.g., single- or dual-hopper rear-loading trucks, route length/distance, labour), and proximity to processing facilities [25].

When it comes to collection frequency, NYC has three modes:

- **Once a week on residents' "recycling day" with a single-hopper truck;**
- **Twice a week on residents' "trash day" using a dual-hopper truck; and**
- **Three times a week for high-rise buildings using a single-hopper truck.**

Treatment process

The collected waste is largely composted. The city also runs the NYC Compost Project via which it teaches composting to its citizens and gives away compost for community gardens, parks, street trees, and similar uses.

Policies

Under the NYC commercial organics rules, segregation of food waste is mandatory for businesses that meet the below criteria:

- **Food service establishments with a floor area of at least 15,000 square feet;**
- **Food service establishments that are part of a chain of 100 or more locations in the city of New York; and**
- **Retail food stores with a floor area of at least 25,000 square feet.**

Larger food waste generators are targeted under regulations and the burden of proving compliance is placed on them while giving them a choice of hiring a private carter for transportation, haul their own waste or process it onsite.

In addition to the environmental benefits of diverting organic materials from landfills, implementing a cart-based food waste collection system is also expected to reduce the city's rodent problem since most trash was previously placed at the curb in bags [26]. With aggressive initiatives like the city-wide organics programme in 2018 and enhanced single-stream recycling in 2020, NYC strives to achieve a goal of zero waste to landfills by 2030.

Conclusion

NYC is a great example for a step-by-step and variable implementation of organics collection for highly densely populated city with separate systems in place for households, schools and commercial establishments.

[23] *Anderson, B. (2017)From Curb to Compost: How the City of New York is Building an Organics Collection Program to Serve 8.5 Million People. Waste 360 Webinar presentation. 16 November 2017.*

[24] *Rueb, E. (2017) How New York Is Turning Food Waste Into Compost and Gas. The New York Times. 2 June 2017.* **www.nytimes.com/2017/06/02/nyregion/compost-organic-recycling-new-york-city.html**

[25] *Anderson, B. (2017) From Curb to Compost: How the City of New York is Building an Organics Collection Program to Serve 8.5 Million People. Waste 360 Webinar presentation. 16 November 2017.*

[26] *Yepsen, R. (2015) BioCycle nationwide survey: Residential food waste collection in the US. BioCycle, 56(1): 53. 15 January 2015.* ***www.biocycle.net/2015/01/15/residential-food-waste-collection-in-the-u-s-2/***

3.9 Oslo, Norway [27,28,29,30,31]

In 2006, the City Council in Oslo decided to establish source segregated collection of food and plastic waste from residual waste of households. It was agreed that this should be sorted into different coloured plastic bags to be sorted at central sorting plants based on the colour.

After some years of planning and building, the first sorting plant was opened in October 2009. After that, several treatment plants were changed and build, and in summer 2013 the biological treatment plant at Romerike went into operation. Since then, this plant has delivered both compressed and liquefied biogas, delivered mainly to buses and waste trucks in Oslo.

Feedstock collected

Food waste is collected from 660,000 inhabitants of Oslo [32] with collection rate of about 25kg food waste per person. It is collected on a weekly basis from the residents, along with other waste. Small amounts of soiled kitchen paper may be added provided they don't contain any soap.

Collection process

The City of Oslo has implemented a collection process which is a combination of door side collection by the city and delivery of waste to kerbside collection points or recycling stations by residents.

The collection system is based on colour coded plastic bags. The residents dispose food waste in a green bag and clear plastic packaging in a blue bag. These green and blue bags are available for free in supermarkets. Residual waste is collected in normal shopping bags and paper and cardboard in a separate container.

All bags are discarded into the same waste container from which the city collects them. The coloured bags are sent to optical sorting plants from where food waste to an anaerobic digester, plastic is sent for recycling and the residual waste to incinerators with energy recovery.

Garden waste, clothes, electronic waste, hazardous waste are taken to collection points or recycling stations by residents.

Images: photograph showing colour-coded bags at the sorting centre (City of Oslo)

[27] *This case study is based primarily based on information provided by Johnny Stuen, Waste-to-Energy Agency, City of Oslo*

[28] *City of Oslo factsheet: Biological treatment of food waste* ***https://www.oslo.kommune.no/getfile.php/134907/Innhold/Avfall%20og%20gjenvinning/Behandlingsanlegg%20for%20avfall/Fact_sheet-Biological_treatment_of_food_waste.pdf***

[29] *City of Oslo factsheet: Biogas and Biofertilizer* ***https://www.oslo.kommune.no/getfile.php/134904/Innhold/Avfall%20og%20gjenvinning/Behandlingsanlegg%20for%20avfall/Fact_sheet-Biogas_and_biofertilizer.pdf***

[30] *Oslo Council, The Source Sorting System in Oslo* ***https://www.oslo.kommune.no/avfall-og-gjenvinning/kildesorteringssystemet-i-oslo/***

[31] *City of Oslo (2017) European Green Capital Award 2019 Application City of Oslo (2017) European Green Capital Award 2019 Application* ***http://ec.europa.eu/environment/europeangreencapital/wp-content/uploads/2017/06/Indicator_7_Waste_Production_and_Management.pdf***

[32] *Jentoft H (2017) Circular bioresources: treatment of food waste, garden waste and sludge from wastewater, Oslo, Norway* ***http://www.eurocities2017.eu/files/uploads/files/Oslo_Circular%20economy%20case%20study.pdf***

Treatment process

The food waste from the sorting centres is sent to the Romerike biogas plant. Here the bags are opened, contaminants like metal, plastic, packaging and other large unwanted materials are removed, and the waste ground to a smaller size. The waste undergoes thermal hydrolysis followed by flashing to kill pathogens, fungi and plant and make the digestion easier and faster.

The waste then undergoes AD under mesophilic conditions (38°C), producing biogas and digestate. The biogas is upgraded to compressed biogas (CBG) and then liquid biogas (LBG). The digestate is treated to produce two different products: a firm digestate with high total solids content of 25%, and a liquid bio concentrate with total solids approx. 15%.

In 2013, the Romerike plant produced 1.164 million Nm^3 biogas from food waste from households and businesses in Oslo and other municipalities. The biogas was sufficient to fuel 135 buses and the biofertiliser enough for 100 medium-sized farms.

Image: Biogas plant (City of Oslo)

Image: biogas-powered buses (City of Oslo)

Image: waste collection vehicles (City of Oslo)

THE CITY OF OSLO AIMS TO INCREASE FOOD WASTE RECYCLING TO

60% BY 2025

Available financial information

The waste handling is fully financed on a non-profit basis via the pay-as-you-throw system. The household charges for collection of all waste begin at Euro 443 per year for 140L bin and vary with bin size.

Citizen engagement

To engage with citizens to raise awareness about the benefits of recycling, how the source sorting system works and the importance of their actions, the City of Oslo undertook communication campaigns and distribution of brochures, advertising campaigns in the media and public spaces, door-to-door campaigns and engaged celebrities to promote source separation of waste.

Policies

Since 1984, the management of household waste is regulated under a separate city regulation which specifies the rights and duties of both the City and the citizens. This regulation gives the City the right to sanction citizens who are failing to source separate at a satisfactory rate, even after several visits and information campaigns. So far, no sanctions have been imposed.

The City of Oslo has changed its procurement policy, favouring non-fossil transportation, and developed a climate and energy strategy for the city. In this strategy, developing electric personal transportation and short distance transportation are important actions, and at the same time cooperating with private transportation companies, to develop a biogas cluster in Oslo for heavy transportation. This is still in the planning stage.

Conclusion

The source segregated waste collection system of the City of Oslo ensures that no biodegradable waste is sent to landfill, which was prohibited in 2009. About 44% of food waste was collected and recycled. The City of Oslo aims to increase this to 60% by 2025 while reducing the food waste generation by 30%.

The highlights of the source segregated collection system in Oslo is its simplicity to implement, colour coded plastic bag collection system supported by the sophisticated optical sorting plants and its focus on production of vehicle fuel for waste collection vehicles and public transport. In addition, the clearly defined targets and the annual residual waste analysis are driving action and steering the City in the direction of increased recycling.

3.10 Seoul, South Korea [33, 34]

The city of Seoul in South Korea has one of the most complex and sophisticated systems in place for the collection and disposal of food waste.

Collection process

Seoul is densely populated with multi-unit building as well as single family houses which comprise about 70% of the city. In the past, there was a flat rate fee for food waste disposal system in multi-unit buildings while a volume-based fee was charged to the single-family houses. But after running a two-year pilot programme starting 2011, the city has now moved to a 'volume-based system' which is implemented with slight variations in different districts. The system is a combination of volume-based waste bags, waste containers, weight-based Radio Frequency Identification (RFID) for households and trucks and payment certificates as shown in the figure 6 [35].

Figure 6: Volume based food waste disposal system

Treatment process

The collected food waste is compacted and then sent to treatment facilities. Food waste is converted into animal feed, composted, anaerobically digested or supplied in its original form to farmers for use on land. The liquid fraction of food waste is sent for treatment to public waste water treatment facilities as shown in Figure 7 [36].

Figure 7: Flowchart of food waste collection and disposal

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[33] *Case study is based on information provided by Dr Jae Yung Kim and Dr Ju Munsol of Seoul National University.*

[34] *Seoul Solution (2016) Minimising food waste: Zero food waste Seoul 2018* ***https://seoulsolution.kr/en/content/minimizing-food-waste-zero-food-waste-seoul-2018***

[35] *Seoul Solution (2016) Minimising food waste: Zero food waste Seoul 2018* ***https://seoulsolution.kr/en/content/minimizing-food-waste-zero-food-waste-seoul-2018***

[36] *Seoul Solution (2016) Minimising food waste: Zero food waste Seoul 2018* ***https://seoulsolution.kr/en/content/minimizing-food-waste-zero-food-waste-seoul-2018***

Policies

Korea joined the London Convention in December 1992 which committed to preventing marine pollution by dumping of wastes into the sea. The initial efforts towards food waste reduction started from there, and were further strengthened by a ban on direct landfilling of food waste in 2005. Further in 2013, food waste water was banned from being released into the sea. These policies forced a change in the disposal and treatment of food waste in South Korea.

Available financial information

The cost of disposal is shared by the municipalities and citizens via the Pay-As-You-Throw system.

Conclusion

The collection of food waste resulted in a 10-14% reduction in its generation, while also reducing marine pollution and pressure on landfills. Food waste is considered a social issue and both citizens and local governments pay for its disposal.

3.11 Conclusion

In this chapter we have given examples from nine cities and towns of different sizes, population configurations and geographical locations. There are several aspects the cases have in common:

- Collection programmes were implemented gradually, after trials, and extended across the wider population once it was shown the system functions;
- Cities utilised various treatment options including composting, AD or returning food waste to animal feed;
- Cities often use compostable bags for collection to reduce contamination of food waste, especially where composting is the chosen treatment method;
- Food waste is often collected separately from garden waste and especially so if AD is the chosen treatment option.

There are varied methods of collection and treatment of food waste available and being implemented across the globe for resource and energy recovery. Learning from these will enable other authorities to implement collection systems most suitable to their own circumstances, population and geography, as well as to model systems within budgetary limitations.

The following chapter explores the treatment options available for food waste whether collected separately or mixed in with with green or inorganic waste.

4. FOOD WASTE TREATMENT TECHNOLOGIES

Having covered the different available food waste collection systems and models in Chapter 3, this chapter presents an overview of the technologies available for the treatment of collected food waste.

The first part of the chapter gives an overview of the technologies available. Section 4.1 outlines the technologies, in alphabetical order, that treat source-separated food waste. Section 4.2 outlines the technologies that treat food waste mixed with other wastes as part of residual waste collections. For each technology the following aspects are briefly outlined: the wastes that are treated, the process, the output products, the appropriate scale for the technology, and the advantages and disadvantages. Policy-makers need to understand the various treatment technologies in order to make informed choices.

It will be clear that those technologies treating separated food waste provide a number of benefits that those treating mixed wastes cannot, including maximising energy recovery, fertiliser production and improved soil health, resulting in economic and environmental benefits.

Section 4.3 provides a summary table which shows how the food waste treatment technologies compare to one another with respect to several parameters.

4.1 Technologies that treat separately-collected food waste

This section sets out a range of technologies that can treat separate food waste. It describes the source of wastes used, the process and the products.

A) Anaerobic Digestion

Anaerobic digestion (AD) will be discussed in detail in Chapters 5 and 6. As those chapters will describe, AD provides a number of benefits over many other treatment technologies.

These benefits include:

- By separately collecting food waste, raising awareness of the cost and quantity of food waste and therefore reducing the quantity of food waste produced;
- Reducing the health impacts of poor waste management;
- Recovering energy - AD recovers 60% more energy than direct combustion[1];
- Producing a nutrient-rich fertiliser;
- Helping replenish soils through the addition of organic matter – the Food and Agriculture Organisation of the United Nations has calculated that, due to soil degradation, the world's soils can only support 60 more harvests [2];
- Creating local jobs through the effective use of local resources;
- Reducing greenhouse gas emissions by up to 2 tonnes of carbon dioxide equivalent per tonne of food waste treated for electricity production with no heat recovery, compared to open landfilling [3]; and
- Overall, moving from a wasteful, linear economy to a sustainable, circular economy.

B) Composting

Composting is an aerobic process that decomposes organic material into a nutrient-rich soil conditioner. Types of composting include backyard or onsite composting, vermicomposting, aerated windrow composting, aerated static pile composting and in-vessel composting (IVC). Both IVC and windrow composting are described in this section as appropriate methods for treating urban food waste, which will often include animal by-products requiring high temperature treatment. IVC is practised throughout Europe whilst we find windrow composting widely implemented in the USA and developing countries.

IN VESSEL COMPOSTING

Source of waste

IVC is often used to treat food and garden waste mixtures, but can also be applied to sewage sludge, farm waste (manure, crop residues), and agro-industrial by-products[4].

Process

In-vessel composting uses a drum, silo, concrete-lined trench or chamber, or similar structure to contain the biowaste at a controlled temperature, moisture and oxygen level. It is well-suited to larger volumes of waste like those managed by local governments, institutional facilities or food processing facilities, especially for wet foodwaste. For the scope of this report, the focus is upon the treatment of food and garden waste typically collected in cities.

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[1] *Valorgas (2014) Valorisation of food waste to biogas, Pg. 33* ***http://www.valorgas.soton.ac.uk/Pub_docs/VALORGAS_241334_Final_Publishable_Summary_140110.pdf***

[2] *Food and Agriculture Organisation of the United Nations (2015) international Year of Soil Conference 2015* ***http://www.fao.org/soils-2015/events/detail/en/c/338738/***

[3] *WBA calculation, based on data collected from the International Energy Agency, Biograce, UK Waste Resources Action Programme, US Environmental Protection Agency, EU Valorgas programme*

[4] *Waste and Resources Action Programme (WRAP). In vessel composting (IVC). http://www.wrap.org.uk/content/vessel-composting-ivc.*

In the first stage of the process, the mixed garden and food waste is delivered to an enclosed reception area. It is then shredded to a uniform size and loaded into what is known as the first 'barrier', which will be a bay/tunnel or chamber depending on the system used. After the first stage (which can take between one and three weeks), the material is transferred to the second 'barrier', where the composting process continues, usually for a similar duration. Processing in two stages ensures that all parts of the composting mass reaches the required temperature and biodegrades. The oxygen level, moisture and temperature are carefully monitored and controlled during both composting stages to ensure the material is fully sanitised – specifically that the material reaches a defined temperature for a certain period, usually up to 70°C for one or two days. Once the sanitisation process is complete the compost is left to mature in an open windrow or an enclosed area for approximately 10-14 weeks to ensure stabilisation.

The composted material is then screened to eliminate contaminants and produce a range of product grades suitable for various end uses, such as soil conditioning. Often the leftover aggregates that are too large for product grades are fed back into the processing system to break down fully.

Products

Composting is a natural, controlled and accelerated process of biodegradation where heat is created by the biodegrading mass itself and its temperature may rise to 70°C. These temperatures are needed to accelerate the biodegradation process and are created by the natural fermentation of the biomass itself.

The compost product contains many of the minerals needed to maintain soil health: N, P, K, as well as organic carbon contained in organic matter. Loss of organic matter in soils in many parts of the world is reducing the ability of the world's soils to retain water and maintain microbial activity beneficial to crops. The replenishment of soil organic matter through the use of compost is a response to this concern. Compost may have a dry matter content of 60%[5] and organic carbon as high as 25% of dry matter [6].

The quality of the final product depends upon a variety of factors, including the inputs and the process used.

Scale

Composting can be operated at all scales. It can be undertaken at single garden scale to large-scale industrial composting of hundreds of thousands of tonnes per year.

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[5] *WRAP (2016) Digestate and compost use in agriculture* ***http://www.wrap.org.uk/sites/files/wrap/Digestate_compost_good_practice_guide_reference_version.pdf***

[6] *Centemero M., Caimi V. (2001) Impieghi del compost: settori di maggior rilevanza, modalità d'uso, scenari attuali di mercato. Atti Corso Compost: produzione ed utilizza, Ed. CIC Rimini - settembre 2001* ***http://www.compost.it/materiali/cic_bc.pdf***

Advantages

- Produces high organic matter compost for a range of plant growing markets – including agriculture and horticulture – helping to restore soils;
- Restores the carbon storage and sequestration capacity of soils;
- Stabilises and sanitises food waste;
- Allows food waste to be collected alongside other organic wastes such as garden waste, reducing the cost of collections; and
- Is a relatively simple, predictable and naturally-occurring process.

Disadvantages

- Does not recover energy, thus reducing the emissions-saving potential;
- Careful management of contaminants and odour are required; and
- The market value and use of compost will depend upon the quality of the input

WINDROW COMPOSTING

Source of waste

Windrow composting is most suitable for processing of garden waste, such as grass cuttings, leaves and cutting from pruning but can be used for source segregated organics such as food waste where allowed. While in some countries such as Australia[7] and USA[8], it is used to treat food waste, in others such as UK and EU, it is prohibited to process food waste using this method due to health and sanitation concerns.

Process

In windrow composting waste is shredded and laid in windrow. A windrow is an elongated pile of waste, typically 2-3 meters high and 3-5 meters wide and pyramid shape. Length of the row depends on the volume of the feedstock and the orientation of the plot of land. The material is periodically turned or aerated manually, or using special equipment like a bucket loader, tractor or a windrow turner.

There are two phases in the composting process: Active and Curing. During the active phase, the biological degradation of waste raises the temperature to at least 55 °C. To kill weeds and pathogens, the temperature of waste needs to be kept higher than 55°C for at least 3 days. This phase can take anything from 8 to 12 weeks in hot climate such as that of Australia[9] to 8 to 9 months in cooler climate such as that of Vermont in USA[10].

The curing process starts when the temperature of the compost reaches about 32 – 37° C and usually takes 1 to 3 months. During this phase, the compost is generally kept aerobic by passive oxygen supply and does not require turning or aeration.

[7]*Sustainability Victoria (2009) Guide to best practice for organics recovery* ***http://www.sustainability.vic.gov.au***

[8]*Vermont Agency of Natural Resources (not dated) Turned Windrow Composting: Sizing your compost pad* ***http://dec.vermont.gov/sites/dec/files/wmp/SolidWaste/Documents/ANR%20Sizing%20Your%20Composting%20Pad.pdf Accessed on 23/03/2018***

[9]*Sustainability Victoria (2009) Guide to best practice for organics recovery* ***http://www.sustainability.vic.gov.au***

[10]*Vermont Agency of Natural Resources (not dated) Turned Windrow Composting: Sizing your compost pad* ***http://dec.vermont.gov/sites/dec/files/wmp/SolidWaste/Documents/ANR%20Sizing%20Your%20Composting%20Pad.pdf Accessed on 23/03/2018***

Upon completion of process, like IVC, the composted material is screened and ready to be used. The larger than specified aggregated maybe returned as feedstock for a second round of composting. Contaminants such as plastic residues, are eliminated.

Products

The screened composted material may be used as soil conditioner, mulch, blended products, and woody parts potentially for pyrolysis, combustion or refuse derived fuel manufacture or returned to the beginning of the process as a bulking product, especially when wet food waste is being treated.

Scale

Like IVC, windrow composting can be implemented at any scale, from single garden to large industries and organic fraction of municipal solid waste of a municipality.

Advantages:

- **Is a relatively simple, predictable and naturally-occurring process;**
- **Requiring little machinery and upfront cost is low;**
- **Subject to availability of land, large amounts of waste can be processed**
- **Produces high organic matter compost for a range of plant growing markets – including agriculture and horticulture – helping to restore soils;**
- **Restores the carbon storage and sequestration capacity of soils;**

Disadvantages:

- **Cannot be used in some countries, such as UK, to treat wastes that contain catering and animals wastes due to Animal By-Products Regulations[11];**
- **There are no emission controls;**
- **Waste is susceptible to environmental changes such as storms and changes in temperature causing disruptions to the process and other problems such as over heating or charring of waste and water runoff;**
- **The process is susceptible to odour emissions;**
- **Active management of vectors such as vermin, birds and insects is required;**
- **Does not recover energy, thus reducing the emissions-saving potential;**
- **The usability of compost will depend on the quality of the input.**

[11] *WRAP (2016) Open Windrow Composting* ***http://www.wrapcymru.org.uk/collecting-and-reprocessing/organic-waste/composting/open-windrow-composting***

C) Liquefaction

Liquefaction – the conversion of food waste into a liquid effluent - can be accomplished by multiple methods. Mechanical and biological liquefaction are outlined below. Hydrothermal liquefaction is not discussed here as to date it has not been widely adopted.

Source of waste

Household and business food waste.

Process

Mechanical systems are driven by an electric motor and use mechanical grinders to shred food waste. At a household scale, they are incorporated into kitchen sink drainage, and the food waste is ground into small pieces before being mixed with water and washed into the drainage system, to be treated with the rest of the waste water and sewage. The grinding mechanism has no knives or blades. Instead, impellers mounted on a spinning plate use centrifugal force to continuously force food waste particles against a stationary grind ring. The grind ring breaks down the food waste into very fine particles (less than 2mm) – virtually liquefying them[12].

Microorganisms or nutrients can be added to the material to accelerate the process– this is then described as biological liquefaction and is a more complex but more effective process [13].

Products

Liquid grey water drained into the waste water network.

Scale

Household scale – fitted into kitchen sinks. Food waste disposers are typically rated between 0.4–0.5 kW[14]. Biological liquefaction would generally be for larger scales.

Advantages

- **At a household scale, it is incorporated into the existing kitchen sink drainage, therefore it saves upon the need to separately collect food waste;**
- **Simple and easy to use; and**
- **Where treated at a waste water treatment works with AD, allows many of the benefits of AD to be realised.**

Disadvantages

- **Waste water systems may not be designed to treat waste foodstuffs in addition to existing sewage loads;**
- **Requires an energy input;**
- **In older cities, the drainage systems will often have difficulty managing extra loads that cause blockage and grease build-ups; and**
- **It is simply used as a means to dispose of food waste rather than a means to produce a quality product.**

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[12] *The Association of Manufacturers of Domestic Appliances (not dated) How food waste disposers work* ***https://www.food-waste-disposer.org.uk/how-they-work Accessed on 08/03/2018***

[13] *Griffith-Onnen I, Patten Z and Wong J (2013) on-site systems for processing food waste* ***http://www.mass.gov/eea/agencies/massdep/recycle/reduce/massdep-food-waste-final-report.pdf***

[14] *The Association of Manufacturers of Domestic Appliances (not dated) How food waste disposers work* ***https://www.food-waste-disposer.org.uk/how-they-work Accessed on 08/03/2018***

D) Rendering

Rendering is a process that converts waste animal tissue and by-products into saleable commodities such as high-quality fat and protein products. These can then be used in the production of animal feed (e.g. pet food), soap, paints and varnishes, cosmetics, explosives, toothpaste, pharmaceuticals, leather, textiles, lubricants, biofuels and other valuable products.

Rendering can be carried out on an industrial, farm or kitchen scale. In the UK there are around 2 Mt of animal by-products sent to rendering plants[15]. Rendering is an energy-intensive process and has a limited application – it can only be used to treat certain feedstocks, namely animal tissue.

1.75m

TONNES OF ANIMAL BY-PRODUCTS ARE PROCESSED ON 26 DEDICATED RENDERING PLANTS IN THE UK.

Source of waste

The most common animal sources are beef, pork, sheep and poultry. The majority of tissue processed comes from slaughterhouses in the form of fatty tissue, blood, bones and offal, as well as entire carcasses, but rendering companies also get their materials from meat and poultry plants, restaurant grease, butcher shop trimmings, the foodservice industry, farms and expired meat from grocery stores.

Process

The rendering process is relatively simple. Animal products not used as food for people are ground so they are uniform in size and then heated to a time and temperature combination necessary to thoroughly cook the material. Fat separates from the protein naturally due to the heat, is centrifuged and ready for use. Protein is ground again to make a consistent protein meal[16].

Rendering uses heat and pressure to sterilise and stabilise animal material. Sterilisation kills harmful microorganisms thus eliminating disease risk. Stabilisation prevents any further decomposition of by-products and makes them suitable for storage and reprocessing for other uses. A key step is removing water. Only a proportion of the feedstock is turned into material, the rest is lost as water which is treated for safe return to the environment.

[15] *Parry, A., P. Bleazard and K. Okawa (2015), "Preventing Food Waste: Case Studies of Japan and the United Kingdom", OECD Food, Agriculture and Fisheries Papers, No. 76, OECD Publishing, Paris.* ***https://www.oecd-ilibrary.org/docserver/5js4w29cf0f7-en.pdf?expires=1525784803&id=id&accname=guest&checksum=097503A68F4EA992CADBEBC498B54F03***

[16] *National Renderers Association.* ***http://www.nationalrenderers.org/about/faqs/#what-is-rendering.***

IN THE US AND CANADA, THE RENDERING INDUSTRY CONSISTS OF MORE THAN THREE DOZEN FIRMS OPERATING MORE THAN 200 PLANTS.

Products

Rendering produces fat (tallow), high-protein meat or grease[17], and the products that can then be created from these.

Scale

In Australia, batch dry cooking is the most widely used type of rendering. Batch cooking systems are well suited to small-scale operations since a single cooker can handle 3,500-5,500 tonnes of raw material per year. On the larger scale, continuous dry rendering systems are used, where capacity ranges from 25,000-100,000 tonnes per year, depending on the size of the heat transfer area of the cooker and the water content of the raw material.

In the US and Canada, the rendering industry consists of more than three dozen firms operating more than 200 plants. This number includes plants that are integrated with meat processing companies to process the captive by-products generated by these firms, and independent renderers that are not directly owned by meat processing companies but instead collect and process by-products from many different sources.

In the UK, 26 dedicated rendering plants process around 1.75m tonnes of animal by-products per year, meaning each plant processes an average of 70,000 tonnes per year.

Advantages

- **Produces highly valued protein supplements for livestock, poultry, and pet foods; and**
- **Amid increases and volatility in the price of conventional feed and concerns about the environmental impact of grain- and soybean-based feeds, rendering food waste provides a very good substitute for conventional animal feed.**

Disadvantages

- **Requires close regulation and stringent legislation on what types of food waste are used;**
- **Requires an energy input;**
- **If the food waste contains animal by-products and is not effectively heat-treated, it can transmit diseases such as foot-and-mouth disease and African swine fever; and**
- **Rendering poses biosecurity concerns due to the transportation of livestock mortalities to multiple locations en-route to the rendering plant.**

[17] *EFPRA. Which By-Products are Rendered?* ***http://efpra.eu/which-byproducts-rendered/.***

4.2 Technologies that treat non-separated food waste (i.e. organic waste mixed in with inorganic waste)

In the instances where organic wastes are not collected separately from other household and business wastes, there are several treatment technologies which can be used. They are included in this report to provide a full overview of the available options for processing organic wastes. The merits and drawbacks of the different technologies are also briefly explored for some technologies, both in relation to each other and to the technologies which treat separated food waste (as set out above).

A) Gasification

Gasification is a process that converts organic materials (e.g. biomass, food wastes) or combinations of organics and inorganics into a combustible gas called syngas, by reacting the material at high temperatures (>700°C) with a controlled amount of oxygen and/or steam. It is therefore a technology that involves thermochemical conversion, like incineration or pyrolysis. The syngas is usually comprised of carbon monoxide (CO), hydrogen (H_2) and CO_2. Gasification as a technology has been slow to develop, with few waste gasifiers operating globally, especially at the scales required to deal with MSW.

Source of waste

Mixed household and business waste, ideally which is non-recyclable.

Process

Thermal gasification takes place in a reactor called a gasifier. Before entering the gasifier, the waste has to be prepared for the gasification process, which involves breaking it down to a suitable size and drying it to suitably low moisture content. The waste should be also free from other undesirable materials, such as stones or metals, which could cause operational problems[18].

Gasification is an intermediate step between pyrolysis and combustion. It is a two-step, endothermic process. During the first step the volatile components of the fuel are vaporized at temperatures below 600°C by a set of complex reactions. No oxygen or other reactive agent is needed in this phase of the process. Hydrocarbon gases, hydrogen (H_2), CO, CO_2, tar and water vapour are included in the volatile vapours. Char (fixed carbon) and ash are the by-products of the process which are not vaporized. In the second step, char is gasified through the reactions with oxygen, steam, CO_2 and/or hydrogen. In some gasification processes, some of the unburned char is combusted to release the heat needed for the endothermic gasification reactions.

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[18] *IEA Task 33. Thermal Gasification of Biomass.* ***http://task33.ieabioenergy.com/content/thermal_gasification.***

Products

The main products of gasification are syngas, and by-products such as char and tars. The composition of the syngas and the level of undesirable components (tars, dust, ash content) produced during the thermal biomass gasification process are dependent on many factors such as feedstock characteristics (composition, water content, granulometry), reactor type and operating parameters (temperature, pressure, oxygen fuel ratio, fluidizing agent).

Gaseous products formed during the gasification may be further used for heating or electricity production, or ideally further processed into high-value chemicals. The main gas components are CO, H_2, CO_2, H_2O, methane (CH_4) and other hydrocarbons.

Scale

Can operate at 100 tonnes per day and over, e.g. Covanta Tulsa Renewable Energy LLC in Tulsa, USA[19].

Advantages:

- **May be implemented for treatment of : an average of just 100 tonnes/day in comparison to larger amounts for incineration with energy recovery [20]; and**
- **According to the World Energy Council, both gasification and pyrolysis are more efficient and score better in environmental impacts than incineration with energy recovery [21]. However, with the lower number of operational plants developed to date than incineration, there is debate over whether these efficiencies can be achieved in practice.**

Disadvantages:

- **Lack of nutrient recovery: like incineration, gasification of mixed waste which includes food waste also wastes the nutrient value of the food waste, which could be converted to fertiliser through composting or AD. Whereas gasification recovers the energy content of the waste, AD both recovers the energy content and the nutrient content of the waste;**
- **Lower efficiency compared to AD in terms of GHG emission reductions [22];**
- **Higher capital costs than incineration [23];**
- **When the moisture content of the waste being treated is high, the energy recovered is low and potentially negative, thus increasing the cost of treatment further.**
- **The mechanical treatment ahead of gasification, sensitivity to feedstock properties, low heating value of waste fuel, costly flue gas clean-up systems, difficulty of syngas clean-up and poor performance at small scale have been a great challenge during gasification of MSW [24]; and**
- **Operates more effectively with homogeneous feedstocks, reducing the flexibility of the plant in comparison to incineration.**

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[19] *Solid Waste of North America (2013) 2013 SWANA Waste-to-Energy Excellence Award Nomination* ***https://swana.org/Portals/0/Awards/2013/WTE_Bronze.pdf***

[20] *World Energy Council (2016) World Energy Resources - Waste to Energy.* ***https://www.worldenergy.org/wp-content/uploads/2017/03/WEResources_Waste_to_Energy_2016.pdf.***

[21] *World Energy Council (2016) World Energy Resources - Waste to Energy.* ***https://www.worldenergy.org/wp-content/uploads/2017/03/WEResources_Waste_to_Energy_2016.pdf.***

[22] *World Energy Council (2016) World Energy Resources - Waste to Energy* ***https://www.worldenergy.org/wp-content/uploads/2017/03/WEResources_Waste_to_Energy_2016.pdf***

[23] *World Energy Council (2016) World Energy Resources - Waste to Energy* ***https://www.worldenergy.org/wp-content/uploads/2017/03/WEResources_Waste_to_Energy_2016.pdf***

[24] *World Energy Council (2016) World Energy Resources - Waste to Energy* ***https://www.worldenergy.org/wp-content/uploads/2017/03/WEResources_Waste_to_Energy_2016.pdf***

B) Incineration with energy recovery

Incineration is the controlled combustion at extremely high temperatures of mixed solid waste to reduce the volume of the waste. The process is highly exothermic (it releases heat) and the objective is the safe disposal of the waste.

Source of waste

Mixed solid waste, including food waste, from municipal, commercial and industrial sources, ideally non-recyclable.

Process

Incineration is a thermochemical conversion technology, like pyrolysis and gasification. Originally, incinerators were designed to reduce the volume of MSW to be disposed of and to destroy pathogens/hazardous substances. Waste incineration where energy is either not recovered or done so inefficiently is classed as disposal and is at the bottom of the waste hierarchy, and is therefore less desirable in terms of overall environmental performance than recycling or recovery options[25].

Waste incinerators have been a technology used for more than a century. Since those days, however, these waste burning facilities have evolved to include energy extraction from the combustion process. Their permitted emission standards have been significantly restricted over time to avoid emission of persistent organic pollutants (POPs) from burning hazardous materials such as polyvinyl chloride. Modern incineration plants have complex air pollutant emission reduction systems. Where energy is recovered from the combustion process, usually in the form of electricity and heat, the process is generally referred to as 'energy from waste' (EfW), waste to energy (WtE) or 'energy recovery'.

EfW technologies are generally seen as a form of disposal in the waste hierarchy.

In many cities, incineration facilities are well located to provide district heating to local communities, which improves the economics of any scheme and helps with public acceptance of the waste facility. Sweden, Denmark, Germany and Japan are examples of countries which send more than 90% of their residual waste to incineration or energy recovery and produce both electricity and district heating from them.

In many countries there is a large amount of potentially combustible residual waste still disposed of in landfill that could be utilised in incineration with energy recovery and therefore there is potential room for growth in both forms of recycling (including AD) and incineration with energy recovery – at the expense of landfilling[26]. However, this is country-dependent and those countries that first built large EfW capacities have seen the increase of recycling result in the reduction of the amount of waste to be burnt, leading to a market in the import of waste to feed these plants in Germany, Denmark, Sweden, Norway, the Netherlands and Austria.

[25] *DEFRA (2014). Energy from waste: A guide to the debate.* ***https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/284612/pb14130-energy-waste-201402.pdf.***

[26] *DEFRA (2014). Energy from waste: A guide to the debate.* ***https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/284612/pb14130-energy-waste-201402.pdf***

Some of the controversies around EfW technologies are that, since they require very large capital investments that need to be amortized over long periods of time, they often lock cities to keep generating high amounts of waste for decades to feed the incinerator and can hinder efforts to increase recycling or reduce the amount of non-recyclable plastics in the waste-stream. Additionally, as most of the materials that can be burned are carbon-based (plastics, wood, food and green waste) it means that carbon that was already stored in those materials will be released into the atmosphere in the form of CO2, worsening global warming. Some estimates put the carbon intensity of EfW, that is, the amount of CO2 released per ton combusted, on the same level as burning coal[27].

Products

The products of waste combustion are generally electricity and heat. Ash is also produced, from which it is possible to extract some recyclable materials as well as waste for landfilling.

Scale

Usually over 100,000 tonnes per year.

Advantages:

- **An advantage of incineration and energy recovery is that food and other waste streams are not required to be separated at source. This saves on collection costs. However, incineration with energy recovery could also be used in conjunction with separate food waste, garden waste and dry recyclable collections, providing a more efficient approach that maximises recycling rates and recovers energy from non-recyclable residual waste; and**
- **Depending on the treatment options for the bottom ash formed by the inorganic constituents of the waste, ferrous and non-ferrous metals can be recovered and the remaining ash can be further enhanced to be used for road construction and buildings[28].**

Disadvantages:

- **Sending food waste to incineration with energy recovery is not an efficient use of the resource compared to AD or composting. One study has estimated AD to be capable of recovering 60% more energy than EfW[29];**
- **Lack of nutrient recovery: Incineration with energy recovery using mixed waste which includes food waste does not capture the nutrient value of the food waste, which could be converted to fertiliser through composting or AD. Whereas incineration with energy recovery recovers part of the energy content of the waste, AD both recovers the energy content (and heat) and the nutrient content of the waste;**
- **Incineration with energy recovery facilities usually require higher tonnages to be cost effective[30], compared with much smaller amounts for composting or AD;**
- **The capital cost of installation is high, although savings can be made against the cost of separate collection of food waste and other recyclables;**
- **Not a good option to treat food waste due to the high moisture content. Thermochemical conversions such as incineration operate best when they treat dry materials[31]. Certainly where food waste constitutes high percentages of total waste, as in developing economies, there are few energy recovery gains to be made from burning high volumes of very wet food waste; and**
- **Incineration releases carbon to the atmosphere in the form of CO2. The impacts from this carbon release are worse in the locations where there is less source segregation.**

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[27] *U.S. EPA Clean Energy web page, "How Does Electricity Affect the Environment," http://www.epa.gov/cleanenergy/energy-and-you/affect/air-emissions.html*

[28] *World Energy Council (2016) World Energy Resources - Waste to Energy.* ***https://www.worldenergy.org/wp-content/uploads/2017/03/WEResources_Waste_to_Energy_2016.pdf.***

[29] *Valorgas (2014) Valorisation of food waste to biogas, Pg. 33* ***http://www.valorgas.soton.ac.uk/Pub_docs/VALORGAS_241334_Final_Publishable_Summary_140110.pdf***

[30] *World Energy Council (2016) World Energy Resources - Waste to Energy.* ***https://www.worldenergy.org/wp-content/uploads/2017/03/WEResources_Waste_to_Energy_2016.pdf***

[31] *World Energy Council (2016) World Energy Resources - Waste to Energy.* ***https://www.worldenergy.org/wp-content/uploads/2017/03/WEResources_Waste_to_Energy_2016.pdf.***

C) Landfill without gas collection

A sanitary landfill is a site for the disposal of solid waste materials. Sanitary landfills are designed to protect the environment from contaminants, which may be present in the waste stream[32]. Historically, waste material has been thrown into pits and left in piles in landfill sites, but more recent practice dictates the waste is buried. Over the course of history, landfills have been the most common method of organised waste disposal and remain so in many places around the world.

Source of waste

Landfills take all types of waste material. Some landfills are designed to take MSW, others to take industrial waste (commercial and institutional waste) and others to take hazardous waste (defined as hazardous for reasons of health or safety risks or pollution risks).

Process

A well-designed landfill site will follow the following steps when waste arrives at the site[33]. First, the waste is weighed on the delivery vehicle as it enters the site. It is taken to the working area and tipped out. The waste is then spread and compacted using a bulldozer or landfill compactor. Daily cover of soil or clay is moved to the working area at the end of each day, and that too is spread and compacted. The final cover material is delivered, spread and compacted after the working area has reached the desired waste depth.

Products

No product – sanitary landfills are simply used as a way of disposing of and storing waste.

Scale

Landfilling of waste is a common method of waste disposal across the world. Landfill sites can vary in size from very small sites taking less than 1,000 tonnes per year to huge sites taking several hundreds of thousands of tons per year, such as the one in Xinfeng, Guangzhou, China which encompasses 227 acres, and the one in Bordo Poniente, Mexico City, Mexico, which encompasses 927 acres[34]. As of 2015, in Peru, there were 10 sanitary landfills, which process the solid waste of close to 30mn residents. Another 20 dumping sites receive approximately 3,500 tonnes/day of waste[35]. In Australia, landfill sites are classified as 'very small' if they take less than 1,000 tonnes per year, as 'small' if they take between 1,000 and 20,000 tonnes per year, 'medium' if they take between 20,000 and 100,000 tonnes per year, and 'large' if they receive more than 100,000 tonnes per year. The majority of Australia's landfills are small or very small, receiving less than 20,000 tonnes of waste per year[36]. At one end of the scale are small, shallow sites with minimal control on the type or quantity of waste entering and no gas collection or leachate management. At the other are large, deep sites with multiple liners where the waste is monitored, compacted and covered, gas is collected for flaring or energy use and leachate is collected and treated to prevent groundwater pollution[37].

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[32] *U.S. EPA. What is a landfill?* ***https://www.epa.gov/landfills/basic-information-about-landfills#whatis.***

[33] *European Commission (2001) Waste management options and climate change* ***http://ec.europa.eu/environment/waste/studies/pdf/climate_change.pdf***

[34] *World Atlas (2017) Largest landfills, waste sites, and trach dumps in the world* ***https://www.worldatlas.com/articles/largest-landfills-waste-sites-and-trash-dumps-in-the-world.html***

[35] *Peru Solid Waste NAMA (2014) Program for supporting up-scaled mitigation action in Peru's solid waste sector* ***https://www.nefco.org/sites/nefco.org/files/pdf-files/7_peru_solid_waste_nama_concept_note.pdf***

D) Landfill with gas collection[41]

Landfilling continues to be the primary option for disposal of much of the MSW generated throughout the world. When designed, constructed and operated properly, a sanitary landfill can offer an effective method for disposing of waste remaining after recovery of valuable materials (e.g. recyclables, organic waste). A sanitary landfill should be designed and operated to maximise safeguards to the environment and public health, and at a minimum include protections for groundwater (e.g. leachate collection and treatment) and landfill gas (LFG) capture and recovery (flaring or utilisation or both) to reduce air pollution and global warming. A sanitary landfill performs like an anaerobic digester wherein organic waste is disposed and decomposes in the absence of oxygen resulting in the generation of landfill gas (LFG), a gas mixture primarily composed of Methane, CO2 and water vapour. Maximising the recovery of LFG requires installation of equipment to collect as much of the gas as possible to prevent escape to the atmosphere.

Process

The installation of a gas collection and control system (GCCS) involves placing piping within the waste disposal area connected to a blower or vacuum system that draws the LFG into a central location for combustion by a flare and/or energy recovery. The collection piping can be horizontal, vertical, or a combination of both types. The piping within the waste connects to wellheads which are then connected to lateral piping that carries the LFG to the central header[42].

Advantages

- **Sanitary landfills are cheaper than other food waste treatment/disposal technologies[38] both in terms of capital cost and operating cost; and,**
- **Can take mixed waste: waste does not have to be separated at source.**

Disadvantages

- **Create lasting detrimental impacts to the environment;**
- **Require large areas of land and so in populated areas create an issue of space and odours;**
- **Lead to the release of greenhouse gas emissions to the atmosphere, contributing to climate change, and, if any leakage from the landfill site occurs, this could contaminate the hydrosphere[39];**
- **Can also be extremely dangerous if not designed properly – unstable landfills can lead to disasters such as landslides, such as the one that killed around 300 people in Manila, Philippines in 2000[40]; and,**
- **Often catch fire emitting toxic substances into the environment.**
- **Management and maintenance costs can become high over time, also requiring long maintenance post-closure**

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[36] *WMAA and Blue Environment (2013) Analysis of landfill survey data* ***https://www.environment.gov.au/system/files/resources/91763f0e-f453-48d0-b33e-22f905450c99/files/landfill-survey-data.pdf***

[37] *European Commission (2001) Waste management options and climate change* ***http://ec.europa.eu/environment/waste/studies/pdf/climate_change.pdf***

[38] *Peru Solid Waste NAMA (2014) Program for supporting up-scaled mitigation action in Peru's solid waste sector* ***https://www.nefco.org/sites/nefco.org/files/pdf-files/7_peru_solid_waste_nama_concept_note.pdf***

[39] *CIRAD, INRA (2015). Food Waste recycling into animal feeding in Vietnam.* ***https://umr-selmet.cirad.fr/content/download/4053/29641/version/2/file/NIAS_REPORT_FW2FEED_VN.pdf.***

[40] *BBC (2000). 'Hundreds' dead in Manila dump collapse.* ***http://news.bbc.co.uk/1/hi/world/asia-pacific/830809.stm.***

[41] *The overview, process and products parts of this section has been authored by Brian Guzzone at ERG (Eastern Research Group, Inc)*

[42] *U.S. EPA, LMOP. LFG Energy Project Development Handbook. June 2017.* ***https://www.epa.gov/lmop/landfill-gas-energy-project-development-handbook.***

LFG that is simply flared does not require any treatment or conditioning, however LFG that will be used as an energy source does. The level of treatment and preparation depends upon the energy use technology and the site-specific LFG composition.

Products

LFG is typically about 45-50% CH_4, 45-50% CO_2, and less than 1% other compounds. The CH4 component of the gas has value as an energy source, giving raw LFG a heating value of about 19 mega joules per cubic metre (MJ/m^3)[43]. In comparison, natural gas in the USA and UK has a heating value between 38-39 MJ/m^3. Prepared LFG can be combusted in reciprocating internal combustion engines, other types of engines, gas turbines, micro turbines, utility boiler/steam turbines, and gas turbine/steam turbines to generate electricity; it can also be used in a variety of other technologies to generate heat including boilers, heaters, kilns, burners, and ovens. Some of the electricity-generating projects also create heat by capturing waste heat from the primary technology. These types of technologies require low to moderate levels of LFG treatment and preparation. LFG can also be cleaned to nearly pure methane for injection into a natural gas pipeline for use in any number of applications, replacing natural gas one-for-one. This pipeline-quality gas can alternatively be used to create vehicle fuel on site as either compressed natural gas or liquefied natural gas, again replacing fossil natural gas resources. As of November 2017, there were 637 currently operating LFG energy recovery projects in the USA, using LFG from approximately 580 landfills[44]. About 75% of these projects generate electricity, about 18% create heat directly, and the remaining 7% clean the LFG to pipeline-quality gas or create vehicle fuel on site[45]. LFG capture projects have been operating for a few decades in all parts of the world including Argentina, Chile, Brazil, Colombia, El Salvador, Europe, Mexico, Poland, Ukraine, China and Republic of Korea[46].

Scale

All scales, although there are minimum requirements of stored biodegradable materials and moisture content to enable biogas production over time. Landfills comprised of dry waste (where foodwaste for example has been collecting separately and excluded from landfill delivery) will produce little or no biogas.

[43] *U.S. EPA, Landfill Methane Outreach Program (LMOP). LFG Energy Project Development Handbook. June 2017.* ***https://www.epa.gov/lmop/landfill-gas-energy-project-development-handbook***

[44] *U.S. EPA, LMOP. Landfill Gas Energy Project Data and Landfill Technical Data webpage. Accessed on 13/12/2017.* ***https://www.epa.gov/lmop/landfill-gas-energy-project-data-and-landfill-technical-data.***

[45] *U.S. EPA, LMOP. LFG Energy Project Data Files [November 2017]. "Aggregated file of currently operational projects (XLSX)". Accessed December 13, 2017.* ***https://www.epa.gov/lmop/landfill-gas-energy-project-data.***

[46] *lobal Methane Initiative (2012). International Best Practices Guide for Landfill Gas Energy Projects.* ***http://www.globalmethane.org/documents/toolsres_lfg_IBPGAppendixA.pdf. Accessed on 04/01/2018.***

Advantages

- **Relatively low cost to implement and does not require the cost of introducing separate collections;**
- **Energy is recovered via methane extraction and combustion; and,**
- **CH_4 has a lifetime of about 12 years in the atmosphere, its actual impact is nearly 90 times more powerful than CO_2 over a 20-year period. Therefore, destruction of CH_4 via flaring or anaerobic digestion, helps mitigate the potential climate effects of landfilled waste.**

Disadvantages

- **Does not support the reduction in food waste quantities that are associated with separate collections of food waste;**
- **Recovers less energy than anaerobic digestion operated in controlled conditions;**
- **Careful management is needed to prevent landfill gas leaks; and,**
- **Does not recover nutrients or help build organic matter in soils.**
- **LFG capture is never 100% efficient, meaning that some methane will still escape to the atmosphere, contributing to global warming and decreased air quality.**

E) Mechanical Biological Treatment (MBT)

Mechanical biological treatment (MBT) describes a number of different processes dealing with the treatment of waste. It is the combination of both biological and physical processes, which can be arranged in a number of different ways. MBT is an established waste treatment technology in many European countries such as Germany, Italy, the UK, and Austria[47].

Source of food waste

Though MBT is capable of dealing with both mixed waste and source separated waste, it tends to be used for the former, for residual or "black bag" waste.

Process

The mechanical part, which is the physical stage of an MBT process, is normally at the front end of the process. The aim of the mechanical process to separate the drier fractions from the wet organic fraction through mechanical separation, leaving on the one hand mixed dry fractions such as plastics, paper and textiles, and on the other an organic-rich fraction or biodegradable fraction which is destined for biological treatment.

Mechanical separation processes can include any number of the following: size reduction or shredding of the waste, separation of ferrous and non-ferrous metals, heat or steam treatment and screening and/or size reduction of outputs. Not all of these processes are used in each MBT facility – what exactly is done will depend on individual aims and circumstances.
The mechanical process can be both a dry and wet process depending on the role of the final product.
Though the mechanical part is normally at the front end of the process, it can also play a key role at the back end of the process. For example, the plant can be designed to have mechanical screening to take out further contaminants and or reduce particle size at the end of the process, especially if the residues are going to be used for a purpose other than landfilling.
The biological processes of MBT include aerobic decomposition to AD, or a combination of the two. AD is outlined in more detail in Chapter 5. The key here is that AD of mixed MSW will not produce a material of appropriate quality without some form of mechanical treatment at the front end of the MBT plant.

[47] *Chartered Institute of Waste Management (CIWM). Mechanical Biological Treatment.* ***https://www.ciwm.co.uk/ciwm/knowledge/mechanical-biological-treatment.aspx.***

Products

The mechanical process recovers dry recyclables such as cardboard, plastics, paper and metals. The biological process, like AD, will produce biogas which can be used in different ways as well as compost, which, depending upon the quality and local regulations, may have a use or be classified as a waste. Contamination of all the recovered materials from MBT is a significant issue resulting in very low yields of reusable materials that often constitute no more than 8% of outputs, the rest being waste. The advantage of MBT is that it reduces the volume of waste through the evaporation process, takes out the putrescible (food waste) fraction, and leaves a drier fraction suitable for burning, also known as refuse derived fuel (RDF). Specialised MBT plants making RDF to specific standards for burning in cement kilns and EfW plants are now common.

For the purposes of this report, the output of MBT from food waste mixed with other wastes is a very low-quality, contaminated compost whose uses are limited mainly to cover of contaminated sites or daily cover of landfills.

The EU Fertiliser Regulations, being revised and awaiting entry into law as we write in early 2018, prohibits the use of mixed waste as a feedstock for fertilisers[48].

Scale

MBT plants can operate at large scale with inputs of more than 1,000 tonnes per day or at a smaller scale. MBT plants are not a final disposal operation, and require disposal options for their outputs – either landfills or incineration.

Advantages

- **Allows recycling of material otherwise inefficiently combusted or landfilled;**
- **Does not require the cost associated with the separate collection of food waste; and**
- **Allows energy recovery from food waste via the anaerobically digested organic fraction.**

Disadvantages

- **Residue material is not of sufficiently high quality to be used in farming or horticulture, thus nutrient and organic matter is wasted;**
- **High cost of construction and operation;**
- **Energy intensive process to separate an organic fraction from recyclables and other material; and**
- **Digestion of organic material containing variable inorganic materials can be a complex process, with an ongoing risk of performance failures.**
- **Requires a final disposal route for the non-recyclable outputs, whether to incineration or landfil**

[48]European Parliament (2017). Review of the Fertilising Products Regulation. ***http://www.europarl.europa.eu/legislative-train/theme-new-boost-for-jobs-growth-and-investment/file-review-of-the-fertilising-products-regulation.***

F) Pyrolysis

Pyrolysis is the heating of an organic material in the absence of oxygen, resulting in the decomposition of organic material into gases and charcoal. It is therefore a technology that involves thermochemical conversion, like incineration, EfW and gasification. Compared to combustion, pyrolysis has a lower process temperature, lower emissions of air pollutants and the scale of pyrolysis is also more flexible than incineration plants[49].

Pyrolysis of MSW on an industrial scale is carried out in rotary kilns, because they provide sufficient heat transfer with relatively low energy consumption. In general, slow pyrolysis of organic waste (e.g., wood, food and garden waste, paper, natural textiles) is usually carried out at temperatures of about 400-500^{0}C and heating rates of 5–20^{0}C/minute under nitrogen flow. Fast pyrolysis is more complicated, but it is also used.

Sources of waste

One of the great advantages of this process is that many types of raw materials can be used, including industrial and domestic residues. The pyrolysis process can use many waste types including MSW, waste plastics, medical waste, rubber and tyres, e-waste, biomass/wood and organic sludge. The fractions of MSW subjected to pyrolysis mainly consist of paper, cloth, plastics, food waste and yard waste.

Products

Pyrolysis is a flexible technology that can generate a combination of solid, liquid and gaseous products in different proportions, by varying the operating parameters such as temperature or heating rate. It also provides an opportunity to transform materials of low-energy density into bio-fuels of high-energy density, and at the same time recover high value chemicals.

Process

Pyrolysis allows the utilisation of all carbon-containing materials both organic and inorganic as opposed to commonly used biological methods of waste disposal.

Scale

Can be designed to operate on as little as 10 tonnes per day[50]

Advantages:

- **Can potentially operate at smaller scale;**
- **No additional oxygen is required for the process (only heat), unlike EfW[51]; and**
- **Potentially more efficient than EfW. However, as outlined in the gasification section above, there is still debate the efficiency of both gasification and pyrolysis compared to EfW.**

Disadvantages:

- **Lack of nutrient recovery: like gasification and EfW, pyrolysis does not obtain the nutrient value of food waste, which could be converted to fertiliser through AD. Whereas pyrolysis recovers the energy content of the waste, AD recovers both the energy content and the nutrient content of the waste;**
- **Lower carbon efficiency compared to AD in terms of GHG emissions[52];**
- **Higher capital costs than EfW due to the complexity of the process; and**
- **There are few operational full-scale facilities treating MSW so operational experiences are limited – lack of technology maturity.**

The following chapters give an overview of the AD process and technology, the products of AD and how the technology can be implemented with the support of incentives, regulations and policies.

[49] *Thermal Science and Engineering Progress (2017)* ***https://ac.els-cdn.com/S2451904917300690/1-s2.0-S2451904917300690-main.pdf?_tid=b8a5a210-df2b-11e7-a16c-00000aab0f01&acdnat=1513076645_08bfddb5b8fc7ad42624169120700043***

[50] *World Energy Council (2016) World Energy Resources - Waste to Energy.* ***https://www.worldenergy.org/wp-content/uploads/2017/03/WEResources_Waste_to_Energy_2016.pdf.***

[51] *World Energy Council (2016) World Energy Resources - Waste to Energy.* ***https://www.worldenergy.org/wp-content/uploads/2017/03/WEResources_Waste_to_Energy_2016.pdf.***

[52] *World Energy Council (2016) World Energy Resources - Waste to Energy.* ***https://www.worldenergy.org/wp-content/uploads/2017/03/WEResources_Waste_to_Energy_2016.pdf***

5. ANAEROBIC DIGESTION

5.1. Introduction and overview

This chapter looks at how anaerobic digestion (AD) technologies can treat food and other wastes collected in cities and transform these streams into energy and soil nutrients. The chapter explains AD as a process and explores its benefits. The different stages of the AD process are discussed, followed by information on the practicalities and financial costs of setting up and operating a biogas plant. The products of AD and their utilisation are discussed here briefly and then in greater detail in Chapter 6.

5.1.1. The process

AD is a series of biological processes in which micro-organisms digest plant and/or animal material in sealed containers, producing biogas, which is a mixture of methane, carbon dioxide and other gases. The organic material left over, known as digestate, is rich in organic matter and nutrients such as nitrogen, phosphate and potash. Biogas and digestate are therefore both important outputs of AD and their uses are explained below.

The difference between AD and composting is that anaerobic digestion occurs within containers in absence of oxygen, whereas composting, or aerobic digestion, requires oxygen.

5.1.2. The waste feedstocks suitable for AD

A wide range of organic matter, such as domestic and commercial food waste, municipal and industrial sewage, agricultural material and livestock manures, can be digested via AD. For this report, 'organic matter' means any material derived from recently-living organisms. It should be noted that when organic materials are landfilled, their decomposition emits biogas in much the same way, and can be captured through landfill gas technologies. These are explained in Chapter 4.

Urban waste for AD may include[1]:

- **Lipid wastes, including fats, oils and greases;**
- **Simple carbohydrate wastes, including bakery waste, brewery waste and sugar based solutions;**
- **Complex carbohydrate wastes, such as fruit and vegetable waste and organic fraction of municipal solid waste (MSW);**
- **Protein waste, such as waste from abattoirs and dairy processing facilities; and**
- **Other waste from commercial and industrial facilities.**

[1] *U.S. EPA (2014). Food Waste to Energy: How Six Water Resource Recovery Facilities are Boosting Biogas Production and the Bottom Line.* ***https://www.epa.gov/sites/production/files/2016-07/documents/food_waste_to_energy_-_final.pdf.***

5.1.3. Products and co-products of AD

The purpose of AD is usually to produce biogas and nutrients. Biogas contains methane and it is the combustion of the methane element which constitutes the energy component of biogas. This energy may be used in many different ways:

COMBUSTED DIRECTLY IN:

- Domestic stoves for cooking or used in gas lamps for lighting, after minor modifications[2,3].

COMBUSTED IN:

- Boilers to generate heat;
- Internal or external combustion engines to produce electricity;
- Combined heat and power (CHP) plants to produce both heat and electricity; and
- Tri-generation systems to provide cooling via absorption chillers in addition to heat and electricity.

UPGRADED INTO BIOMETHANE:

- To be used as vehicle fuel in gas-powered vehicles;
- To be used in place of natural gas in industrial, commercial and domestic uses; and
- Carbon dioxide may be extracted for commercial use, for example as a feedstock in greenhouses.

PROCESSED INTO HIGHER VALUE PRODUCTS SUCH AS BIO-PLASTICS OR BIO-CHEMICALS.

A co-product of the AD process is a material called ‘digestate’, containing water, nutrients and organic carbon suitable for soils. Digestate is the remaining part of the material fed into the digester once the gas is extracted. The digestate may be used as a bio-fertiliser and applied to land [4] as ‘whole digestate’, composted, or separated into liquid and solid fractions before being applied to land . Elemental fertilisers may also be extracted from digestate for more targeted applications. These are considered in greater detail in Chapter 6.

[2,3]*Sasse L, Kellner C and Kimaro A (1991). Improved Biogas Unit for Developing Countries.* ***http://www.susana.org/_resources/documents/default/2-535-sasse-1991-improved-biogas-unit-for-developing-countries.pdf***

[4]*World Biogas Association (2016). The contribution of Anaerobic Digestion and Biogas towards achieving the UN Sustainable Development Goals.*

5.1.4. The benefits of AD

The AD of food waste has multiple benefits in the form of:

RENEWABLE ENERGY PRODUCTION:

- Production of baseload energy for sustained energy use;
- Production of energy that can be stored and used to meet peak load demand;
- Generation of electricity for on-site, local or injection into the electricity grid;
- Off-grid, localised energy production;
- Enhanced energy security from domestic sources;
- Reduced dependence on fossil-fuel energy;
- Generation of heat from CHP units within biogas plants;
- Generation of biomethane for vehicle fuel; and
- Generation of biomethane for on-site, local or injection into the natural gas distribution network.
- Generation of energy in combination with other forms of power generation, e.g. together with wind and solar power

CLIMATE CHANGE MITIGATION:

- Reduced greenhouse gas emissions and particulate emissions by substituting fossil fuels such as coal and oil as energy supplies to buildings, homes and industry;
- Reduced greenhouse gas emissions from vehicles by substitution of diesel and gasoline with biomethane as fuel;
- Reduction of uncontrolled methane emissions in dumps and landfills and generation of renewable energy from untreated food and other organic wastes;
- Capture of biogas from landfills avoiding methane emissions;
  Substitution of synthetic and mineral fertilisers with digestate bio-fertiliser; and
- Reduction of deforestation by replacing solid-biomass-based domestic fuels with biogas.
- Using digestate to restore the carbon storage and sequestration capacity of soils

CONTRIBUTING TOWARDS A CIRCULAR ECONOMY:

- Improving the self-sufficiency and sustainability of industries by extracting the energy from their own effluents and using it for the self-generation of electricity and/or heat; and
- Recirculating nutrients and organic matter in organic wastes through AD and returning them to the soil in the form of digestate bio-fertiliser.

IMPROVING URBAN AIR QUALITY:

- Substituting biomethane for fossil fuel in vehicles; and
- Substituting biogas for solid fuel for domestic cooking and heating.
- Avoiding the uncontrolled release of methane from landfills, which then acts as an ozone precursor in the atmosphere, deteriorating air quality

CONTRIBUTING TOWARDS FOOD SECURITY:

- Restoring soils through the recycling of nutrients, organic matter and carbon;
- Increasing crop yields through use of nutrient-rich digestate bio-fertiliser; and
- Recirculating phosphorus, which is essential for the growth of plants.

These benefits of AD are closely linked to many of the UN Sustainable Development Goals, including 2, 3, 5, 6, 7, 9, 11, 13 and 15.

IMPROVING HEALTH AND SANITATION THROUGH BETTER SOLID WASTE MANAGEMENT:

- Treating and recycling organic wastes to reduce odours and the spread of diseases from uncontrolled dumping;
- Preventing spread of diseases through collection and proper management of organic waste;
- Improving sanitation and hygiene through decentralised and local treatment of organic and sewage waste;
- Protecting water bodies; and
- Reducing the carbon load of wastewater to reduce impact on water bodies.

ECONOMIC DEVELOPMENT AND JOB CREATION:

- Generating short-term construction employment and long-term equipment manufacturing and maintenance employment, as well as plant operations employment;
- Encouraging growth of new enterprises by providing reliable electricity that can be stored and used when needed, i.e. baseload energy;
- Generating employment in the waste sector by collecting food and other biogenic wastes separately and through sales of digestate; and
- Improving quality of life in marginal farming communities and reducing migration from these by improving crop yields and sanitation, lighting and heating.

In addition to contributing to the UN SDGs, AD of food waste has the following advantageous characteristics:

- **DIVERSE AND LOCAL FEEDSTOCK** – AD is a flexible process and can take multiple, locally available feedstocks in varying quantities, including household food waste, abattoir waste, brewery slops, fruit waste and palm oil mill effluents. It must be noted that some operational aspects of a biogas plant need to be adjusted for variation in feedstock to sustain the biological process and optimum gas production.

- **FLEXIBILITY OF SCALE** – AD has no minimum scale of implementation and its maximum scale is limited only by the amount of feedstock available within feasible distances. AD can provide anything from cooking gas for one family to baseload energy for a manufacturing facility, depending on the size of the plant and feedstock. It can be implemented to digest food waste of a family, community, restaurant, industry or city.

- **FLEXIBLE USE OF BIOGAS** – Biogas can be utilised in a way that is most beneficial for the generator. If the plant is built onto a distillery, biogas produced can be used to generate heat; if the plant is run on municipal food waste, then the biogas can be upgraded and used as fuel for collection vehicles or local public transport buses; if there is a need for electricity, the best use may be generation of electricity via a CHP engine.

- **MULTIPLE REVENUE STREAMS** – Each of the products and by-products of AD – electricity, heat, cooling, biomethane, carbon dioxide, digestate and elemental fertiliser – can be a revenue stream. For example, a biogas plant employing a CHP engine can generate income or reduce expenditure from the electricity and heat generated and the digestate produced. Similarly, a biogas plant upgrading biogas to biomethane can generate income from the biomethane and also potentially from carbon dioxide and digestate.

5.1.5. Examples of existing AD plants in city contexts

AD of food waste is an established technology. It has been implemented widely for the treatment of food waste and wastewater streams from sewage. Selected global examples are cited below[5,6,7].

- RESIDENTIAL FOOD WASTE – Munich (Germany), Milan (Italy), Forbach (France), Madrid (Spain), Vienna (Austria), Upsala (Sweden), Oslo (Norway)[8], Zurich (Switzerland), Wijster (the Netherlands), Hinjewadi, Pune (India)[9], Malur (India)[10,11].
- COMMERCIAL FOOD WASTE – Bernau (Germany), Hartberg (Austria), Skrzatusz (Poland)[12], London (UK)[13], Chennai (India)[14], Chiba (Japan)[15].
- FOOD AND DRINKS PROCESSING INDUSTRY
  - BREWERIES – Heineken (Nigeria), SABMiller (Uganda) AB InBev (Russia), Diageo (Kenya, Ghana), Beer Thai (Thailand)[16], Khon Kaen Brewery (Thailand)[17], Brakina Brewery (Burkina Faso)[18];
  - ABATTOIRS – Jan Kempdorp Abattoir (South Africa)[19], Grossfurtner St Martin (Austria)[20];
  - FRUIT AND VEGETABLE PROCESSING – Bonduelle (Hungary)[21];
  - DAIRY PROCESSING – Lactalis Retiers (France), Danone (Belgium), Amul Dairy (India)[22]; and
  - CONFECTIONARY – Mars, Veghel (Poland)[23].
- MUNICIPAL WASTE WATER WITH FOOD WASTE – Riihimaki (Finland)[24], Ulsan (South Korea)[25], Radeberg (Germany)[26], Sheboygan Regional Wastewater Treatment Facility, Wisconsin, the West Lafayette Wastewater treatment facility, Indiana (USA)[27].

5.2. The Process of AD

5.2.1. Description of biogas plant processes

A biogas plant treating food waste will consist of a reception area, where the food waste from various sources is received. The waste will reside in the reception area for some hours whilst it is loaded into the next stage - pre-treatment.

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[5]Bin2Grid (2016) Good practice on segregated collection of food waste **http://www.bin2grid.eu/documents/73603/136534/D2.1_Good+practice+on+segragated+collection+of+food+waste.pdf**

[6]Bin2Grid (2016) factsheets on Good Practice of Biogas upgrade **http://www.bin2grid.eu/documents/73603/136970/Eng_Bin2Grid_revision.pdf/2dbe8c8b-1656-4336-8438-a15fcd632331**

[7]Waterleau (2014) Environmental solutions for the food and beverage industry **http://barley-malt.ru/wp-content/uploads/2014/03/food-and-beverage_eng.pdf**

[8]City of Olso (not dated) Circular economy in practice **https://www.oslo.kommune.no/english/politics-and-administration/green-oslo/best-practices/circular-economy-in-practice/#gref accessed on 27/02/2018**

[9]Indian Biogas Association (2017) Biogas Magazine 03 **https://biogasindiantechassociation.app.box.com/v/Biogas-Magazine-E03**

[10]Mantri G (2017) How this Bengaluru company is leading the way in turning wet waste into green fuel **https://www.thenewsminute.com/article/how-bengaluru-company-leading-way-turning-wet-waste-green-fuel-71908**

[11]Kakkar H (2017) Good Businesses 2017: Maters of Waste **https://www.outlookbusiness.com/specials/good-businesses_2017/masters-of-waste-3744**

[12]FABbiogas. Best Practice: Biogas plant in Skrzatusz, Wielkopolska **http://www.fabbiogas.eu/fileadmin/user_upload/Download/D3.2_factsheet_Skrzatusz_english.pdf**

[13]Xergi Case Study: Willen Biogas **https://www.xergi.com/cases/willen-biogas.html Accessed on 05/03/18**

[14]Ministry of New and Renewable Energy (2017) Akshay Urja Newsletter Volume 10 Issue 4&5 **http://mnre.gov.in/file-manager/akshay-urja/january-april-2017/EN/Images/41-43.pdf**

[15]Global Environment Centre (2012) Waste recycling technologies adopted in Eco-towns in Japan **http://nett21.gec.jp/Ecotowns/WRT_Eco-towns.pdf**

[16]Beer and Brewer magazine (2011) Asian breweries realise the overlooked green energy potential of waste water **http://www.globalwaterengineering.com/media/Asian_breweries_realise_the_overlooked_green_energy_potential_of_waste_water.pdf**

This generally involves maceration of the feedstock, screening and pressing. Packaging, such as plastic bags, is stripped out, while any metallic items such as cutlery may be removed using magnetic devices to prevent damage to moving parts. In addition, grit (such as glass, egg shells, ceramics, bones and sand) may need to be removed at the pre-treatment stage, if the digester does not have an internal capability of extracting these. If not removed, grit may build up at the bottom of the tank over a period of time leading to loss of volume and failure of the system.

After the pre-treatment process, the food waste is fed to the digester where it undergoes decomposition in the absence of oxygen. This process can take place at different operating temperatures and system set-ups (discussed further below). During this process, biogas is released and collected in biogas storage tanks or in an inflatable dome. To reduce the sulphur content in biogas, it is piped to a desulphurisation unit. The biogas, which is rich in methane, may be processed further depending upon the desired end use: electricity, heat, cooling or vehicle fuel. Within the digester, the organic material that is left over after digestion, or digestate, is extracted and may then undergo pasteurisation, followed by composting or separation of wet and dry solids for application to agricultural land, depending on the use and regulations of the jurisdiction.

The AD process is shown in Figure 8 below:

Figure 8: The AD process – inputs, outputs and processes

[17] *Envirex Thailand brewery installs wastewater treatment plant, generating biogas and reducing sludge volume* ***http://www.evoqua.com/en/brands/Envirex/Pages/boon-rawd-brewery-thailand-cd.aspx Accessed 17/12/2017***

[18] *FasoBiogaz (2015) General information* ***http://www.fasobiogaz.com/wp-content/uploads/2017/05/FasoBiogaz_General-information.pdf***

[19] *Global Methane Initiative (2013) Successful applications of anaerobic digestion from across the world* ***https://www.globalmethane.org/documents/GMI%20Benefits%20Report.pdf***

[20] *Fab Biogas. Best-Practice: Biogas Plant in St Martin, Upper Austria.* ***http://www.fabbiogas.eu/fileadmin/user_upload/Download/D3.2_factsheet_St.Martin_english.pdf***

[21] *Veolia. Europe's leading producer of canned goods reduces its energy bill thanks to biogas.* ***https://www.veolia.com/en/our-customers/achievements/industries/food-beverage/hungary-bonduelle. Accessed on 17/12/2017.***

[22] *Ministry of New and Renewable Energy (2017). Newsletter Jan-April 2017.* ***http://mnre.gov.in/file-manager/akshay-urja/january-april-2017/EN/Images/41-43.pdf.***

[23] *Veolia. Mars turns its wastewater into clean energy.* ***https://www.veolia.com/en/our-customers/achievements/industries/food-beverage/netherlands-mars. Accessed on 17/12/2017.***

[24] *Watrec. Solution to Circular Economy's biowaste challenge.* ***http://www.watrec.com/references/our-projects/biogas-plants/riihimaki-biogas-plant/. Accessed on 17/12/2017.***

[25] *Kang Ho (2013). IEA Task 37 South Korea Country Report.* ***http://task37.ieabioenergy.com/country-reports.html.***

[26] *Fab Biogas. Best-Practice: Biogas Plant in Radeberg, Germany.* ***http://www.fabbiogas.eu/fileadmin/user_upload/Download/D3.2_factsheet_Radeberg_GER_english.pdf.***

[27] *U.S. EPA (2014). Food Waste to Energy: How Six Water Resource Recovery Facilities are Boosting Biogas Production and the Bottom Line* ***https://www.epa.gov/sites/production/files/2016-07/documents/food_waste_to_energy_-_final.pdf.***

5.2.2. Within the digester

Many different types of anaerobic digesters are available. These vary in configuration, retention time, pre- and post-treatment requirements and operating temperature among other things, depending upon the principal feedstocks being treated. During AD, the breakdown of organic compounds is achieved by a combination of many types of bacteria and archaea (microbes).

The biomass added to the digester is broken down into sugars, amino acids and fatty acids (hydrolysis), fermented to produce volatile fatty acids and alcohols (acidogenesis) followed by the conversion into hydrogen, carbon dioxide and ammonia and, finally methanogens produce biogas from acetic acid and hydrogen. These stages are shown in Figure 9 below[28].

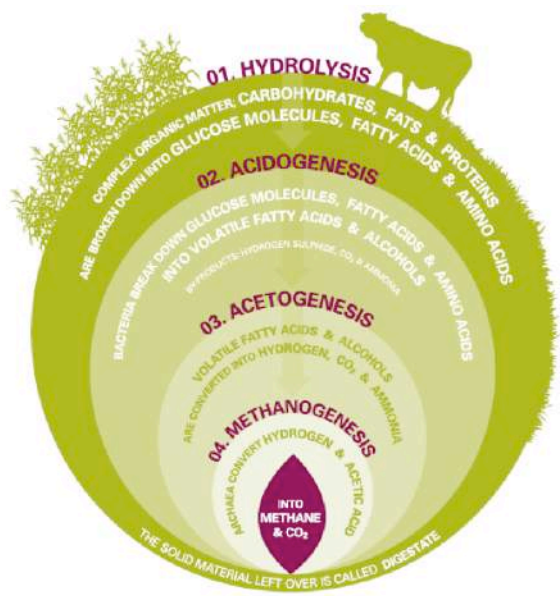

Figure 9: The four stages of the AD process

AD of food waste takes place at two optimum temperature ranges, 35-40°C (mesophilic) and 55-60°C (thermophilic)[29]. Most food waste AD plants around the world operate in the mesophilic range as less heat is required to maintain that temperature and also the digestion process is more stable under these conditions; examples are plants in London, UK[30], the town of Hartberg, Austria, and city of Milan, Italy[31].

Thermophilic reactors, though requiring greater attention to operate, are sometimes installed as they accelerate degradation rates, creating higher yields of biogas and reduce pathogens in the digestate produced.

[28] *ADBA (2017). The Practical Guide to AD (Second Edition).* ***http://adbioresources.org/library/purchase-the-practical-guide-to-ad.***

[29] *ADBA (2017). The Practical Guide to AD (Second Edition).* ***http://adbioresources.org/library/purchase-the-practical-guide-to-ad.***

[30] *Agrivert. North London AD Facility.* ***https://www.agrivert.co.uk/where-we-operate/north-london-ad-facility.***

[31] *Bin2Grid (2016). Good practice on segregated collection of food waste.* ***http://www.bin2grid.eu/documents/73603/136534/D2.1_Good+practice+on+segragated+collection+of+food+waste.pdf.***

Thermophilic digesters are in operation in, among others, the cities of Augsburg (Germany), Forbach (France) and City of Zurich (Switzerland). These digest municipal, commercial and industrial food waste as well as green waste[32]. Hermitage Municipal Authority (USA) co-digests food waste with wastewater[33].

5.2.3. Digester configurations

Based on the constituents and consistency of the food waste treated, an anaerobic digester can be designed as a 'wet', 'dry', 'liquid' or 'co-digestion' system. Figure 10 provides information about these configurations[34].

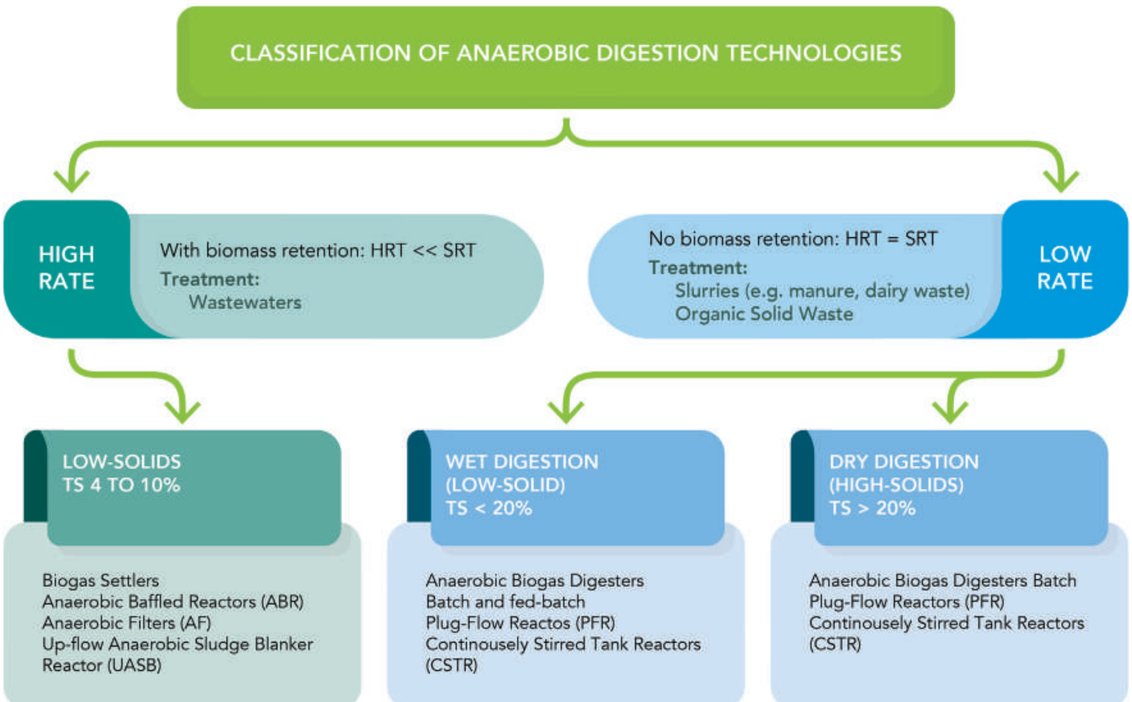

Figure 10: Different types of AD technology (HRT: Hydraulic Retention Time, SRT: Solids Retention Time)

Wet Digestion

Wet digestion is suitable for AD of most food wastes such as source segregated food waste collection from residents, commercial and industrial organic wastes from supermarkets, food processing plants and food services. Digestion of food waste in a wet system may take place in a CSTR (Completely/Continuously Stirred Tank Reactor) digester, a term often misused for a displacement digester, where a small volume of fresh feed is input to displace an equal amount of digestate exiting from the outlet. The feedstock contains typically less than 15% dry solid matter but can be up to 20%. In a CSTR digester, all stages of the AD, namely hydrolysis, acidification and methanogenesis, occur in parallel. These are the more common, cylindrical shaped digesters.

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[32]*Bin2Grid (2016). Factsheets on good practice of biogas upgrade.* **http://www.bin2grid.eu/documents/73603/136970/Eng_Bin2Grid_revision.pdf/2dbe8c8b-1656-4336-8438-a15fcd632331.**

[33]*Waste Management World (2016). VIDEO: Food Waste Co-Digestion a Success at Pennsylvanian Wastewater Plant.* **https://waste-management-world.com/a/video-food-waste-co-digestion-a-success-at-pennsylvanian-wastewater-plant.**

[34]*Spuhler D (not dated) Anaerobic Digestion (General)* **https://www.sswm.info/sswm-university-course/module-6-disaster-situations-planning-and-preparedness/further-resources/anaerobic-digestion-%28general%29**

Plug flow digesters, on the other hand, treat food waste entering the system as a distinct unit that undergoes the various stages of AD sequentially, with little or no mixing. While horizontal plug flow systems operate within the 25-40% dry solids range, vertical systems can treat feedstock with 45-50% dry solids. These are more efficient than the CSTR as reactions take place under closer to optimum conditions and there is less likelihood of untreated feedstock leaving the digester.

In multistage systems, the processes of AD take place sequentially in multiple tanks. Typically, the acidogenesis stage of the process is carried out in one tank while the methanogenesis stage in another. This accounts for the different pH levels and process times required during these two stages for optimum biogas production, resulting in smaller digester volume or higher biogas yield. Wet digestion can take place under either mesophilic or thermophilic conditions.

Dry Digestion

Dry digestion is most suitable for organic waste with a higher component of solids such as food waste that is collected along with garden waste. It is a minimal disruption option for composting plants looking to upgrade or upscale their operations or who wish to improve odour or space management.

Static dry digestion systems work under mesophilic conditions and are designed like garages (i.e. a simple concrete room with a door), where new feedstock is mixed in with the digestate from the previous batch to provide microorganisms to start the digestion process. Factoring in the recirculation, the hydraulic retention time is about 50 days. While there is little pre-treatment required for dry digestion, post digestion it is important to remove contaminants like plastic, metals and ceramics, stabilise the digestate to minimise emissions and run-off, and potentially pasteurise it to reduce pathogens, to obtain an organic soil amendment that is nutritionally high and does not pose a risk to plant and human health or the environment.

Examples of towns where dry digestion has been implemented include San Jose (USA)[35], Munster (Germany)[36], Munich (Germany)[37] and Busan (South Korea)[38]. It is a good option for emerging economies where the contamination rates in source segregated food waste may be difficult to control and reduce.

Liquid Digestion

Liquid digestion is most suited for food and drink industries which generate large volumes of wastewater with low suspended solids such as effluent from breweries, sugar factories, drinks factories, starch factories, potato processing and confectionary manufacturing. Some examples from around the world are noted in Section 5.1.5. These systems typically have low hydraulic retention times of less than two days by forming a granular microbial

[35] *U.S. EPA. Zero Waste Case Study: San Jose.* **https://www.epa.gov/transforming-waste-tool/zero-waste-case-study-san-jose.**

[36] *Organic Waste Systems. DRANCO plant Munster Germany.* **https://www.youtube.com/watch?v=mk22oKWYPcQ&feature=youtu.be.**

[37] *Abfallwirtschaftsbetrieb München. Renewable Energy for Munich – Green Electricity from Biowaste.* **https://www.awm-muenchen.de/fileadmin/PDF-Dokumente/awm/Folder_TFA_2012_englisch_fin_72dpi.pdf.**

[38] *Korea Environmental Industry and Technology Institute. Electric power production technology with food waste.* **http://www.eiskorea.org/01_EnvironmentalTech/01_newTech_down.asp?schMenuCode=M9300&schTabCode=&strIdx=805&strFileIdx=1&schCom=&schSearch=&intPage=1.**

structure around a fixed membrane to maintain a high density of microbes and microbial activity. Thereafter, the process is similar to that explained above for wet digestion, biogas is utilised for energy and digestate is transported for utilisation on land.

Co-digestion

Cities can benefit from the possibility of treating their food waste along with wastewater sludge from sewage plants, where environmental regulations allow. Such co-digestion of different waste streams appears to be on the increase because there are benefits to both parties. Wastewater treatment plants or recovery facilities which typically have high energy requirements benefit from the high energy value of food waste while food waste collectors benefit from any excess capacity of the wastewater treatment plants and lower capital cost of upgrading existing facilities – the economies of scale of larger sites. Together these make the AD of both food waste and wastewater sludge environmentally and economically more feasible.

There are a number of examples of co-digestion of wastewater sludge and food waste in the USA: the Central Marin Sanitation Agency, San Rafael, California; Sheboygan Regional Wastewater Treatment Facility, Wisconsin; West Lafayette Wastewater treatment facility, Indiana; and Janesville Wastewater Treatment facility, Wisconsin[39]. It has also been implemented in South Korea in many plants, including Yongyeon, Ulsan, Hyuncheon Goyang-si, Anrak Busan, Seobyun Daegu and Dongchun Incheon[40], Riihimaki, and Oulu in Finland[41], Zirl in Austria[42] and Radeberg in Germany[43].

Co-digestion of food waste with manure and other agricultural residues has also been implemented globally, though as these plants are generally situated in rural areas. These operations are not discussed further in this report, as the focus is on urban food waste.

5.2.4. Composition of biogas

Biogas is composed primarily of methane and carbon dioxide with trace amounts of nitrogen, hydrogen, oxygen, water vapour, hydrogen sulphide and ammonia. Table 3 shows typical ranges of these compounds in biogas[44].

TABLE 3: TYPICAL COMPOSITION OF BIOGAS FROM NORMALLY FUNCTIONING DIGESTERS

Compound	Chemical	Range %
Methane	CH_4	50 – 75
Carbon dioxide	CO_2	25 – 50
Nitrogen	N_2	0 – 10
Hydrogen	H_2	0.01 – 5
Oxygen	O_2	0.1 – 2
Water vapour	H_2O	0 – 10
Hydrogen sulphide	H_2S	10 – 30,000 ppm
Ammonia		0.01 – 2.5 mg/m^3

[39] *U.S. EPA (2014). Food waste to energy: How six water resource recovery facilities are boosting biogas production and the bottom line.* **https://www.epa.gov/sites/production/files/2016-07/documents/food_waste_to_energy_-_final.pdf.**

[40] *Kang Ho (2013). IEA Task 37 South Korea Country Report.* **http://task37.ieabioenergy.com/country-reports.html**

[41] *Gasum.* **https://www.gasum.com/en/About-gas/biogas/Biogas-plants/. Accessed on 16/12/2017.**

[42] *FABBiogas (2015). Best Practice: Biogas Zirl, Tyrol, Austria* **http://www.fabbiogas.eu/fileadmin/user_upload/Download/D3.2_factsheet_Zirl_english.pdf**

[43] *FABbiogas (2015). Best Practice: Biogas plant in Radeberg, Germany* **http://www.fabbiogas.eu/fileadmin/user_upload/Download/D3.2_factsheet_Radeberg_GER_english.pdf**

[44] *ADBA (2017). The Practical Guide to AD (Second Edition).* **http://adbioresources.org/library/purchase-the-practical-guide-to-ad.**

The methane in biogas is energy rich and combustible. It is the constituent responsible for its energy content and varies depending on feedstock. Hydrogen sulphide in the biogas is highly toxic and can cause corrosion of plant equipment. Water vapour interferes with pipework, gas flow and combustion of biogas. Therefore, both are undesirable and are removed from the biogas before it is used. Desulphurisation and drying of biogas are now standard procedures and are needed to achieve the full expected lifespan of the equipment.

The ammonia present in the biogas is also flammable and toxic to humans. When biogas is combusted, ammonia is converted into nitrous oxide which is a greenhouse gas. However, it is present in very small quantities and if its percentage rises, it interferes with the digestion process itself and is hence managed during the AD process. Another impurity which is sometimes found in biogas is siloxanes. Siloxanes are produced from AD of materials found in soaps and detergents. On combustion, these form silicon dioxide and cause build-up of matter on the engine and exhaust gas surfaces. Hence, processes must be in place to either avoid feedstock with siloxanes or biogas must be treated to remove them to maintain the efficiency of the equipment.

The extent to which cleaning is required varies with the equipment needed for the utilisation of biogas. A rough guideline is provided in Table 4[45].

TABLE 4: REQUIREMENTS TO REMOVE COMPONENTS DEPENDING ON BIOGAS UTILIZATION

Application	H_2S	CO_2	H_2O	Siloxanes
Boiler	< 1000 ppm	No	No	No
Cooker	Yes	No	No	No
Stationary engine	< 250 ppm	No	No	Yes
Vehicle fuel	Yes	Recommended	Yes	No
Natural gas grid	Yes	Yes	Yes	Eventually

5.2.5. Biogas production relative to feedstock inputs

The rate and quantity of biogas production depends upon a number of factors including the proportion of digestible volatile solids in the feedstock, the operating temperature and hydraulic retention time of the digester and the digestion technology used. Table 4 gives examples of food waste feedstocks and indicative values of biogas that can be produced, and what they mean in terms of the amount of electricity generated or the distance that can be travelled by different vehicle types when running on biomethane produced from one tonne of food waste feedstock[46,47,48].

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[45] *ADBA (2017). The Practical Guide to AD (Second Edition).* ***http://adbioresources.org/library/purchase-the-practical-guide-to-ad.***

[46] *ADBA (2017). The Practical Guide to AD (Second Edition).* ***http://adbioresources.org/library/purchase-the-practical-guide-to-ad.***

[47] *Zafar S (2015) Biogas from slaughterhouse waste* ***https://www.bioenergyconsult.com/biogas-from-slaughterhouse-wastes/ Accessed on 26/02/2018***

[48] *Fuel economy for double-decker gas bus: 2Km per kg; fuel economy for Scania 18T rigid gas truck: 3.8Km per kg – both provided by Scania Group; fuel economy for CNG car: 5.6kg/100km* ***(http://www.cng4you.cz/en/how-much-is-it/calculator.html)***

With all waste streams, the purity of the waste will determine its performance inside the digester. Contamination from plastics, glass, sand or gravel will slow down the process, reduce gas yields and lead to increased cleaning and maintenance of the plant. It is therefore necessary to stress the need for clean feedstocks to maximise plant operations and biogas yields.

TABLE 5: EXAMPLES OF FOOD WASTE FEEDSTOCK, THEIR BIOGAS POTENTIAL AND ALTERNATIVE USES

Food waste feedstock source	Biogas produced (m^3/wet tonne)	Distance travelled by different vehicles when running on biomethane produced from 1 tonne of feedstock (km)			Electricity generated (MWhe/ tonne)
		Car	Double-decker bus	Heavy goods vehicle	
Potatoes (18%-20% TS)	100-120	872	98	186	0.27
Bread	400-500	3,567	400	759	1.09
Cheese	>600	4,756	533	1,012	1.45
Vegetables	50-80	515	58	110	0.16
Mixed food (e.g. supermarket, restaurant)	75-140	852	95	181	0.26
Molasses (80-90% TS)	450-579	4,079	457	868	1.24
Brewery waste (20% TS)	60-100	634	71	135	0.19
Abattoir waste	120-160	1,110	124	236	0.34

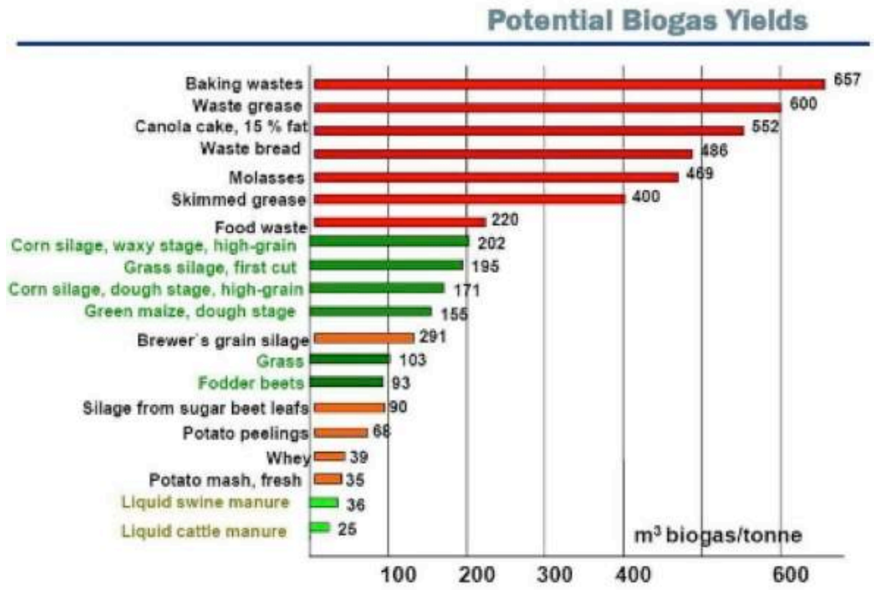

Figure 11: Potential Biogas yields[49]

5.2.6. Biogas utilisation

As discussed previously, biogas is the main product of AD and its energy can be used for the production of heat, light, electricity, cooling, or vehicle fuel. Each of these technologies are discussed in detail in Chapter 6.

5.2.7. Digestate production and use

For every tonne (1,000kg) of feedstock entering an AD plant, 900 to 950kg of digestate is produced, before any account is taken of water that may be added to the process to ensure the solid content of the digester is suitable for the process and technology. Digestate is rich in available nutrients and of significant value as a soil amendment for agricultural land, city landscaping and urban gardening (depending on the digestate quality and any local legislative requirements).

Depending on the consistency and the end use of digestate, digestate can be used either as a final product, or further treated into higher value products as shown in Figure 12 [50].

[49] *Bruce Dorminey (2012). Biogas Technology: "Cow Power" Catching On in US.* ***http://www.renewableenergyworld.com/articles/2012/04/biogas-technology-cow-power-catching-on-in-us.html. Accessed on 03/01/2018.***

[50] *FUCHS, W. and DROSG, B. (2013). Assessment of the state of the art of technologies for the processing of digestate residue from anaerobic digesters. Water Sci Technol. 2013, 67(9), 1984-1993*

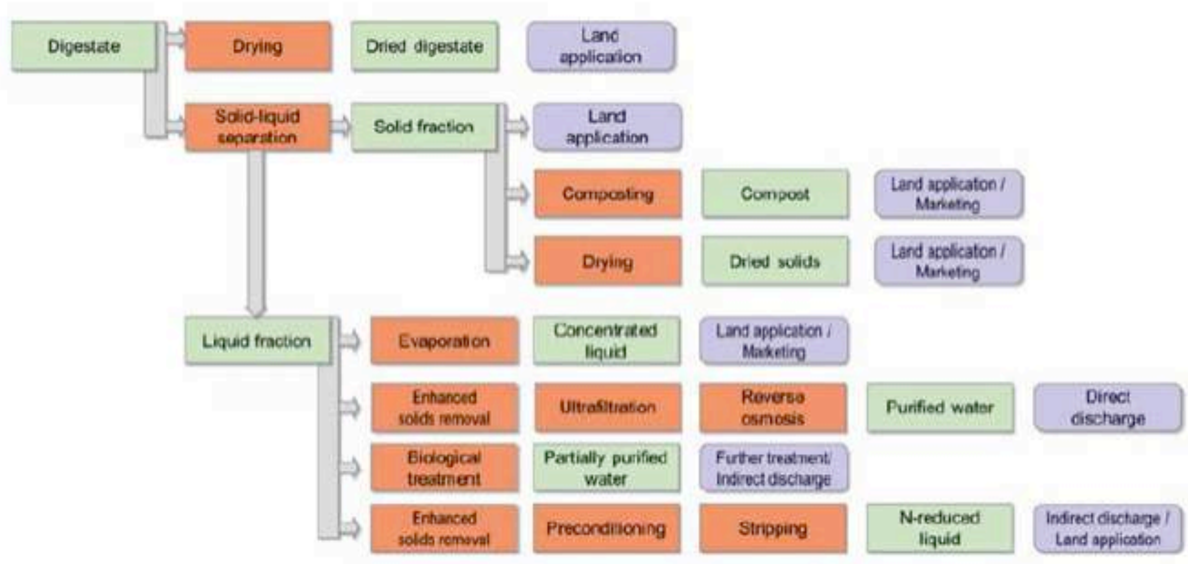

Figure 12: Overview of viable options for digestate processing

Digestate may be used whole or separated into solid and liquid parts. The solid fractions may be processed into compost and/or dried into dried solids for land application. The liquid fractions maybe concentrated into liquid fertiliser or partially treated and sent to a wastewater treatment facility or fully treated and discharged. When digestate is separated into liquor and fibre (>15% dry matter) fractions, soluble nutrients (in particular ammoniacal nitrogen and potash) remain mostly in the liquor, while phosphate remains mostly in the fibre.

The benefits and utilisation of digestate is discussed in detail in Chapter 6.

5.3. Financial considerations

The long-term financial sustainability of a food waste collection and digestion system heavily relies on having a sound financial model. The costs likely to be incurred in establishing the processes and infrastructure of food waste collection systems are discussed in Chapter 3. In this section, the turnkey cost of a food waste digestion plant is explored, the methods of financing it are discussed and the various potential income streams via sale of its products and benefits are considered.

5.3.1. Capital cost

The capital cost of developing an AD plant is the upfront investment required for:

- Feasibility study;
- Planning and permitting procedures;
- Purchasing of land/site for the plant;
- Connection to electricity and gas grids and water supplies;
- Connection to road systems to access plant;
- Connection to effluent treatment for wastewater (if applicable);
- Civil engineering works;
- Equipment for pre-treatment of feedstock such as macerator, de-packaging equipment and pasteuriser;
- Feeding technology including mixing pits, pumps and feeder;
- Digester equipment including steel/concrete tanks, mixer, heating circuits, sensors, cover and gas storage;
- Post digestion storage of digestate and gas storage;
- Equipment for biogas cleaning;
- Equipment for biogas utilisation including boilers, CHP engine, heat exchangers and upgrading technology;
- Digestate storage and treatment including tanks, separation or composting technology where applicable; and
- Machinery to move waste around the plant (mechanical diggers, forklifts, bulldozers and conveyor belts).

These costs vary with country-specific permitting procedures and regulations (e.g. on permitting, licensing, pasteurisation, digestate standards), the technology installed (e.g. level of automation, dry or wet digestion), size of the plant, condition of the incoming food waste, contractual arrangements between the operator and any construction companies and differing local costs of commodities such as steel and concrete. Chapter 6 discusses in detail the costs related to the use of biogas such as installing a CHP engine or upgrading technology and connecting to the respective grid, digestate treatment such as separation of liquid and solid fractions and other possible products and by-products of AD such as capturing carbon dioxide. Based on data available from the USA, Denmark, the UK and Italy, the capital cost for a 30,000 tonne per year capacity plant may be $400-$600/tonne of annual capacity. A larger 50,000 tonne plant may have a capital cost of $300-$400/tonne[51,52,53,54]. A 30,000 tonne annual capacity plant would therefore cost between USD 12 and 15 million. These are example costs only and a detailed feasibility study is required on a project-specific basis due to variability in pricing, as discussed earlier.

The breakdown for the capital costs is estimated as follows[55]:

- Up to 10% will go towards development costs, e.g., planning, designing, tendering process;
- 10-20% will go towards civil works including purchase of land for the site;
- 50-60% will go towards the building of the digester and associated mechanical and electrical equipment, e.g., the biology, digester, mixer, pre-treating the waste, dealing with the digester waste; and
- 20-30% will go towards the energy generation components. For gas-to-grid this includes the upgrading equipment, grid connection costs, injection, boiler, etc.

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[51] *Denmark Country report (2017)* ***http://task37.ieabioenergy.com/country-reports.html***

[52] *Department of Energy and Climate Change (2014) RHI Biomethane Injection to Grid Tariff review* ***https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/315608/Biomethane_Review_Final_-_FOR_PUBLICATION.pdf***

[53] *National Renewable Energy laboratory (2013) Feasibility study of anaerobic digestion of food waste in St. Bernard, Louisiana* ***https://www.nrel.gov/docs/fy13osti/57082.pdf***

Table 5 below gives select examples of food waste digesters that have been implemented around the world and their costs. As seen, the capital cost varies with the feedstock, country, year of construction and the end use of biogas and digestate. These examples have been compiled to give the reader an estimate of the order of magnitude of investment required.

TABLE 6: EXAMPLES OF FOOD WASTE DIGESTERS

Plant name/site	Country	Capacity (tonnes/yr)	Utilisation	Headline capital cost (USD)	Year
Harvest Energy Garden, Lake Buena Vista, Florida[56]	USA	130,000	Electricity and heat (CHP)	30,000,000	2014
UW-Oshkosh Urban Dry Digester, Oshkosh, Wisconsin[57]	USA	10,000	Electricity and heat (CHP)	4,700,000	2011
New Horizons Energy, Athlone, Cape Town[58]	South Africa	200,000	Biomethane	30,000,000	2017
Elgin Fruit Juices, Grabouw, Western Cape[59]	South Africa	20,000	Electricity and heat (CHP)	1,600,000	2013
Grossfurtner, St. Martin[60]	Austria	10,000	Electricity and heat (CHP)	2,100,000	2003
Biokraft, Hartberg[61]	Austria	7,000	Electricity and heat (CHP)	2,400,000	2004
AVA, Augsburg[62]	Germany	55,000	Biomethane-to-grid	20,000,000	2013
Ganser Umwelt, Munich[63]	Germany	30,500	Electricity	3,600,000	1997
Finsterwalkder Umwelttechnik, Bernau[64]	Germany	6,000	Electricity	1,700,000	2000
Agrivert, West London[65]	UK	50,000	Electricity	15,000,000	2014
Tamar, Hoddesdon[66]	UK	66,000	Electricity	19,500,000	2015
Boleszyn, Mazury[67]	Poland	43,900	Electricity and heat (CHP)	6,200,000	2012
Skrzatusz, Wielkopolska[68]	Poland	33,600	Electricity and heat (CHP)	6,200,000	2012

[54] *Dr Confaloneiri A and Dr Ricci M (2017) communication with Italian Composting and Biogas Association* ***https://www.compost.it/***

[55] *Department of Energy and Climate Change (2014) RHI Biomethane Injection to Grid Tariff review* ***https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/315608/Biomethane_Review_Final_-_FOR_PUBLICATION.pdf***

[56] *American Biogas Council (2014) Biogas project profile: Harvest Energy Garden – Central Florida* ***https://www.americanbiogascouncil.org/projectProfiles/lakeBuenaVistaFL.pdf***

[57] *American Biogas Council (not dated) Biogas project profile: UW-Oshkosh Urban Dry Digester* ***https://www.americanbiogascouncil.org/projectProfiles/oshkosh_wi.pdf***

[58] *GreenCape (2017) The business case for biogas from solid waste in the Western Cape* ***https://www.greencape.co.za/assets/Uploads/GreenCape-Biogas-Business-Case-Final.pdf***

[59] *GreenCape (2017) The business case for biogas from solid waste in the Western Cape* ***https://www.greencape.co.za/assets/Uploads/GreenCape-Biogas-Business-Case-Final.pdf***

[60] *Fab Biogas. Best-Practice: Biogas Plant in St Martin, Upper Austria.* ***http://www.fabbiogas.eu/fileadmin/user_upload/Download/D3.2_factsheet_St.Martin_english.pdf***

[61] *Bin2Grid (2016) Good practice on segregated collection of food waste* ***http://www.bin2grid.eu/documents/73603/136534/D2.1_Good+practice+on+segragated+collection+of+food+waste.pdf***

[62] *Bin2Grid (2016) Factsheets on good practice of biogas upgrade* ***http://www.bin2grid.eu/documents/73603/136970/Eng_Bin2Grid_revision.pdf/2dbe8c8b-1656-4336-8438-a15fcd632331***

[63] *Bin2Grid (2016) Good practice on segregated collection of food waste* ***http://www.bin2grid.eu/documents/73603/136534/D2.1_Good+practice+on+segragated+collection+of+food+waste.pdf***

[64] *Bin2Grid (2016) Good practice on segregated collection of food waste* ***http://www.bin2grid.eu/documents/73603/136534/D2.1_Good+practice+on+segragated+collection+of+food+waste.pdf***

[65] *WBA member data (ADBA)*

[66] *WBA member data (ADBA)*

[67] *Fab Biogas. Best-Practice: Biogas Plant in Boleszyn, Poland.* ***http://www.fabbiogas.eu/fileadmin/user_upload/Download/D3.2_factsheet_Boleszyn_english.pdf***

[68] *Fab Biogas. Best-Practice: Biogas Plant in Skrzatusz, Wielkopolska, Poland* ***http://www.fabbiogas.eu/fileadmin/user_upload/Download/D3.2_factsheet_Skrzatusz_english.pdf***

5.3.2. Financing an AD plant

Based on the nature, scale and objectives of a food waste digestion project, funding may be accessed via private capital, venture capital, banks, governments, international agencies or funds or a combination of these. Some of these sources are listed below[69]. These vary considerably for each project and all available resources should be evaluated for a sound and sustainable financial model:

PRIVATE SECTOR
- Public Private Partnerships – joint ventures/ partial divestures, construction/service contracts, lease agreement, concession
- Infrastructure Investment Funds
- Privatisation/full divesture
- Private risk mitigation
- Crowdfunding
- Corporate and municipal bonds

INTERNATIONAL ORGANISATIONS
- Green and Climate Funds
- Concessional Loans
- Export agencies
- Partial financing – partial loans, viability gap funding, challenge funds, technical assistance grants
- Sharia compliant finance
- Public risk mitigation

PUBLIC SECTOR
- Capital grant schemes
- Municipal development funds
- Development Financing Institutions

OTHER SCHEMES
- Tax exemptions
- Pooled financing
- Viability gap funding
- Public risk mitigation

The cost of financing will depend upon the source of financing and may vary considerably. As in any industrial enterprise, funders will often be looking for a specific rate of return on a project, which is weighed against the risk of the project, before deciding whether to invest.

5.3.3. Operating costs

Operating costs consist of staff costs, equipment maintenance and replacement, parent company overheads, specialised consultancy, testing costs and the disposal cost of de-packaged and contaminated materials (e.g., plastic, metal), energy and water consumption, machinery fuel and machinery maintenance and repairs. Excluding any cost of de-packaged and contaminated material, the operating cost may be \$35-\$55/tonne for a 30,000 tonne per year plant and \$30-\$45/tonne for a 50,000 tonne per year plant [70,71,72].

The disposal cost for de-packaged and contaminated material depends on the amount produced and the waste facilities these are taken to.

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[69] James Alexander, City Finance Programme, C40 Cities – Presentation at CCAC Waste Initiative Global Workshop for City Leadership, 28th September 2017, Baltimore, USA.

[70] Department of Energy and Climate Change (2014). RHI Biomethane Injection to Grid Tariff Review. ***https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/315608/Biomethane_Review_Final_-_FOR_PUBLICATION.pdf.***

[71] Denmark Country report (2017). ***http://task37.ieabioenergy.com/country-reports.html -*** *EUR/GJ figure quoted, converted to \$/tonne of feedstock based on assumption of 30,000 tonnes per annum average plant size.*

[72] NREL (2013). Feasibility Study of Anaerobic Digestion of Food Waste in St. Bernard, Louisiana. ***https://www.nrel.gov/docs/fy13osti/57082.pdf.***

5.3.4. Income

The primary income generated from AD is from the sale of electricity, heat or biomethane produced from the biogas. In addition, there may be income from receiving gate fees for accepting the incoming waste, sale of digestate as organic fertiliser and various government support schemes relating to the production of renewable energy. Income can also be measured in terms of avoided costs. A waste collection operator or municipality currently discharging food waste to landfill or incineration will usually face a landfill gate fee (see below) to dispose of the waste. In more economically developed nations a landfill gate fee will often be that imposed by the landfill operator which covers the cost of landfill management; plus, a landfill tax imposed by State or regional authorities, imposed as a disincentive to tipping at landfill. Landfill gate fees vary enormously from region to region and within countries. To take one example, the landfill tax fee in the United Kingdom is £86/tonne on top of which the landfill management fee is added. Landfill costs therefore usually exceed £120/tonne of waste discharged (2017 figures). Discharging source segregated waste at an AD plant in the UK can cost as little as £30/tonne, leading to a saving for the waste collection operator of £90/tonne.

These savings can help pay for the cost of implementing segregated food waste collections.

In less economically developed countries, landfill gate fees can vary from zero upwards. Landfills in Brazil typically charge a tipping fee of less than US$20/tonne [73] whilst open dumping at zero cost is also rife.
The revenue streams are discussed in detail in the following section.

Tipping or Gate Fees

A 'tipping fee' or 'gate fee' is a fee that may be charged by food waste digester operators, energy-from-waste plants or landfill operators for responsibly disposing of the organic waste generated. The fee may be charged by the weight or volume of waste received and this may vary according to purity, quality, biogas production potential and quantity.

Typically, a gate fee will have to be priced to compete with other forms of treatment. Where zero gate fees apply to open and uncontrolled dumping of waste, charging a gate fee for treatment in an AD plant may be difficult. In fact, no recovery or recycling operation can compete with the zero cost of open dumping, the environmentally worst option for any waste.

Where landfill gate fees are applied, often these determine the charges an AD plant may implement. Clearly, regulations to avoid food waste being disposed of at landfills are needed to ensure this waste is delivered to recovery plants. Taxes on landfill disposal and landfill bans on food waste are examples of policies which can be used (see Chapter 7).

Sale and utilisation of electricity

Currently the most common form of income generation for biogas plants is the sale of electricity generated via an internal combustion CHP engine. The electricity generated is often first used to meet the electricity demand of the biogas plant itself (this is called its 'parasitic load'). The excess may then be sold to neighbouring enterprises via micro-grids or to a bigger utility via a grid connection.

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[73] *Ribeiro S G (2010) Waste Management in Brazil* ***http://www.seas.columbia.edu/earth/wtert/meet2010/Proceedings/presentations/GUERREIRO.pdf***

The electricity generated may be sold to the utilities or traders at the wholesale price that applies to any generator whether from renewable or fossil sources. Prices for the sale of electricity will be determined by local factors and markets. In free market conditions these will rise and fall according to market demand and supply, both locally and nationally.

In other situations, local energy costs are dictated by political rather than market factors, which can maintain, for example, lower prices than free market conditions would otherwise create. Controlled and subsidised markets are unattractive for new energy producers and partially explain the failure to take up new renewable energy technologies in these countries. A map of global energy subsidies along with the explanation of their consequences is available from the International Monetary Fund [74].

Beyond the sales price of the electricity itself into a local market grid, the electricity produced via digestion of food waste is renewable and has additional benefits for the environment and society. This fact has been acknowledged by some city, state and national governments who have tried to incentivise generation of renewable electricity or stimulate this via regulatory requirements and direct cash back schemes such as the feed-in tariff. Here, renewable energy producers are paid above market prices, which is achieved by adding an amount to the consumers' final electricity bill, which is then paid to those renewable producers. Market-based mechanisms such as tradable renewable energy certificates are also widespread. Under these market-based systems, generators of energy (such as utility companies) are obliged to source a certain percentage of their production from renewable energy sources, including biogas in some cases. The generators of renewable energy are given a certificate for every unit of energy produced. This certificate can be used to meet their own renewables obligations or traded with other generators who are short of meeting their renewables obligation. These certificates therefore acquire a monetary value and create a source of income for the renewable energy generator that allows them to charge a higher than market price for the biogas produced.

Chapter 7 discusses the various regimes of incentives used to stimulate the growth of renewable biogas production as part of a policy options review. In brief, both feed-in tariffs and renewable energy certificates have been widely used all around the globe. Feed-in tariffs for renewable energy production are implemented in more than 100 countries/states for many different sources of renewable energy production; however relatively few include energy from biogas[75] within those frameworks. Renewable energy certificates have been implemented in countries like Australia[76] and the USA[77]. The UK has transitioned from the certificates to a feed-in tariff policy.

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[74] *Gasper V (2015). How large are global energy subsidies?* ***http://www.imf.org/en/News/Articles/2015/09/28/04/53/sp051815. Accessed on 04/01/2018.***

[75] *Renewable Energy Policy Network for the 21st Century (2017). Renewables 2017: Global Status Report.* ***http://www.ren21.net/wp-content/uploads/2017/06/17-8399_GSR_2017_Full_Report_0621_Opt.pdf.***

[76] *Clean Energy Regulator, Australian Government (2017). REC Registry.* ***https://www.rec-registry.gov.au/rec-registry/app/home.***

[77] *United States Environmental Protection Agency (2017) Green Power Markets* ***https://www.epa.gov/greenpower/green-power-markets***

Sale and utilisation of heat

Of the energy potential of biogas produced, typically 35-40% is captured in the form of electricity while much of the rest can be captured as heat via a CHP engine. Similar to the electricity generated, the heat produced is first used to meet the heat demands of the digester, for example for maintaining feedstock temperature or pasteurisation. The excess heat generated may be used for heating onsite buildings or processes to save costs, or exported and sold for additional revenue for district heating, food processing, greenhouses, aquaculture or drying of cereals/ spices, among many other uses[78]. Capturing heat from biogas, and being able to monetise it, is critical to the long-term financial feasibility of a biogas plant. Given the benefits of renewable heat generation from AD, various incentive schemes have been implemented in Europe. The UK has incentivised heat production via a cash back scheme known as the Renewable Heat Incentive while Austria, Estonia, Finland and the Netherlands support heat production via feed-in premium schemes. Under feed-in premium schemes the generator of heat may be compensated for the price difference between wholesale and renewable heat generation prices or by a fixed additional payment for use of CHP[79]. These incentives for heat are less common than those for electricity due to challenges in the transmission and utilisation of heat.

Sale of upgraded biogas or biomethane

The biogas produced during AD of food waste may be upgraded to remove carbon dioxide, sulphur gases and water, and match the properties of natural gas or renewable natural gas. Biomethane can be bottled[80], injected into the gas grid or transported via tank trucks to be used as natural gas substitute in gas grids, for industrial purposes or for use as transport fuel including in passenger cars, buses, heavy goods vehicles and waste collection trucks.

While upgrading biogas to biomethane has a higher upfront cost than installing a CHP engine, it may be a more viable option in countries where an extensive gas distribution network is already available, like UK, Italy, Belgium and the Netherlands, or where there is infrastructure to support and fuel natural gas vehicles, such as in Sweden. In some countries, governments are further incentivising the upgrade to biomethane by offering financial incentives such as Renewable Heat Incentive in the UK[81], tax exemptions offered in Sweden[82] or the Stimulering Duurzame Energieproductie (SDE+), an operating grant in the Netherlands[83] to stimulate the adoption of digestion of organic waste.

Monetising GHG emissions

Digestion of food waste results in mitigation of greenhouse gas emissions. Quantifying and monetising this mitigation potential will depend on the business-as-usual scenario in the local context and can create additional revenue streams and stimulate deployment of capacity. Table 6 below gives indicative values of the greenhouse gases mitigated if the energy generated from food waste is used in transport, for the production of electricity or for the production of heat.

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[78] *WIP Renewable Energies (2015). Sustainable Heat Use of Biogas Plants – A Handbook, 2nd Edition.* ***http://www.biogasheat.org/wp-content/uploads/2015/03/Handbook-2ed_2015-02-20-cleanversion.pdf.***

[79] *European Commission (2017). Optimal use of biogas from waste streams.* ***https://ec.europa.eu/energy/sites/ener/files/documents/ce_delft_3g84_biogas_beyond_2020_final_report.pdf.***

[80] *Valorgas (2012). Valorisation of food waste to biogas.* ***http://www.valorgas.soton.ac.uk/Deliverables/120825_VALORGAS_241334_D5-2_rev[0].pdf.***

[81] *Ofgem (2017). Tariffs and payments: Non-Domestic RHI.* ***https://www.ofgem.gov.uk/environmental-programmes/non-domestic-rhi/contacts-guidance-and-resources/tariffs-and-payments-non-domestic-rhi.***

[82] *IEA Bioenergy. Member Country Reports. Sweden.* ***http://task37.ieabioenergy.com/country-reports.html.***

[83] *Netherlands Enterprise Agency (2017). Stimulation of Sustainable Energy Production (SDE+).* ***https://english.rvo.nl/subsidies-programmes/sde.***

TABLE 7: GREENHOUSE GAS EMISSIONS REDUCTION BY ALTERNATIVE USES OF FOOD WASTE-BASED BIOGAS

Food waste feedstock source	Biogas produced (m^3/ wet tonne)	GHG emissions reduction if used in transport (kg CO_2e)	GHG emissions reduction if used in electricity (kg CO_2e)	GHG emissions reduction if used for heat (kg CO_2e)
Potatoes (18%-20% TS)	100-120	1,946	1,899	1,976
Bread	400-500	2,506	2,315	2,631
Cheese	>600	2,753	2,499	2,920
Vegetables	50-80	1,872	1,844	1,890
Mixed food (e.g. supermarket, restaurant)	75-140	1,942	1,896	1,972
Molasses (80-90% TS)	450-579	2,612	2,394	2,756
Brewery waste (20% TS)	60-100	1,896	1,862	1,919
Abbatoir waste	120-160	1,995	1,936	2,034

**Assumed the food waste would have gone to an open landfill instead with no landfill gas recovery [84]; when used for transport, diesel vehicles [85] are used as a comparator; when used for electricity, the global electricity mix [86] is used as a comparator; when used for heating, the EU fossil heat average [87] is used as a comparator.*

Since carbon or greenhouse gas emissions are not natural commodities or utilities that can be sold in the market, carbon markets have been created by various governments and inter-governmental organisations to price the mitigation of emissions.

Carbon markets function by capping the total number of permissible emissions within the jurisdiction of the market. Emissions allowances are then distributed between countries/industries corresponding to the cap. Under this mechanism, surplus allowances can be traded and sold to other countries/industries or carbon credits may possibly be sourced from outside the market to meet their emission reduction targets. The key to the success of this mechanism is to ensure the amount of emission allowances in the market is sufficiently scarce and penalties for emitting more than the cap are sufficiently high. By the law of demand and supply, the more entities demand the allowances, the higher the price of the allowances will become. Under these conditions, the countries/industries are incentivised to invest in carbon abatement technologies to sell resulting surplus allowances. Low demand for allowances could indicate a downturn in the economy or the lowering of mitigation costs due to technological improvements or an overestimation of distributed allowances (which can be adjusted on an annual basis).

[84] *US Environmental Protection Agency (2015) Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM)* **https://www3.epa.gov/warm/pdfs/WARM_Documentation.pdf**

[85] *Joint Research Center (2013) Joint Research Centre EUCAR-CONCAWE project* **http://iet.jrc.ec.europa.eu/sites/about-jec/files/documents/report_2013/wtt_v4_pathways_1-oil_gas_july_2013.xlsx**

[86] *International Energy Agency (2017) CO2 emissions from fuel combustion* **https://www.iea.org/publications/freepublications/publication/CO2EmissionsfromFuelCombustionHighlights2017.pdf**

[87] *NFCC (2016) Assessment of impact on biogas producers of proposed changes to sustainability criteria* **https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/577055/Annex_E_-_Report_on_sustainability_criteria.pdf**

The Clean Development Mechanism (CDM) adopted under the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC), provided a mechanism for generating carbon credits and implementing carbon markets on an international level till 2012. The European Union's Emissions Trading Scheme (EU ETS) provides the support on a European level, South Korea, Australia, Swiss cap and trade schemes on a country level, and California, USA and Quebec, Canada cap and trade scheme on a state level amongst others[88, 89]. The Paris Agreement provides a framework for continuing carbon markets under articles 6.2 and 6.4 beyond the Kyoto Protocol. There is a growing international push for more action on carbon pricing[90]. In 2016, about 40 national governments and over 20 cities, states, and regions, announced a commitment to put a price on carbon. These entities are responsible for almost a quarter of global GHG emissions.

Since 2015, four new carbon pricing initiatives have been implemented:

- The Republic of Korea ETS started on January 1, 2015;
- The Portugal carbon tax entered into force on January 1, 2015, covering all energy products used in non-EU ETS sectors;
- On January 1, 2016, British Columbia launched an ETS that will cover the liquefied natural gas (LNG) facilities that are currently under construction, once they become operational;
- Australia is back on the carbon pricing map with the introduction of a safeguard mechanism to limit and price emissions on July 1, 2016. This establishes a new ETS, following the abolishment of the Australian Carbon Pricing Mechanism in 2014.
- In 2015, China announces its plans for a national ETS.

Figure 13 (below) is a summary of national and subnational carbon pricing initiatives implemented, planned or under consideration around the world[91].

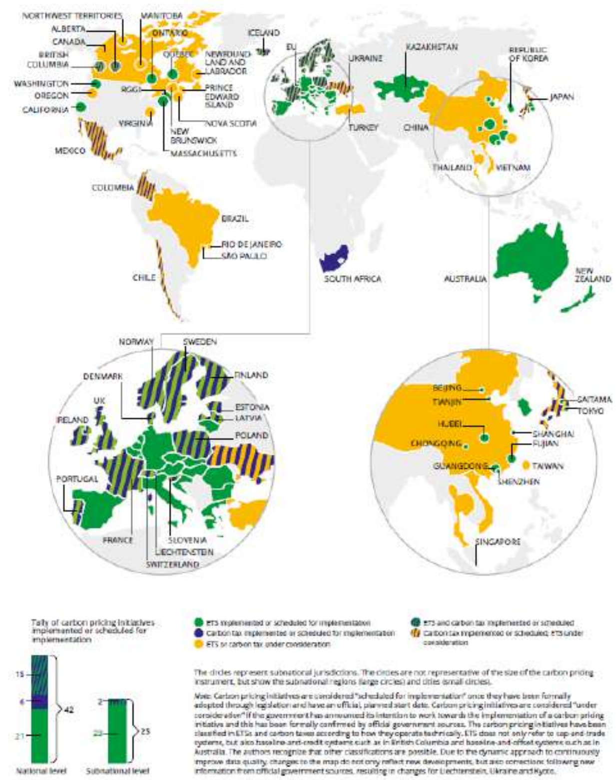

Figure 13: Summary map of regional, national and subnational carbon pricing initiatives implemented, scheduled for implementation and under consideration (ETS and carbon tax)

Integrating food waste digestion projects with these mechanisms can incentivise wide-scale deployment of collection and digestion infrastructure. This requires the recognition of avoided GHG emissions from biogas production within the emission trading systems so that such plants can be eligible for carbon credits that can then be monetised on carbon credit trading markets, for example via one of the CDM approved methodologies, such as 'AMS.I.I.' (biogas/biomass thermal applications for households/small users).

[88] *REN 21 (2017) Renewables 2017 Global Status Report* ***http://www.ren21.net/wp-content/uploads/2017/06/17-8399_GSR_2017_Full_Report_0621_Opt.pdf***

[89] *World Bank Group (2017) State and Trends of carbon Pricing 2017* ***https://openknowledge.worldbank.org/bitstream/handle/10986/28510/wb_report_171027.pdf?sequence=5&isAllowed=y***

[90] *World Bank and Ecofys. 2016. "Carbon Pricing Watch 2016" (May), Washington, DC.* ***https://openknowledge.worldbank.org/bitstream/handle/10986/24288/CarbonPricingWatch2016.pdf?sequence=4&isAllowed=y***

[91] *World Bank Group (2017) State and Trends of carbon Pricing 2017* ***https://openknowledge.worldbank.org/bitstream/handle/10986/28510/wb_report_171027.pdf?sequence=5&isAllowed=y***

Sale and utilisation of digestate

The value attached to digestate varies significantly from country to country, based on the treatment it has undergone and the final form in which it is marketed. In semi-arid countries such as the Sahel region in Africa, Bangladesh, Egypt and Tunisia, where the soil carbon and hence its water retention capacity is low, carbon- rich digestate and compost is highly valued. Use of digestate and compost in these countries can lead to higher yields, improved farm incomes, stabilised communities, reduce forced emigration and reduce poverty- induced hunger. In most EU countries, the composting of digestate from municipal waste has been made mandatory. This adds to the initial capital cost of the digester, but in the long run improves the digestate revenue stream. The nutrient value of digestate and its market value are well established in Italy. A number of countries operate certification programmes like the American Biogas Council Digestate Certification scheme[92] and European Compost Network-Quality Assurance Scheme (ECN-QAS)[93] have developed standards and certification schemes for digestate which enables its monetisation as a marketable product. However, in some high-income countries such as the UK and Australia where farming uses large volumes of synthetic fertiliser, the value of digestate is not recognised. Despite its high nutrient value, many biogas plants give away the digestate to agricultural enterprises for free. Examples of digestate markets that have remained isolated to individual initiatives are the integration of food waste digestate into a gardening supplies business by Richgro in Australia[94]. Having clear regulations around safety and quality standards can enable the monetisation of digestate and create additional revenue.

5.4. Health and safety

Ensuring that every individual working for and at an AD facility has a safe environment to work in is the primary responsibility of every employer running an AD plant. Basic training and safety procedures can help prevent a vast majority of incidents from occurring, while also enabling employees to identify and respond effectively to situations as they may arise , which can threaten safety, plant performance or the environment. Implementing simple health and safety measures can not only save lives but also save money [95]. Risk assessment is the process of evaluating each activity and process taking place on site and can be broken down into the following five steps [96]:

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[92] American Biogas Council. **http://digestate.org/. Accessed on 17/12/2017.**

[93] European Compost Network. **https://www.compostnetwork.info/ecn-qas/. Accessed on 17/12/2017.**

[94] Landia. UK Companies Join Forces for New Richgro AD Plant in Australia. **http://www.landia.co.uk/Display-of-news?Action=1&NewsId=325&M=NewsV2&PID=711.**

[95] This section heavily derives from ADBA (2017). The Practical Guide to AD (Second Edition). **http://adbioresources.org/library/purchase-the-practical-guide-to-ad.**

[96] Health and Safety Executive. Risk -Controlling the risks in the workplace. **http://www.hse.gov.uk/risk/controlling-risks.htm. Accessed on 28/11/2017.**

IDENTIFY THE POTENTIAL HAZARDS:

- To identify potential hazards, the operator of the plant should go step by step, considering processes, activities and substances present on the site that may pose a risk to health and safety. Some potential hazards at a biogas plant may be vehicle movements on site, use of mobile plant and machinery such as forklifts, production and storage of explosive gas, electrical systems, moving parts of machinery such as pumps, shredders, conveyor belts, and walking floors, working in confined spaces and working at heights.

WHO MAY BE HARMED AND HOW:

- This step involves considering each potential hazard identified and evaluating which person or job role may be impacted and how, taking into account the different needs of individual workers such as those who are young, expectant mothers, people with disabilities, people whose first language is different from the primary language of communication and temporary workers.

EVALUATE THE RISK OF THE INCIDENT TAKING PLACE AND APPROPRIATE PRECAUTIONS:

- The next step after identification of potential hazards and their impact, is taking all reasonably practical steps to manage the risk. These will include personal protective equipment and clothing (such as use of gloves, steel toe boots), administrative controls (identifying and implementing procedures to make work place safe), engineering controls (using work equipment or other measures to control risk), substitution (replacing the potentially hazardous material or machinery with a less hazardous one) and elimination (designing out the hazard).

RECORDING THE FINDINGS:

- Keeping written records of risk assessment is important for ongoing and effective risk management. These records should be made easily accessible for reference. Written communication of procedures ensures clearer understanding and consistency across the business.

REVIEWING AND UPDATING RISK ASSESSMENT:

- It is important to review the risks and update the assessment on a regular basis to keep up with the changing activities, processes and people working at the AD plant. It may be done on a yearly or biannual basis or when there are any changes, based on the plant and how is it run.

As AD operations are complex and deal with a highly explosive gas (methane), both personal and process safety measures must be undertaken. If an incident happens, lapses in procedures should be identified, learnt from and corrected. Regular inspections from the health and safety enforcing authority of the jurisdiction can ensure compliance and accountability of duty-holders.

5.5. Establishing good practice

Stakeholders involved in the anaerobic digestion food waste – such as industrial/commercial generators, waste management and environment arms of jurisdictions, companies providing food waste collection services, operators of biogas plants, developers, consultants, suppliers, insurers, regulators and other trade bodies related to the sector – may organise themselves into groups to establish and share sector best practices to improve operational, environmental and health and safety performance. This activity has been shown to facilitate the improved understanding and sharing of good practice.

In addition to improving plant performance and return on investment, sharing best practices can reduce operational risks and the cost of insurance premiums, further improving the financial performance of the plant. The sharing of best practices can take the form of practical guidance, case studies with outstanding features highlighted, or check lists on risk management, procurement or operational performance [84], or an industry certification scheme as has recently been launched in the UK [85]. Voluntary certification schemes can play a big role in driving high standards as they typically involve independent auditing and reviews of processes and an ongoing commitment to continual improvement.

5.6. Comparison of technologies

The table below lists the treatment technologies discusses in Chapter 4 and 5 and how they compare against the following set of parameters:

- SUPPORT FOR FOOD WASTE REDUCTION – as outlined in chapters two and three, the introduction of separate food waste collections supports food waste reduction as households and businesses become more aware of the quantity and cost of the food waste they are creating.
- COST COMPARISON – This column compares the relative costs of procuring and implementing the technology. Since these vary significantly based on the level of sophistication, the existing infrastructure, regulations and local parameters, the comparison is on a scale with 1 being the least and 5 the most costly technology. This is based on a number of studies that report on the cost of the different municipal solid waste (MSW) treatment technologies, including the ISWA UNEP Global Waste Management Outlook report[86] and others[87,88].
- RENEWABLE ENERGY PRODUCTION – Does the technology lead to the generation of energy as a product? For example, landfilling on its own is just a means of storing waste, but does not produce biogas for energy, in comparison to LFG extraction.
- NUTRIENT RECOVERY – Does the technology recover the nutrients in the food waste such as nitrogen, phosphorus and potassium? For example, after liquefaction, the nutrients in the food waste are lost to the sewer or burnt with the biodiesel produced, whereas these can be recovered and recirculated by rendering, composting, AD and MBT.
- ABILITY TO BUILD SOIL ORGANIC MATTER – Soil organic matter is important for retention of water and nutrients and prevention of erosion. The contribution of the technology to building soil organic matter and hence agriculture is evaluated in this column.

[84] ADBA (2017). Best Practice Checklists. **http://adbioresources.org/our-work/best-practice-scheme/best-practice-checklists/.**

[85] ADBA (2017). Best Practice Scheme. **http://adbioresources.org/our-work/best-practice-scheme/.**

[86] UNEP and ISWA (2015) Global Waste Management Outlook **http://web.unep.org/ietc/what-we-do/waste-management-outlooks**

[87] Eunomia Research and Consulting (not dated) Costs of Municipal Waste Management in the EU **http://ec.europa.eu/environment/waste/studies/pdf/eucostwaste.pdf**

[88] PlasCarb (2015) Evaluation of the regional and political waste management strategies across Europe **http://www.plascarb.eu/assets/content/20151208_FoodWasteReport_WP9_final_publish.pdf**

TABLE 8: COMPARISON OF TECHNOLOGIES TABLE

TECHNOLOGY	SUPPORTS FOOD WASTE REDUCTION	COST SCALE 1-5 (LOW-TO-HIGH)	ENERGY PRODUCTION	NUTRIENT RECOVERY	CAN BUILD SOIL ORGANIC MATTER
FOOD WASTE SEPARATELY COLLECTED					
Anaerobic digestion	✓	4	✓	✓	✓
In-vessel composting	✓	3	x	✓	✓
Windrow composting	✓	2	x	✓	✓
Liquefaction	✓		Dependent on context		x
Rendering	✓		Dependent on context		x
FOOD WASTE COLLECTED IN RESIDUAL WASTE					
Gasification	x	5	✓	x	x
Incineration and energy recovery	x	4	✓	x	x
Landfill without gas extraction	x	1	x	x	x
LFG extraction	x	2	✓	x	x
Mechanical Biological Treatment	x	2	✓(with AD)	x	x
Pyrolysis	x	5	✓	x	x

This table shows that AD is a technology that enables renewable energy generation, nutrient recovery and building of soil organic matter, essential for mitigating climate change, sustainable growth and industrialisation. Due to the multiple benefits of AD, it is already the preferred method of recycling food waste for a number of businesses, industries, institutions and cities and is the focus of this report.

5.7. Conclusion

As a technology for food waste utilisation, AD is flexible, effective and sustainable and contributes towards a circular global economy. The following chapter explores the various products of AD which can further provide the benefits of production of renewable energy, climate change mitigation, energy and food security and sustainable and inclusive growth for all.

6. PRODUCTS OF ANAEROBIC DIGESTION

This chapter illustrates the use of the products of anaerobic digestion (AD), notably biogas, electricity, heat, biomethane, digestate, carbon dioxide and cooling. Once biogas has been produced there are a number of considerations regarding its use.

- **How much biogas is available and which technology is best suitable for use at this scale?**
- **Are there any onsite energy needs that can be met from the energy captured from biogas? In what form?**
- **Are there any local businesses or industries that could use the energy? In what form?**
- **Is a connection to the electricity or gas grid feasible?**
- **Which products of biogas have a currently operating market?**
- **Where is the most feasible final destination of the digestate produced?**
- **Are there any financial incentives available for the products of biogas?**
- **Are there any operating biogas plants in the jurisdiction?**
- **Are there any local factors that have enabled their success?**
- **Is a new technology available that others have not yet taken up?**

6.1. Biogas for cooking and lighting

The simplest and easiest way of using biogas is to directly burn it and use the heat and light generated for cooking, heating and lighting. This set up is usually most feasible for micro-scale digesters which digest food from a family or a community and the biogas produced can substitute fossil fuel kerosene and liquified petroleum gas (LPG), or traditional solid biomass fuels like wood and coal. Direct use of biogas is implemented where the micro-scale of digestion makes the use of combined heat and power (CHP) engines financially prohibitive.

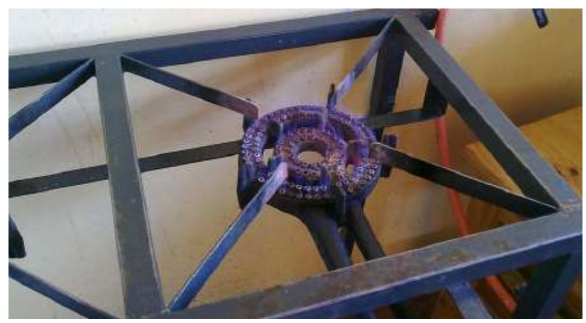

Image: Biogas stove

In Africa and Central and Eastern Europe, over 30% of fine particulate matter in the urban air originates from domestic burning of solid fuel such as wood and charcoal for heat and cooking. Using biogas to cook instead of biomass reduces particulate matter pollution in kitchens by 80%[1]. The use of biogas in place of fossil fuel can improve air quality, contributing to reduce the 4.2 million premature deaths that result from air pollution worldwide[2]. Utilising biogas stoves and gas lamps for cooking and lighting can prevent these emissions and is better for indoor air quality, and the health of the residents.

Domestic and community food waste digestion plants offer decentralised treatment of organic waste which is a challenge that many developing countries' municipalities face. On a household level, food waste digestion has been successfully implemented in Alappuzha, Kerela, India[3,4], as a waste management strategy.

[1]*Berkeley Air Monitoring Group (2015) Quantifying the health impacts of ACE-1 biomass and biogas stoves ni Cambodia* **http://www.snv.org/public/cms/sites/default/files/explore/download/quantifying_the_health_impacts_of_ace-1_biomass_and_biogas_stoves_in_cambodia.pdf**

[2]*World Biogas Association (2017) Factsheet 1: How biogas can help improve urban air quality* **http://www.worldbiogasassociation.org/wp-content/uploads/2017/07/WBA-Urban-Air-Quality-Biogas-factsheet1.pdf**

Community level digestion of food waste has been implemented in a few Amma Canteens, where the waste generated at the establishment is combined with nearby vegetable market waste for digestion and the biogas produced is used in cooking at the canteen, substituting a fraction of the LPG[5].

Small-scale biogas plants are, however, not common in densely populated urban areas due to limitation of the area/space available. Where implemented, households with the digester are known to accept food waste from neighbours to meet the capacity of the digester and produce sufficient biogas at the required pressure. In rural areas, the micro-scale AD model is well established due to availability of animal manure and crop residues to supplement food waste.

Pilot small-scale biogas plants[6] and products[7,8], are being experimented in developed countries to evaluate the feasibility of AD of food waste in urban areas.

6.2. Biogas boilers

Biogas can be burned directly in a boiler to generate hot water or steam which may be used to meet the operational needs of the biogas plant or 'parasitic load', used on site for process heating or transported via a district heating network. Biogas boilers can capture up to 85% of the energy in the biogas in the form of hot water.

Compared to the other uses of biogas (burning in a CHP engine or upgraded for use in the gas grid or as transport fuel), very little gas cleaning is required, reducing investment and operational costs. The extent to which biogas needs to be cleaned varies with the size and type of boiler. However, it is recommended that hydrogen sulphide be kept below 1,000 parts per million (ppm), and the dew point around 150°C8 to prevent corrosion and deterioration of equipment.

Boilers are made from cast iron or mild steel, the former giving longer operational life and the latter being cheaper to purchase. Once the biogas has been cleaned, conventional gas burners and gas lamps can easily be adjusted to biogas by changing the air to gas ratio[9].

The food and drink industry is an example where biogas boiler technology is well established and implemented. Some examples include Toyama City Eco Town where food waste based biogas boilers provide energy for Mitsubishi Rayon Toyama Production Centre[10], Bonduelle canning facility in Nagykoros, Hungary[11], Elgin Fruit Juices in South Africa[12] and Diageo's Glendullan distillery in Scotland[13].

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[3] *United Nations Environment Programme (2017) Solid approach to waste: how 5 cities are beating pollution.* ***https://www.unenvironment.org/news-and-stories/story/solid-approach-waste-how-5-cities-are-beating-pollution. Accessed on 05/12/2017.***

[4] *The Print (2017). What India can learn from this scenic Kerela town about waste management.* ***https://theprint.in/2017/12/03/india-learn-alappuzha-waste-management/. Accessed on 5/12/2017.***

[5] *Sarumathi, K (2015). Green food.* ***http://www.thehindu.com/features/downtown/green-food/article7239236.ece#.***

[6] *LEAP Micro-AD.* ***http://communitybydesign.co.uk/pages/the-project. Accessed on 06/12/2017.***

[7] ***SimGas http://www.simgas.com/products/urban/gesi550/item27 Accessed on 05/03/2018***

[8] *Homebiogas 2.0.* ***https://homebiogas.com/. Accessed on 06/12/2017.***

[9] *This section derives from ADBA (2017). Practical Guide to AD.* ***http://adbioresources.org/library/purchase-the-practical-guide-to-ad/.***

[10] *Mitsubishi Rayon (2014). Corporate Social Responsibility Report.* ***https://www.m-chemical.co.jp/en/csr/pdf/csr_report_mrc_2014.pdf.***

[11] *Veolia. Europe's leading producer of canned goods reduces its energy bill thanks to biogas.* ***https://www.veolia.com/en/our-customers/achievements/industries/food-beverage/hungary-bonduelle. Accessed on 22/12/2017.***

[12] *GreenCape (2017). The business case for biogas from solid waste in the Western Cape.* ***https://www.greencape.co.za/assets/Uploads/GreenCape-Biogas-Business-Case-Final.pdf.***

[13] *Clearfleau (2016). Whisky power: bio-energy transforms distillery sector.* ***http://clearfleau.com/diageo-whisky-power-bio-energy-transforms-distillery-sector/.***

6.3. Electricity

The energy in biogas can be captured in the form of electricity via engines. The technologies available to do this conversion are numerous and well established. These include gas engines (Pilot injection engines, Gas-Otto engines), fuel cells, micro-gas turbines, Rankine Cycles (Organic and Clausius), Kalina Cycles, Stirling Engines, exhaust gas turbines or CHP engines[14] .

Of all these available options, use of CHP engines is most common as they have an overall energy efficiency of up to 85%[15], of which up to 35% is in the form of electricity and 50% as heat. The heat is captured in the form of hot water from the engine cooling jacket and high-grade heat from the exhaust gases. The hot water and heat from exhaust gases may be used as is, or captured for further generation of electricity. The electricity produced can be used to meet the operational needs of biogas production or 'parasitic load' (such as pumps, macerators, agitators), used for onsite processes (such as building lighting, process electricity), transmitted to a local consumer via mini-grid or injected into a local electricity network. Like biogas boilers, in order to use biogas in CHP engines, siloxanes, hydrogen sulphide and water content should be brought within permissible limits.

The capital cost of a CHP engine can be expected to be between $750 and $1800 per kW[16,17,18,19], depending on a number of factors including the engine type, engine size, whether or not heat recovery is added, and whether it is a custom-built or package engine. The cost of connecting to the grid, if applicable, varies with the distance from the plant, connection assets required and voltage level. These parameters vary with the provider and grid and will be negotiated on a project-specific basis.

Examples of successfully operating food waste based biogas plants generating renewable electricity are available all around the world at various scales, including: local food courts in Malaysia using food scraps to generate electricity to light a few bulbs[20]; Harvest Energy Garden processing food waste from Walt Disney World Resort and other industrial, commercial and institutional sources to generate 3.2 MW of electricity (and 2.2 MW of recoverable heat)[21]; City of Chiba, Japan digesting food waste from food manufacturing industries, retailers and households[22]; and Elgin Fruit Juices, South Africa running part of their juicing operations on electricity generated from fruit, vegetable and other food waste[23].

[14] *WIP Renewable Energies (2015). Sustainable Heat Use of Biogas Plants – A Handbook, 2nd Edition.* ***http://www.biogasheat.org/wp-content/uploads/2015/03/Handbook-2ed_2015-02-20-cleanversion.pdf.***

[15] *ADBA (2017). The Practical Guide to AD (Second Edition).* ***http://adbioresources.org/library/purchase-the-practical-guide-to-ad.***

[16] *UK MARKAL Model Documentation (2007).* ***http://www.ucl.ac.uk/energy-models/models/uk-markal/uk-markal-manual-chapter-5-appendix.***

[17] *Midwest CHP Application Center* ***http://www.midwestchptap.org/Archive/pdfs/060216_CHP_and%20AnaerobicDigester_Applications.pdf.***

[18] *Carbon Trust (2010). Introducing combined heat and power.* ***https://www.carbontrust.com/media/19529/ctv044_introducing_combined_heat_and_power.pdf.***

[19] *U.S. EPA (2017). Catalog of CHP Technologies.* ***https://www.epa.gov/sites/production/files/2015-07/documents/catalog_of_chp_technologies.pdf.***

[20] *Chen, Grace (2017). Food courts tested on green technology.* ***https://www.thestar.com.my/metro/metro-news/2017/11/11/food-courts-tested-on-green-technology-local-councils-in-three-states-aggressively-promoting-waste-m/.***

[21] *American Biogas Council (2014). Harvest Energy Garden - Central Florida.* ***https://www.americanbiogascouncil.org/projectProfiles/lakeBuenaVistaFL.pdf.***

[22] *Global Environment Centre Foundation (2011). Waste Recycling Technologies and Recycling Promotion Initiatives in Eco-towns in Japan.* ***http://nett21.gec.jp/Ecotowns/data/et_a-07.html.***

The electricity produced in this way can:

- Mitigate climate change;
- Replace fossil fuel energy with renewable energy;
- Help meet regulatory requirements for emissions;
- Meet both base load and peak energy demands;
- Bring energy security and independence;
- Result in operational cost savings; and
- Diversify income via additional income stream.

Image: CHP Engine on a biogas plant (Schwedt)

6.4. Heat

Utilising heat is critical to the economic and environmental performance of a biogas plant. Up to 50% of the energy captured in biogas is available as heat via a CHP engine. Of the heat generated, 20-40% is required to meet the needs of the biogas plant such as heating the tanks and pasteurisation of feedstock/ digestate and the rest is surplus. This surplus heat may be used to generate additional electricity or may be used for space heating, process heat, drying, district heating, cooling and other uses.

Typical consumers of heat from biogas plants are those with a usually high and continuous heat demand throughout the year, e.g. large meat producers, cheese factories, breweries, aquacultures, laundries, recreation centres, hospitals, swimming pools and spas. The demand of hotels, canteens, food storages, schools and private residential housing is usually less regular.

For the planning of heating systems, the total, annual and peak heat demands as well as the temperature of heat required by the end user should be assessed in as much detail as possible.

While there is plenty of heat available and many uses to which it can be put, there are a few challenges with its utilisation that have prevented its adoption on a similar scale as electricity:

[23] *GreenCape (2017). The business case for biogas from solid waste in the Western Cape.* ***https://www.greencape.co.za/assets/Uploads/GreenCape-Biogas-Business-Case-Final.pdf.***

- Seasonal variation in heat demand – While heat is produced all year round with a CHP engine, there is competing demand for it during winter and little demand for it in summer. For example, in winter, the requirement for heat to maintain the digester temperature increases and also there is a higher demand for heat in greenhouses and district heating networks. During summer, the demand of both digesters as well as greenhouses and district heating is negligible. This seasonality in demand causes wastage of heat in summer. However, this can be overcome by converting it into cooling using vapour absorption or absorption chillers, or upgrading biogas to biomethane to be injected into the gas grid where it may be used to meet baseload energy, or storing biogas to generate heat when needed. Heat storage facilities can help balance these variations but are very cost intensive. In warmer climates, where seasonality is not an issue, the need for heat is limited by the proximity of industrial uses.
- Need for an end user of heat – As mentioned earlier, the parasitic load of heat of a digester accounts for about 20-40% of the heat produced, the rest being available for other uses. The infrastructure required to transport heat is expensive and incurs significant heat losses. Hence it is important that an onsite or local end user of heat be identified to make its capture most profitable.
- Heat temperature and quantity – Another factor in utilisation of heat is the temperature and the quantity of the heat produced and required. While some industrial processes such as drying require high grade heat, maintaining digester and greenhouse temperatures need low grade. While a CHP engine can produce both, a match in the demand and supply is needed for efficient use.
- Cost of infrastructure – Laying the infrastructure of heat transfer (insulated, pressure resistant pipes, building a mini grid) can be expensive and often has to compete with existing fossil fuel based infrastructure.

Some potential uses of heat that have been successfully implemented are discussed below.

6.4.1. District heating

District heating (or heat networks) is a network of insulated pipes which deliver heat, in the form of hot water or steam, from the point of generation to the end user. It is a system for distributing heat generated in a centralised location to residential and commercial enterprises to meet their space and water heating requirements.

District heating networks vary considerably in size and length – small-scale systems can supply heat to only a few households, whereas large-scale systems can service entire communities, industrial areas or cities.

A biogas-based heat network would carry heat captured from a CHP engine or boiler in the form of hot water or steam. Such a network can benefit an off-grid or poorly serviced local community or industrial/ commercial enterprise without its own reliable heating source.

Besides energy independence, a biogas heating system also mitigates greenhouse gas emissions by substituting fossil fuels. It is also an additional source of income for the biogas plant. The installation of a district heating system for waste heat from biogas plants is associated with considerable capital costs. The pipes carrying the hot water or steam need to be very well insulated and are usually installed underground, though there are systems with aboveground pipes. Additional equipment may include heat exchangers and connection equipment, heat storage systems and calorimeters[24]. The larger the distance between the biogas plant and the heat consumer, the higher the costs and losses. But once set up, district heating networks can be a steady source of income for the biogas plant.

District heating networks are in operation in multiple towns such as Polderwijk, Netherlands, where biogas, produced from co-digestion of food waste with animal manure, is combusted in two separate CHP units, one serving the digester on site while the other is located in a residential area 5km away from the plant. In order to reduce costs and heat loss, biogas is transported via a biogas-pipeline instead of a heat-pipeline for use in the second CHP unit. The heat from this second CHP unit is used for district heating. The project, a collaboration between the municipality, a local energy company and a farm, is a good example of how to create an area with a sustainable and energy efficient heating system, whereby the heat released by the CHP unit is used for district heating in a residential area[25].

Other examples of long-term successfully operating projects include the municipality of Este, in the Veneto region of Italy[26], Hengelo in Netherlands[27,28], and Dannenberg, Germany[29].

6.4.2. Heating greenhouses

Greenhouses often have a high energy demand in order to create the optimum growing conditions for plants - 20-25°C. Heating costs can therefore be among the highest operational costs of food production using greenhouses. Thus, use of heat from biogas plants can constitute a reliable and cheap heat source. As with district heating, minimising the distance between the greenhouse and biogas plant will help in keeping costs and heat losses low.

Examples of successful integration of biogas-based heat use in greenhouses are Vehmaan biogas plant in Finland[30], Kaisei plant in Japan[31] and Leamington/Kingsville in Ontario, Canada[32].

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[24] *WIP Renewable Energies (2015). Sustainable Heat Use of Biogas Plants – A Handbook, 2nd Edition.* ***http://www.biogasheat.org/wp-content/uploads/2015/03/Handbook-2ed_2015-02-20-cleanversion.pdf***

[25] *IEA Bioenergy (2011). Biogas Pipeline for Local Heat and Power Production in a Residential Area, Zeewolde, NL.* ***http://www.iea-biogas.net/files/daten-redaktion/download/Success%20 Stories/success_story_zeewolde2011.pdf.***

[26] *Mayors in Action (2016). Webinar: Enhancing heating & cooling strategies at local level.* ***http://www.mayorsinaction.eu/fileadmin/user_upload/general_folder/Events/Webinars/STRATEGO_ webinar/DeFilippi_STRATEGO_webinar.pdf.***

[27] *OWS. Hengelo 2011.* ***http://www.ows.be/biogas-plants/references/hengelo-2011/. Accessed on 22/12/2017.***

[28] *Verstichel S (2015). DRANCO Technology for anaerobic digestion of organic waste* ***http://www.synpol.org/.cm4all/mediadb/Murcia%2009%20S.%20Verstichel.pdf***

[29] *Fab Biogas. Best-Practice: Biogas plant & bio-methane filling station Dannenberg.* ***http://www.fabbiogas.eu/fileadmin/user_upload/Download/D3.2_factsheet_Dannenberg_english.pdf.***

[30] *Gasum. Vehmaa biogas plant.* ***https://www.gasum.com/kaasusta/biokaasu/biokaasulaitokset/vehmaan-biokaasulaitos/.***

[31] *Ushikubo A (2013). Recycling of food waste in Japan.* ***https://www.oecd.org/site/agrfcn/Session%204_Akikuni%20Ushikubo.pdf.***

[32] *Waste Management World (2012). Biogas from AD: A winner for Ontario Greenhouse Grower.* ***https://waste-management-world.com/a/biogas-from-ad-a-winner-for-ontario-greenhouse-grower. Accessed on 22/12/2017.***

6.4.3. Industrial process heating

Industrial facilities use heat for a wide variety of applications including washing, cooking, sterilising, drying and process heating (heating an industrial vessel to raise the temperature to the required level). Food processing industries such as breweries, fruit and vegetable canning industry and dried herbs and spice industries have a high heat requirement, some of which can be met by the heat generated by a biogas boiler or a CHP engine.

In many instances, waste generated by those industries transforming foodstuffs can be used as feedstock in the digester, thereby not only reducing the operational energy cost but also offering a viable method for waste management. In addition, use of biogas heat can help industries meet their permitted emission limits, ensure a reliable source of renewable energy, reduce their dependence on fossil fuels and reduce costs.

Use of heat for onsite industrial processes has been implemented in Grossfurtner in St. Martin, Austria[33] and a Remo-Frit plant in Belgium[34].

If located next to an industrial plant, the heat from a biogas plant can be exported such as in Chiba, Japan, where food waste from households and businesses is digested and the biogas is supplied to the neighbouring JFE Steel plant where the biogas is combusted for electricity and steam to be used as process heat[35].

6.5. Upgrading biogas to biomethane

The upgrading of biogas to biomethane refers to the process of increasing the methane content of biogas to more than 90%, while removing carbon dioxide, hydrogen sulphide and water. The standards for quality of biomethane vary with use, country and existing infrastructure.

Biogas produced by digestion of food waste can be converted into biomethane for injection into the gas distribution grid, or for use as renewable transport fuel.

Technology to upgrade biogas to biomethane has matured and has been widely implemented all around the globe. An estimated 500 upgrading plants are currently operating globally, with about 187 in Germany, 90 in the UK and 62 in Sweden. Many other countries including the USA, South Korea, Netherlands and Switzerland also operate biomethane plants, some focussing on injection to gas grid, while others use it as vehicular fuel. While only some of these plants digest food waste, the average scale of food waste digesters makes upgrading of biogas a viable choice.

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[33]*FAB Biogas. Best-Practice: Biogas Plant St. Martin, Upper Austria.* ***http://www.fabbiogas.eu/fileadmin/user_upload/Download/D3.2_factsheet_St.Martin_english.pdf.***

[34]*Remo-Frit Sustainability.* ***https://www.remofrit.be/en/sustainability/. Accessed on 22/12/2017.***

[35]*Chiba Biogas Center.* ***http://nett21.gec.jp/Ecotowns/data/img/a07-1L.pdf. Accessed on 22/12/2017.***

Upgrading of biogas to biomethane has the following advantages:

- HIGH ENERGY EFFICIENCY – The percentage of energy captured by upgrading of biogas can theoretically approach 100%.
- ENERGY STORAGE – In the form of biomethane, energy can be stored and transferred when it is required and to where it is needed.
- EXISTING EQUIPMENT – Once biogas has been upgraded to the established standard, it can be used via existing infrastructure and equipment for natural gas without needing any modifications.
- POTENTIALLY MULTIPLE SOURCES OF INCOME – In addition to income through sale of captured energy and digestate, the sale of carbon dioxide can add an additional income stream to the business.
- REDUCED DEPENDENCE OF FOSSIL FUELS – Biomethane produced from food waste is a renewable form of energy and can replace natural gas which is a fossil fuel.

Several technologies for biogas upgrading are commercially available. Five of the most common ones are presented below:

TABLE 9:

UPGRADING TECHNOLOGY	DESCRIPTION[36]	PURITY OF METHANE (CH4)[37]
Pressure Swing Adsorption (PSA)	CO_2 is separated from the biogas by adsorption on a surface under elevated pressure. The adsorbing material is usually activated carbon.	>96%
Water wash (Physical absorption) (Pressurised water scrubbing)	Solution of CO_2 in water under high pressure (CO_2 has a higher solubility in water than CH_4, therefore it will be dissolved to a higher extent than CH_4, particularly at lower temperatures).	>96%
Amine scrubbing (Amine gas treating) (Chemical absorption)	Chemical reaction of CO_2 with aMDEA (activated methyldiethanolamine) to remove it from the biogas.	>99%
Membrane	Permeation of CO_2 through hollow fibre membranes to separate the gases.	>99%
Cryogenic	Newly developed technique that involves the staged cooling of biogas to allow the extraction of CO_2. This technique makes use of the distinct boiling/sublimation points of the different gases.	>99%

[36] *IEA Bioenergy (2009). Biogas upgrading technologies – developments and innovations.* ***https://www.iea-biogas.net/files/daten-redaktion/download/publi-task37/upgrading_rz_low_final.pdf.***

[37] *Clearfleau (2017) Summary report on biogas for commercial vehicle fuel* ***http://clearfleau.com/summary-of-report-on-biogas-for-commercial-vehicle-fuel-july-2017/***

Membrane separation and water wash are the two most widely used technologies for upgrading biogas to biomethane in Europe[36].

The choice of technology depends on the standard of biomethane needed, available funds, available technology providers and operating cost. These factors depend on individual circumstances of the plant, so a full feasibility study will need to be conducted to choose the most appropriate technology.

The total cost for biogas upgrading depends on a number of factors, including:

- **The quality of raw biogas and biomethane required;**
- **Scale of operation – cost per unit decreases with increase in scale;**
- **Location of the plant with respect to distribution system;**
- **Technology used for upgrading;**
- **The available auxiliary power; and**
- **Environmental regulations[37].**

An International Renewable Energy Agency (IRENA) technology brief on biogas in transport reports the following specific cost for upgrading[38]:

TABLE 10: COSTS FOR BIOGAS UPGRADING

RAW BIOGAS UPGRADING CAPACITY (M^3/HR)	COST (USD/M^3 CH_4)
20	1.07
50	0.50
100	0.35
200	0.25
500	0.17-0.25
1,000	0.14-0.18
2,000	0.09-0.16

For larger industrial waste plants of raw biogas capacity ranging between 1,000 and 2,000 m^3/hr, the costs of upgrading range between \$0.09 and \$0.18 per m^3 of biomethane produced. This means that for a 30,000 tonne/year plant (which produces a maximum of 7.8 million m^3 of biomethane per year), upgrading would add between \$700,000 and \$1,400,000 in costs.

[36]*IEA Bioenergy. Task 37 Member Country Reports.* ***http://task37.ieabioenergy.com/country-reports.html.*** [39]*IRENA (2017). Biogas for Road Vehicles Technology Brief.* ***http://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Mar/IRENA_Biogas_for_Road_Vehicles_2017.pdf.***

[37] *IRENA (2017). Biogas for Road Vehicles Technology Brief.* ***http://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Mar/IRENA_Biogas_for_Road_Vehicles_2017.pdf.***

[38] *IRENA (2017). Biogas for Road Vehicles Technology Brief.* ***http://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Mar/IRENA_Biogas_for_Road_Vehicles_2017.pdf.***

6.5.1. Gas production – biomethane-to-grid

Once the biogas has been upgraded into biomethane, for those countries that have a gas distribution network (GDN), it can be injected into the gas grid.

For the gas to be injected into the grid, the quality of biomethane required is determined by the network or the country regulations. In order to facilitate a connection, the GDN will need to know a series of characteristics from the AD operator including the location of the biomethane production facility, the anticipated volumes and hourly flow profile, anticipated gas composition (e.g. 96% methane) and the date at which they intend to connect. While the exact specifications for gas quality vary, the parameters include: Wobbe index, methane content, gas relative humidity, dust levels, carbon dioxide, oxygen and hydrogen percentages, and hydrogen sulphide and sulphur levels. An example of an upgrading standard used by Switzerland is shown in Table 11 below[39].

The quality and volume of injected gas is monitored at the point of entry into the grid. The point of injection is usually operated via a remote valve that allows the grid operator to shut off a plant injecting into the grid at any point, if they believe the gas is not compliant[40].

To inject the gas into the grid, two additional costs are required (on top of the digester costs): the cost of upgrading (covered in previous section) and the cost of injecting into the gas grid. The cost for biomethane grid injection (based on cost analysis in Germany) amounts to between USD 0.06 and $0.12 per m^3 of methane produced[41]. This means that for a 30,000 tonne/year plant (which produces a maximum of 7.8 million m^3 of biomethane per year), grid injection would add between $470,000 and $930,000 in costs.

Food waste-based gas-to-grid plants are operating in Oulu[42] and Riihimaki[43] (Finland), Dagenham (UK)[44] and Zurich (Switzerland)[45].

TABLE 11: EXAMPLE OF NATIONAL UPGRADING STANDARD (SWITZERLAND)

PARAMETER	UNIT	DEMAND IN STANDARD	
Methane content	Vol-%	>96	>
Gas relative humidity	phi	<60%	
Dust	-	Technically free	
CO_2	vol-%	<6	
O_2	vol-%	<0,5	
H_2	vol-%	<5	
H_2S	mg/ nm^3	<5	
S	mg/ nm^3	<30	

[39] *IEA Bioenergy (2006). Biogas Upgrading to Vehicle Fuel Standards and Grid Injection.* **http://task37.ieabioenergy.com/files/daten-redaktion/download/publi-task37/upgrading_report_final.pdf.**

[40] *ADBA (2017). The Practical Guide to AD (Second Edition).* **http://adbioresources.org/library/purchase-the-practical-guide-to-ad.**

[41] *IRENA (2017). Biogas for Road Vehicles Technology Brief.* **http://www.irena.org/DocumentDownloads/Publications/IRENA_Biogas_for_Road_Vehicles_2017.pdf.**

[42] *Gasum. Oulu biogas plant.* **https://www.gasum.com/kaasusta/biokaasu/biokaasulaitokset/oulun-biokaasulaitos/. Accessed on 22/12/2017.**

[43] *Gasum. Riihimaki biogas plant.* **https://www.gasum.com/kaasusta/biokaasu/biokaasulaitokset/riihimaen-biokaasulaitos/. Accessed on 22/12/2017.**

[44] *ReFood.* **https://refood.co.uk/refood-opens-latest-state-art-ad-facility-london/. Accessed on 22/12/2017.**

[45] *IEA Task 37 (2014). Biowaste and sewage sludge recovery: separate digestion, common gas upgrading and heat supply.* **http://task37.ieabioenergy.com/case-studies.html.**

6.5.2. Vehicle fuel production – biomethane for transport

Biogas, once upgraded to a well-defined standard, may be used as fuel in any passenger or heavy goods vehicle that can run on gas. Upgraded biomethane can be used in both dedicated gas vehicles and dual-fuel vehicles which offer diesel and gas-mix compression ignition engines.

Biomethane as a vehicle fuel uses the same engine and vehicle configuration as natural gas, therefore vehicles that previously ran on natural gas can be used to run on biomethane – they just need to be configured to run on the right fuel (compressed natural gas [CNG], compressed biomethane [CBM], liquid natural gas [LNG], liquid biomethane [LBM]).

There are more than 1 million natural gas vehicles all over the world with new models regularly released. Argentina, Brazil, China, Colombia, Germany, India, Iran, Italy, Pakistan, Sweden and Switzerland have relatively well-developed natural gas vehicle infrastructures, for which biomethane could easily be implemented as a renewable alternative to fossil natural gas[46].

Vehicles running on biomethane have distinct advantages as compared to diesel vehicles:

- √ **Very low pollutant emission levels: particulate matter and nitrogen oxides especially**
- √ **Very low CO_2 emissions, up to 65% less than an equivalent Euro V diesel (well-to-wheel greenhouse gas emissions can be reduced by 80-95% compared to convention fuels)**
- √ **Low-noise engines: significantly lower than an equivalent Euro V diesel**

Biomethane derived from organic wastes can achieve 70% greenhouse gas emission reductions in passenger cars when compared to gasoline[47], as shown by the chart in Figure 14 below. These emission reductions are greater than electric cars (54% reduction under the current electricity mix in the EU) due to still high use of non-renewable sources for the generation of electricity.

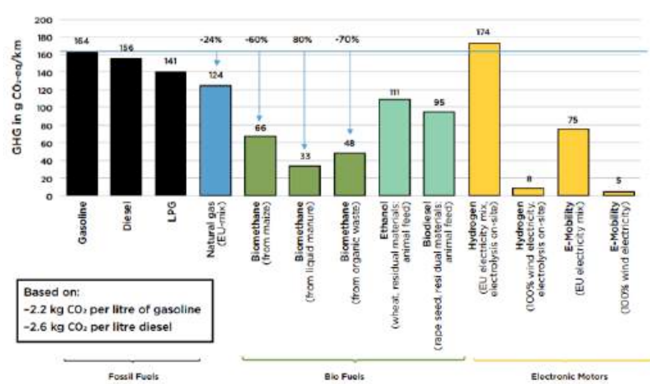

Figure 14: Comparative GHG emissions from passenger cars running on different fuels

[46]IRENA (2017). Biogas for Road Vehicles Technology Brief. **http://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Mar/IRENA_Biogas_for_Road_Vehicles_2017.pdf.**

[47]IRENA (2017). Biogas for Road Vehicles Technology Brief. **http://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Mar/IRENA_Biogas_for_Road_Vehicles_2017.pdf.**

TABLE 12: EXAMPLES OF CITIES USING BIOMETHANE VEHICLES

CITY	OPERATORS	NUMBER AND TYPE OF VEHICLE POWERED BY BIOGAS
Berlin[4]	Berlin City Cleaning Services (BSR)	150 garbage trucks
Lille	Lille Métropole Communauté Urbaine (LMCU) authority	430 buses
Madrid	EMT Madrid	945 buses
Santa Monica	City of Santa Monica	100 buses
Reading	Reading Buses	39 buses
Nottingham	Nottingham City Transport	53 buses

The requirement of quality for biomethane to be used as vehicle fuel is different from that needed for injection in grid. While exact specifications vary, the parameters of quality include: Lower Wobbe index, motor octane number, water dew point and sulphur and ammonia levels. As an example, standards for Sweden are shown in Figure 15 below[8]:

Image: Biogas bus - City of Oslo

Figure 15: Example of national standard for biomethane

Swedish national standard for biomethane

PARAMETER	UNIT	DEMAND IN STANDARD
Lower Wobbe index	MJ/nm³	43,9 – 47,3¹
MON (motor octane number)	-	>130 (calculated according to ISO 15403)
Water dew point	°C	<t²-5
$CO_2+O_2+N_2$	vol-%	<5
O_2	vol-%	<1
Total sulphur	mg/ nm³	<23
NH_3	mg/ nm³	20

Once the biogas has been upgraded to biomethane, it can either be:

1. Transported to the filling stations via public gas pipelines: In this case, the biomethane needs to be compressed to the pressure at which the pipeline is operated (more below), and abide by the gas quality requirements. The grid injection unit also needs to be planned, financed, built and operated.
2. Bottled or transported by trucks in high-pressure (200-250 bars) gas bottles: Here, the biomethane must also reach certain quality requirements for methane and water vapour content. This option involves additional transportation and capital equipment costs and most likely extra costs for compression at the filling station.
3. Directly used at a filling station at the location of biomethane production.
4. For any of the above options, to use biomethane as a transport fuel, it must either be compressed or liquefied. This is to make it easier to store and distribute.

Compressed biomethane (CBM)

The biomethane is compressed to 250-300 bar pressure to reduce the storage volume (to less than 1% of the volume it occupies at standard atmospheric pressure) and increase the energy density to useful levels. It is then stored in a bank of storage cylinders ready for fuelling. The equipment in a compressed gas refuelling station usually consists of gas conditioning to remove any residual moisture and contaminants, a compressor, storage and a dispenser. There are many examples where biomethane is used on its own or combined with natural gas in public transport buses and waste collection trucks including Lille (France) [48], Reading (UK)[49], Chennai (India)[50] and South Korea [51].

Liquid biomethane (LBM)

Liquid biomethane is usually created by compressing and cooling the biomethane to well below zero (methane has a boiling point of -164°C), which converts the gas to a liquid and cuts its volume to 1/600th of the original, making it possible to ship the LBM in special tankers. LBM is a way of transporting biomethane long distances when pipelines are not an option. The infrastructure for LBM can be extensive and expensive.

Liquid biomethane fuels Santa Monica's Big Blue Bus program in California, USA; the City's transit department operates a significant proportion of its bus fleet on renewable natural gas (biomethane) liquefied into LBM, reducing the fleet's carbon footprint by nearly 90%[52].

An LBM plant has been in operation since 2012, in Linköping, Sweden. The plant produces transport fuel for cars, trucks and buses[53].

Comparison of Compressed Biomethane and Liquid Biomethane

Table 10 below gives a financial evaluation from Clearfleau[53.2] of both CBM and LBM options as an alternative to a 250kW CHP unit, based on data for a medium-scale creamery site:

TABLE 13: FINANCIAL EVALUATION FROM CLEARFLEAU OF BOTH CBM AND LBM OPTIONS

	Units	CBM	LBM	
			Exc. CO_2	Inc. CO_2
Capital investment	£k	5,323	6,416	6,516
IRR (15 years)	%	13.9	9.3	11
NPV	£k	1,038	-237	305
Profit	£k/yr	930	856	967
Payback (discounted by 10%)	years	8.8	13.4	11.2
Payback (simple)	years	5.7	7.5	6.7

[48] Lille Metropole. Biomethane production and its use in captive fleets. **https://www.polisnetwork.eu/uploads/Modules/PublicDocuments/biogasmax-torun_lille.pdf.**

[49] Gas Vehicle Hub. CNG buses in Reading. **http://www.gasvehiclehub.org/case-studies/10-case-studies/80-cng-buses-in-reading.**

[50] Mahindra World City. **http://www.mahindraworldcity.com/press/mahindra-inaugurates-its-bio-cng-plant-in-mahindra-world-city-mwc.aspx. Accessed on 22/12/2017.**

[51] IEA Bioenergy Task 37. Member Country Reports. **http://task37.ieabioenergy.com/country-reports.html.**

[52] Clean Energy. Big Blue Bus Raises the Green Standard with Renewable Natural Gas. **https://www.cleanenergyfuels.com/customer-success-stories/big-blue-bus-success-story/.**

[53] Backman M, Rogulska M. Biomethane use in Sweden. The Archives of Automotive Engineering – Archiwum Motoryzacji. 2016; 71(1): 7-19. **http://dx.doi.org/10.14669/AM.VOL71.ART1 and http://archiwummotoryzacji.pl/images/AM/vol71/PIMOT_71_Backman_7-20.pdf.**

[53.2] Clearfleau (2017) Summary report on biogas for commercial vehicle fuel **http://clearfleau.com/summary-of-report-on-biogas-for-commercial-vehicle-fuel-july-2017/**

The evaluation shows an attractive payback, but individual projects will require detailed evaluation. The LBM solution involves higher capital cost and generates the longest payback but also facilitates capture and re-use the CO_2 removed from the biogas. LBM is better for long-haul operations because it has a higher energy density and so more fuel can be stored in the same space. This extends vehicle range and reduces refuelling frequency.

On top of the infrastructure and capacity needed to produce the biomethane, to roll out biomethane use in transport there also needs to be sufficient availability of biomethane vehicles and refuelling infrastructure (that is – a market and access to it).

CNG stations have pressurised dispensers and use a compressor that can deliver biomethane to vehicles at a pressure of 200 bar. These stations are connected to the gas grid via a pipeline connection. The costs of such systems depend on the overall pressure of the relevant gas grid (i.e. higher gas grid pressures mean that the amount of additional compression required is reduced, thereby reducing costs).

LNG stations consist of leak-tight dispensers and a cryogenic tank for storing the LNG fuel. LNG is delivered to these stations by road tanker. Refuelling stations need planning appropriately and need access to gas mains at the correct pressure as well as electricity to power the refuelling station.

Costs of refuelling stations include direct costs of fuelling (equipment on site, costs of gas/electricity grid) and indirect costs of fuelling (costs for building structures, land). Analysis indicates that costs for CNG stations are around $0.27 per litre (compared to approximately $0.07 per litre for petrol/diesel stations). These costs cover transport to site, operations at site and operations refuelling [54].

Studies have found the cost of a 10,000 kg/day CNG refuelling station, which includes both capital and infrastructure costs, to be around USD 1.15 million. This amounts to around $115/kg, or $8/kWh. For a smaller 1,000 kg/day station, the cost was found to be around $355,000, amounting to $355/kg or $26/kWh[55,56].

For LNG, the cost for refuelling stations was found to be lower. For a 10,000 kg/day LNG refuelling station, total costs were estimated at $530,000, amounting to $53/kg or $4/kWh. For the smaller 1,000 kg/day station, the cost was estimated at $140,000, amounting to $140/kg or $10/kWh[57].

Three more detailed case studies are outlined below:

CASE STUDY 1:

John Lewis Partnership, UK

The John Lewis Partnership (JLP) operates 12 heavy trucks on biomethane and had 43 more on order due to be delivered before the end of 2017. The vehicles fill up at a grid connected filling station at Leyland in Lancashire. The gas is certified as biomethane via the Renewable Transport Fuel Obligation (RTFO) scheme, ensuring that it meets the sustainability criteria laid out by the UK Government. The gas is created from food waste and food processing sources.

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[54] *Ricardo Energy & Environment (2016). The role of natural gas and biomethane in the transport sector.* ***https://www.transportenvironment.org/sites/te/files/publications/2016_02_TE_Natural_Gas_Biomethane_Study_FINAL.pdf.***

[55] *Ricardo Energy & Environment (2016). The role of natural gas and biomethane in the transport sector.* ***https://www.transportenvironment.org/sites/te/files/publications/2016_02_TE_Natural_Gas_Biomethane_Study_FINAL.pdf.***

[56] *LowCVP (2011). Biomethane for Transport - HGV cost modelling http://bit.ly/2oQcQEs*

[57] *Ricardo Energy & Environment (2016). The role of natural gas and biomethane in the transport sector.* ***https://www.transportenvironment.org/sites/te/files/publications/2016_02_TE_Natural_Gas_Biomethane_Study_FINAL.pdf.***

The biomethane lorries emit 84% less carbon dioxide than diesel equivalents, noise levels are halved and driver reaction has been very positive. Although the lorries are more expensive to buy than diesel trucks, the fuel is lower priced so in the long term it is financially more beneficial. The JLP plans to replace the majority of their diesel heavy trucks with gas as they come up for replacement.

Justin Laney, General Manager of Fleet, said "There were several barriers to overcome before we had a viable alternative to a diesel truck. The last of these was achieving a 500-mile range using compressed gas. Now that's been overcome, our gas trucks can do the same work as our standard diesel trucks. They have significant environmental and driver benefits and a sound business case."

CASE STUDY 2:

Berlin City Cleaning Services, Germany [58]

The Berlin City Cleaning Services (BSR) operates a biomethane plant in Ruhleben, Berlin. The plant uses 60,000 tonnes per year of source segregated food waste, which comes from weekly collection of food waste by garbage trucks, to produce 4.5 million m^3 biomethane per year (550 m^3/hr). The biomethane produced by the plant powers 150 Mercedes Benz Econic CNG garbage trucks, which represent over 50% of its fleet. The BSR owns three of its own gas filling stations. Benefits include 2.5 million litres of diesel and 12,000 tonnes of CO_2 avoided every year, and electricity not used to cover its own demand is exported into the grid.

CASE STUDY 3:

Lille Metropolitan Region, France [59]

The metropolitan region of Lille currently runs a fleet of about 430 waste-to-energy buses on biogas. The buses run on 108,000 tonnes per year of the organic wastes produced by the city's 500,000 inhabitants (4,111,000 m^3/yr of biogas produced, equivalent to 4,480,000 m^3 of diesel). The project, budgeted at €75 million, started in 1994 with four of these buses, and has since expanded to the current number. The buses, powered by a mix of natural gas and biogas, are refuelled directly in three bus depots located next to biogas producing plants. Through installing an Organic Valorisation Centre in the peripheral neighbourhood of Sedequin, half of the city's bio-wastes are turned into biomethane to fuel these buses. Residuals produce 25,000-30,000 tonnes of compost per year for agriculture, reducing dependence on synthetic fertilizers for local and regional farmers (60% of LMCU's communes are rural), contributing to strengthening food and energy security. The city has recently started to power its waste collection trucks with pure biomethane too.

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[58] *European Biogas Association (2016). Biomethane in Transport.* ***http://european-biogas.eu/wp-content/uploads/2016/05/BiomethInTransport.pdf.***

[59] *UrbanNEXUS CaseStudy_Lille* ***http://www2.giz.de/wbf/4tDx9kw63gma/07_UrbanNEXUS_CaseStudy_Lille.pdf***

6.6. Digestate – a valuable co-product

After food waste has been anaerobically digested and biogas released, the residual material that remains is called digestate or biofertiliser. Digestate is rich in micro-organisms, carbon, micronutrients and other nutrients including nitrogen, phosphate, potash, calcium, magnesium and sulphur. In batch and dry digesters, a fraction of the digestate is returned to the digester to 'seed' the fresh feedstock with the micro-organisms responsible for AD.

When returned to land as soil amendment or conditioner, it improves soil water holding capacity while nutrients that were absorbed during the production of the food become available for further production. In many countries, after adequate treatment, digestate can be applied to agricultural land or used as bedding material for urban landscaping projects, home gardens, in horticulture or in forestry [60]. One tonne of digestate can be worth up to USD $6 in the UK [61], and after composting into certified compost, up to USD $20 in Italy[62].

From 'wet' digestion, digestate can be used 'whole', without any separation of fibre and liquid fractions. Or the fibre and liquid fractions can be separated, with the fibre fraction then in many cases itself being composted (see 'Digestate into Compost' section below)

The nutrients and market value of digestate vary according to the type of feedstock and digestion process used. An example of nutrient composition of food waste-based digestate is in Table 14 below[63].

TABLE 14: EXAMPLE OF NUTRIENT CONTENT OF FOOD WASTE-BASED DIGESTATE

NUTRIENT	CONTENT (KG/TONNE OF FRESH WASTE)
Dry Matter (%)	3.3
pH	8.3
Total Nitrogen (N)	5.4 kg
Total Phosphate (P2O5)	0.8 kg
Total Potash (K2O)	1.9 kg
Total Calcium (Ca)	1.2 kg
Total Magnesium (MgO)	0.14 kg
Total Sulphur (SO3)	0.62 kg

Use of digestate on agricultural land results in

- Reduced use of manufactured fertilisers – The nutrient value of digestate (outlined above) reduces the need to purchase artificial fertilisers as it works as a substitute.
- Increased crop yield – By replacing the use of manufactured fertilisers, the same level of digestates can further enhance yields. This is due to the impacts on soil biology, supply of micronutrients and trace elements, and the existence of plant hormones. Results will vary according to digestate type, crop type, geography and climate.

[60] WRAP (2011). New Markets for Digestate from Anaerobic Digestion. **http://www.wrap.org.uk/sites/files/wrap/New_Markets_for_AD_WRAP_format_Final_v2.c6779ccd.11341.pdf.**

[61] WRAP (2009). Waste Protocols Project. Anaerobic Digestate. **http://www.organics-recycling.org.uk/uploads/category1060/Financial_impact_assessment_for_anaerobic_digestate.pdf.**

[62] CIC (2009). **https://www.compost.it/attachments/617_Nota_Mercato_2010.pdf.**

[63] WRAP (2016). Field experiments for quality digestate and compost in agriculture. **http://www.wrap.org.uk/sites/files/wrap/DC-Agri_Work_Package_2_-_Digestate_nitrogen_supply_and_environmental_emissions.pdf**

- Reduced land degradation – In semi-arid countries, like Mali and Oman, digestate adds carbon content to the soil which improves its water retention capacity and also returns nutrients to the soil. This mitigates land degradation due to nutrient and carbon depletion.
- Cost saving – Nutrient rich, waste-based biofertilisers are highly valued in countries where farmers are heavily dependent on expensive and imported mineral fertilisers.
- CO_2 mitigation – Plants photosynthesise carbon from the atmosphere into complex carbohydrates which directly or indirectly, through food chain, constitute as food for human beings. Digesting food waste carries it further to biogas and digestate. The carbon in biogas is returned to the atmosphere, but the carbon present in the digestate is captured and stored in the soil, thereby removing it from the atmosphere, thus helping in CO_2 mitigation.
- Reduced energy usage – Manufacturing inorganic fertilisers is an energy intensive process. Substituting them with digestate reduces the energy demand of agriculture and the corresponding greenhouse gas emissions.
- Digestate is a wet material in its natural state and the addition of moisture to soil is an added value in the more arid regions.

Image: Digestate

However, like nutrients, impurities may also be present in digestate. Examples are pieces of inert materials or larger pieces of digestible ones, biological contaminants such as pathogens and weed seeds. Other contaminants such as heavy metals and persistent organic pollutants, may be present in digestate when food waste is co-digested with wastewater. The presence of these unwanted substances is dependent on their presence in the feedstock. While thermophilic digestion or pasteurisation removes biological contamination, inert materials and larger pieces of digestible materials can be dealt with in pre- or post-treatment stages of digestion. Heavy metals and persistent organic pollutants remain a problem and can be avoided by carefully selecting the feedstock.

In order to minimise the spread of pathogens, food waste digestate is heavily regulated in many countries. The required standards of quality and stability vary in different countries. While some countries require pasteurisation of digestate, others require composting and storage. It is important to contact the environmental regulators in your jurisdiction to discuss how and where it can be used.

Digestate certification schemes have been set up such as American Biogas Council Digestate Certification scheme [64], European Compost Network-Quality Assurance Scheme (ECN-QAS)[65] and Sweden Waste Management digestate certification which certifies close to 70% of digestate produced from biowaste[66,67]. While certification is an upfront cost, it can ensure long-term revenue for the biogas plant by increasing its marketability.

Best practice dictates that digestate should be stored in tanks with gas-tight covers with biogas collection – this is to ensure that no gases (methane, ammonia, hydrogen sulphide) are released into the atmosphere. Additional infrastructure such as bunding for spillage safety, or spillage and leakage detectors, may also be required, but this is up to each regulating body. The location of the digestate tank can either be at the AD plant where it is produced or at the place where the digestate will be used/applied. Whilst stored, the digestate will need to be stirred or agitated to ensure homogeneity before it is applied or transported.

When planning a biogas plant, it is important to take into consideration the possible avenues of markets for digestate keeping in mind the treatment, transport and application costs and benefits.

If transportation is required, the form of digestate (whole or separated liquids and solids), the transformation of digestate (e.g. by drying) before or after transport, the number of vehicles required, the distance between the biogas plant and destination for application and access to the user, all have cost implications. In addition, availability of the land to take the digestate must be considered as these will be dictated by seasonal restrictions and crop requirements.

Examples of agreements between biogas plants and farmers for digestate sale are common. Examples of integration of food waste digestate into a gardening supplies business is Richgro in Australia[68].

DIGESTATE INTO COMPOST

Where the transformation of digestate from municipal waste into compost is required prior to marketing as a soil amendment, as in much of the EU, the standards and quality considerations for compost apply. In the following text some detail about the market for compost is provided.

First among the critical elements is contamination. Compost produced containing hidden or visible contaminants is often banned from sale where regulations exist or can only be used for low value applications such as daily landfill cover.

Hidden contaminants include heavy metals which are present in the initial feedstock. Sewage sludge often contains heavy metals (e.g. lead, cadmium, nickel, chrome, copper, zinc) due to contamination from industrial processes. Other hidden contaminants include Persistent Organic Pollutants (POPs) such as dioxins and polychlorinated biphenyls (PCBs), which again derive largely from industrial processes. As POPs are bio-accumulators, their presence in compost then spreads to soil that is used to produce food and for animal grazing, which is potentially hazardous for human and animal health.

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[64] *American Biogas Council.* ***http://digestate.org/. Accessed on 17/12/2017.***

[65] *European Compost Network.* ***https://www.compostnetwork.info/ecn-qas/. Accessed on 17/12/2017.***

[66] *Avfall Sverige (2017) Swedish Waste Management* ***https://www.avfallsverige.se/in-english/index.php?eID=tx_securedownloads&p=139&u=0&g=0&t=1520343550&hash=d3b80beb8360689eb8ca0ff00a20934bd7834c92&file=/fileadmin/user_upload/Publikationer/Avfallshantering_2017_eng_low.pdf Accessed on 21/12/2017***

[67] *IEA Task 37 (2016). Member Country Reports. Sweden.* ***http://task37.ieabioenergy.com/country-reports.html.***

[68] *Landia. UK Companies Join Forces for New Richgro AD Plant in Australia.* ***http://www.landia.co.uk/Display-of-news?Action=1&NewsId=325&M=NewsV2&PID=711.***

It is useful therefore to note which feedstocks will commonly have potential to contain hidden contaminants. For example, leaves collected from public areas alongside busy roads are likely to contain high concentrations of lead (where this is still used in petrol) and particulate from diesel emissions.

It is therefore useful to create quality standards for the final compost produced from aerobic composting of digestate to ensure that contamination from heavy metals and chemical compounds are kept within limits acceptable for animal and human health. Such regulations exist in most advanced economies, including Italy where some 6.5 million tonnes of food and garden waste were composted in 2017, that form the end of life standards for food waste (D.Lgs.75 of 2010 [legislative decree]). The USA has State rather than Federal standards but the USA Composting Council has a programme called 'Seal of Testing Assurance Program' which certifies compost quality.

Visible contaminants include those which are non-compostable and remain at the end of the process as they have failed to biodegrade. As noted above, these may include potential compostable fractions, such as oversize pieces of wood, that have not yet broken down. These may be recycled into the composting process time and time again or shredded to smaller pieces to increase the speed of biodegradation.

Non-compostable contaminants that remain at the end of the process are present because they were collected with the food or garden waste. Composting does not produce contaminants but cannot biodegrade non-compostable materials. The most common of these are plastics of various types which pollute the food and garden waste streams. Similarly, aluminium cans, glass containers and bottles and ceramics, all of which are present in catering and kitchens, often are thrown in mistakenly with food scraps and arrive at the compost plant.

Most commonly, plastics are found with food and garden waste, for two reasons: firstly, plastics are ubiquitous so we find them in almost every packaging used to contain food – from yoghurt cups to vegetable bags to meat and fish containers to drink bottles; plastic films are particularly present in food waste because much food is wrapped in these. But secondly, and most importantly, plastics cannot be composted and are a contaminant whether the digestate is composted or not. Their presence in the digestate presents a technical as well as a cost issue, for their removal is necessary in either case. These plastics either need to be avoided in the collection process or sorted and extracted before and after the process (by screening). This is discussed further in Chapter 3 on collections.

The use of compostable films (recognised and certified by a harmonised European standard known as EN13432/2000 and in the USA by ASTM 6400) in collections and in some food packaging can help to overcome the contamination problem, as these plastics are designed and certified to naturally biodegrade within the composting process. Collection systems which use these compostable plastic materials (or other compostable materials such as paper bags) are therefore designed to reduce contamination upstream. The City of Milan, which collects food waste separately from its 1.4 million citizens, uses compostable bin liners and has a contamination level below 5% of the total volume collected and treated [69].

Compostable materials are made from

renewable plant extracts such as starches and sugars and from fossil fuel polymers. The final performance of compostable materials has in fact little to do with the polymers they are made of but all to do with the bio-chemical engineering of their end-of-life. So paradoxically a totally plant based polymer may be designed to not biodegrade whilst a totally fossil fuel based polymer may be designed to biodegrade.

An example from Italy of the features of compost from integrated anaerobic-aerobic processes is shown below:

Dry matter	71.5%
Moisture content	28.5%
Organic carbon as % of dry matter	23.3%
Total N as % of dry matter	2.3%
Total P as % of dry matter	1.5%
Total K as % of dry matter	1.5%

The final material at the end of the composting process needs to be free (by some standards, such as the UK and Italy) of at least 99.5% of all visible contaminants, including pieces of gravel, stones, plastics and glass. Further, the material needs to be free of potentially harmful levels of hidden contaminants such as heavy metals and POPs and infestant seeds such as weeds.

Once certified the compost material has several destination options:

1. BULK TO FARMERS

This is the main and traditional market for composting plants, the sale of large volumes of un-packed, untreated compost to farmers for spreading on their fields. Agronomical analysis of soils is needed to show how much compost is needed to add desired quantities of N, P, K, and organic matter to maintain fertility. This may be as much as 50t/hectare annually for field crops, less for fruit trees/vines.

Typically, a farmer will not pay more than the value of the N, P, K delivered by the compost and thus sales values of bulk compost rarely surpass €15/20 per tonne, including delivery to the field. Depending upon distance, the price can often be zero.

2. FLORICULTURE AND HOBBY MARKETS

In these market places smaller quantities of compost are required by end users, often as little as 20 litre bags for domestic users. The composted material, as it leaves the composting plant, needs additives to give sufficient nutrient value to ornamental plants and this must be further treated by a producer of gardening substrates. Typically, these may contain peat, chips of wood bark, animal bone flour, or guano. One of the more sophisticated examples of compost converted into high quality garden substrata can be seen here: *https://www.fertil.it/catalogo-2017/.*

Prices for these materials depend upon the mixes, the packaging, the end use, and the marketing ability of the producers. Typically, a 15 litre bag will cost around €10-15 at the retail point and will convert back to a per tonne price to the composting plant/converter in excess of €300/tonne. Clearly, the conversion costs, marketing, sales force, transport and distribution, packaging and additives constitute a large part of this. Nevertheless, the opportunity for additional income from higher value products is obvious.

3. SPECIALISED AGRICULTURAL MARKETS

The lack of organic matter in many regions of the world, especially the arid areas, creates enormous market opportunities for organic matter such as that delivered by compost. In Tunisia, small composting plants on the outskirts of Tunis visited by one of our authors in 2010 even paid farmers to bring organic wastes to their plants to transform into compost as the sales price of the compost (€100/tonne +) guaranteed the profitability of the exercise.

[69] *CIC (2015). Annual report of the Italian Composting and Biogas Association.* ***http://www.renewablematter.eu/partners/CIC/CIC%20annual_report2015eng.pdf.***

In the Nile Valley where crops may be cultivated and harvested throughout the year, organic matter is at a premium and is paid in excess of €100/tonne by Nile farmers. In Bangladesh, the compost plant at Dhaka sells the final product also in excess of €100/tonne to local farmers despite this being among the poorest countries of the world[70].

Other market places for compost exist in site – specific areas, such as for soil remediation; for green areas such as public parks and gardens; for golf courses and sport grounds; in the USA seeded compost is sprayed onto newly formed roadside banked areas to accelerate plant growth and avoid soil erosion; in the vineyards of Tuscany, food waste from Tuscan cities is recycled into compost specifically designed to improve vine growth and to repress potentially damaging fungi.

The issue of compost quality is elaborated on because there is a common thread into AD, as seen in Chapter 5. Where digestate is used as a raw product it obtains a virtually zero value from the farming market. Where digestate is further transformed into higher value products through a post-anaerobic process, its potential value is higher though there are costs associated in this transformation.

There are many limiting factors in the production of compost and not least among these is the available area of the production site, not an issue in the vast expanses of many countries, but certainly a problem to be taken into account in crowded urban areas where space is at a premium.

The maturing period for compost can take as long as 60 days and space for these volumes needs to be found. Storage of compost prior to market takes further space, whether packaged or not. Material flows caused by seasonality both in the feedstocks entering into composting and in the final products and their use, requires the flexibility of storage space. Distance from dwellings needs to be maintained because the composting process produces odours and if not well contained within the plant can be a nuisance to the local community. The external maturing process will also cause some odours. The noise from heavy goods vehicles entering and exiting the plant can be tiresome for neighbours and being a plant which treats waste, it will be open to receiving deliveries at least six days a week.

Composting technologies are however, mature, well-known, tried, tested and relatively easy to design, build and operate within a time frame of one to two years. Composting can be a first and rapid answer to treating food and other biogenic wastes coming from urban collection systems.

Indeed, in many developed economies such as Germany, Italy, Netherlands, Belgium, France, composting has been the mainstay of food waste treatment since the early 1990s. The arrival of fiscal incentives for the production of renewable energy subsequently led to the increase in AD technologies for these waste streams and new plants were built incorporating AD into compost. In other nations, where composting of food waste was

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[70]Sinha A H M M(2012) Public-private partnership and decentralised composting approach in Dhaka, Bangladesh ***http://www.uncrd.or.jp/content/documents/04_Sinha-Waste%20Concern-Bangladesh.pdf***

not widely practiced, such as the UK, the renewable energy incentives led to the development of an AD industry without the aerobic composting of digestate and garden waste incorporated, leading to operators looking for markets for digestate rather than higher added value products.

Below are images from digestate composting section the AD plant of Bassano del Grappa (VI), Italy[71].

Images: Digestate composting section of the AD plant of Bassano del Grappa (VI), Italy (Provided by ETRA SpA)

6.7 Carbon dioxide (CO_2)

30-40% of biogas is carbon dioxide (CO_2), its second largest constituent. When biogas is upgraded to biomethane, the carbon dioxide is removed to increase the percentage of methane (CH_4) in the gas. Methane carries the energy content of biogas and is used for the generation of heat or as a transport fuel as already covered earlier in the chapter.

The by-product and often undervalued product of this process is CO_2. CO_2 produced in this way can be used by industries and agriculture for additional revenue stream such as in carbonated beverages, food processing applications such as chilling and freezing, modified atmosphere packaging and temperature control for products being stored and transported[72], water treatment applications such as pH reduction to neutralise process and waste water streams, and as an automotive component in many gas mixtures. The CO_2 used therefore displaces CO_2 produced from fossil fuels, reducing the industry's carbon footprint.

Some examples of CO_2 utilisation around the world are the New Horizons Energy Athlone, South Africa plant which upgrades biogas from organic fraction of municipal solid waste and bottles CO_2 produced from the upgrading biogas for food and beverage, agriculture and industrial uses[73]. Ecofuels in Netherlands captures CO_2 from its upgrading operations to be used as gaseous fertiliser in greenhouses, cooling agent in industrial applications or for production of dry ice[74].

An additional area which is being explored is the use of renewable CO_2 for the growing of algae. Growing algae requires nutrients, water, sunlight and CO_2.

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[71] *Provided by ETRA SpA*

[72] *Air Liquide* ***https://industry.airliquide.co.uk/sa-industrial-carbon-dioxide Accessed on 05/03/18***

[73] *GreenCape (2017) The business case for biogas from solid waste in the Western cape* ***https://www.green-cape.co.za/assets/Uploads//GreenCape-Biogas-Business-Case-Final-v12-with-cover2.pdf***

[74] *Pentair Haffmans Ecofuels, Netherlands Case Study* ***https://foodandbeverage.pentair.com/en/case-studies/ecofuels Accessed on 22/12/2017***

Using CO_2 from the AD process can help reduce costs for growing algae. The algae can then be used to produce clean energy in the form of biodiesel, bioethanol or again used as a feedstock in AD.

Power to gas:

The CO_2 produced in the digester, can be further converted into biomethane in process commonly referred to as 'power-to-gas' or 'biomethanation'. In this process, CO_2 from the digester and hydrogen from an external source are biologically converted into methane via hydrogenotrophic methanogenesis by single celled microorganisms called archaea. This reaction is highly exothermic or generates heat, which can be captured and reused. The methane produced goes through a similar gas cleaning process as biogas and can be injected into the gas grid or used as vehicle fuel.

This process may take place within the digester or by using a separate stream of CO_2 produced as a by-product of upgrading as shown in the figure below[75].

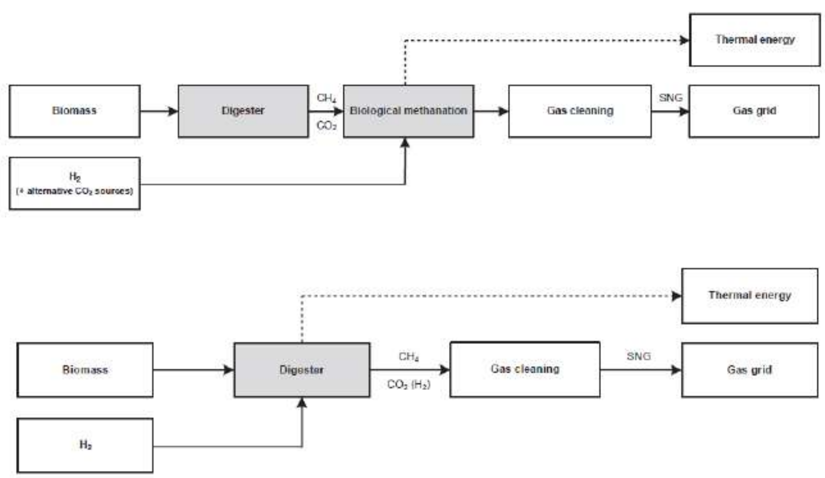

Figure 16: Process flow diagrams for biological methanation in a separate reactor (above) and for in situ biological methanation (below)76

While this process can be achieved by purely catalytic reactions, combining it with biogas production has the following advantages:

- Existing source of CO_2;
- Heat generated during biomethanation can used to maintain the temperature of biogas digester; and
- Gas cleaning process of upgraded biogas and methane generated from power-to-gas system is the same, which results in reduced capital and operational costs.

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[75]Gotz M, Lefebvre J, Mors F, Koch A M, Graf F, Bajohr S, Reimert R and Kolb T (2016) Renewable Power-to-Gas: A technological and economic review, Renewable Energy, Volume 85, Pages 1371-1390

[76]Gotz M, Lefebvre J, Mors F, Koch A M, Graf F, Bajohr S, Reimert R and Kolb T (2016) Renewable Power-to-Gas: A technological and economic review, Renewable Energy, Volume 85, Pages 1371-1390

Power-to-gas methane technology has been implemented successfully at the Audi e-gas plant in Wertle Germany and has been operational since 2013. Industrial and agricultural biowaste are digested at the Hitachi Zosen Inova biogas plant. The biogas upgraded and the CO_2 stream is supplied to the nearby Audi AG power-to-gas plant where it is used for methanation. The waste heat from this process is supplied back to the biogas plant for regeneration of amine scrubbing solution used in the upgrading process[77].

6.8 Cooling

Though seldom used, the heat from biogas can be used for chilling by using trigeneration or 'combined heat, power and cooling' (CHPC) systems. In these systems, there is a flexibility of using heat when needed and when not, heat can be converted for cooling. These systems work through vapour absorption or absorption chillers. So, for example, in winter, heat from a CHPC can be used to warm a building, while in summer it may be used to cool it. CHPC systems also have application in food and drinks industry where cooling it often required. Such a system has been installed in the Municipality of Este, Veneto, Italy by the operator SESA SpA.

6.9 Conclusion

Biogas from food waste can be put to many uses to the benefit of the people, environment and economy. In order to make the collection and digestion of food waste a norm, in cities and industries, a number of barriers need to be overcome. With the required knowledge and policy support, this can be achieved.

Chapter 7 highlights the ways that developers and policy makers can help in creating an environment where food waste collection and digestion becomes profitable and the chosen method of waste management.

[77] *Hitachi Zosen Inova* ***http://www.hz-inova.com/cms/en/home?page_id=5178***

Anaerobic Digestion of Food Waste: the case of the AD plant of Bassano del Grappa (VI)

City/District served

District of Vicenza and few municipalities of the district of Padua – Region Veneto

Type of authority collecting the food waste

Food waste is mostly collected by ETRA SpA (the same company which owns and run the AD plant), a public company in charge of the integrated waste management system (collection and treatment) in the districts Vicenza and part of the district of Padua. In some municipalities food waste is collected by other waste collection companies.

Type of establishments served

Mainly from households and commercial establishment whose waste is assimilated to municipal waste

Number of households/people/businesses/industries served

Around 480,000 inhabitants (around 73,5 kg/inh/y, as calculated by ETRA)

Volume of food waste treated annually (tonnes).

In 2016 the plant has treated around 41,000 t/y (35,000 t/y food waste and 6,000 t/y garden waste)

Co-digestion of food waste with other feedstocks

Basically the plant digests only food waste mixed with garden waste; actually, garden waste has a negligible biogas production potential; its primary scope is to facilitate the release of biogas from the digester.

Biogas produced on an annual basis

Around 5,000,000 m^3/y in 2016 (142 m^3/tonne food waste)

Biogas utilisation

Electricity production. The company is moving toward biogas upgrading; biomethane will be used as a transport fuel

Heat utilisation

A small amount of heat is exploited for the pre-heating of the feedstock to digestion (to a temperature of 37°C). The plant is about to implement a new heat recovery unit for several applications within the plant boundaries (i.e. heating of offices)

Digestate utilisation

Digestate is separated into a liquid phase (to WWTP) and a solid phase (mixed with garden waste and composted); The solid-liquid separation is done through screw squeezing and further centrifugation of the liquid phase. Solid phase composting is done by Advanced Composting technology (ACT) in which digestate is turned and forcedly ventilated through windows followed by curing and finally screening through 10mm holes as shown in images above.

Case Study: Provided by Italian Composting and Biogas Association and ETRA SpA

Income/revenue streams

Incomes come from food waste and garden waste gate fees and electricity production. No data available, but interestingly the plant declares that gate fees are variable and calculated on the basis of the amount of Incomes come from food waste and garden waste gate fees and electricity production. No data available, but interestingly the plant declares that gate fees are variable and calculated on the basis of the amount of impurities in food waste collected from each municipality. Until 2015 the plant benefit of subsidies for each kWh put into consumption, according to a green certificates granting scheme

Policies have enabled digestion of food waste

Increasing landfill gate fees pushed forward the implementation of separate collection schemes; region Veneto has always been at the top of the ranking among Italian regions in terms of separate collection performances (now 72.91% against an average national rate of 52.54%) and the organic fraction (food waste + garden waste) are the main drivers. Anaerobic digestion.

The plant was initially intended as an integrated facility for the anaerobic treatment of both food waste and mixed MSW in separate digesters. The introduction by region Veneto of an exemption from the MSW pre-treatment obligation before landfilling (set by the 1999/31/EC Directive) whenever MSW contains until 15% putrescible organic waste has further pushed forward the separate collection of food waste; AD of mixed MSW was soon abandoned by the plant.

Barriers faced

At the beginning, the main barrier was represented by technical constraints when treating mixed MSW (frequent digesters clogging and extraordinary maintenance costs); in this sense, the treatment of food waste from separate collection must be considered a net advantage rather than a barrier

Unique and outstanding features

Connection of the plant with the Waste Water Treatment Plant settled 1km far from it, where liquid digestate is pumped and treated; from liquid digestate Ammonia is recovered as Ammonium sulfate (according to a stripping technology) and put into consumption for different potential applications, such as nutrient for WWTPs, catalyst for resins hardening and mineral fertilizer. The WWTP is supplied by the electricity produced by the AD plant. Another important feature consists in the relationships with the surrounding territory (see below); after initial tensions with the population, a hard work has been made to set up a dialogue which ended with the implementation of a Committee involving company, citizens and the administrations of the municipality of Bassano del Grappa and the adjacent one, which discuss and solve all the problems related to the plant operations (mostly referable to odor emissions)

Public perception

Households are settled in the nearby, few hundred meters far from the plant. After the first years of activity, during which concerns were expressed by the population mainly associated to odor emissions, the company is now generally well accepted by the territory. This is due to the high environment protection levels assured (the plant is entirely run in closed buildings kept under negative pressure, with exhaust air depuration with a scrubber+biofilter system), the periodical monitoring of the emissions to the atmosphere and the implementation of a Committee involving company, citizens and the administrations of the municipality of Bassano del Grappa and the adjacent one, which discuss and solve all the problems related to the plant operations

7. POLICY RECOMMENDATIONS, BARRIERS AND IMPLEMENTATION

In this final chapter, recommendations are made to decision-makers and policy-makers – above all, that, with the global commitments that have been made, separately collecting food waste from businesses and households is of vital and urgent importance and should be implemented, and that anaerobic digestion (AD) is the most cost-effective treatment technology in full cost analyses. The barriers to developing biogas projects and ways of overcoming these are considered. The policies and associated implementation measures form part of a "How to" implementation guide for municipalities and countries seeking to implement food waste management solutions.

In previous chapters, the benefits of food waste collection and AD were discussed in detail: climate change mitigation, renewable energy generation, sustainable industrialisation, food security, and better health and sanitation. Chapter 3 looked at examples of municipalities, industries and businesses that have successfully integrated these collections into existing waste management systems. Although no formal global statistics of food waste collection exist, it is clear that, even with progress in some jurisdictions, food waste digestion is only in its infancy and there is great scope for development. This chapter therefore provides the framework for municipalities to implement better food waste management policies, while adjusting to their own circumstances.

7.1. Policy recommendations

As was highlighted in Chapters 3-6, separate collections of food waste has significant advantages over other food waste collection and treatment techniques. Although there will be initial set-up costs, over time, separate food waste collection for households and businesses will deliver societal savings compared to all other options. Given the importance of prevention activities described in Chapter 2, therefore, the following policy recommendations can be considered:

- **Undertake large-scale food waste awareness-raising and prevention campaigns;**
- **Require businesses to separately collect food waste;**
- **Provide separate collections of food waste to households; and**
- **Require use of all food waste in line with the food management hierarchy, whether this is through use as animal feed, composting or AD.**

These policies are essential for urban areas and the wider world to reach their commitments under the climate change treaty and the SDGs. The following sections explain the barriers to implementation of these policies, the wider policy context that local policy-makers might be working in, and the implementation process that should be followed.

7.2. What are the principle barriers to developing better food waste management policies?

The benefits of food waste collection and treatment are numerous. Besides lack of awareness of these benefits, the possible reasons for why this form of collection and treatment is not a norm globally are explored.

7.2.1. Low cost of landfilling, no cost to illegal dumping

Globally, landfilling is still the most widely used method of disposal of municipal solid waste, as shown in Figure 14 below[1]. Besides landfills, which are often managed and closed areas, up to 33% of waste is still illegally dumped in low-income and middle-income countries in open, unmanaged dumps or directly into the environment (city streets, fields, rivers, lakes, the sea)[2] .

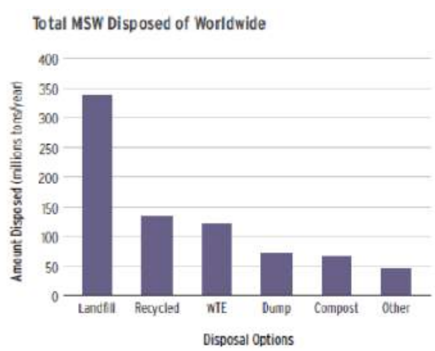

Figure 17: Disposal of MSW worldwide

In most countries, sending waste to landfill is very low cost, and in some countries there is no direct cost at all. Fees mostly account for direct management costs of the sites, but do not consider costs of the environmental damage, waste of resources, GHG emissions and immediate health impacts resulting from this practice. The costs of any alternative waste management options or policies to avoid waste, have to compete with these prices, and therefore these low or non-existent prices are a significant disincentive for municipalities and businesses to invest in separate food waste collection and treatment infrastructure. Other forms of waste management beyond dumping are difficult to achieve without internalising the external costs of landfilling. Regulation, for example through a landfill tax, and comprehensive controlling mechanisms to guarantee compliance, can help make climate-friendly methods more competitive.

7.2.2. Investment costs and access to finance

The upfront cost of food waste collection and digestion is a barrier to its adoption. As discussed in Chapter 5, the cost of a 30,000 tonne per year capacity plant may be $400-$600/tonne of annual capacity. A larger plant may have a capital cost of $300-$400/tonne. The relatively high upfront cost, a perception of financial risk, difficulty in importing technology due to currency barriers, and structuring finance to provide for operating costs are challenges faced by jurisdictions and businesses in obtaining finance for the projects. Outlined in Section 7.3 are the initiatives, mainly from national governments, that support the financial case for the digestion of food waste. In Thailand, national government support helped make AD viable for starch mills, breweries and palm oil mill effluent. The government aided building of biogas plants initially through capital grants and then soft loans and co-financing biogas projects. Once familiarity increased, more banks were willing to lend and corporate financing became available, thus improving access to finance[3].

[1] *The World Bank (2012) What a Waste: A Global Review of Solid Waste Management* ***https://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/What_a_Waste2012_Final.pdf***

[2] *The World Bank (2012) What a Waste: A Global Review of Solid Waste Management* ***https://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/What_a_Waste2012_Final.pdf***

[3] *Situer J (2016) Rapid deployment of industrial biogas in Thailand: factors of success* ***http://www.ieabioenergy.com/wp-content/uploads/2016/05/P13-Rapid-deployment-of-industrial-biogas-in-Thailand-factors-of-success-Siteur.pdf***

IN MANY COUNTRIES, SYNTHETIC NITROGEN FERTILISERS ARE ALSO SUBSIDISED , FURTHER DIS-INCENTIVISING THE USE OF RENEWABLE, LOW CARBON FERTILISERS SUCH AS DIGESTATE.

7.2.3. Availability of subsidised fossil fuel energy and fertiliser

An estimated $5.3 trillion was spent worldwide on subsidising fossil fuels in 2015, of which nearly half was spent on coal subsidies [4]. Over the course of decades, these subsidies heavily distort the energy market in favour of fossil fuel based energy.

The low energy prices resulting from these subsidies pose a challenge for renewables-based energy to compete with. With increased scale of implementation and maturing of technology, the cost of producing energy from food waste is decreasing, however, it is still not always competitive and also needs to be supported.

In many countries, synthetic nitrogen fertilisers are also subsidised [5], further dis-incentivising the use of renewable, low carbon fertilisers such as digestate.

7.2.4. Lack of technical know how

To start a food waste collection and digestion programme in countries where it is already widely implemented, such as in Sweden, the USA and Korea, or sectors such as breweries, abattoirs and restaurants, the technical and regulatory knowledge as well as supply chain may be readily available. The parties interested in setting up a new biogas plant are able to visit and learn from the experiences of both successful and unsuccessful attempts at implementation.

However, in countries and sectors in which AD has not been implemented yet, technical knowledge, regulatory support and procurement of equipment, are often missing.

This challenge may be faced at the time of initial conceptualisation and construction, or operation and maintenance of the biogas plant.

The lack of knowledge may be remedied by undertaking site visits, study tours, consulting experts and respected academicians, getting in touch with the relevant trade associations, learning from early adopters' experiences and successful case studies in other countries or sectors, or hiring consultants. The authors of this report (WBA and the C40 Cities Food, Water and Waste Programme), are available to help in this respect.

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[4] *Coady D, Parry I, Sears L and Shang B (2017) How large are global fossil fuel subsidies, World Development, Volume 91, March 2017, Pages 11-27* ***http://www.sciencedirect.com/science/article/pii/S0305750X16304867***

[5] *An economic appraisal of withdrawing fertilizer subsidies in India (English)* ***http://documents.worldbank.org/curated/en/180341468253188752/An-economic-appraisal-of-withdrawing-fertilizer-subsidies-in-India***

7.2.5. Lack of long term policy frameworks and political will

An AD industry needs initial regulatory and financial support to deliver climate, energy, food and health benefits. Some of these benefits, such as climate change mitigation and food security, are not visible in the short term.

The timeline for implementation of a project from conceptualisation to start of operation may also be up to three years or even more depending on the regulatory environment in the country. Formulation and implementation of policy and building food waste and digestion infrastructure can take up to five years, varying from country to country. Development of an AD industry requires long term, sustained commitment from the government and often suffers from the lack of political will to support it.

This challenge may be addressed by raising the awareness about the many benefits of AD of food waste among policy makers as well as commercial and industrial enterprises.

7.2.6. Low monetary value of biogas and digestate

While over 100 countries have a feed in tariff incentive in place for renewable electricity generators, not all of these include the production of energy from biogas. Similarly, heat produced from biogas and digestate produced from digestion of food waste has to compete with the heavily subsidised prices of fossil fuel based heat and mineral fertilisers in many jurisdictions.

The climate change mitigation, energy independence, food security and health benefits of AD are not internalised into the monetary value that biogas fetches, just like the damage caused by fossil fuel based energy is not factored into its monetary value.

This challenge requires action on a global scale to rethink and restructure our energy, carbon and health valuation of commodities and actions. Local authorities and national governments can however act, and within the framework of the SDGs and the Paris Agreement, these policies can be formulated.

7.2.7. Lack of public awareness

The success of a separate food waste collection and digestion system depends very heavily on public participation. Achieving the desired quantity and quality of food waste segregation requires additional effort on the part of households. Industries that install digesters on-site are required to make an investment and weigh the costs and benefits of doing so. Commercial and retail establishments are required to separate their food waste which needs processes in place for each employee to follow.

Each of these establishments are asked to do something different from “business as usual”. In order to fully adopt and integrate these processes, they are asked to buy into the benefits of AD. In order to make separation of food waste a norm, rather than an exception or extra effort, public education and continuous communication is required.

This challenge can be addressed by the administration of the jurisdiction, in schools and universities, in local community centres, high rise buildings, door-to-door canvassing, local shops, by trade organisations, at tradeshows and exhibitions through a variety of communication mediums.

7.2.8. State of infrastructure for biogas utilisation

Another challenge faced by developers of biogas plants is the state of the infrastructure required to fully utilise the products of digestion, such as a stable electricity grid to connect to, or an existing district heating network within reasonable distance, or a gas grid to inject upgraded biomethane.

This is a challenge that can be addressed at the planning stage of a project by looking for local base load and peak load consumers. A number of currently successful plants have been built on sites which needed high amounts of energy for their own processes or could help a local community or neighbouring industry meet its energy demands. For example, in Chiba, Japan, food waste from households and businesses is digested and the biogas is supplied to the neighbouring JFE Steel where the biogas is used combusted to produce electricity and steam to be used as process heat.

7.2.9. Availability of feedstock

While food waste is generated in cities, often only a small percentage of it is available for digestion as it is not being currently separated and collected. This creates an artificial limitation of feedstock. A number of digesters in Germany and the UK are facing feedstock shortages and are not running to capacity. This prevents new biogas plants from being built due to concerns about profitability and capacity management.

This challenge can be addressed at the planning stage of the project by realistically considering the sources of feedstock from surrounding industries. Similar to selling biogas products to neighbouring industries, feedstocks may be obtained from them, such as from food and processing industries, local community, fruits and vegetable markets and so on.

7.3. Mechanisms and policies to support food waste digestion

The section below explores different mechanisms and policies that can help incentivise the roll out of food waste collections for digestion. They help overcome many of the barriers outlined above, and ensure that when the cost-benefit analysis of separate food waste collections and treatment through AD are undertaken, more of the benefits, such as renewable energy, are recognised financially. These policies are frequently implemented at national or supranational level. In many cases it will be the role of the municipality only to understand how the mechanisms work and how they can be accessed, not to implement them themselves. As outlined in Section 7.4 below, municipal policy-makers need to understand how to access any national policy support. This section is therefore for reference rather than for municipal policy-makers to necessarily implement themselves.

7.3.1. The role of targets

High level targets set by countries and cities set the intent of the government and direction of future growth. These can be a very useful driver in triggering collection of source segregated food waste and use of AD for its recycling.

Targets have a number of benefits:

- **They encourage policy-makers to clarify and prioritise the most important policy goals;**
- **They allow any available funds to be channelled to meet the agreed target; and**
- **They encourage quantification and measurement of policy goals, discouraging vague commitments.**

Relevant targets that can be considered are outlined below.

Emissions reduction targets

In 2015, 195 parties signed the Paris Agreement, of which 174 have ratified it or officially accepted it [6]. These parties are now working on their Intended Nationally Determined Contributions (INDCs) with the expectation that the sum of all their contributions will keep the rise in global temperature to well below 2°C and pursue efforts to limit it below 1.5°C [7].

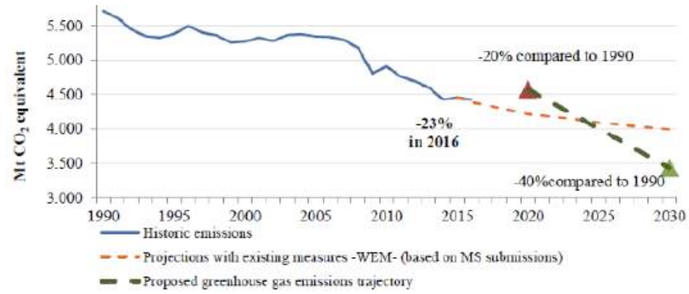

Figure 18: Progress towards meeting Europe 2020 and 2030 targets (total EU GHG emissions)

In 2007, the European Union (EU) had set a target of reducing its greenhouse gas emissions by 20% from 1990 level by 2020. By 2016, it had already reached a 23% reduction and is aiming to reach a 40% by 2030. The figure below shows the progress towards these targets [8]. Projections suggest that with the current measures, the 2030 target will not be achieved and further measures are required – hence the recently-agreed Circular Economy package making separate food waste collection obligatory by the end of 2023 across the EU under the revised Waste Framework Directive [9].

The Swedish government, for example, has set a goal of zero net GHG emissions by 2050 and a fossil fuel free vehicle fleet by 2030. These have been identified as key drivers for the development of the biogas industry in the country [10].

Renewable energy targets

One of the main advantages of the digestion of food waste is the energy produced from it, in the form of biogas. As discussed in earlier chapters, this energy can be used as it is or converted to heat, electricity, cooling or biomethane for grid injection or vehicle fuel. Almost all countries have targets for meeting their primary and overall energy needs from renewables[11]. These may be part of reaching its carbon emission reductions targets, improving national energy independence and security, and sustainable development.

In 2009, the EU set itself a renewable energy target of 20% of primary energy demand by 2020. This target was then devolved to a specific target for each country in the EU. This policy has been a huge success in increasing the share of renewables in the energy system, with the renewable share of energy supply doubling in 11 years[12]. Biogas based energy represents about 7.6% of the primary renewable energy production in the EU[13].

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[6] *United Nations Climate Change: Paris Agreement* ***http://unfccc.int/paris_agreement/items/9485.php Accessed on 08/03/2018***

[7] *Ibid*

[8] *European Commission (2017) Two years after Paris – Progress towards meeting the EU's climate commitments* ***https://ec.europa.eu/clima/sites/clima/files/strategies/progress/docs/swd_2017_xxx_en.pdf***

[9] ***https://ec.europa.eu/commission/priorities/jobs-growth-and-investment/towards-circular-economy_en***

[10] *European Commission (2016) Optimal use of biogas from waste streams* ***https://ec.europa.eu/energy/sites/ener/files/documents/ce_delft_3g84_biogas_beyond_2020_final_report.pdf***

[11] *REN 21(2017) Renewables 2017 Global Status Report* ***http://www.ren21.net/wp-content/uploads/2017/06/17-8399_GSR_2017_Full_Report_0621_Opt.pdf***

[12] *Eurostat (2017) Renewable energy in EU* ***http://ec.europa.eu/eurostat/documents/2995521/7905983/8-14032017-BP-EN.pdf/af8b4671-fb2a-477b-b7cf-d9a28cb8beea***

[13] *European Commission (2016) Optimal use of biogas from waste streams* ***https://ec.europa.eu/energy/sites/ener/files/documents/ce_delft_3g84_biogas_beyond_2020_final_report.pdf***

Biogas based energy production targets

Countries or jurisdictions may set targets to build a certain number of digesters or generate a targeted amount of electricity from AD or treat a targeted volume/weight/percentage of food waste via AD. Such targets identify AD as the choice of treatment for food waste and directly help in the development of the industry.

Austria, for example, has a target of adding 200MW of installed capacity from solid biomass and biogas during 2010-2020 while Thailand targets to achieve 600MW installed biogas based energy generation capacity by 2021. The Republic of Korea has set itself a target of 161GWh of biogas generation by 2030[14].

Food waste prevention targets

As outlined in Chapter 3, the world has committed to reduce food waste by 50% per capita by 2030 under the SDGs. This can only be measured and achieved in countries and municipalities which have a full understanding of food waste sources and its relationship to consumer behaviour.

Japan and the United Kingdom have introduced food waste reduction targets within individual industries and at household levels[15]. In 2015, U.S. EPA and the U.S. Department of Agriculture (USDA) announced the U.S. food waste challenge, the nation's first-ever non-binding voluntary goal toward a 50 percent reduction in food loss and waste by 2020 through a combination of food loss prevention and recovery as well as industrial use, anaerobic digestion (AD) and composting of food waste[16]. Chapter 3 of this report discusses a number of initiatives that can be taken to prevent food waste such as raising awareness, communication, institutional and regulatory initiatives. In addition to these, introducing separate food waste collections can make citizens, industries and businesses more aware of the food waste being generated and can lead to reduced generation. This has been seen in Wales, where over the period in which separate food waste collections for households was introduced, the amount of food waste produced declined by 11%[17].

Recycling targets

Food waste recycling targets may be introduced to specifically target the collection and recycling of food waste. The drivers behind these may be environmental benefits, resource efficiency, energy independence, sanitation, surface and marine water quality or lack of landfill space. These may be introduced as a part of overall recycling and waste management strategy or on its own for jurisdictions or businesses. A recycling target has the benefit of being simple and measurable compared to other waste management objectives, such as resource efficiency.

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[14] *REN 21(2017) Renewables 2017 Global Status Report* ***http://www.ren21.net/wp-content/uploads/2017/06/17-8399_GSR_2017_Full_Report_0621_Opt.pdf***

[15] *Parry A, Bleazard P and Okawa K (2015) preventing case studies: case studies* ***http://www.oecd-ilibrary.org/docserver/download/5js4w29cf0f7-en.*** *pdf?expires=1513101671&id=id&accname=guest&checksum=9F4A499BCEF1ED1B6D43C3F98B004E13*

[16] *USDA (US Department of Agriculture). 2015. USDA and EPA join with private sector, charitable organizations to set nation's first food waste reduction goals. Release no. 0257.15. September 2015.* ***www.usda.gov/wps/portal/usda/usdahome?contentid=2015/09/0257.xml***

[17] *WRAP Cymru (2015) Household food waste in Wales* ***http://www.wrapcymru.org.uk/hhw2015***

For jurisdictions: The EU has a 50% recycling (including composting and AD) target for 2020, which will increase to 65% for 2035[18]. In USA, few communities have policies and/or regulations to mandate organic waste diversion or establish zero waste goals as shown in table below[19].

TABLE 15:

CITY, STATE	GOALS (E.G., TARGETS) FOR PROGRESS TOWARD ZERO WASTE	TARGET YEAR(S)
Oakland, CA	Zero waste	2020
San Francisco, CA	Zero waste	2020
Minneapolis, MN	50/80 percent	2020/2030
Dallas, TX	40/60 percent/Zero waste	2020/2030/2040
San Diego, CA	75/90/100 percent	2020/2035/2040
Los Angeles, CA	Zero waste	2025
Seattle, WA	70 percent	2025
New York City, NY	90 percent relative to 2005 levels	2030
Austin, TX	Zero waste	2040

Source: Bodamer 2015

For sectors and businesses: in Japan, the 'food waste recycling law' lays out recycling targets for food related businesses as shown in the table 16[20].

TABLE 16: RECYCLING TARGETS FOR FOOD RELATED BUSINESSES IN JAPAN

SECTOR	RECYCLING TARGET
Food manufacturers	85%
Food retailers	45%
Food wholesalers	70%
Catering services/restaurants	40%

Diversion from landfill targets

Targets for the reduction of organic waste sent to landfills are an effective mechanism to encourage the source segregation of food waste at collection point. While some may choose to use AD for treatment and recycling of the waste thus collected, it does not mandate energy and nutrient recovery. The food waste or organic waste thus collected may be treated using AD, composting or any other technology as discussed in Chapter 5 of this report. The EU, as part of its Landfill[21] Directive, has laid down a 65% reduction target for the tonnage of biodegradable municipal waste being sent to landfill , which member states are largely on course to achieve. Under the new Landfill Directive provisionally approved in 2018, no waste may be sent to landfill after 2035 that could be disposed of or recycled alternatively, and landfill must represent no more than 10% of any nation's waste disposal options[22]. In the United States, five states—California, Connecticut, Massachusetts, Rhode Island, and Vermont—have adopted food waste disposal bans that primarily target the commercial and industrial sector (e.g., food wholesalers, distributors, manufacturers, processors; supermarkets, resorts, conference centers)[23].

[18] *European Parliament (2017) Circular economy package: Four legislative proposals on waste* **http://www.europarl.europa.eu/RegData/etudes/BRIE/2017/599288/EPRS_BRI(2017)599288_EN.pdf**

[19] *Bodamer, D. 2015. 10 Major U.S. Cities with Zero Waste Goals. 27 July 2015.* **www.waste360.com/waste-reduction/10-major-us-cities-zero-waste-goals.**

[20] *Food waste recycling law, Japan* **http://nett21.gec.jp/Ecotowns/data/et_c-08.html**

[21] *The Council of European Union (1999) Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste* **http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:31999L0031&from=EN**

[22] *The Council of European Union (2018) EU ambassadors approve new rules on waste management and recycling* **http://www.consilium.europa.eu/en/press/press-releases/2018/02/23/eu-ambassadors-approve-new-rules-on-waste-management-and-recycling/**

[23] *Leib, E.B., C. Rice, and J. Mahoney. 2016. Fresh look at organics bans and waste recycling laws. BioCycle. November 2016.* **www.biocycle.net/2016/11/10/fresh-look-organics-bans-waste-recycling-laws/**

7.3.2. Policies to meet targets

While targets help focus policies on important areas, policies need to be implemented to reach these targets. Each of the policies below supports a specific benefit of AD of food waste, including: reduction of greenhouse gas emissions, production of renewable energy, waste management, sanitation, recirculation of nutrients, via market mechanisms, financial incentives, capital grants, and regulations.

Pricing greenhouse gas emissions

Food waste collection and digestion impacts greenhouse gas emissions from its management in multiple ways. These are mainly positive, but some negative:

- Methane emissions avoided from food waste degradation in landfills;
- Replacement of fossil fuel based energy with renewable energy, leading to GHG emission savings;
- Reduced emissions from production, mining and transport of mineral fertilisers by substituting with locally produced biofertiliser/digestate;
- Separate collection of food waste potentially leading to a reduction in its generation, and therefore in the associated emissions;
- Added emissions from construction and operation of digesters and associated equipment; and
- Added emissions from vehicles collecting food waste and delivering digestate unless these are powered by biogas or renewable electricity.

These emissions reductions are summarised below:

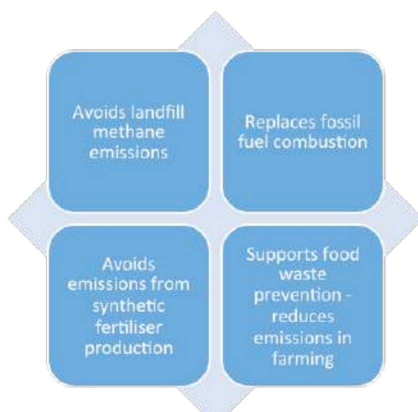

Figure 19: Emissions reductions delivered by separate food waste collections and AD

For the best environmental performance of a collection and digestion system, however, it is important to take all of these into consideration and optimise the collection routes, digestion plant location, final use of biogas and digestate. Well-designed systems result in considerable reduction in greenhouse gas emissions as compared to sending the food waste to a landfill or other treatment option. This reduction in emissions, if incentivised correctly, not only improves the environmental and economic performance of the digester, but also acknowledges the role of AD as a greenhouse gas abatement technology rather than only a renewable energy generation technology. It will also incentivise further innovation in cost-effective abatement.

Pricing greenhouse gas emissions effectively would significantly increase the cost of landfilling, fossil fuel-based energy, synthetic fertilisers and unsustainably produced food, making for a fairer playing field for low carbon, circular technologies like AD. For now, we are collectively footing a bill of trillions of dollars in environmental damage, climate change, deteriorating soil quality, poor health and sanitation. The two methods of pricing greenhouse gas emissions are through trading schemes and taxes. It is important that all the emissions that AD can avoid are included in these schemes (emissions from landfill, fertiliser manufacturing etc.).

A) Emissions trading schemes

Emissions trading schemes allocate emissions between businesses and/or citizens, with limits/caps then placed on total emissions. These caps are then reduced over time to target levels. Allocations can be free to participants below certain levels, or auctioned, or have minimum prices set. These allocations can be traded to ensure the most efficient allocation among participants – those who add most value per tonne of carbon dioxide-equivalent emissions would offer more than those who can add less value.

One of the first such mechanisms, implemented globally in 2006 under the Kyoto protocol, was the Clean Development Mechanism. It aimed at stimulating sustainable development and emission reductions via trading of Certified Emission Reduction (CER) credits. It registered 7,796 projects with 1.9 billion CERs issued (or abated tonnes of CO_2 eq.) [24].

California introduced a cap-and-trade scheme in 2013. This was the world's fourth largest scheme after the EU scheme (see below), the Republic of Korea's, and the Chinese province of Guangdong (with the rest of China due to adopt a scheme within the coming years). California's emissions trading system is expected to reduce greenhouse gas emissions from regulated entities by more than 16% between 2013 and 2020, and by an additional 40% by 2030 [25]. Like many other emissions trading schemes, the cap-and-trade rule applies to large electric power plants, large industrial plants, and fuel distributors (e.g. natural gas and petroleum).

The EU Emissions Trading Scheme (EU ETS) has been operating since 2005. It currently covers the electricity generation, iron and steel, mineral processing (for example, cement manufacture) and pulp and paper processing sectors. The EU ETS has also been plagued by persistently low carbon prices – for those that do have to pay for their pollution. Emissions allowances (EUAs) have cost less than €10 per tonne since late 2011, far below most estimates of the social cost of carbon and below the level thought to be necessary to drive deep decarbonisation [26].

B) Carbon taxes

A carbon tax directly sets a price on carbon by defining a tax rate on greenhouse gas emissions; an emitter of a greenhouse gas pays an amount per tonne of carbon dioxide-equivalent emitted. It is different from emissions trading schemes in that the emission reduction outcome of a carbon tax is not pre-defined but the carbon price is[27]. It therefore does not guarantee reductions in emissions to target levels, but does provide certainty on the cost of emissions. The revenue from this tax can be diverted to the development of clean energy in the jurisdiction.

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[24] *Clean Development Mechanism* ***http://cdm.unfccc.int/index.html Accessed on 26/01/2018***

[25] *Center for Climate and Energy Solutions: California cap and trade* ***https://www.c2es.org/content/california-cap-and-trade/ Accessed on 08/03/2018***

[26] *Carbon Brief (2017) Q&A: Will the reformed EU Emissions trading System raise carbon prices* ***https://www.carbonbrief.org/qa-will-reformed-eu-emissions-trading-system-raise-carbon-prices***

[27] *The World Bank: Pricing Carbon* ***http://www.worldbank.org/en/programs/pricing-carbon Accessed on 08/03/2018***

Carbon taxation has been used extensively as a climate change and clean energy policy instrument across the globe. The value of the carbon tax varies from less than $1 per tonne CO_2 eq. in Mexico, Poland and Ukraine to $87 per tonne CO_2 eq. in Switzerland and $140 per tonne CO_2 eq. in Sweden[28].

Carbon pricing initiatives have been implemented in 67 national and subnational jurisdictions covering 8 GT CO_2 eq. or 15% of global GHG emissions [29].

Renewable energy incentives

Many jurisdictions have provided incentives to renewable sources of energy in order to reduce fossil fuel combustion for electricity and heat generation, and for transport.

These fall into three broad categories:

1) Direct cash payments

The most common policy instrument for incentivising production of renewable electricity and heat is through direct cash payments such as 'feed in tariffs' and 'feed in premiums'. The utilities or companies operating the electricity/heat grid are required to pay the renewable energy generator a fixed feed in tariff or a variable feed in premium above the market price of energy. This premium payment may be funded by passing on the extra expenditure to the consumers via billing, government funding or the tax payer via an additional tax. Feed in tariffs/premiums are typically guaranteed for a period of 15 to 20 years and are digressed as the technology starts to mature.

Feed in tariffs/premiums may be structured as percentage of retail/wholesale price of electricity, fixed tariff in addition to the retail/wholesale price of electricity or a capped premium to cover the difference between the retail/wholesale price of electricity and the base price of electricity from renewable sources.

Feed in tariffs/premiums thus encourage the deployment of renewable energy technologies by providing certainty on returns to the generator. Feed in tariffs/premiums for renewable energy production are implemented in over 100 countries and states for many different sources of renewable energy production; however very few include energy from biogas[30] within those frameworks.

Feed in tariffs for electricity has been instrumental in the growth of biogas industry in Germany, Czech Republic, France[31] and Thailand[32]. Feed in premium for electricity has been implemented in Denmark, France, Austria, Germany and Italy[33]. Feed in premiums for heat has been implemented in Austria, Estonia, Finland and the Netherlands[34].

2) Quota obligations and renewable energy certificates

The production of renewable energy can also be stimulated top down, via market based mechanisms such as tradable renewable energy certificates. These have been used to encourage renewable electricity generation as well as renewable transport fuel or biomethane in this case. Under this mechanism, generators of energy (such as utility companies) are obliged to source a certain percentage of their production from renewable energy sources. Biogas is among those.

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[28] *World Bank, Ecofys and Vivid Economics (2017) State and Trends of Carbon Pricing 2017 (November), by World Bank, Washington, DC* ***https://openknowledge.worldbank.org/bitstream/handle/10986/28510/wb_report_171027.pdf?sequence=5&isAllowed=y***

[29] *Ibid*

[30] *Renewable Energy Policy Network for the 21st Century (2017) Renewables 2017. Global Status Report* ***http://www.ren21.net/wp-content/uploads/2017/06/17-8399_GSR_2017_Full_Report_0621_Opt.pdf***

[31] *European Commission (2016) Optimal use of biogas from waste streams* ***https://ec.europa.eu/energy/sites/ener/files/documents/ce_delft_3g84_biogas_beyond_2020_final_report.pdf***

[32] *Siteur J (2012) Rapid development of industrial biogas in Thailand* ***http://www.iipnetwork.org/IIP-10.%20BiogasCaseStudy.pdf***

[33] *European Commission (2016) Optimal use of biogas from waste streams* ***https://ec.europa.eu/energy/sites/ener/files/documents/ce_delft_3g84_biogas_beyond_2020_final_report.pdf***

[34] *ibid*

The generators of renewable energy are given a certificate for every unit of energy produced. This certificate can be used to meet their own renewables obligations or traded with other generators who are short of meeting their renewables obligation. These certificates therefore acquire a monetary value and create a source of income for the renewable energy generator that allows them to pay a higher than market price for the biogas acquired.

Renewable energy certificates have been implemented for electricity in Australia[35], Sweden and Norway (which operate a common market for these). Obligations and certificates for transport fuels have been implemented in the UK and the Netherlands and for heat in Romania. The UK has transitioned from the certificates to a feed in tariff policy, and Poland to power auctions.

3) Energy/Procurement Auctions

Another effective instrument for building biogas technology capacity is energy auctions, demand auctions or procurement auctions. This mechanism is based on governments or jurisdictions procuring renewable energy (biogas in this case) capacity and technology via an auction where project developers submit bids with the price per unit of electricity that they are able to deliver. The authority evaluates the bids on the proposed price and other criteria and enter into power purchase agreements with the successful bidder[36]. Specific rules must be set to ensure high implementation rate of awarded projects in a timely manner.

The advantage of procurement auctions is that they are flexible in design and technology to enable the most cost-effective solutions. It informs the policy makers of the status of the market and actual price. It reduces the financial and operational risk of the jurisdiction as development, operation and delivery is all in the hands of the project developer. It is a transparent system which enables an open and fair procurement process. The associated administrative and transactional costs are relatively high in this process and there is a danger of over aggressive bidding, leading to underbuilding and delays[37].

Argentina, Peru, South Africa, Italy and Spain have implemented biogas-based power auctions, some of which have been plagued with under subscription due to uncertainty of availability of feedstock[38].

Waste management policies

A number of waste management targeted policies may be implemented in order to reduce generation of food waste and maximise the source segregated collection of unavoidable food waste. Three are discussed here:

1) Pay-As-You-Throw (PAYT)

PAYT schemes are based on the 'polluter-pays' principle. The generators of waste, which may be households, industries or businesses, have to pay to contribute towards the disposal of the food waste generated by them. The payment could be based on the actual weight or volume of food waste generated or on the number of bins and collection frequency or prepaid bags used.

It is recommended to split the payment into a base minimum fee and a variable component. The fixed base fee minimises illegal disposal of waste and there is a strong driver to reduce the variable component. In a way, the base fee covers the unavoidable food waste while the variable part covers disposal of the partially avoidable or avoidable waste.

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[35] *Clean Energy Regulator, Australian Government (2017) REC Registry* ***https://www.rec-registry.gov.au/rec-registry/app/home***

[36] *IRENA and CEM (2015), Renewable Energy Auctions – A Guide to Design* ***http://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/IRENA_RE_Auctions_Guide_2015_1_summary.pdf***

[37] *ibid*

[38] *IRENA (2017) Renewable Energy Auctions: Analysing 2016. IRENA, Dhabi* ***http://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Jun/IRENA_Renewable_Energy_Auctions_2017.pdf***

A PAYT system implemented in the County of Aschaffenburg, Germany for over 20 years is based on kerbside collections of waste. The scheme has been successful in increasing food waste capture and decreasing residual waste. It may be noted that the total waste management fee in the county has decreased over this time period due to the dramatic decrease in the residual waste and the corresponding expense, going to incinerators[39]. PAYT has been implemented through Radio Frequency Identification (RF ID) in South Korea. It is based on actual weight of disposed food waste. The collection and billing system has been discussed in chapter five. The role of PAYT in food waste prevention has been discusses in Chapter 2.

2) Landfill bans

A number of jurisdictions have banned the disposal of organic waste via landfills, in a phased manner. This policy instrument is most generally applied to commercial organic waste generators over a certain capacity. This policy instrument works through a phased overhaul of the existing waste management systems towards separated food waste collections and recycling.

A ban on commercial organic waste disposal to landfills by businesses and institutions generating one tonne or more food waste per week has been imposed by the State of Massachusetts since 2014[40]. The ban on organics to landfill goes hand in hand with setting targets for diversion of organics from landfills as discussed in Section 7.3.1

Similarly, Scotland has imposed a ban on biodegradable organic waste from landfills from 1st January 2021[41].

3) Recycling requirements

Requirements may be laid down for businesses, institutions and industries to recycle food waste or make it available for recycling. This puts the obligation of disposal on the enterprises.

Scotland required larger generators of food waste (>50 kg per week) to separate food waste for collection from 2014, then increased the scope to smaller generators (>5kg per week) from 2016 and has now banned all biodegradable organic waste from landfills from 1st January 2021[42].

The Scottish regulations lay out obligations and duty of care responsibilities:

- Food waste producer: minimisation of contamination to improve separate collection via clearly labelled containers.
- Food waste collector: to restrict collection to food waste that meets the requirements of the disposal facility like biogas plant or composting facility.
- Food waste treatment facility: to accept only good quality food waste needed to produce for digestate or compost that complies with regulatory standards and to notify the authorities about rejected loads and the reason for rejection.
- Farmers, contractors or land managers: to check the digestate/compost for quality and ensure compliance to animal by-product, fertiliser application, and other applicable regulations[43].

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[39]*Morlok J, Schoenberger H, Styles D, Galvez-Martos J and Zeschmar-Lahl (2017) The impact of pay as you throw schemes on municipal solid waste management: the exemplar case of the county of Aschaffenburg, Germany* ***www.mdpi.com/2079-9276/6/1/8/pdf***

To achieve Japan's sector level recycling targets, as mentioned previously, individual food related businesses have annual incremental recycling rate requirements. Recycling requirement for food related businesses are determined based on the individual business's performance in the preceding year as shown in the Table 17 below[44].

TABLE 17: RECYCLING REQUIREMENTS FOOD RELATED BUSINESSES BASED ON PERFORMANCE IN JAPAN

STANDARD RECYCLING RATES FOR EACH YEAR= STANDARD RECYCLING RATES FOR PRECEDING YEAR + ADDITIONAL POINTS ASSIGNED ACCORDING TO STANDARD RECYCLING RATES FOR PRECEDING YEAR

Preceding year's standard recycling rate class	Additional points
Businesses at 20% to <50%	2 %
Businesses at 50% to <80%	1 %
Businesses at 80% or more	Maintain or improve

- Inaugural year: FY 2008
- If the recycling rate is less than 20% for FY 2007, the standard recycling rate is deemed to be 20% for the purpose of calculation.

Capital grants

Another instrument for support and growth of the biogas sector are financial grants or making capital available at low interest rates for the biogas projects. When the technology is relatively unknown in a sector or country, the risk of such a project is perceived to be high and banks are either unwilling to lend capital or ask for collateral against it or charge a high rate of interest to cover that risk. By funding pilot projects or making capital grants for the first few adopters or making capital available at low interest rates, governments can help get the industry off the ground and build investor confidence.

This instrument has been used successfully to build the biogas industry in Thailand[45]. The Chinese government is funding 100 pilot projects in 100 cities for recycling of kitchen waste from restaurants with a focus on AD[46]. This investment is expected to seek the best solutions and kick start the recycling of food waste in China. In California, the Department of Resources Recycling and Recovery (CalRecycle) provides funding through its Organics Grant Program for public and private solid waste management projects such as composting and AD. During its first cycle of grants in Fiscal Year 2014-2015, CalRecycle awarded five grantees roughly US$3 million each, for a total of US$14.5 million. This past cycle (FY2016-2017), CalRecycle awarded 10 grants ranging from more than US$500,000 to US$4 million, for a grand total of US$24 million[47].

[40] *Commonwealth of Massachusetts (2018) A success story: The Massachusetts Commercial Organics waste ban* ***http://www.mass.gov/eea/agencies/massdep/recycle/reduce/food-waste-video.html***

[41] *Scottish Environment Protection Agency (2012) Waste (Scotland) Regulations 2012* ***https://www.sepa.org.uk/environment/waste/zero-waste/***

[42] *Scottish Environment Protection Agency (2012) Waste (Scotland) Regulations 2012* ***https://www.sepa.org.uk/environment/waste/zero-waste/***

[43] *Ibid*

[44] *Food waste recycling law, Japan* ***http://nett21.gec.jp/Ecotowns/data/et_c-08.html***

[45] *Situer J (2016) Rapid deployment of industrial biogas in Thailand: factors of success* ***http://www.ieabioenergy.com/wp-content/uploads/2016/05/P13-Rapid-deployment-of-industrial-biogas-in-Thailand-factors-of-success-Siteur.pdf***

[46] *Mr Zhang Yue (2016) Municipal organic waste – methane and resource recovery in China at Global Methane Forum, Washington DC* ***https://www.globalmethane.org/forum/presentations/biogas/tuesday-session-1/Tuesday_Biogas_ZhangYue_Global_Methane_Forum.pdf***

[47] *CalRecycle. 2017. Organics Grant Program web page. Not dated, accessed November 2017.* ***www.calrecycle.ca.gov/Climate/GrantsLoans/Organics/default.htm***

7.4. “How to” process to implement food waste collection and anaerobic digestion

This report has explained why it is so critical to introduce food waste collections for digestion, and outlined the considerations regarding collection, communications, treatment options and related policies that need to be made.

A step-by-step guide to implementation of food waste collection and digestion in your jurisdiction is provided below. It can be used by urban politicians and officials as a checklist to implement sustainable food waste management policies.

This is a summary of the process, followed by a detailed description:

- **Assess waste sources – know your waste**
- **Establish the base case**
- **Assess the national policy and regulatory framework**
- **Identify the required expertise, potential partners**
- **Develop food waste prevention strategies**
- **Assess the feasibility and cost-benefit of different collection and treatment techniques**
- **Propose an integrated waste management strategy**
- **Run a pilot programme, phasing-in changes**
- **Prepare financing and implementation model**
- **Set sufficient budget for communications and public relations and continue public outreach over the long term**
- **Set high operational standards**
- **Monitor, evaluate and feedback improvements**

1) Assess waste sources – know your waste

The first step in any waste management improvement is to assess the waste sources within the geographical area. If food waste sources are currently unknown, this needs to be a particular focus. In each area there will be household, commercial and industrial producers of food waste, with different levels of homogeneity of material. For example, most households will generate mixed wastes, while some businesses may generate large quantities of a single material, such as oils and fats, which may have particular value on the market due to their known properties. Therefore, the numbers of households, businesses and food processing facilities in the area need to be known. For households, the average amount of food waste produced per household needs to be estimated, possibly through simple exercises involving collecting and weighing. This needs to be differentiated by type of household (e.g. apartment vs. house, income group) and seasonality (different levels of food waste are produced over a year).

For businesses, the type of business will have an effect on the quantities of waste produced, so an understanding of the numbers of food retail, catering, food processing, offices and other food waste-generating businesses will be important.

As well as quantities of food waste, estimating participation rates in food waste collections will be important. While these can reach levels of nearly 90%, participation rates can be lower in certain household and businesses, such as where food waste caddy space is limited. Where food waste is heavily contaminated with material such as plastics, it will not then be suitable for digestion, so an assessment of the likelihood of contamination should be made as well as considering how to limit this.

The aim of this exercise is essentially to estimate the quantity and quality of food waste that can be collected. Food waste also needs to be characterised by measures such as its biogas and methane yield, solid fraction etc.[48]. This will then need to be reduced following the success of any prevention activities – as outlined in (3) below.

2) Establish the base case

The next step is to establish the 'base case' for municipal, industrial and commercial food waste management processes in your jurisdiction. The 'base case' is essentially the existing waste management system, against which the costs of any changes to the collection and treatment operation need to be assessed. The current collection and treatment methods must be understood, and the costs of the various aspects known. If there are regions or areas that already operate separate collections of food waste, including through traditional methods for animal feed, then these can be built upon.

The environmental impacts of existing treatment and disposal techniques should be quantified and monetised.

An addition to the base case can be where regulations are changing and stricter environmental standards are being introduced at either regional or national level, which would impact the cost of the base case scenario in future.

3) Assess the national policy and regulatory framework

As outlined in Section 7.3 above, an understanding of the wider policy framework and how local waste management can be coordinated with this is essential for the effective implementation of any scheme. The regulatory environment also needs to be evaluated and understood. There are significant health and safety, environmental, land management and water quality safeguards which need to be in place to operate AD plants, which will be governed by national legislation, or may need developing at a wider level.

4) Identify the required expertise, potential partners

Municipalities need to understand the skills and experience required to deliver changes to food waste management. These include policy development, project management, lifecycle carbon analysis, communications, public sector finance, project finance, contracting, procurement and tendering, logistics, planning, engineering, environmental management, and experience of AD operations.

[48] *ADBA (2017). Practical Guide to AD* ***http://adbioresources.org/library/purchase-the-practical-guide-to-ad/***

Some of these skills will not be available in the municipality from the start of the project. The municipality in this case then needs to build links with experts in other public sector institutions, intergovernmental organisations, academia and the private sector.

5) Develop food waste prevention strategies

Identify the food waste prevention strategies best suited for each of the food waste generator categories (e.g. household type x, y and z, and business type x, y and z). These may be one or a combination of activities - communication (e.g. leaflets, knocking on doors, stickers) and media activities (e.g. local newspaper announcements), engagement with non-profit organisations and trade associations, institutional initiatives, and reporting and regulatory initiatives. These have been discussed in Chapter 3.

6) Assess the feasibility and cost-benefit of different collection and treatment techniques

As outlined in previous chapters, separate collection of food waste for digestion offers a variety of benefits to jurisdictions. However, the cost of establishing separate collections and building new digestion plants are significant, and need to be compared not only against the base case scenario but also to the other options outlined in Chapter 4. The cost of separate food waste collections includes the household and business food waste containers, communication requirements, collection vehicles etc. (see Chapter 3).

Then the capital and ongoing operational cost of the AD plant needs to be accounted for (see Chapters 5 and 6 on AD and its products). This is often the most difficult and complex aspect of the process. For AD, the expected income stream depends on factors such as what the local demands are for energy – if there is a high demand for an output such as heat, or the local municipality is seeking to reduce air pollution through a move to biomethane vehicles, then the income the overall project can generate will be much higher, therefore reducing a cost to the waste management aspect of the project. Chapter 6 outlined all the potential uses for biogas, and the selection of what to use it for will have a significant impact on the overall project economics.

The use of digestate also needs to be considered at this stage. No assumptions can be made about the market for digestate without initial market testing. Income streams from digestate can be achieved with proper consideration, which will improve the overall economics of the project.

This feasibility stage is where an understanding of the national policy framework on waste, carbon and energy can also become extremely important – the project will be more viable if it can benefit from all the wider policies outlined in Section 7.3.

This is also where the assessment of the indirect costs of the current system is important – all of the carbon and health costs of the different options need to be calculated.

7) Set sufficient budget for communications and public relations

Communications play a very significant role in the success of a food waste collection and digestion project, especially when it comes to municipal projects. Communications include:

- Educating the public about climate change, energy security, food security, sanitation and sustainable industrialisation and why it is important;
- Raising awareness about how individual citizen's every day actions contribute towards these bigger targets;
- Making people and enterprises aware of their changed waste disposal responsibilities;
- Providing clear instructions on the separation of waste – what is considered food waste, what cannot be put into food waste recycling, whether liners for food waste caddies can be used or not, and what kind of liners can be used;
- Providing clear instructions on troubleshooting problems: how to prevent spread of rodents and disease, what to do if you get maggots, how to keep your bin clean etc.;
- Communication of collection schedules and any variations that may happen due to inclement weather or holidays; and
- Communication about where help can be sought in case of problems, such as phone numbers and email addresses.

It is therefore essential that sufficient budget is allocated to communications activities. Chapter 3 on food waste collections has examples of communication activities that have been most effective.

8) Propose an integrated waste management strategy

During this part of the process, an integrated waste management strategy that includes collection and treatment of food waste from municipal, commercial and industrial generators should be laid out. It will be integrated with all the other decisions on waste, consumption, resource efficiency and energy that the jurisdiction is making. It considers not only food waste, but issues like the frequency of general waste collections, the collection of garden and other non-food organic wastes, dry recycling and the treatment facilities available. How can food waste collections be best integrated into this wider strategy? What other service changes are being made? Is existing land or infrastructure available to support food waste treatment – for example at sewage sludge treatment works or other existing digestion facilities?

The International Solid Waste Association's (ISWA) *Solid waste: Guidelines for Successful Planning* provides further details on this[49]. Consultation with stakeholders is a key aspect of this.

9) Run a pilot programme, phasing-in changes

Before making significant investments, running a pilot programme for food waste collection and digestion can help in ironing out functional difficulties that may be faced during the actual project. Different processes and equipment for collection may be tested during the trial run with fewer inhabitants, enterprises or industries. Participation and contamination rates can be assessed.

Analysis of the feedstock can be used to specify requirements for the biogas plant. This allows the optimisation of feedstock mixing and biogas production when the construction of any digestion plants are specified, so that full scale investment can be made with higher confidence and fewer operational issues.

Further to this, a phased approach to any changes could be considered, meaning some areas could initially be covered by a scheme, with lessons learned then being taken to the next phase of investment. The first phase could include areas which are likely to have higher participation rates, with the more challenging areas being tackled later.

[49] *International Solid Waste Association (not dated) Solid waste: Guidelines for successful planning* ***http://www.iswa.org/index.php?eID=tx_iswaknowledgebase_download&documentUid=2512***

10) Prepare financing and implementation model

As outlined in Section 7.2 above, and has been widely disseminated[50], financing improvements in waste management is one of the principle barriers to implementation, especially in developing countries. For business food waste, where private sector collection arrangements are likely to be the norm, the cost to the municipality is likely to be in the form of enforcement of any regulations and in ensuring appropriate treatment capacity is planned effectively. For household food waste, where municipal authorities are more likely to have responsibility, 'The Global Waste Management Outlook' discusses the various options for financing of municipal waste collection and treatment capacity[51]. It describes the municipality as the "Client" in the following model, while the operator could be the private sector or the municipality itself:

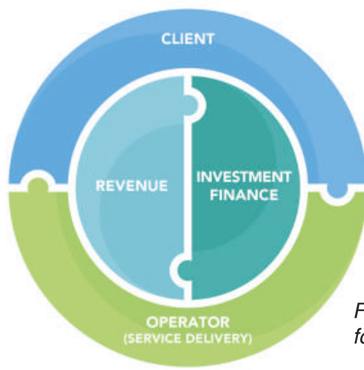

Figure 20: Financing Mechanisms for Waste Infrastructure

Local circumstances will dictate whether both the collection and treatment are operated by the municipality, or contracted out to the private sector: "There is no evidence to show that either private or public service provision or financing for MSWM is more frequent or is more efficient or beneficial than the other."[52] In terms of food waste treatment through AD, there are many different models that a municipality can follow itself or through a tendering and contracting process. They need to cover the designing of the plant, its construction, its ownership and its transfer and could include:

- Build- Operate-Transfer
- Build-Own-Operate-Transfer
- Build-Own-Operate
- Build-Lease-Transfer
- Design-Build-Finance-Operate
- Design-Build-Operate-Transfer
- Design- Build-Transfer-Operate

What is unique about the construction of an AD plant is its integration into local markets. It needs to be integrated not only into the local waste collection system, but also into the local energy network (or developed to create a new network) and agricultural community. Where local energy, fertiliser, water and organic matter costs are high the project will be of far more value to the local market than where these costs are low, impacting on the cost effectiveness of the project.

[50] *UNEP ISWA (2015) Global Waste Management Outlook Waste* ***http://web.unep.org/ietc/sites/unep.org.ietc/files/GWMO_flyer_0.pdf***

[51] *Ibid Sections 5.4. and 5.5*

[52] *Ibid*

THE MICROBIOLOGY OF DIGESTION AND ITS RELATION TO GAS OUTPUT IS A COMPLEX PROCESS AND MANY PROJECTS FAIL DUE TO A LACK OF UNDERSTANDING OF THE PROCESS

Whether contracting services or providing services in-house, the most important aspect of introducing new services is clarity regarding what is being proposed, set out in clear documentation, covering all details of the project.

11) Set high operational standards

Once food waste collections and digestion are operational, ongoing management is required. For collections it will be to ensure service level agreements are accorded to and participation rates are met.

If a municipality is to own and operate an AD plant then it needs experience of operations. The microbiology of digestion and its relation to gas output is a complex process and many projects fail due to a lack of understanding of the process. Experience is essential so will need to be bought in where not available. Where contracting the operation of the service or plant municipalities much ensure the operations have the equivalent experience and expertise. Literature and advice is available through a number of different means[53].

12) Monitor, evaluate and feedback improvements

Ongoing monitoring of the project needs to be undertaken to test its effectiveness against the initial goals.

This will include periodic feedback from the inhabitants of jurisdiction, businesses and industries on the performance of collection system to help in optimisation of the process and improve the experience of the participants.

It also includes aspects such as cost, participation rates, monitoring of contamination levels and other factors of importance to the digestion process.

If the policy is not meeting the original rationale then it should be amended or stopped.

These are the “Monitoring, Evaluation and Feedback” stages of the project [54]:

Figure 21: The cycle of monitoring, evaluation and feedback

[53] *See* ***http://task37.ieabioenergy.com/biogas-handbook.html*** *and* ***http://adbioresources.org/library/purchase-the-practical-guide-to-ad***

[54] *Institute for Government (2011) Policy making in the real world: evidence and analysis* ***https://www.instituteforgovernment.org.uk/sites/default/files/publications/Policy%20making%20in%20the%20real%20world.pdf***

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Appendix 10

Cré – Residential Food Waste Management

Date: February 2020

Job Reference: 415819

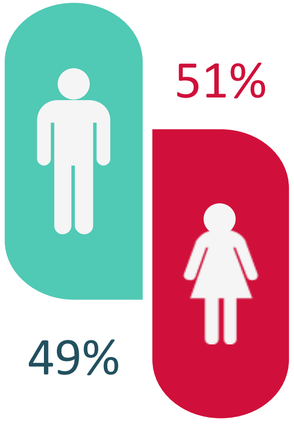
Research Details

What?	• Research was needed to assess attitudes & behaviours among consumers in relation to food waste recycling. • RED C Research was commissioned to carry out the survey.
How?	• Research was conducted using RED C's online omnibus using our online panel of over 41,000 active panel members. Quota controls are used to ensure a nationally representative sample of RoI adults aged 18+ are surveyed.
How many?	• A sample size of 1,012 was achieved.
When?	• 23-28th January 2020.

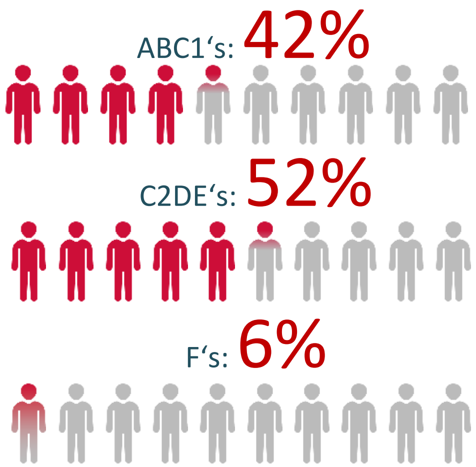
REDLINE

Weighted to be representative of all adults aged 18+ using the latest CSO census data on the following demographics

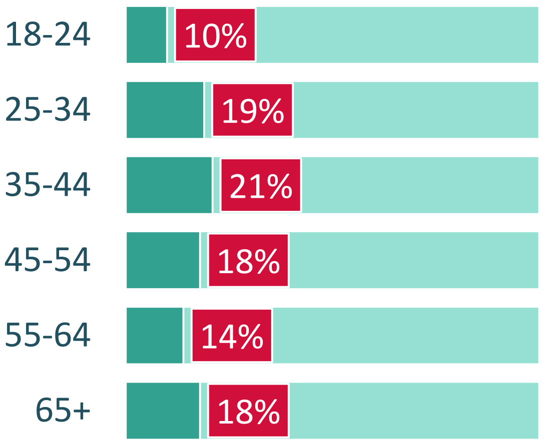
Gender



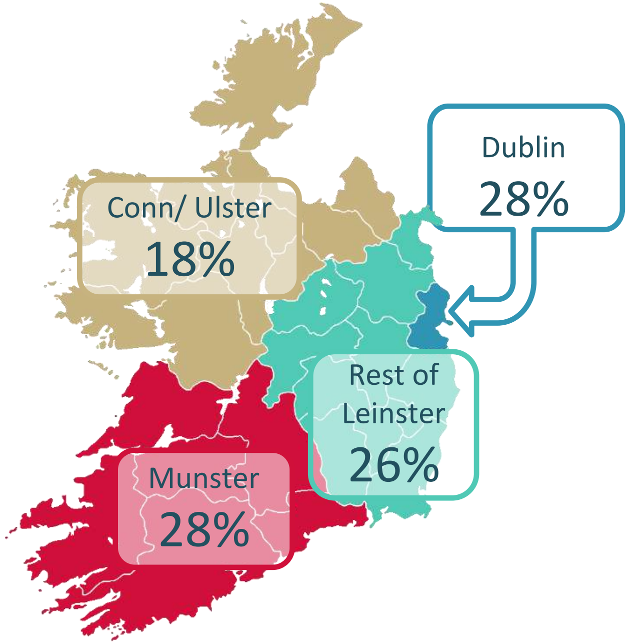
Social Class



Age



Region

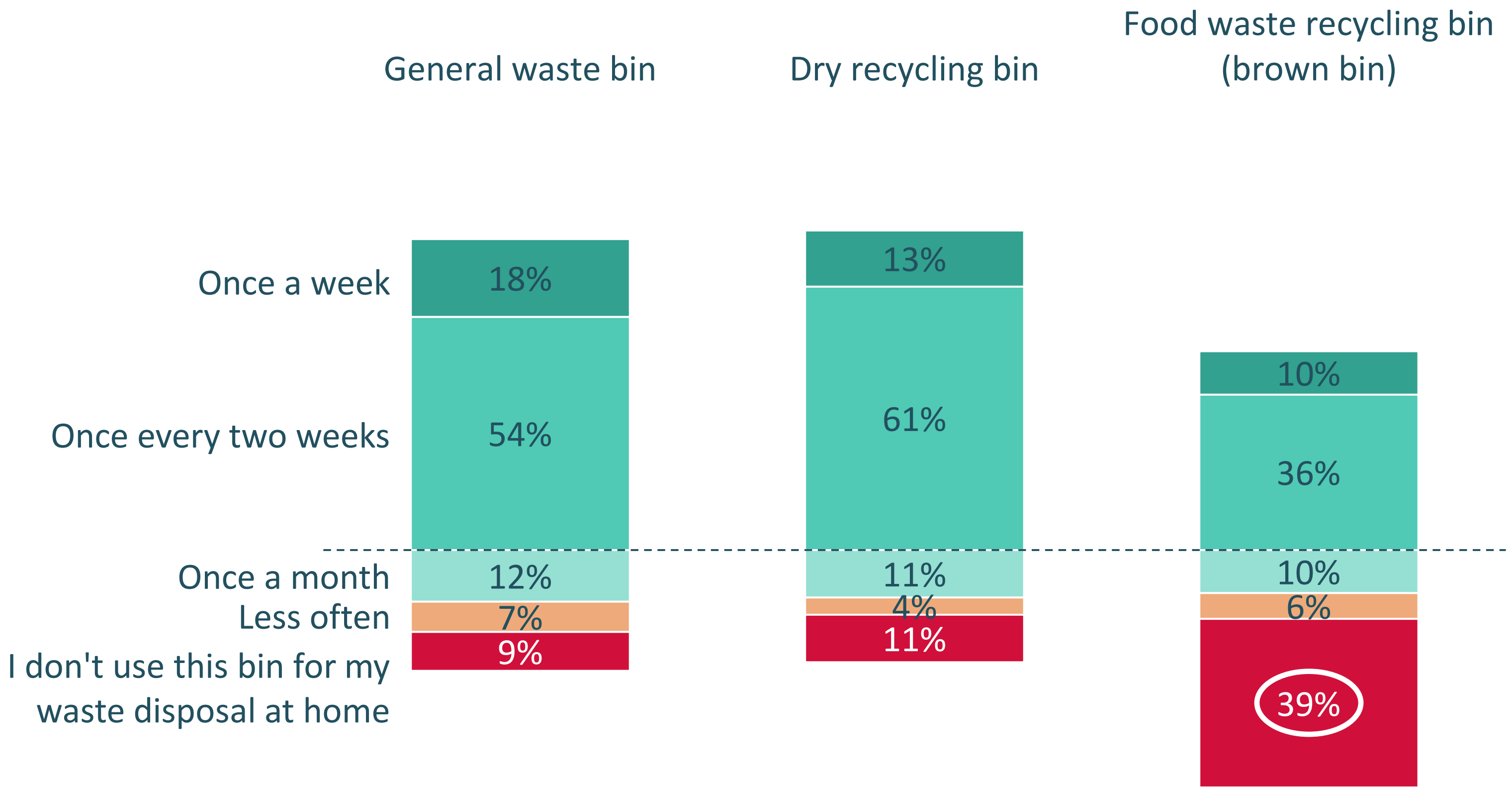


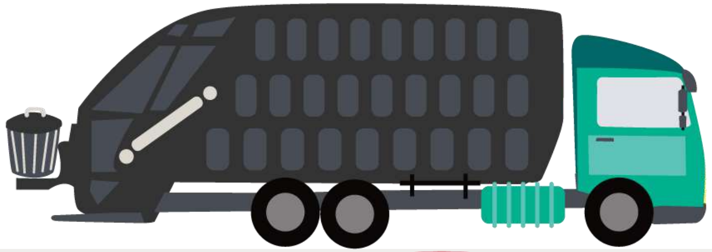
Prevalence of Usage

Frequency of Bin Usage X Bin Type

(Base: All Adults 18+; n=1,012)

Q1. Please indicate the frequency with which you put each of the following bins out for collection by your waste collector at home.





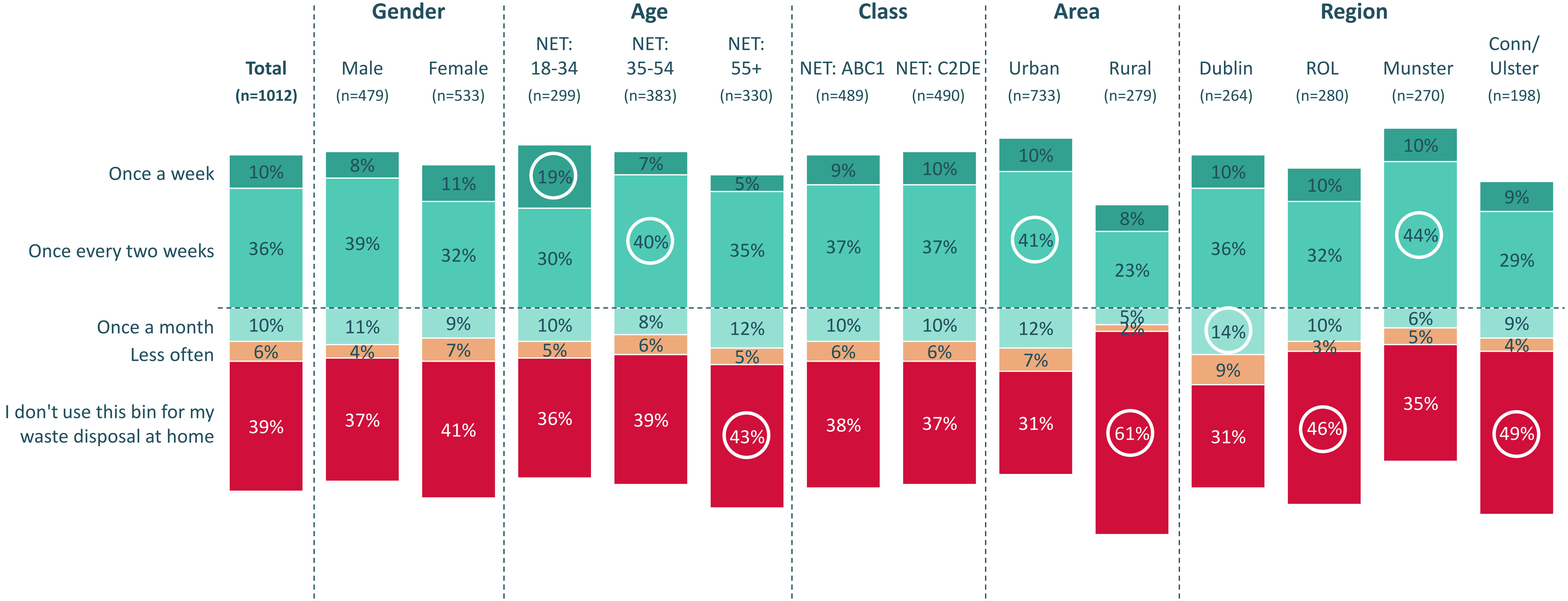
Just under 2 in 5 say they don’t use a food waste bin at home, while 46% say they use this bin type more than once a month. In comparison, over 70% use their general waste bin or their dry recycling waste bin with the same frequency.

(Q.1)

Frequency of Bin Usage – Food Waste Recycling

(Base: All Adults 18+; n=1,012)

Q1. Please indicate the frequency with which you put each of the following bins out for collection by your waste collector at home.



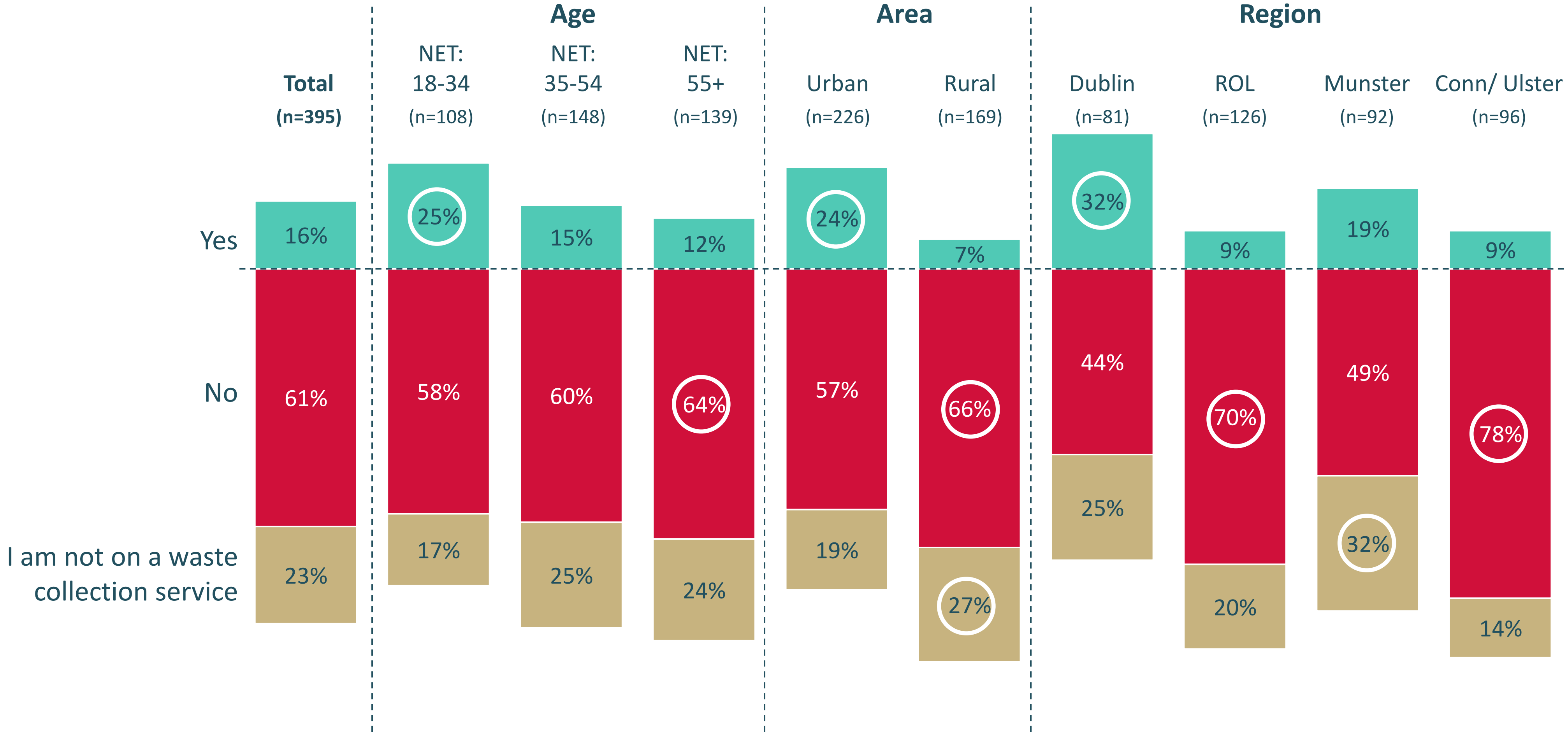
Younger adults and those living in urban areas report more frequent usage of a food waste recycling bin. In contrast, those aged 55+ and those in rural areas, particularly in ROL and Conn/Ulster report not using this bin type for waste disposal at home.

(Q.1)

Prevalence of Food Waste Recycling Bin Being Provided by Collector

(Base: All Adults 18+ Not Using a Food Waste Recycling Bin; n=395)

Q2. Have you been given a food waste recycling bin (brown bin) by your waste collector?



Only 1 in 6 of those who don't use a food waste recycling bin have been provided this bin by their waste collector, while 3 in 5 say their collector has not provided them with a food waste recycling bin. Those least likely to use this bin type (i.e. those in rural areas, ROL and Conn/Ulster) are also more likely to say they haven't been provided this bin type by their waste collector.

(Q.2)

Main Reason For Not Using a Food Waste Recycling Bin

(Base: All Adults 18+ Not Using a Food Waste Recycling Bin; n=395)

Q3. What is the main reason you do not use a Food Waste Recycling Bin?

	Total	Area		Region			
		Urban (n=226)	Rural (n=169)	Dublin (n=81)	ROL (n=126)	Munster (n=92)	Conn/ Ulster (n=96)
My waste collector did not give me a food waste recycling bin	36%	34%	38%	27%	38%	30%	49%
I am not on a waste collection service	14%	11%	17%	12%	13%	23%	5%
I do my own recycling/composting	12%	8%	16%	8%	14%	11%	14%
It attracts vermin	6%	6%	5%	7%	6%	7%	1%
It's too messy/smelly	5%	7%	2%	7%	4%	5%	5%
I give it to animals	4%	2%	6%	-	6%	9%	-
Collection is too expensive	3%	4%	3%	2%	5%	2%	4%
Didn't know about them	3%	3%	4%	1%	4%	1%	8%
Just not interested in using it	3%	3%	3%	5%	3%	3%	3%
Don't produce food waste	3%	2%	4%	2%	4%	3%	3%
No space for the extra bin	3%	4%	1%	8%	1%	2%	2%
Have communal bins and food waste/compost bin not available	3%	5%	-	10%	1%	1%	-
I bring my waste myself to a collection centre	1%	1%	2%	1%	1%	1%	1%
I don't know what goes into it	1%	1%	1%	-	1%	2%	1%
Collection is too infrequent	1%	1%	1%	3%	1%	-	-
Other	2%	3%	2%	3%	1%	3%	3%
Don't know	3%	4%	2%	4%	3%	3%	2%

Over 1 in 3 of those who don't use a food waste recycling bin say this is because the waste collector did not provide them with this. Not being on a waste collection service and doing their own composting/recycling are also among the top 3 reasons. Those based in Dublin are also more likely to cite having communal bins where food waste recycling bin is not provided.

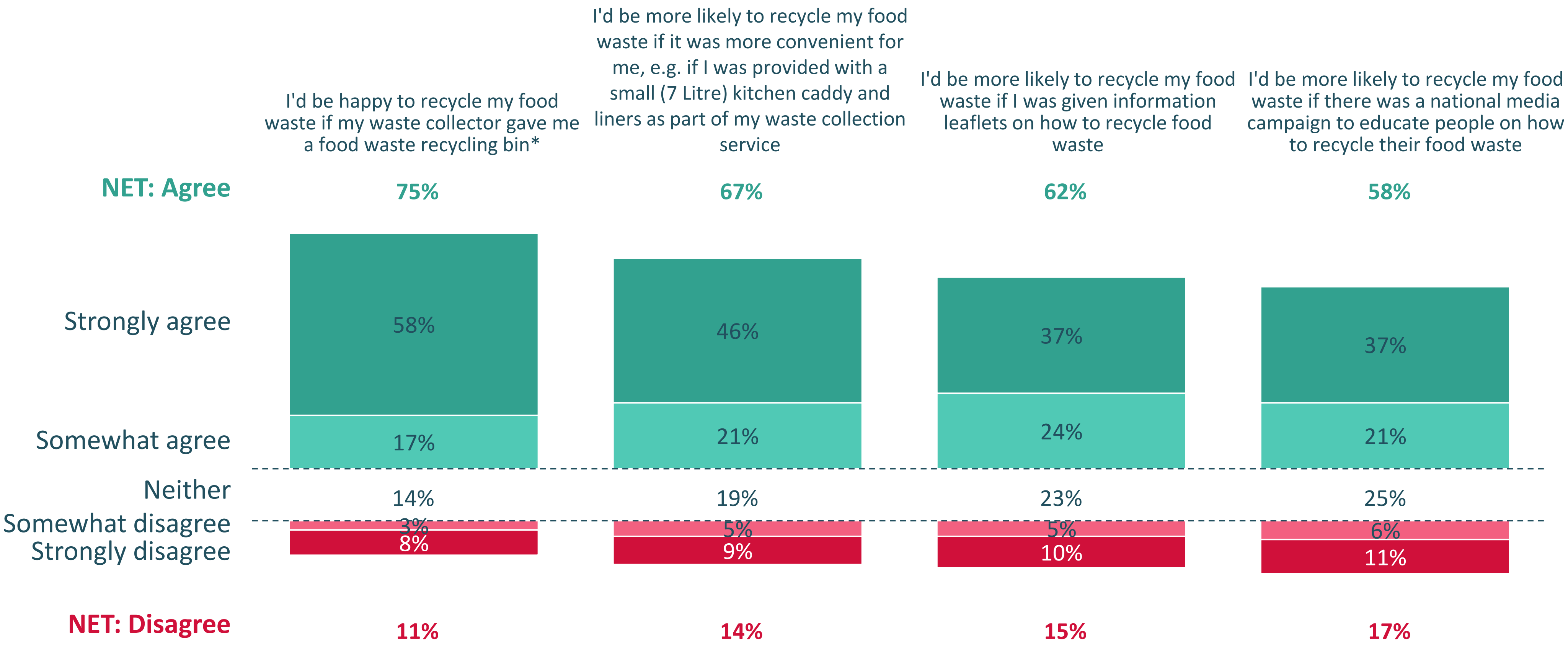
(Q.3)

Attitudes Towards Food Waste Recycling

Attitudes Towards Food Waste Recycling - I

(Base: All Adults 18+; n=1,012)

Q4. Here are some statements other people have made in relation to recycling their food waste. Please indicate the level to which you agree or disagree with these statements.



*Only asked of those who were not provided a food waste recycling bin by their waste collector, n=395

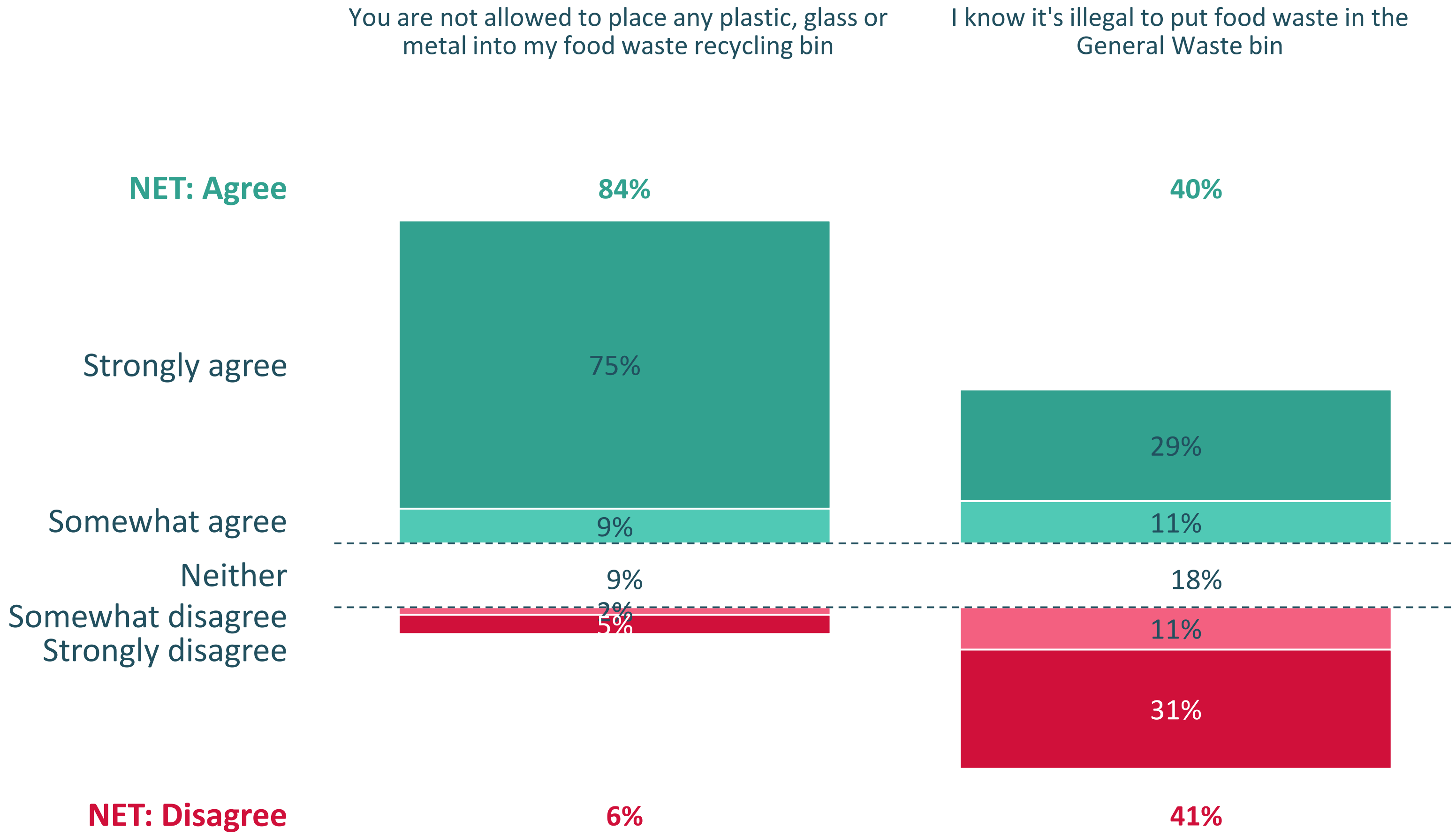
3 in 4 say they'd be happy to use a food waste recycling bin if they were given one*. Approx. 5 in 7 say they'd recycle food waste more if they were given a convenient kitchen caddy. Just over 3 in 5 would like more information on how to recycle food waste and a similar proportion are in favour of a national media campaigns to inform and encourage them on the issue.

(Q.4)

Attitudes Towards Food Waste Recycling - II

(Base: All Adults 18+; n=1,012)

Q4. Here are some statements other people have made in relation to recycling their food waste. Please indicate the level to which you agree or disagree with these statements.



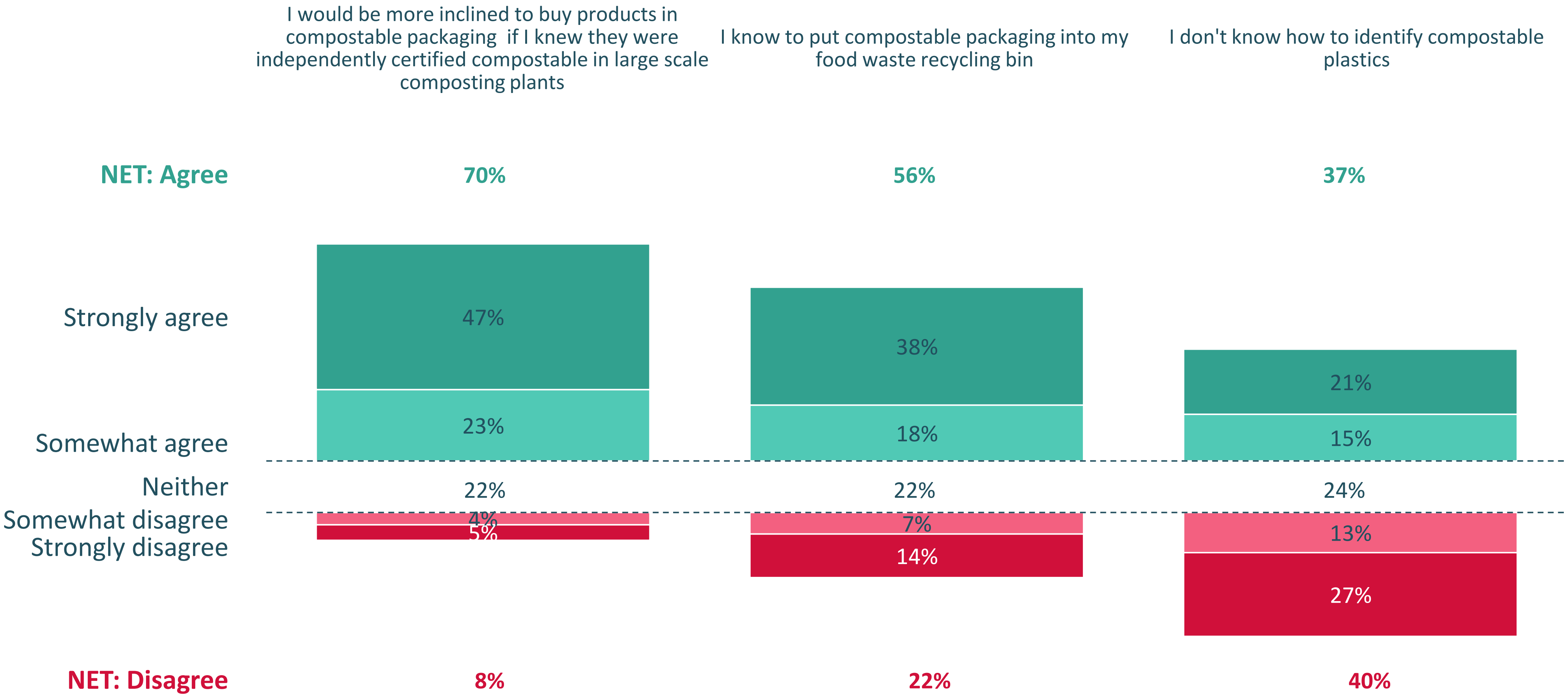
Over 8 in 10 agree that they are not allowed to put plastic, glass or metal into the food recycling bin. However, there is some confusion in relation to whether or not it is illegal to put food waste into the general waste bin, with equal proportions agreeing and disagreeing with this statement.

(Q.4)

Attitudes Towards Food Waste Recycling - III

(Base: All Adults 18+; n=1,012)

Q4. Here are some statements other people have made in relation to recycling their food waste. Please indicate the level to which you agree or disagree with these statements.



7 in 10 say they would be more likely to buy products in compostable packaging if they knew these were compostable at large scale. And while 56% know that they can put compostable packaging in this bin, just under 2 in 5 say they don't know how to identify compostable packaging.

(Q.4)

Attitudes Towards Food Waste Recycling X Demographics of Those Who Agree

(Base: All Adults 18+; n=1,012)

Q4. Here are some statements other people have made in relation to recycling their food waste. Please indicate the level to which you agree or disagree with these statements.

	You are not allowed to place any plastic, glass or metal into my food waste recycling bin	I'd be happy to recycle my food waste if my waste collector gave me a food waste recycling bin	I would be more inclined to buy products in compostable packaging if I knew they were independently certified compostable in large scale composting plants	I'd be more likely to recycle my food waste if it was more convenient for me, e.g. if I was provided with a small (7 Litre) kitchen caddy and liners as part of my waste collection service	I'd be more likely to recycle my food waste if I was given information leaflets on how to recycle food waste	I'd be more likely to recycle my food waste if there was a national media campaign to educate people on how to recycle their food waste	I know to put compostable packaging into my food waste recycling bin	I know it's illegal to put food waste in the General Waste bin	I don't know how to identify compostable plastics
Total (NET AGREE)	**84%**	**75%**	**70%**	**67%**	**62%**	**58%**	**56%**	**40%**	**37%**
Male	84%	72%	68%	64%	58%	56%	57%	42%	35%
Female	85%	78%	71%	70%	65%	60%	55%	39%	38%
NET: 18-34	81%	77%	72%	72%	67%	62%	58%	32%	46%
NET: 35-54	82%	75%	63%	67%	58%	54%	51%	36%	35%
NET: 55+	89%	74%	76%	64%	62%	60%	62%	53%	31%
NET: ABC1	86%	75%	75%	65%	58%	58%	57%	37%	37%
NET: C2DE	83%	75%	66%	70%	64%	60%	56%	44%	36%
Urban	85%	74%	70%	68%	61%	58%	57%	39%	37%
Rural	83%	76%	70%	64%	63%	59%	54%	44%	36%
Dublin	86%	59%	70%	67%	61%	56%	58%	39%	36%
ROL	86%	72%	76%	72%	68%	64%	55%	42%	41%
Munster	84%	79%	69%	67%	60%	59%	59%	47%	35%
Conn/ Ulster	78%	85%	60%	61%	55%	52%	52%	31%	34%

While most demographics are in line with the average in terms of their attitudes, there seems to be some confusion in relation to using food recycling bins with a higher proportion of younger adults (18-34yrs) saying they don't know how to identify compostable packaging and older adults (55+yrs) over indexing in thinking it is illegal to dispose of food waste in the general waste bin.

REDC

(Q.4)

Key Findings

Key Findings

1. Less than half of Irish adults report using a food waste recycling bin for disposing of food waste at home. In contrast, 3 in 4 report using a dry recycling waste bin. Younger adults and those living in urban areas report more frequent use of food waste recycling bins.

2. Of those who don't use a food waste recycling bin at home, the vast majority have not been provided this type of bin by their waste collector. Only 1 in 6 of those who don't use this bin type currently, claim to have been provided with a food waste recycling bin.

3. In addition, older adults (55+ yrs) and those living in rural areas, who are more likely to say they don't use a food waste recycling bin at home, also tend to over index in terms of not being provided a food waste recycling bin by their provider.

4. The barrier posed by the lack of provision of food recycling waste bins is reiterated once again with 1 in 3 of those not using a food waste bin citing this as the main reason. Lack of knowledge and hassle of separating food waste do not feature particularly notably as barriers.

5. In addition to tackling the provision issue, efforts should be made to make food recycling easier and more convenient for consumers, such as providing smaller kitchen caddy for food waste recycling as well as providing information and education in relation to correct use of this bin type (e.g. leaflets, media campaigns etc.)

THANK YOU

REDC

Appendix 11

Household food waste collections guide

This publication updates the 2009 guide and pulls together the findings from more recent studies and pilots conducted by WRAP and others. Through the various sections, this guide is designed to support local authorities by detailing good practice and evidence which can help inform the design and delivery of high capture, cost-effective food waste collections.

Section 3: How much food waste can be collected for recycling?

This section describes the factors that influence and dictate how much food waste is likely to be collected for recycling by a household food waste collection. It lists indicative yields for the different collection profiles used to collect household food waste and presents a formula to calculate the likely yield of food waste that local authorities might expect their service to achieve.

Contents

Project code: RCY114-001 **Date:** February 2016

3.1 Factors influencing how much food waste can be collected for recycling

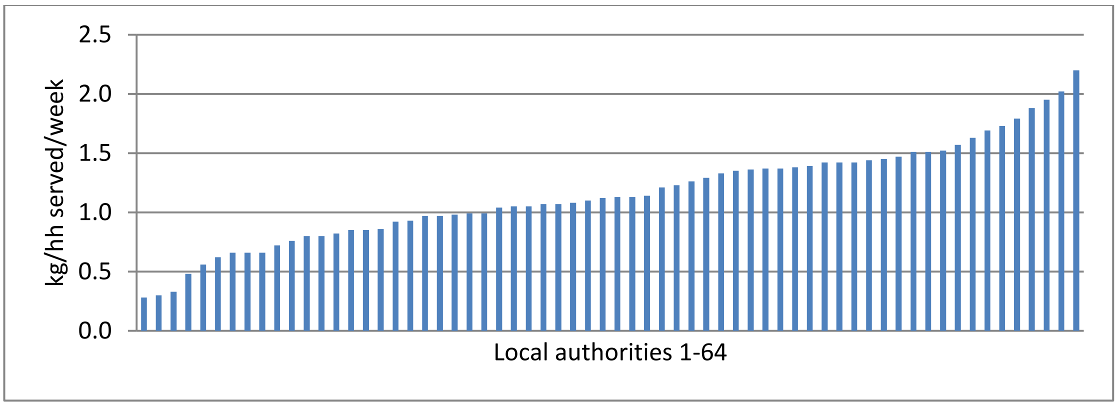
It is now well established research that the majority of households produce large quantities of waste food, both avoidable and un-avoidable, which predominantly ends up in the residual waste. However, despite increasing awareness of the issue, participation in household food waste collections is typically lower than participation in other recycling services such as kerbside dry recycling. Part of the issue is that food recycling services currently have low coverage and have been introduced much more recently than well-established dry recycling collections. Because of the relative infancy of food recycling in the UK there is much less of a social norm for storing and presenting food waste for collection in a food waste recycling service than in other countries internationally. The perception of some that food waste recycling can be both smelly and messy, the so-called 'yuck' factor (see Section 2), is a barrier limiting participation in a food waste collection.

There are also a number of other key factors that will influence how many households are likely to engage with a service. These factors can be listed under the following headings:

- collection profile: whether food is collected separately or mixed with garden waste;
- frequency of collection: whether food waste is collected weekly or fortnightly;
- correlation with deprivation;
- frequency of residual waste collections;
- provision of caddy liners to households;
- property types; and
- quality of service (including communications).

As a result of these different factors, there is a wide variation in the performance of household food waste collections across the UK. Figure 3.1 illustrates the diversity of performance (measured as kg/hh served/week) of separate weekly food waste collections delivered by 64 UK local authorities in 2012/13.

Figure 3.1 Yield from separate weekly food waste collections from selected local authorities (N.B. each column represents a separate local authority) (WRAP 2014)



3.1.1 Collection profile: food waste collected separately or mixed with garden waste

A key factor that will determine how much food waste is collected for recycling is whether food is collected separately or mixed with garden waste. Evidence from the original WRAP funded trial schemes conducted between January 2007 and March 2009 (see Figure 3.2), and data from household food waste collections introduced since then, demonstrates very clearly that separate food waste collections are more successful in capturing food waste for recycling than collections where food waste is collected mixed with garden waste. Part of the reason for the difference relates to the collection frequency collection of these services (section 3.1.2).

Evidence from waste composition analysis studies of mixed food and garden waste collections consistently shows that the amount of food waste collected by those services is between one-third and one-half (depending on the frequency of the collection) of that where food waste is collected separately.
http://www.wrap.org.uk/sites/files/wrap/Food_Garden_Waste_Report_Final.pdf

Analysis by WRAP of the performance of household food waste collections from across the UK has identified the following 'indicative yields' for food waste for the three common food waste collection profiles – assuming a service is well designed and implemented[1]:

- Separate weekly collections: 1.5 kg/hh served/week;
- Weekly mixed food and garden waste collections: 0.8 kg/hh served/week;
- Fortnightly mixed food and garden waste collections: 0.5 kg/hh served/week.

3.1.2 Frequency of food waste collection

The 'indicative yields' detailed in 3.1.1 also illustrates that the frequency of a food waste collection service has an influence on the amount of food waste collected. While separate food waste collections are invariably weekly, mixed food and garden waste collections are provided both on a weekly and a fortnightly basis. Evidence from waste composition analysis shows that, when food waste is collected mixed with garden waste and that service is provided weekly, the amount of food waste collected is greater than for a service where mixed food and garden waste is collected fortnightly.

3.1.3 Correlation with deprivation

As is the case for other materials, participation – and therefore yields – in a food waste collection service is influenced by the levels of deprivation in the area. This relationship is often viewed too simplistically; there are many examples of high levels of participation from areas of relatively high deprivation. But where all other things are equal, the evidence from WRAP supported food waste collections has demonstrated a clear link between deprivation and performance when other factors are limited and

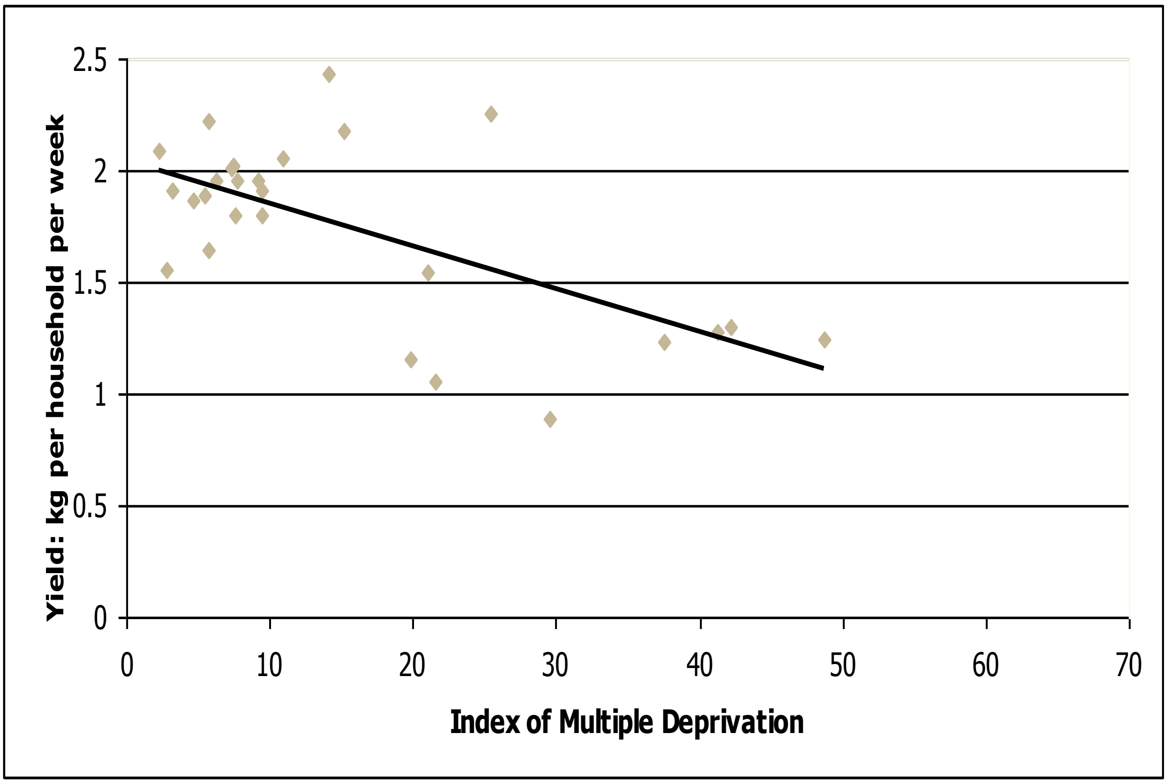
[1] WRAP 2014

controlled. Since households in all communities present similar quantities of food waste for collection, the difference in overall yield appears to be down to different levels of participation.

In general, the greater the level of deprivation, the lower the overall yield of food waste collected for recycling. Figure 3.4 below illustrates this using the Index of Multiple Deprivation in England as measured by the Office for National Statistics (www.gov.uk/government/statistics/english-indices-of-deprivation-2015).

More detailed information on the relationship between the performance of food waste collections and deprivation is provided in the report, 'Evaluation of the WRAP separate food waste collection trials' available on the WRAP website (www.wrap.org.uk/node/14212).

Figure 3.4 Correlation between food waste yields (kg/hh served/week) and Index of Multiple Deprivation

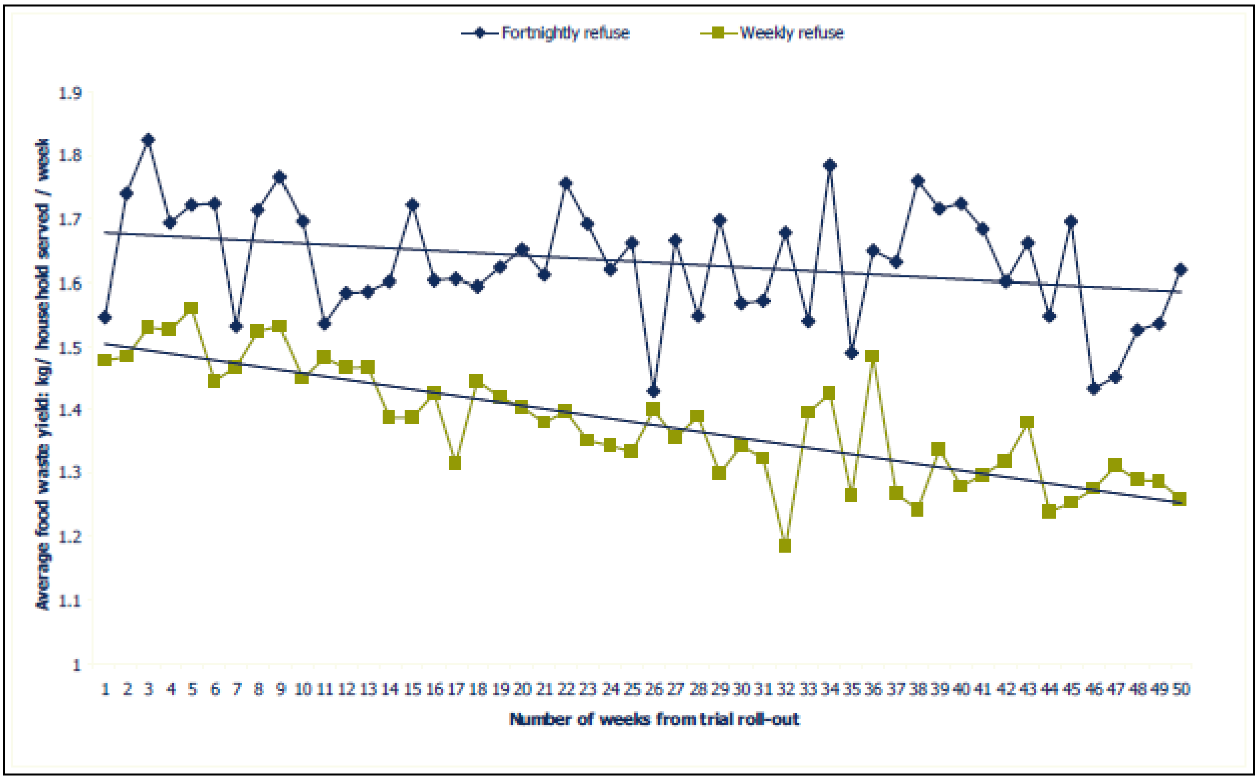


3.1.4 Frequency of residual waste collections

Yields of food waste collected for recycling are strongly affected by the frequency of residual waste collections. Weekly separate food waste collections allied to fortnightly residual collections have been shown to collect more food waste than those aligned to weekly residual collections. Figure 3.5 illustrates this by plotting the yields of food waste collected by weekly separate collections when delivered alongside both weekly and fortnightly residual waste collections. Of note is the significant decline in yields of food waste over time associated with weekly residual waste collections.

More detailed information on the relationship between the performance of food waste collections and the frequency of residual waste collections is provided in the report, 'Evaluation of the WRAP separate food waste collection trials' available on the WRAP website (www.wrap.org.uk/node/14212).

Figure 3.5 Trends in food waste yields (per household served) achieved during the WRAP supported trials – comparison of trials with fortnightly and weekly collections



Note: Mean food waste yields across 34 rounds with fortnightly refuse collections and 27 rounds with weekly refuse collections, standardised across 50 weeks from roll-out of each respective trial included in analysis.

Source: WRAP

3.1.5 Property types

The type of property, either in terms of its physical characteristics (e.g. whether it's terraced or detached) or in terms of tenure (e.g. whether it is owner occupied or rented), will have an impact on householder participation in a food waste collection service.

The physical characteristics of a property can limit the options for the storage and presentation for collection of external food waste containers and thereby increase the onus on households compared to ground level properties. In the case of high-rise flats, the collections options available to a local authority are also limited (see Section 8 for information on the collection of food waste from flats).

3.1.6 *How liners are made available to residents*

Liners are used in the majority of food recycling schemes as a means of encouraging clean storage of food waste and helping transfer to the external storage container. There are a number of liner supply mechanisms in operation by local authorities which determines the access to households and the cost of liners to residents. Factors such as whether there is a requirement on residents to go out and purchase liners, their willingness to pay and whether they are affordable, or if they are provided free and in varying quantities, all heavily influence the level of householder participation. Further detail is covered in Section 4 of the guide which deals specifically with liners.

3.1.7 *Quality of service (including quality of communications)*

The quality of a food waste collection service will have a direct impact on how likely householders are to participate in it. Negative experiences, for example in the form of missed bins or a failure to deliver replacement containers when requested to do so, may provide householders with a justification to stop using a service.

There will always be a proportion of householders who refuse to engage with a service. However, providing a good quality food waste collection service will help keep service users on your side. It is particularly important to ensure:

- there is clear information and good quality communications (see Section 6);
- proper containment is provided to enable householders to participate (see Section 4.1);
- the introduction of a new service is well executed (see Section 10); and
- collections are made on schedule.

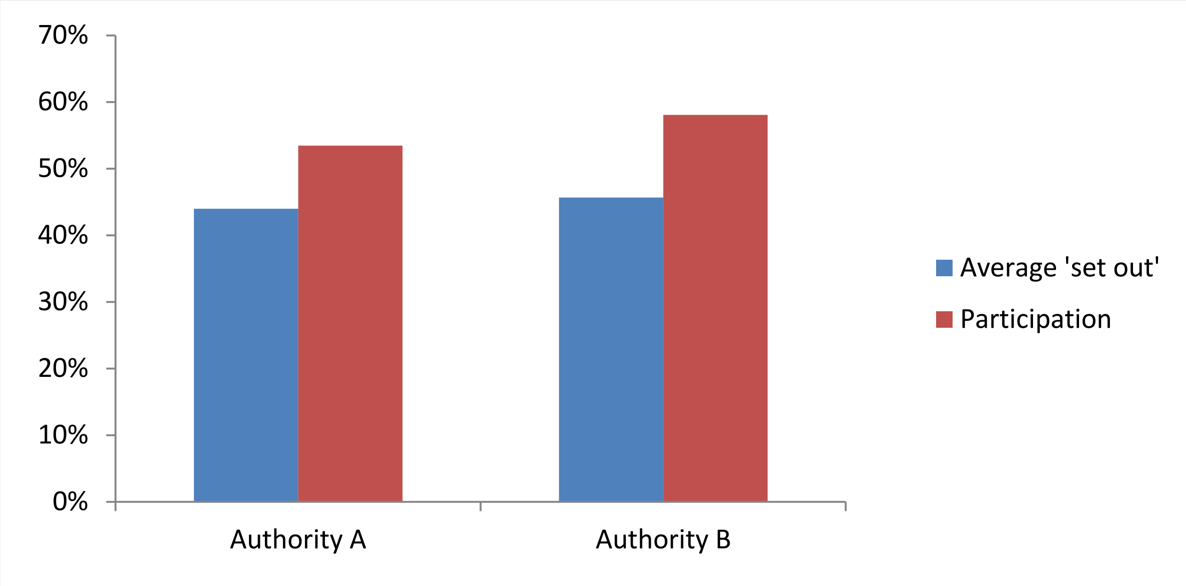
3.2 Participation

Participation in a food waste collection service is closely linked to the total yield of food waste collected. In simple terms, the higher the participation, the higher the yield. However, it is important to understand the nuances of participation in a service to be able to maximise the efficiency of that service.

Monitoring participation in separate weekly food waste collections has generated much useful information. For example, despite householders being provided with a collection each week, a reasonable percentage of service users choose not to present their food waste for collection at each collection.

As a result, the 'set out' rate on any given week is likely to be some 10–15 percentage points lower than the actual participation rate in a service. Figure 3.6 illustrates this point by presenting the results of participation monitoring carried out by WRAP in 2014.

Figure 3.6 Comparison of 'set out' and participation rates



As stated above, participation rates in food waste collections are typically lower than in other recycling services. Even the best performing services are likely to achieve participation rates of less than 70% and, as outlined above 'set out' rates will be lower.

For a separate weekly food waste collection:

- Poor participation = <35%
- Average participation = 35–55%
- Good participation = >55%

3.3 Predicting how much food waste you're likely to collect

3.3.1 Indicative yields

There is a wide variation in the actual yields reported by local authorities providing a food waste collection service. However, the following 'indicative yields' provide a useful comparison of the typical yields likely to be achieved by the three common food waste collection profiles – assuming a service is well designed and implemented:[2]

- Separate weekly collections: 1.5 kg/hh served/week;
- Weekly mixed food and garden waste collections: 0.8 kg/hh served/week; and
- Fortnightly mixed food and garden waste collections: 0.5 kg/hh served/week.

[2] WRAP 2014

3.3.2 Food waste 'ready reckoner'

For a more refined estimate of the likely yield that a separate weekly food waste collection will achieve, a 'ready reckoner' is available using information generated by the original WRAP funded food trials. These trials identified a correlation between separate weekly food waste collections, the frequency of residual collections and the level of deprivation. Data from the trials were used to produce a 'ready reckoner' to enable rough predictions of food waste yields in different local authorities to be made.

These predictions apply only to **separate weekly collections** of food waste where householders are provided with kerbside containers, kitchen caddies and liners (see Section 4).

WRAP has updated the model, which previously used indices of multiple deprivation, to enable it to be used by local authorities across the UK. The model uses the percentage of households in Social Groups D and E in a local authority area (derived from the 2011 Census) as a measure of deprivation and applies it to the following formulas:

- For areas with fortnightly residual waste collection (i.e. alternate weekly collection):
  = 2.1614 – (% Social Groups D and E × 2.2009) ± 0.40 kg/hh/week

- For areas with weekly residual waste collections using sacks:
  = 1.8121 – (% Social Groups D and E × 1.14385) ± 0.25 kg/hh/week

- For areas with weekly residual waste collections using bins:
  = 1.5307 – (% Social Groups D and E × 1.0736) ± 0.25 kg/hh/week

Appendix A lists the percentage of households in Social Groups D and E for all UK local authorities.

The ready reckoner provides a **likely range** for anticipated food waste yields at the start of the service assuming that the service is implemented well, has clear communications and good initial liner supply. As outlined in Section 2 participation in food recycling schemes can deteriorate if quality or good scheme design is not maintained in the delivery of the service.

3.3.3 Kerbside costing tool

WRAP's 'Kerbside costing tool' is available to local authorities via its local authority portal http://laportal.wrap.org.uk/ The tool produces a series of benchmark costs and standard operational data, through service modelling, which local authorities can use when evaluating their current recycling service and considering service changes. The resulting benchmarks are based on the performance (yields of food and dry recycling) and cost of a modelled good practice system operated across a range of geographical areas. More information about the 'Kerbside costing tool' can be found in Section 9.1.1.

www.wrap.org.uk/hhfoodwastecollections

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