Bio-waste composting

Management options for 6 composting strategies

ACR+ MED

ACR+ (the Association of Cities and Regions for Recycling and sustainable Resource management) is an international network of members who share the common aim of promoting the sustainable consumption of resources and management of waste through prevention at source, reuse and recycling. Currently, ACR+ has around one hundred members, mainly local and regional authorities as well as national networks of local authorities representing around 1 100 municipalities.

In November 2012, ACR+ extended its activities to include the Southern Mediterranean countries, the Balkan and Turkey, corresponding to the Union of the Mediterranean region. This extension, called ACR+MED, applies the same principles, aims and target groups as ACR+, while taking into account the socio-cultural and economic specificities of the region.

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Introduction

This technical report is organized into six sections: (1) an overview of bio-waste streams, (2) applicable portion of the bio-waste stream, (3) estimates of avoided collection and disposal costs attributed to diversion of bio-waste, (4) the description of 6 bio-waste composting strategies, (5) a summary of the 6 composting strategies, and (6) a review of potential compost markets.

Based on the structure of the US Environmental Protection Agency report: 'Organic Materials Management Strategies' (1999), this report aims to highlight the different possible composting strategies that can be considered by local authorities and other public/private stakeholders dealing with bio-waste. Data, (sub-) chapters and case studies presented here are mainly extracted from EU reports and research studies and allow thus for a fully updated and adapted report.

The content of this report is meant to provide best available information on bio-waste composting strategies for all countries. However, this publication is of particular interest for those countries that are still heavily reliant on landfilling of bio-waste. The strategies presented and the cases studied in this report have particularly been implemented in EU-15 countries and can be used as pilots for other countries in the process of initiating and/or improving their bio-waste management strategies.

Not all the composting strategies described in this report have been developed in the same way or with the same intensity. This report therefore does not reflect the current bio-waste management situation in the EU but rather the possible decentralised and centralised options of treating bio-waste. There is no single best strategy and most probably a mixture of different composting strategies may be adopted by decision makers at the local and/or regional level.

It is important, in accordance with the waste hierarchy, and for the purpose of reduction of greenhouse gas emissions originating from waste disposal on landfills, to facilitate the separate collection and proper treatment of bio-waste in order to produce environmentally safe compost and other bio-waste based materials. Therefore it should be encouraged to practice the separate collection of bio-waste, with a view to performing composting and digestion, to ensure the treatment of bio-waste in a way that fulfils a high level of environmental protection and to make use of environmentally safe materials produced from bio-waste. Setting minimum requirements for bio-waste management and quality criteria for compost and digestate from bio-waste are important in order to guarantee a high level of protection for human health and the environment.

This report does not consider anaerobic digestion and the bio-waste prevention measures focus only home & community composting. Anaerobic digestion and other bio-waste prevention measures, such as closed loop gardening techniques, food waste avoidance, food waste donations, animal feeding, etc. will be described in upcoming technical reports in 2014 and 2015.

On a basic level, the message of this report is that composting is feasible at almost every scale, and it works. The most important part of a successful composting operation is choosing a strategy or combination of strategies that works for a particular situation.

1. An overview of composting strategies

Bio-waste makes up the bulk of discarded Municipal Solid Waste (MSW) however varying according to socio-cultural, geographic and economic criteria. In recent years, numerous strategies in the European Union and elsewhere in the world have been set up to divert bio-waste from the municipal waste stream and create beneficial uses for it. Not all these strategies have been initiated with the same intensity. This technical report provides a detailed analysis of each of the strategies listed above, based on programs implemented by public and/or private organizations/institutions.

The strategies described in this technical report include the following:

1. Home & community composting of household bio-waste
2. Municipal green waste collection and centralized composting
3. On-site institutional composting of bio-waste
4. Off-site composting of commercial food waste
5. Household source-separated composting systems
6. Mixed waste composting at centralized processing facilities

2. Applicable portion of the bio-waste stream

Analysing waste streams is not a straightforward and easy task since reliable data[1] on municipal waste are clearly not as available as may be thought.

In order to be able to estimate the applicable portion of the bio-waste stream that can be diverted from landfilling or Waste-to-Energy in the different composting strategies (Section 4) several calculation methods and data can be used. However, whatever method used, the limitations are considerable, as most data are based on national averages.

Considering the municipal waste composition analysis is one way for determining bio-waste streams. The regional composition of bio-waste in the municipal or household waste fraction varies according to a range of factors, including geographical location, meteorological season, urban or rural characteristics of the region, type of settlements, standard of living, and food and drink habits. In European countries, between 22% and 49% of municipal solid waste consists of food and green waste. In some Mediterranean regions this proportion is much larger and consists of percentages of fermentable waste (up to 70%) because of a relatively large use of vegetables and fruit in the daily diet, tourism that generates extra waste from meals and a lower presence of packaging and bulky waste due to a less wealthy economy.

The average bio-waste portion in the Municipal Solid Waste (MSW) for selected geographical regions varies from 37% (EU-15), to 47% (Balkan, Turkey and EU-13)[2], and up to 59% in the

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[1] A little side note has to be made regarding data quality. Data quality depends on the availability of technical and administrative tools. Waste surveys carried out by statistical offices can only collect such information from waste collectors currently available. Possibilities of getting additional information are very restricted and may lead to weak estimates. Besides this the highly dynamic development of waste management is in contrast with the relatively slow development of waste control and data collection. This leads to an underestimation of the amounts collected.

Middle East and North Africa (MENA) region. However, when looking at absolute data, the countries of EU-15, due to the higher overall MSW generation, produce the most bio-waste. EU-15 citizens generate on average 200 kg/cap/y followed by MENA citizens generating 167 kg/cap/y and finally 155 kg/cap/y for EU-13 and Balkan citizens. In this sense it can be said that the potential for bio-waste composting strategies is high for the three geographical regions.

Additional information on bio-waste streams can be found in different research studies carried out by universities, public authorities, institutions, and finally in the different case studies presented in this technical report.

Bio-waste sub streams: food and green waste

Bio-waste[3] is composed of two major sub streams: food waste[4] (also called food scraps) and green waste[5].

The quantities of food waste generated depend on the standard of living, seasonal aspects, food preparation and consumption patterns, and the number and age of persons living in the households. The values range between 30 and 90 kg/cap/y[6]. Calculations made on behalf of the EU[7] study based, among other sources, on Eurostat and national data assume a default value of 90 kg/cap/y as the average municipal food waste potential in EU-15. Another study[8], based on data collected from US EPA, DEFRA, WRAP and Perkan, provides figures of 212 to 298 kg of household food waste per year.

In contrast to the food waste potential, the literature reports that the weight of green waste greatly varies. Values from 20 kg/cap/y to more than 700 kg/cap/y have been reported. This variation between countries and within countries between regions can be explained by differences in rainfall, temperature, type of natural vegetation, gardening practices, garden area (related to type of building) and length of growing season.

Household versus municipal food and green waste

Data on the ratio household versus assimilated food and green waste provide interesting information for all composting strategies and more particularly for composting strategies by institutional and commercial entities. For the sake of this report, and based on an Irish[9] and US EPA study[10], we assume a ratio of 50%/50% of household against assimilated food waste and a ratio of 80%/20% of household against assimilated green waste.

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[2] *Municipal waste management in accession countries, Eurostat 2002*
[3] *Bio waste: "Biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises, and comparable waste from food processing plants (Waste Framework Directive, Directive 2008/98/EC)*
[4] *Food waste: biodegradable kitchen & processing plant waste from households, restaurants, caterers and retail premises composed of raw or cooked pre-consumer and post-consumer waste (ACR+)*
[5] *Green waste: biodegradable garden and park waste from households, public & private green spaces composed of grass, branches and similar waste (ACR+)*
[6] *Modeling Biowaste Flows for Life Cycle Assessment – calculation of the potential and collected weight of kitchen and garden waste, Sonja Schmidt and Claudia Pahl-Wostl*
[7] *Bio Intelligence Service, Final Report – Preparatory study on food waste, October 2010*
[8] *Food waste within food supply chains: quantification and potential for change to 2050,Julain Parfitt, Mark Barthel and Sarah Macnaughton, 2010*
[9] *Indecon study on behalf of the Irish Department of Environment, Community & Local Government, June 2012*
[10] *Organic Materials Management strategies, US EPA, 1999*

3. Estimations of avoided collection & disposal costs

The management of bio-waste involves several different costs and benefits. This section focuses on one benefit in particular: the possible (under certain conditions) reduction in residual waste collection and disposal costs, or ‘avoided costs for some strategies. These avoided costs result from the diversion of bio-waste from the waste stream through different composting strategies.

Avoided disposal costs include the amount saved on landfill or Waste-to-Energy costs (gate fees and taxes) by diverting waste to another, optimised solid waste management strategy. Care must be used when estimating cost avoidance based on the national/regional averages for landfilling costs because local conditions will more than likely be different. If a low cost disposal area uses these averages, then the cost avoidance estimations will be overstated. Conversely, a high disposal cost area will underestimate the savings potential. No matter what the landfill costs are, however, there is a resulting avoided disposal cost to be gained by diverting bio-waste through other improved management methods.

This report uses the typical indicator of ‘cost per tonne’. Cost per tonne is the net cost divided by the tonnes of waste managed. The cost per tonne in this technical report tries to make comparisons on the basis of complete paths, considering average collection and treatment costs. Comparing the average cost of one path to another should be done with care, recognizing that average costs reflect economies of scale. Another factor explaining the high diversity of costs among countries lies in the fact that the general cost of living differs from country to country. This technical report is not meant to provide a ‘full costs accounting’, including upfront, investment, operating and back-end costs, of the 6 bio-waste composting strategies but rather a good indication of costs comparisons between different composting strategies and between composting strategies and the option of landfilling.

Residual waste collection & landfilling costs[11]

Landfilling costs vary widely within and between countries. Two of the few comprehensive sources for information on residual waste collection and landfilling costs in Europe are two studies made for the European commission, which provide some data on collection and landfilling[12] costs[13] for residual waste. Similar information for Balkan countries, Turkey and MENA countries is more difficult to find. Some information on this issue was collected by ACR+ through surveys organized as part of the Horizon2020 Capacity building program. The range and average costs are presented in Annex 2 of this technical report. Collection costs for residual waste revolve around €30 to 126/t, with a median value of €67/t while landfilling costs vary from €23 to 157/t with a median value of €108/t as an average[14].

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[11] *Throughout the report, the term ‘charge’ is used to refer to the sum of the prevailing level of tax and the gate fee, therefore representing the total cost of landfilling.*
[12] *‘Overview of the use of landfill taxes in Europe’, ETC/SCP working paper 1/2012*
[13] *‘Costs for Municipal Waste Management in the EU, Eunomia Research & consulting Ltd*
[14] *Déchets municipaux en Europe, vers une société européenne du recyclage, ACR+, 2009*

Selective bio-waste collection and composting costs

One of the aims of selectively collected bio-waste is to remove a large enough portion of bio-waste, and to reduce volume sufficiently, to allow residual waste to be collected less regularly. In southern countries this may mean reducing the collections of residual waste from 4 to 6 times a week, to daily, up to 2 or 3. In the northern areas it is a more a question of moving towards weekly to fortnightly collections. In order to be able to reduce the collection rounds for residual waste the capture of bio-waste through separate collection must be such that the amount in residual waste is cut down by 10 – 20% and more in weight. If the source separation of food-waste is added as a further service, with no modifications to the previous scheme for MSW collection, the total number of collection rounds and (obviously) the cost of the collection service are bound to increase. But this does not necessarily happen when and where bio-waste collection and the source separation of key dry recyclables are integrated within the overall collection scheme. Separating out bio-waste allows the issue of collection frequencies, vehicles, containers, and logistics to be reviewed across all the waste streams. This is why it must be seen as an integrated rather than an 'add-on' service.

Savings can be considerable where home and community composting and other on-site composting options (institutions or commercial establishments) divert large portions of their bio-waste, since no collection costs are to be considered. Similarly, residential source-separated composting and mixed waste composting programs might result in decreased mixed waste collection service or frequency.

Comparing costs of bio-waste selective collection[15] is particularly difficult for various reasons such as: modalities and frequency of collection, types of bio-waste collected simultaneously (green and food waste), collection material and infrastructure for collection (e.g. two fraction divided trucks), population density, just to name a few. Collection costs for bio-waste (food or food & green waste) revolve around €40 to 178/t, with a median value of €82/t. Selective collection of green waste only is estimated at more or less €39/t as an average[16].

The costs of compost plants are typically affected by cost of land acquisition, the requirements for land per unit of capacity, scale, plant utilisation rate, the choice of technology, especially the degree of process control, the purity of source separation, the nature and length of contracts and the materials received, the need for structural carbon-rich materials, revenues for sale of product, related to the quality of input material and the maturity of the end product. Composting costs for bio-waste revolve around €39 to 94/t with a median value of €70/t. Composting of green waste, cheaper, is in the range of €22 to 67.5/t with a median value of €31/t (see Annex 2)

[15] *Average collection costs includes bin purchase and distribution*
[16] *Déchets municipaux en Europe, vers une société européenne du recyclage, ACR+, 2009*

4. Bio-waste management strategies

This section discusses six bio-waste management strategies - home & community composting, municipal green waste composting, on-site institutional composting, off-site commercial composting, mixed waste composting and household source-separated composting. Each strategy is supplemented with specific case studies allowing for a better understanding of the strategies. The following generic information is provided for each strategy:

1. Strategy description: general features of the strategy are described.
2. Case studies presented: per strategy a few best practices are analysed and presented.
3. Technical challenges: technical difficulties and limitations of the strategy are discussed.
4. Applicable portion of the waste stream: estimate of the quantity of bio-waste that could be/is targeted annually. The applicable portion for each strategy is estimated in isolation of other strategies.
5. Costs per tonne diverted: information from existing programs is used to develop estimates of the cost per tonne of bio-waste diverted. Cost estimates do not include costs to homeowners.

4.1 Home & community composting of household bio-waste

Strategy summary

Strategy Description	Home & community composting of household bio-waste is promoted through outreach, bin subsidization, education, and training
Technical Challenges	Possible technical problems include odours, flies, pests, and undersized bins. Proper education and bin selection can mitigate, and possibly even eliminate, these difficulties
Applicable Portion of the Waste Stream Diverted	A home composting strategy allows for an average composting range of 50 – 162 kg/cap/y of bio-waste while a community composting strategy allows for composting between 22 – 73 kg/cap/y
Costs Per Tonne Diverted	Ranging from €26 - 38 for home composting programs to €54 - 145 for community composting programs. Midrange costs vary from €32/t for home composting to €93/t for community composting.

Strategy description

Elements of home & community composting programs might include outreach, bin subsidization, and educational workshops. Home & community composting program outreach efforts often include distribution of flyers and brochures, production of videos and radio advertisements, and informational displays at local events, public gardens, and gardening stores. To encourage greater participation, many programs subsidize the purchase of suitable, effective composting bins. Some smaller municipal programs also provide education to householders/communities on how to build bins from chicken wire, wood pallets, or other materials. Many municipalities organize training programs such as master composter programs. In these programs, a compost specialist trains a group of volunteers, who themselves become master composters. They in turn train others in the community on proper composting techniques. Other municipalities produce show-and-tell programs. These programs include demonstration gardens and composting education in local school science curricula, which allows children to learn about composting in the classroom and then bring the knowledge home to teach to their families. As an economic incentive some municipalities reduce the overall waste charges to citizens when participating in home & community composting programs.

Staff needs for a successful home & community composting program depend on the size of the community and on whether bins are being distributed. Many municipalities have recycling coordinators or other staff who spend a certain percentage of their time encouraging and promoting home & community composting, while large-scale city or regional programs tend to have coordinators who work full time on the program. Volunteers often do some of the work.

Below are a few cases of home & community composting programs implemented by local authorities and regions. The programs range from extensive bin subsidies, technical assistance, and outreach efforts to programs that emphasize primarily education and outreach.

Case studies

Case 1: Home composting: City of Kent (United Kingdom)

- 34% of the Kent residents carried out home composting in 2010
- 50% target by 2020
- By 2008, 200 Compost advisors had been accredited
- Theatre show performed in 400 schools, reaching 36 000 children
- Nearly 70 000 subsidized composting bins sold
- An exhibition unit visited all districts, promoting home composting
- Citizens made aware of the project by radio advertisements and road shows
- The annual financial benefits were estimated at €750 000 in 2009/10 and could be up to 2 million euro in 2020

Case 2: Home composting: Flanders Region (Belgium), since 1993

- 42% of Flanders households participate actively in home composting representing 922 000 households
- Separate collection of bio-waste organized in 67% of the region, the remaining benefiting from green waste collection 4x/year
- Grasscycling and other closed loop gardening methods highly promoted reducing the green waste to be (home) composted
- Bins and boxes are partly subsidized by the Municipality and the Region
- Network of more than 2 000 Master Composter and 50 Compost Expert train the trainers
- Compost and demonstration places (more than 30 in Flanders) and closed loop gardening educational centres (3x) for educational purposes
- Brochures, compost educational box, strategy monitoring reports,…
- Estimated 100 000 tonnes of bio-waste diverted from landfilling/incineration yearly (20 to 80 kg/cap/y)

Case 3: Terra Terra - home composting project, Porto (Portugal)

- 1 million inhabitants, 416 000 households, 1538 inh/km^2
- MSW generation of +/-500 kg/inh/y
- Subsidized compost bins (for free) distributed to households, schools, institutions and companies with gardens located in Lipor's Municipalities.
- Potential reduction > 4 000 ton bio-waste/year generated (~400 kg bio-waste /year/compost bin), assuming 10 000 compost bins distributed and used.
- LIPOR might thus prevent the emission of 704 ton CO_2/year *(1 ton waste incinerated = 0.176 ton CO_2).*
- 3 hour hands-on composting course organized by technicians of Lipor (Master Composters), mandatory for every responsible who wants a compost bin. Information material & a 4 l Bio-waste Bucket distributed to participants.
- Until august of 2013, LIPOR distributed more than 6 900 composting bins and 79 sites of community composting were running.
- According to the monitoring visits, participants produce around 475 kg bio-waste/year per composting bin and the quality of compost is very good
- 1 Full Time Technician (Master Composter for training, monitoring visits and administrative tasks), 4 l Bio-waste Bucket=2€, Compost bin = €40

Case 4: Community composting in Région PACA (France)[17]

- Wooden composters of 550 l in series
- One or more wooden boxes for the storage of wood chips
- One or more wooden boxes for the maturation process
- An information panel
- Residents receive a bio-waste bucket of 10 l
- The municipal service adds wood chips and controls the process
- Compost is used for communal gardens or recovered by residents for plants
- 5 to 6 tonnes of compost produced yearly
- Investment costs: €2 000 to €2 500
- Operational costs: €500/year

Case 5: Community composting in the city of Zürich (Switzerland)

- Initiated by citizens since 1992
- 15% of citizens participate in Home or Community Composting (CC)
- Financed partly through housing companies
- Low-rise apartments
- Wire containers, wooden boxes & heaps
- Kitchen waste (90%) & garden waste (10%)
- 997 CC projects varying from 2 to 5 up to >100 households, average of 33 households per CC park
- 1 fulltime coordinator for the city of Zürich
- Households contribute financially
- Operations and maintenance: mainly volunteers
- Brochures, CDs, dedicated website developed and promoted
- Rules, pictograms, and contact details on panels at CC parks

Case 6: Community composting in Pallas Sobira (Spain)[18]

- Initiated in 2006 (4 units), currently 31 CC units
- Mountainous village in the Pyrenees
- 7 625 inhabitants, 5.4 inhabitants/km^2 for a total surface of 1 355 km^2
- Community composting units in nuclei of less than 100 inhabitants
- 52 composters installed with a capacity of 800 litres
- ~ two composters per unit, one for processing & one for maturation
- Inhabitants themselves are responsible for adding structural materials 'browns' provided by the municipality and stored in a box
- Close communication & monitoring between responsible municipal staff & inh
- In parallel initiatives are taken for selective collection of bio-waste in the largest village (> 300 inhabitants), from commerce and institutions, as well as for the green waste
- The costs can be subdivided as follows: personnel costs: €71 000; management costs: €21 500 = total of €92 500.

[17] *Micro-compostage collectif des biodéchets en bac, recueil de recommendations de mise en oeuvre, GESPER, 2006*
[18] *Gestion de bioresiduos de competencia communal, Ministerio de Agricultа, Alimentacion y medio ambiente Madrid, 2013*

Technical challenges

The primary technical challenges associated with home & community composting include odours and pests. Odours can be emitted when the compost pile is not turned often and anaerobic decomposition occurs. Pests (e.g., rats, and mice) might enter compost bins if they are not properly enclosed and/or secured.

In order to avoid these challenges and ensure that the right materials are composted, technical assistance, including training and assistance, is essential. If municipalities do not adequately educate and promote continual, correct use of a composting pile, individuals might experience minor problems and refuse to ever contemplate composting again. This, in turn, could impact other waste diversion efforts attempted by the municipality.

The supply of sufficient wood chips (structural materials) in the community composting programs is essential in order to have the right carbon/nitrogen balance for an optimal composting process. Even better is the option whereby participants to the programme are encouraged to collect and store ‘browns (structural materials)’ throughout the year in order to feed the composting boxes/bins on a continuous basis.

Applicable portion of the bio-waste stream diverted

In most cases, home & community composting applies to two major components of the household bio-waste stream: food and green (garden) waste. Food waste generation may well differ geographically, southern countries thereby generating more food waste than northern countries. Similarly but reversed it is likely that Northern European countries will generate more green waste than Southern European and Mediterranean countries.

However, not all the food waste is suitable for home and community composting. Approximately 72% of the food waste generated by households is potentially available for home & community composting. This includes all food waste except meat, fish, cheese, milk, and fats and oils. However, it has to be mentioned that some municipalities/regions (e.g. Catalonia) do allow these parts to be included with moderation for collection and further treatment, mostly when using in-vessel composting systems. For the green waste potential allowance of 10% for large household green waste items - tree trunks and large limbs - that are not easily compostable at residential level should be made. The quantities diverted from centralized treatment has been estimated according to a number of studies, cases analysed and presented in Table 1 hereunder.

Table 1: Potential (P) and current (C) food waste and/or green waste diverted by home and community composting according to a number of reference studies / cases analysed

	Participation rate hhld in composting activities	**Home composting**			**Community composting**[19]
	%	Bio-waste	Food waste[20]	Green waste	Bio-waste
		kg/hhld/y	kg/cap/y	kg/cap/y	kg/hhld/y
EU	20 – 55 (P) (1)		90 (P) 212 – 298 kg/hhld/y (P)	20 – 700 (P)	
EU-15 (2)			72 (P)	90 (P)	
Belgium (Fl)	42 (C)	20 – 80 (C) (3)			50 – 75 (C)
UK[21] [22] [23]		220 (P)	137 (P)		
France			100 (P) 96 urban[24] 125 rural	160 (P)	150 (C)
Sweden			100 (P)		175 (C) (3)
Switzerland					85 – 100 (C)
Applicable portion range		**50 - 162 kg/cap/y**			**22 – 73 kg/cap/y**

(1) 20% in urban areas to 55% in suburban/rural areas
(2) ACR+ calculation: 100 kg food waste /cap/y x 72% compostable = 72 kg/cap/y and 100 kg green waste/cap/y x 90% compostable = 90 kg/cap/y
(3) Calculated for 100% households in Flanders. Amount would be higher if calculated according to the participating families only (42%)
(4) Semi-automated composting system (baseline of apartments)

Other factors will affect the possibility for home and community composting such as willingness of the population to participate and of course all the measures taken by local and regional authorities to engage their residents in such programs. Realistically it may be assumed that 20% of urban and 55% of rural households could participate actively in a home and community composting program.

[19] *Vergelijkende analyse van de projecten van buurtcomposteren, VLACO vzw JJ Dohogne, 2008*
[20] *Preparatory study on food waste – Final report, BIOIS, October 2010*
[21] *Dealing with food waste in the UK, Eunomia, Dr. Dominic Hogg, 2007*
[22] *Sustainable ways of dealing with household food and garden waste in the UK, WRAP, 2007*
[23] *Assessment of the options to improve the management of Bio waste in EU – Final report, ARCADIS, 2010*
[24] *Guide méthodologique du compostage partagé, ADEME, novembre 2012*

Costs per tonne diverted

The costs of home & community composting programs generally fall into four categories: staffing, public education and outreach, bin purchasing, and bin distribution. Education efforts often continue well into the project, and some municipalities provide also home visits on request. These visits are meant to provide instructions on composting techniques and/or are used for monitoring purposes. Master composters (often volunteers) or municipal experts may carry out these tasks. Frequently, bins are subsidized by grants and homeowners make up the difference. In some cases, as mentioned in the strategy description, there is also the cost associated to the reduction of waste charge for participating households.

Municipally sponsored home & community composting program costs can vary significantly. Some programs include significant start-up costs associated with bin subsidization and initial education and outreach programs. In these cases, the costs for initiating the programs are high compared to the amount of waste diverted after the first year. But since bins typically last for 10 years (and some are now even warranted for up to 25 years) and only minimal additional funding might be needed from the municipality to sustain the program, program costs decrease over time. There is a wide range of compost bin prices; the simplest units can be as inexpensive as €15, while the largest and most expensive, mostly for community composting purposes, can cost as much as several hundred euro. Prices vary depending on how many bins are purchased at once; most municipalities have been able to obtain bins at wholesale prices by purchasing bulk quantities. In general, home composting bin subsidy costs range from €25 to €50 while a community composting set up may require subsidies as little as a few hundred euro to more than €15 000. Typical home & community composting program costs, corresponding to the values presented in the case studies are provided in the table hereunder.

Table 2: Program costs per year and per tonne diverted for selected municipality home & community composting schemes

	Home composting Flanders	**Community composting PACA (France)**[25]	**Community composting Zürich (Switzerland)**[26]
Capacity of composting units	240 l	550 l boxes in series	800 l boxes in series
N° of participating households	1	45	50
Estimated quantities of bio-waste (kg/hhld/year) composted	+/- 250	5 000 to 6 000	8 000 (1)
Investment costs (€) (2)	25 – 55 (3)	2 000 – 2 500	4 000
Operational costs (€/hhld/y) (4)	4	500	30 (5)
Total costs (€/year)	6.5 – 9.5	700 – 750	430
Total cost range (€/t)	**26 – 38**	**+/- 120 – 145**	**54**

(1) 3.1 kg/household/week = 155 kg/household/year
(2) 10 year write-off
(3) Costs for municipalities: subsidized bins at €25 and boxes at €55
(4) Public education and outreach for home composting programs. Community composting programs typically also have part time workforce to account for
(5) The system works mainly through volunteers

[25] *Micro-compostage collectif des biodéchets en bac, recueil de recommendations de mise en oeuvre, PACA,2006*
[26] *Inventory of good practices regarding (bio-waste minimization in Europe, 2011*

Above figures are in line with the outcomes of a study carried out by ARCADIS[27] suggesting a cost of €34 per tonne of waste being home composted. The figures released in a comprehensive manual by the Spanish government[28] shows figures ranging from €40-80 per tonne for home composting to €31-74 for community composting.
The costs home composting helps to avoid depend upon the collection system being used, and the way in which home composting affects participation in the collection scheme. There may be circumstances, for example, where a household is home composting, but where it continues to participate in a bio-waste collection scheme. Midrange costs vary from €32/t for home composting to €93/t for community composting.

4.2 Municipal green waste collection & centralized composting

Strategy summary

Strategy Description	Green waste (e.g., leaves, grass, prunings and tree wood and bark) from households and assimilated municipal sources is collected and composted at a central location.
Technical Challenges	Odours from centralized compost facilities are the primary technical problem, but storm water management, litter control, and siting and permitting issues can be of concern as well.
Applicable Portion of the Waste Stream Diverted	Green waste collection schemes allow for quantities from 60 to 160 kg/cap/y depending on the collection scheme or mix of collection schemes.
Costs Per Ton Diverted	Ranging from €36 per tonne diverted via recycling centres to €70 per tonne for kerbside collection. Midrange costs are estimated at €52/t.

Strategy Description

Municipal green waste consists of a range of materials including tree wood and bark, prunings from young trees and shrubs, dead and green leaves and grass clippings and originates from domestic dwellings and municipal parks, gardens, street trees and reserves. The green waste from municipal parks, gardens,… is either brought to recycling parks or treated on the spot. Very often mobile shredders from the municipality chip the wood and branches for use as mulching material in parks, gardens,…

Collection programs

In many cities in the developed world, green waste is collected separately from other waste and is mechanically shredded and then composted, either alone or with other bio-waste. There are many ways to collect green waste, ranging from sophisticated selective collection programs to simple drop-off programs. Two general methods of selective collection are bag/bin collection and bulk collection. Bag/bin collection operations usually rely on existing rear loading truck fleets and crews to collect the green waste. Bulk green waste including large prunings and branches, when collected selectively, is often either chipped on the street

[27] *Assessment of the options to improve the management of Bio waste in EU – Final report, ARCADIS, 2010*
[28] *Gestion de Biorresiduos de Competencia Municiapl, Guia Para la Implantacion de la Recogida Separada y Traitamiento de la Fraccion Organica – Ministerio de l'Agricultura, Alimentacion y Medio Ambiente, Madrid 2013*

using a mobile chipper or collected in bundles and taken to a composting site where it is chipped. Drop-off systems can replace kerbside collection completely or cover periods of the year when there is no kerbside selective collection. If the composting facility is centrally located, the drop-off can simply be set up on site. In many cases this is not possible; therefore, secondary sites, such as at municipality recycling centres, are created. A roll-off container can be used for temporary storage; when full, it can be hauled to the nearest compost facility.

Frequency of collection will largely depend on seasonal (summer versus winter) and geographical (North versus South) aspects.

Composting facilities

Green waste composting facilities range from low-technology operations, where piles of leaves are turned periodically with front-end loaders, to high-technology operations, where size reduction equipment, dedicated windrow turners, and screening equipment are used. An advantage to using high-technology processing methods, aside from producing a higher quality product, is that compost can be produced and moved off site within a year, making space for the following year's material.

Available land is a key criterion for determining the most appropriate composting method for a given site. Many municipalities use front-end loaders for a variety of purposes; therefore, a portion of the equipment time can be allocated to the composting program. Capital and operating costs for this equipment can be considered proportional to the volume of the total material handled by the front-end loader or to the percentage of time the equipment is working at the composting site. In general, the cost of a windrow turner rises with increases in capacity, and operating costs increase with the complexity of the model.

If branches are accepted at the site, they must be reduced in size prior to composting. Small quantities of brush can be processed through a chipper, but a tub grinder or wood scrap processing equipment is needed to process large sizes and quantities. Branch chips can be used for landscaping or as structural material when composted with high nitrogen material such as grass. Leaves and grass can also be size-reduced in a tub grinder to shorten the time required to complete the composting process. Expensive equipment, such as tub grinders or compost screens, can be purchased jointly and shared among municipalities.

Even windrow turners can be shared, although they must be transported from site to site more frequently than the other equipment.

Case studies

Case 1: Collection scheme for garden waste in Flensburg (Germany)

- Three collection options for citizens
- 'Green 60', a 60 litre bag (€2.5 /bag) for disposal of small quantities of garden waste. Net weight of the bag may not exceed 15 kg.
- Recycling centres: self-delivery of bulky garden waste (hedges and bushes) for a fee or with a 'green waste card' (households only. Green waste card for loose green waste in bags (€15): max 10 bags of 120 l. At each delivery the back of the card is post signed. Green waste card for bulky green waste: max 5 m^3 at €31. Minimum delivery is 0.25 m^3
- Private waste collection on request for large quantities needing large containers

Case 2: Collection of garden waste: Flanders (Belgium)

- Small garden waste to be collected weekly to monthly depending on the period of the year (winter/summer)
- Mostly 40 to 120 litre bins used for collection of bio-waste
- Branches & other larger garden waste collected on request or 4x a year in areas where no weekly/bi-weekly bio-waste collection is organised
- Grass, branches & other larger garden waste brought to recycling centres
- Proportion between small garden waste/branches/tree stumps: 76%/22%/2%
- Selectively collected green waste amounts to 560 000 t/y or 83 kg/cap/y
- Collected waste transported to dedicated authorized compost facilities
- Part of the shredded branches & large green waste used as structural material in composting facilities

Case 3: Collection of grass cuttings, hay and leaves in Compostela Inserta (Spain)

- 1 650 tonnes of grass cuttings, hay and leaves from public parks and gardens and professional gardeners collected per year
- The green waste has less than 1% impurities
- The collected materials are mixed with shredded bulking materials such as wood, tree and bush cuttings originating from public parks and gardens
- The mixing rate is green waste 2 / bulking 1
- The green waste is treated in windrows that are turned by a machine towed by tractor
- The fermentation phase is 8 weeks followed by a 12-week maturation phase
- The treatment costs are estimated at €46/t (€36/t operational costs and €10/t investments costs)
- The shredder and turner are rented while the tractor and sieve are owned
- The compost (A-class) is 100% sold to gardening companies at €30/t

Technical challenges

Collection systems

Disadvantages of bulk collection systems include contamination of leaves by street trash and oil, and leaf piles that blow into the streets. Bulk collection methods usually require scheduled collection and associated parking bans if needed. Drop-off programs are not as convenient as kerbside collection strategies; therefore, participation and diversion rates for drop-off programs might be lower. Drop-off systems may have to monitor closely on impurities, more specifically when containers are used. The frequency of the collection has to

Composting facilities

Odour can be a problem at green waste composting facilities. Factors that contribute to odour generation include types of materials collected, management issues, siting, and climatic conditions.

Grass clippings in particular become anaerobic and emit offensive odours very quickly due to their high moisture and nitrogen content. It is critical to process grass clippings as soon as possible after delivery to avoid odour problems and ground-water contamination. While small amounts of grass provide the necessary nitrogen to accelerate the composting process and produce finished compost with desired nutrient content, too much grass has a decidedly negative impact on composting sites. Adding structural carbon-rich materials is a common practice to overcome this challenge. This points to the logic of promoting grasscycling programs in conjunction with leaf collection.

While grass is the primary contributor to odour, leaf composting alone can also produce odours when improperly managed. It is advantageous to site composting facilities not too close to residential areas, as odorous compounds get diluted with distance; otherwise, siting and permitting battles can arise. In addition to odour problems, storm water management and litter problems might be of concern and must be planned for accordingly.

An important point is that where garden waste collections are offered free of charge, they tend to undermine the potential for home composting. The convenience that free garden waste collections offer to households in terms of depositing garden waste tends to discourage dealing with the material at home through home composting. Rather, the option of charging for garden waste collections (typically, with higher charges for collection of refuse) needs to be available in order to further encourage home composting if there is to be a doorstep collection of garden waste at all.

If combining a green waste collection with home composting (recommended) the focus should be on collecting grass clippings and other nitrogen rich material rather than the bulky green waste. Composting grass clippings at home can hamper the process if not properly managed as compared to the bulky green waste that is most suitable as structural material for home composting the nitrogen rich fraction, mostly food waste. Another way of reducing the need to collect and treat grass cuttings is grasscycling whereby grass is cut in tiny little pieces and left on the lawn.

Applicable portion of the bio-waste stream diverted

Green waste composting programs target leaves, grass, and branches generated mainly by the residential sector but including also green waste from the commercial sector and public areas such as parks, street trees and banks.

In contrast to food waste, the literature reports that the weight of green waste potential/cap/year greatly varies. Values from 20 kg/cap/y to more than 700 kg/cap/y have been reported[29] for household green waste. This seems to be due to a number of factors, such as the climate and soil conditions, the season, the growth of different plant types, the type and extent of land use for building, the garden area/capita, and the use of garden area. Green waste from assimilated municipal sources varies and depends on the number of public and private institutions/businesses, the green areas per institution/business, the number of parks, street trees and banks.

Table 3: Potential (P) and Current (C) green waste quantities collected for selected green waste collection programs as according to a number of reference studies / cases analysed

	Overall	Kerbside collection program	Recycling centre (drop-off)
	kg/cap/y		kg/cap/y
Europe		20 – 700 kg/cap/y (P)	
EU-15 (1)	90 (P)		
Flanders (B)[30]		83 kg/cap/y (C)	60 (C)
France[31]	160 (P)		
Germany[32]			5 – 60 (C)
Italy		118 kg/hhld/y	
Applicable portion range	**60 – 160 kg/cap/y**		

(1) ACR+ calculation: 100 kg green waste/cap/y x 90% compostable = 90 kg/cap/y

Running this strategy in parallel with a green waste prevention program (grass cycling by leaving the grass cuttings on the ground, wood chips used as ground cover protection or as natural walls, home & community composting,…) may considerably reduce the green waste available for collection and centralized composting.

[29] Modeling Bio waste flows for Life-Cycle Assessment – calculation of the potential and collected weight of kitchen and Garden waste, Sonja Schmidt and Claudia Pahl-Wostl, 2007
[30] Ecowerf – inter-communal cooperation – collecting and recycling household waste in the Leuven area
[31] Guide méthodologique du compostage partagé, ADEME, novembre 2012
[32] Modeling bio-waste flows for life-cycle assessment – calculation of the potential and collected weight of kitchen and garden waste, Sonja Schmidt and Claudia Pahl-Wostl, 2007

Costs per tonne diverted

A variety of factors influence the cost of green waste composting programs including the collection strategy used (e.g., drop-off or kerbside), the materials targeted (e.g., leaves, grass, branches, or some combination thereof), the frequency of collection, the quantity of green waste generated, the technology used for turning compost windrows or grinding brush (e.g., dedicated equipment versus existing or shared resources), and numerous other factors.

To develop a midrange cost estimate for green waste collection, it is necessary to consider the relative quantities and costs of green waste drop-off versus kerbside/bulk collection programs. Kerbside/bulk collection programs divert approximately twice the amount of green waste of drop-off collection programs. For drop-off programs, the cost of collection is a lot less since individuals drop off their yard trimmings at the compost facility at their own costs. However, there is still a transport cost for bringing the centrally collected green waste to the treatment facility. For kerbside collection, an average cost of €39 per tonne collected is assumed while bulk collection may reduce costs to €28 per tonne collected.

Whether the green waste is brought to a composting facility via kerbside/bulk collection or dropped off by residents or commercial landscape contractors, once at the facility, further costs will be incurred as the material is turned into finished product. Both programs can (and most often do) of course run simultaneously and the costs per tonne diverted will rely on the quantities collected per program.

Table 4: Program costs per tonne diverted for 3 different green waste collections & composting schemes

	Kerbside collection program (€/t)	**Bulk collection program** (€/t)	**Recycling centre (drop-off)** (€/t)
Collection costs	39	28	0
Transport costs from recycling centre to treatment facility			5
Treatment costs	31	31	31
Cost average per collection scheme	**70**	**59**	**36**

Green waste diversion average overall costs for the programs analyzed range from a low of €36/t diverted for programs that rely on drop-off collection to a high of €70/t diverted for programs that use more extensive kerbside collection and processing operations. Midrange costs per tonne green waste diverted for a combination of a kerbside collection and drop-off system, taking into account that twice as much green waste will be collected by the kerbside collection, would be €58/t.

4.3 On-site institutional composting of bio-waste

Strategy summary

Strategy Description	Institutional establishments and business facilities process food and/or green waste at an onsite composting operation.
Technical Challenges	Regulatory requirements are the greatest difficulty faced by institutional & business composting sites.
Applicable Portion of the Waste Stream Diverted	Educational establishments (universities, schools,…), hospitals, hotels, restaurants, retailers, (wholesale) markets, and others generate various amounts of bio-waste. Values of 0.3 – 3 tonnes/employee/year for restaurants and 110 – 800 tonnes/year for retailers can be pushed forward.
Costs Per Ton Diverted	Costs vary from €55 to €237 per tonne of material diverted. The median value is €94.

Strategy description

Institutional establishments, such as universities, schools, hospitals, rest homes and other are uniquely suited to composting on-site because they typically generate large quantities of bio-waste and have land available for composting. Institutional composting can reduce disposal costs or, as is the case at schools and universities, provide opportunities for research and development of new compost technologies. However, the principal motivation to engage in some institutions, such as schools, is for environmental and pedagogical reasons, cost benefits being a secondary motivation, contrary to commercial facilities.

The involvement of all stakeholders in institutional establishments, such as municipality, inspection services, users, parents, and personnel, right from the identification of the composting initiative throughout the process of planning, preparation, implementation and monitoring & evaluation is essential for success. Animation by technical services of the municipality, enterprises and associations is also important in order to ensure the functioning and pedagogical development of the composting unit.

Composting in institutional establishments can be done in bins and boxes, pavilions or through electro mechanical (semi-automated) composting units. Besides institutional establishments, commercial facilities such as hotels, catering services, supermarkets, and so on may choose to compost on-site, despite less land available, making use mainly of semi-automated composting units.

Case studies

Case 1: Composting in boxes in schools, CAT Sarrebourg (France)

- System closest to home composting
- Food waste is disposed of in the boxes using alternated layers of wood chips and food waste at a rate of 0.5 to 1
- A separate box for wood chips
- Regular turnings (preferably once a month) required (1 to 2 hours) done by school personnel/students
- Maturation boxes
- Mature compost reached after 6 to 8 months
- Quantities preferably not exceeding 5 t/y corresponding to schools serving more or less 200 meals/day or 156 kg food waste/week
- Investment costs estimated at €3 000 to €4 000
- Advantages are the simplicity, adaptability and low costs; disadvantages are the limited quantities that can be treated and the manual turning

Case 2: Nursing home at Bergerac (France)

- 250 residents, 500 meals a day
- 390 kg food waste/week mixed with wood chips
- Wood chips provided by municipal services
- Compost pavilion of 20 m^3
- The compost pavilion is composed of 4 cells, two cells for composting of 2.5 m^3 and 2 cells for the maturation process of 7.5 m^3
- The gardener is in charge for collection (6 days/week), feeding the composter, and follow up, requiring 0.5 to 1 hour/day
- After 1.5 months, the compost in the making is turned back in a maturation box (1/2 day's work by the gardener)
- Liquids, meat, fish, fats and oils are avoided

Case 3: Composting platform in school at Roche (France)

- 400 meals served per day
- Composting in windrows
- 70 m^3 (+/-23 t) wood chips and 17 m^3 (6.3 to 7.2 t) food waste treated
- Total surface of 200 m^2 required with a slight slope to collector
    - Platform for composting of 30 m long and 6 m wide allowing for turning on both sides
    - 20 to 30 m^2 area for stocking of wood chips
- Applicable only for establishments with sufficient space
- Composting process takes 6 to 8 months
- A windrow turner (hired at €200 for each turning) used 6 to 8 times during the composting process
- School volunteers manage the operations

Case 4: Green waste windrow on-site composting at 18-hole golf course – Flanders (Belgium)

- Yearly average green waste generation at 18-hole golf course: Greens:25 m^3; Trees: 25 m^3; Fairway + practice + semi-rough (mulch mowing); Rough: 100 m^3; areas outside game: (wood, branches, leaves,…): 50 m^3 making a total of 200 m^3 or +/- 100 tonnes;
- Seasonal aspects to be considered
- Wood and branches to be chipped, stored and gradually used as structural material for composting process
- Large quantities of grass problematic for composting process
- Composting on site requires technical knowhow, investment costs and strict follow up
- Investments costs between €6 750 - €8 750, operational costs between €4 600 - €5 100

Case 5: Nordiska Folkhogschool (Sweden)

- School of 200 pupils
- Canteen providing 400 meals/day
- Aletrumman T75 composter (2005) and biofilter
- Kitchen waste (pre food consumption mainly) + waste from 15 families living in the vicinity of the school
- 50 kg/day or 250 kg/week or 13 500 kg/year
- Manual feeding of 5 to 10 buckets/day
- Wood chips added empirically depending on humidity of waste
- Investment cost of €13 000
- Electricity consumption of 19 kWh/day in winter
- Wood chips at 5 euro per 25 litre or 300 €/t

Case 6: Gliffaes Country House Hotel (Wales - United Kingdom)

- Hotel with 23 rooms serving +/-100 meals a day
- Installation of an accelerated composter: A700 system (since 2007)
- Composting of kitchen waste and plate (meal) waste
- +/-20 kg/day, more or less 1 t/month
- Same volume of wood chips added (+/- 40 l/day)
- Dedicated collection bins in the kitchen of 15 to 60 l
- Automated emptying of the fresh compost in a wheelbarrow
- Fresh compost undergoes maturation process of 6 to 8 months
- Mass reduction of 90% (12 t/y gives +/- 1 t of compost)
- Feeding of the composter, control and cleaning: 15 min/day
- Benefits (collection) amount to 400 euro/year

Case 7: Leclerc supermarket in Pont l'Abbé (France)

- Installation of an electro mechanical composting unit since 2009
- Quantitative goal: compost 85% of the 800 t generated food waste/y
- Mainly damaged food waste, fruit and vegetables that have been altered and outdated food products
- Food waste recovered by employees during set up of the rays
- Brought to the electro mechanical composter Kollvik (1545 model)
- The person responsible that handles the composter needs 0.5 t/day
- 400 to 500 kg/day of food waste, or 110 t/y are composted
- The composter is considered as performing well but does not allow for the treatment of the targeted food waste according to the goal

Technical challenges

Institutional and commercial on-site composting has important constraints but offers also opportunities for selective sorting at source of food waste. Some limitations for the more sophisticated (semi-)automated in vessel systems should be considered such as higher overall costs and the possible need for space for the final maturation process of the system output material.

Facilities such as schools, hospitals, nursing homes, hotels,… have sanitary constraints, imposed by rules with regard to conditioning and circulation of food and food waste. The application of the 'forward movement' principle, excluding the contact between 'proper' and 'contaminated' food waste has its implications regarding space management, circulation and management of tasks. 'Forward movement' means that waste has to be eliminated upstream of food preparation areas and downstream of the food distribution sector. An evacuation circuit of waste should never cross a circuit for the preparation of meals.

Institutional composting facilities, including small on-site systems, are often required to undergo similar regulatory and siting processes as large solid waste disposal and processing facilities. These permit requirements probably represent the single largest barrier to widespread composting by this sector.

Applicable portion of the bio-waste stream diverted

Distinction for this strategy has to be made between composting in boxes, pavilions, windrows and composting in semi-automated accelerated compost units. Similarly to the home and community composting strategy, approximately 72% of the food waste generated by the residents of the different institution types is potentially available for composting in boxes, pavilions and/or windrows. This includes all food waste except meat, fish, cheese, milk, and fats and oils. Semi-automated accelerated compost usually accepts 100% of the food waste.

90% of the green waste - making allowance of 10% for large household green waste items (tree trunks and large limbs) - is compostable in the boxes, pavilions and windrow composting schemes. The semi-automated accelerated compost units use mainly wood chips or similar as structural material to optimise the composting process. Table 6 shows the potential for diverting bio-waste from several types of institutions using unit diversion rates estimated.

Table 5: Potential (P) and Current (C) bio-waste (food & green waste) diversion for on-site composting for selected cases

	Food waste				**Green waste**
	Collective restaurants	Commercial restaurants	Retailers (3)	Local markets	18 hole golf course
France[33] [34] [35]	125 – 264 g/pers/y (P) (1) 4.5 t/y (P)	175 – 230 g/pers/y (P) (2) 6 t/y (P)	138 – 507 tonnes/y (P) 800 t/y (P) 110 t/y (C) (4)	188 t/y (P)	
Belgium[36]					100 t/y (C)
US[37]	260 g/pers/y (C)				
Norway		3 t/employee/y (P)			
UK	1.4 t/employee/y (P)	0.3-2.8 t/employee/y (P) 200 g/pers/y (C) (5)			
Sweden	125 g/pers/y (C)				
Applicable portion range	**Commercial and collective restaurants: 0.3 – 3 tonnes/employee/year** **Retailers: 110 – 800 tonnes/year**				

(1) 125 g for enterprises to 264 g for socio medical health establishments
(2) 175 g for quick restoration to 230 g for traditional restaurants
(3) 138 tonnes for retailers with 50 to 199 employees and 507 tonnes for retailers with more than 200 employees
(4) Case study 'Leclerc supermarket Pont l'Abbé' France
(5) Case study Gliffaes Country House Hotel (Wales)

Costs per tonne diverted

Table 7 provides a summary of the costs of on-site institutional and commercial programs for which capital and operating costs are available. The cheapest system relies on simple on-site 'low-technology' composting in boxes, pavilions and/or windrows while the semi-automated 'high-technology' systems are more expensive.

[33] Etude estimative de la production de bio déchets au sein des établissements de restauration, rapport d'étude – version finale, ADEME, novembre 2011
[34] Pertes en gaspillage alimentaire. Marges de manœuvre et verrous au stade de le remise directe au consommateur (distribution et restauration) et en restauration collective. Ministère de l'agriculture, de l'alimentation, de la pêche, de la ruralité et de l'enseignement du territoire, novembre 2011
[35] Preparatory study on food waste – Final report, BIOIS, Oct 2010
[36] Groenafval beheer op golfterreinen, VLACO vzw, JJ Dohogne, 2007
[37] The implementation of Cafeteria Food Waste Recycling programs- A best practice Guide for Ramsey & Washington County K-12 Schools

Table 6: Program costs per year and per tonne diverted for selected on-site composting schemes

	Box composting school	Pavilion composting nursing home	Windrow composting school	Green waste composting golf course	Semi-automated Nordiska Folkhogskol
Estimated quantities of bio-waste (kg/year) composted	+/- 5 000	+/- 20 440	+/- 19 000	+/- 100 000	+/- 13 500
Investment costs (€) (1)	3 000 – 4 000	10 000 – 15 000	10 000 – 15 000	6 750 – 8 750	13 000 – 20 000
Operational costs (€/year) (2)	0	1 200 – 1 400	1 000 – 1 800	4 600 – 5 100	1 200
Total costs (€/year)	300 - 400	2 200 – 2 900	2 000 – 3 300	525 - 575	2 500 – 3 200
Total costs (€t)	**60 - 80**	**107 - 141**	**71 - 117**	**55 - 57**	**185 - 237**

(1) 10 year write-off for all composting schemes/units

(2) The operational costs may encompass time input for filling (+/- 0.5 hours/day), controlling and managing the final product as well as the purchase of the wood chips (or cardboard in some cases), adding of lime, as the use of electricity (semi-automated, high technology systems).

The single largest financial benefit of this on-site composting strategy is that the bio-waste, as is the case for the home & community composting strategy, does not require collection. Besides this benefit, it should be highlighted that in cases whereby the compost is not used directly on-site it can be sold in bulk or in smaller bags subject to quality control and standards. However, the costs incurred for analysis of compost samples as part of quality control system can be costly and may dissuade new initiatives being taken.

4.4 Off-site composting of commercial food waste

Strategy summary

Strategy Description	Commerce/institutions — supermarkets, restaurants, schools, nurseries, and others — generate food waste and receive commercial collection services for separate collection and composting.
Technical Challenges	Compacted food waste can generate odorous liquids that leak from collection vehicles. Also, the containers used to store the food waste before collection can become quite odorous themselves and need to be cleaned or exchanged, which can cause logistical problems.
Applicable Portion of the Waste Stream Diverted	Educational establishments (universities, schools,…), hospitals, hotels, restaurants, retailers, (wholesale) markets, and others generate various amounts of food waste. Values of 0.3 – 3 tonnes/employee/year for restaurants and 110 – 800 tonnes/year for retailers can be pushed forward.
Costs Per Tonne Diverted	Costs vary from €79 to €272 per tonne of material diverted. The median cost for collection and processing is estimated at €152/t

Strategy description

Commercial food waste generators that receive private or public collection services, such as supermarkets, food processing companies, restaurants, and schools, have the potential for diverting large amounts of food waste. Food waste in those facilities can represent 60 to 90 percent of the total waste stream. Sorting the food waste in dedicated containers at the premises and offering it for selective collection is highly relevant as it does not require much additional workload for the employees, the available space for adding additional containers is not a major problem and the potential quantities that can be diverted from landfilling are high (see Table A3-3 in Annex 3).

There are several ways for food waste collection. For larger generators, roll-off compactors can be filled on site then hauled directly to a composting site. Smaller generators have their materials collected more frequently by compactor trucks from smaller outside containers, such as dumpsters, or by a service that swaps full containers for empty ones. Whether the collection is organised by the private or public sector will vary per country and will depend among other issues on legislative obligations, the cost efficiency of the chosen collection system and the technical, financial (including cost recovery) organisational possibilities for the municipality to organise the collection by itself.

Case studies

Several pilot and full-scale schemes are described below:

Case 1: Harvest Fine Foods divert 120 tonnes of food waste per year from landfill, UK 2011

- Pre-prepared fruit and vegetable service to clients
- A total of 12 x 240 litre food waste bins for collection of food waste
- Collection three times per week
- A total of more or less 120 tonnes of food waste is collected yearly
- Average lift weight is 108 kg/bin
- Collector uses portable heavy duty scales to weigh each bin for management reporting (not for charging purposes)

Case 2: Collection of food waste of school canteens and awareness raising for food waste reduction in Alban, France[38]

- 4 schools divert food waste by collecting its separately in food waste bins provided by the inter-municipality SITOA
- A food waste reduction awareness raising program runs in parallel
- The food waste per plate varies from 96 g (primary schools) to 139 g (higher education institutes).
- Reduction achieved from 96 g to 52 g/plate in primary schools
- In 8 months, 27 tonnes (objective of 75 tonnes) of food waste were collected and sent to an agricultural anaerobic digestion plant
- Financial benefits for not sending to incineration = €6 750
- Collection & treatment costs lower as compared to incineration costs
- The financial benefits of the reduction of food waste at the source has not been estimated

Case 3: MGM resorts restaurants food waste collection (US)

- MGM collects surplus food and food waste from its 165 restaurants
- MGM collects only pre-consumer food waste, including vegetables and fruits, bread, meat and dairy and requires that most restaurants, buffets, separate food waste inside their kitchens
- Food recovery quantities at the MGM Resorts properties have rapidly increased from 3 350 tonnes in 2007 to more than 14 000 tonnes in 2011
- Two distinct end users collect and process the waste:
  - a pig farm that feeds 3 000 pigs per day. The farm does additional sorting of the food waste, pulling out non-edible items. State requirements for animal feed, cooking the food waste to required temperatures prior to feeding the pigs.
  - a local composting facility.
- Both companies have implemented systems for food waste collection that removes material off the property as quickly as possible — an essential component of the program.
- Currently, about half of the food waste collected goes to animal feed, and half to composting

[38] http://www.optigede.ademe.fr/fiche/collecte-des-dechets-alimentaires-de-cantine-scolaire-et-valorisation-par-methanisation-sensib

Case 4: Sharp Health Care food waste collection, San Diego (US)

- Two hospitals (417 and 212 maintained beds) joined the program in 2012
- Hospitals share one central kitchen managed by Sodexo
- The central kitchen serves 629 beds plus two cafeterias
- Pre-consumer and post-consumer food waste is captured by kitchen staff from patient rooms and cafeteria trays
- Food waste at the hospitals was determined to be 80% of the weight
- 3.5 tonnes of clean food waste are collected for composting every week or 182 t/y
- Waste is brought to a composting site – the greenery
- The hospital has also a single stream recycling for paper and plastic waste.
- The total diversion rate for the entire health care system is approximately 36%.

Case 5: Operação Restauração 5 Estrelas (Operation 5 Stars Catering), Porto (Portugal)

- The project is implemented in the 8 Lipor's associated municipalities as well as protocols with the municipalities of Esposende and Viana do Castelo (Resulima multi-municipal system) and recently with Ambisousa inter-municipal system.
- In 2013, the project covers more than 1 500 establishments (restaurants, canteens, etc.) spread over 17 door-to-door selective collection circuits.
- Bio-waste is disposed in specific containers and collected 3 up to 7 days a week. 'Operação Restauração 5 Estrelas' also provides information and awareness material.
- In 2012, the project made it possible to compost 14 500 tons of bio-waste.
- In more than 5 000 discharges/year, there was not any non-compliance.
- According to the 2013 bio-waste characterization, the selectively collected bio-waste was of high quality with only 3% of contaminants.
- The delivery of bio-waste in Lipor's Organic Valorization Plant is totally free, since the material fulfills the quality criteria.

Technical challenges

As for other strategies targeting food waste mainly, food waste in particular is a potential breeding ground and shelter for mould, micro-organisms and pests. It must therefore be disposed of as soon as possible. The waste stream should proceed separately so cross-contamination (contact between waste and food) is avoided. Compactors without interlayers and compactor trucks can leak substantially and create odours and messy conditions. This problem can be alleviated by using roll-off compactors with watertight interlayers.

Another problem is encountered by waste collectors (public, private or public/private partnerships) that collect dumpsters and clean these containers at the customers' site. The resulting wastewater must be handled appropriately. In some cases the wastewater is captured in a separate container in the collection vehicle and then dumped into its sewage system (for which it has a permit). In an attempt to reduce the frequency with which the containers need to be cleaned, some waste collectors have tried to use degradable liners to protect the container sides; for example, biodegradable (compostable) food waste bags that are held in place in the containers with oversized rubber bands. This option can reduce the number of times the containers require washing.

Applicable portion of the bio-waste stream diverted

The commercial sector has strong potential to contribute to the diversion of food waste. As the separately collected food waste is destined to be treated in centralized 'in-vessel' composting systems, products from animal origin can be treated as well. Therefore 100% of the food waste generated by the commercial sector can be collected and treated centrally.
Table 7, very similar to Table 5 presented in the previous composting strategy (on-site institutional composting), shows the applicable portion of food waste for diversion from several types of institutions.

Table 7: Applicable portion of food waste available for off-site commercial composting for selected cases

	Food waste			
	Collective restaurants	Commercial restaurants	Retailers	Local markets
France[39] [40]	125 – 264 grams/person/year (P) (1)	175 – 230 grams/person/year (P) (2)	138 – 507 tonnes/year (P) (3)	
France[41]	4.5 tonnes/year (P)	6 tonnes/year (P)	800 tonnes/year (P) 110 tonnes/year (C) (4)	188 tonnes/year (P)
US[42] [43]	260 grams/person/year (C)	1.36 tonnes/employee/year	1.36 tonnes/employee/ year	
Norway		3 tonnes/employee/year (P)		
UK (5)	1.4 tonnes/employee/year (P)	0.3-2.8 tonnes/employee/year (P)		
Sweden	125 grams/person/year (C)			
Applicable portion range	**Restaurants: 0.3 – 3 tonnes/employee/year** **Retailers: 110 – 800 tonnes/year**			

(6) 125 g for enterprises to 264 g for socio-medical health establishments

[39] *Etude estimative de la production de bio déchets au sein des établissements de restauration, rapport d'étude – version finale, ADEME, novembre 2011*
[40] *Pertes en gaspillage alimentaire. Marges de manœuvre et verrous au stade de le remise directe au consommateur (distribution et restauration) et en restauration collective. Ministère de l'agriculture, de l'alimentation, de la pêche, de la ruralité et de l'enseignement du territoire, novembre 2011*
[41] *Preparatory study on food waste – Final report, BIOIS, Oct 2010*
[42] *The implementation of Cafeteria Food Waste Recycling programs- A best practice Guide for Ramsey & Washington County K-12 Schools*
[43] *Identification, characterization and mapping of food waste and food waste generators in Massachusetts, Final report, 2002*

(7) *175 g for quick restoration to 230 g for traditional restaurants*
(8) *138 tonnes for retailers with 50 to 199 employees and 507 tonnes for retailers with more than 200 employees*
(9) *Case study 'Leclerc supermarket Pont l'Abbé' France*
(10) *Case study Gliffaes Country House Hotel (Wales)*

Costs per tonne diverted

In the commercial sector, the costs of collection and processing are often not easily accessible, as they are considered proprietary information. Several factors influence the costs of the collection such as: food waste generation rates per employee for different types of generators, participation rates based on survey information, efficiency of food waste separation, collection frequency, and container weight limits. Commercial food waste may be collected by the municipal waste services (public and/or public/private on behalf of the municipality) or private haulers. The collection costs may be charged per haul based on the volume of the container or per kg/t, provided the collection truck has a weighing system. The quantity of food waste generated at each commercial site and the distance between generators, in case a private hauler is in charge of collection, have the greatest impact on commercial food waste collection costs. The program costs for commercial waste collection and subsequent composting in 'in-vessel' systems are presented in Table 8 based on values presented in Table A2-3 (Annex 2).

Table 8: Program costs per tonne diverted for commercial waste composting

	Collection costs (€/t) as part of municipal waste collection	Composting costs (in-vessel) (€/t)	Total costs (€/t)
Costs range	40 - 178	39 - 94	79 - 272
Median costs	**82**	**70**	**152**

4.5 Household source-separated composting systems

Strategy summary

Strategy Description	Residents separate specified bio-waste, food waste and /or green waste materials and set them out for collection and processing.
Technical Challenges	Due to concerns about odour and health, programs that include food waste should consider collecting these materials more often, especially in warmer climates. When collected for centralised management, food waste containing products from animal origin is subject to the EU Animal By-Products Regulation (1774/2002).
Applicable Portion of the Waste Stream Diverted	Potentially 100% of the food waste and 90% of the green waste generated by households can be treated in 'in-vessel' plants. Values identified in literature and case studies vary from 25 - 145 kg/cap/y for bio-waste to 25 – 80 kg/cap/y for food waste.
Costs Per Tonne Diverted	Costs (collection + composting) per tonne diverted ranges between €79/t and €272/t, the median value being €152/t.

Strategy description

Increasing sensitivity about the poor quality of mixed waste compost obtained via Mechanical Biological Treatment (MBT) started a wave of residential collection programs targeting the bio-waste fraction of solid waste. Several pilot programs in the late 1980s demonstrated that the compost produced with residential source-separated feedstock contained substantially lower levels of toxic heavy metals and physical contaminants, such as glass and plastic, than mixed waste compost.

A variety of operational options are available for collecting source-separated bio-waste[44]:

- The material types collected options are: single stream food waste collection, single stream green waste collection and mixed food and green waste (mostly small garden waste) collection. The material type will affect the value and available markets of the end-product. To comply with the Animal By-Products Regulations, food waste including meat, fish, fats,… must be treated in an enclosed unit via anaerobic digestion (AD) or in-vessel composting (IVC) even though some countries, legally or not, still allow these materials being treated in windrow composting plants; whereas garden waste can be composted externally in windrows. As a result, green waste requires simpler, less costly treatment infrastructure than food waste[45];
- The collection system can be either a door-to-door collection or a drop-off/bring system. Drop-off systems allow collections from areas with high population density, where space is limited. However, higher participation and yields are found using door-to-door collection[46];
- The container options such as 60-180 l wheeled bins, 5-23 l vented/unvented caddies and possibly compostable caddy liners. The size of the containers is dependent on material types collected (larger containers are required if including green waste), frequency of collection, and expected yields. The costs increase when providing caddy liners but it makes it more publicly acceptable, cleaner for collection crews, and allows for slightly higher yields[47]
- The coverage options such as all properties, a phased approach (i.e. 10 000 households per year), flats, schools, businesses,…
- Frequency options: bi-weekly, weekly, fortnightly,… More frequent collections may be required in warmer climates or over the summer period to avoid odours and hygiene problems[48] (e.g. Catalonia (Spain) frequencies: 3-4 x/week for door-to-door collection and 3-7 x/week for road containers). Weekly collections in northern countries may allow frequency of residual collection to be reduced to alternate week collections;
- Vehicle options: new specialized vehicles, double shifting refuse vehicles, or a combination with current set-up (i.e. green waste rounds);
- Finally, in some cases whereby the bio-waste treatment facility is distant from collection points the use of satellite trucks and transfer stations might be considered.

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[44] *Waste in Action, An investigation into food waste management, Georgina Lamb & Lisa Fountain, Nov. 2010*
[45] *ACR+, Municipal Waste in Europe – Towards a European Recycling Society'. Victories Editions 2009*
[46] *WRAP, 'Evaluation of the WRAP Separate Food Waste Collection Trials' 2009*
[47] *WRAP, 'Food Waste Collection Guidance', 2009*
[48] *ACR+, Municipal Waste in Europe – Towards a European Recycling Society'. Victories Editions 2009*

Local authorities are likely to prefer different options depending on the current operational set-up, required yields, financial costs, proximity of treatment facilities, quality of output material and political acceptability.

Summarising: the technologies on the market for biological treatment of segregated bio-waste fall into three basic categories:

- Open windrow composting – suitable for garden waste or garden, fruit and vegetable waste, or in some countries, garden waste and all catering waste from households;
- In-vessel composting – suitable for mixed food and garden waste. Process optimised through appropriate blending of food and garden wastes at the facility rather than commingled collection of bio-wastes;
- Anaerobic digestion – suitable for treating feed stocks with a high proportion of household food waste, but depending upon the technology, requiring some additional material.

Case studies

Several pilot and full-scale residential organics programs are described below:

Case 1: Ratingen-Lintorf Composting plant (Germany)[49]

- 50 000 tonnes (composting plant) bio-waste and green waste,
- 60 000 tonnes (wood facility) seasoned and unseasoned wood
- Start-up date in 1997
- Completely enclosed, automated row composting with automated turning
- For preparation and production the material is shredded and sifted, metals are removed with an iron separator and finally it is sorted by hand (impurities > 60 mm)
- Approximately 4 to 5 weeks duration of intensive rotting
- Fresh an mature compost produced
- RAL-labelled compost
- Markets: soil and compost suppliers, private gardeners, agriculture, local authorities

Case 2: The ECOPROGETTO compost site in Venezia (Italy)[50]

- One third of food waste collected through door-to-door collection using small buckets for houses and bins at high-rise buildings. Two thirds are collected through drop off using side-loading of containers
- Collection frequency twice weekly for kerbside collection and 3 times weekly for road containers
- The site accepts food waste collected both in bio-bags and normal PE bags, although the former is preferred
- Compost site at 4 km from the city at 1 km from the nearest dwelling
- The site treated 62 500 tonnes in 2005 of which 38 000 tonnes food waste and 23 450 tonnes green waste
- Input mixture of 50/50 (food waste / bulky materials). Wooden rejects from previous process cycles make up for the lower quantities of green waste collected
- Treatment in bio-boxes (Herhof type) followed by 15 days in an

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[49] *UmweltBundesAmt, Ecologically sustainable recovery of bio-waste, suggestions for policy-makers at local authorities, March 2012*

[50] *Dealing with food waste in the UK, Eunomia Dr. Domici Hogg, March 2007*

enclosed post-treatment stage using turned windrows

- This process is followed by 45-day curing stage in a covered, but not fully enclosed area
- Odour treatment by self-regenerative thermal purification of air
- Compost produced up to 20 000 tonnes, used mostly by farmers free of charge
- 10% of output is used by producers of potting mixes, who stockpile the compost in order to gain better maturity and stability. The product is then blended with peat and sold as a potting mix

Case 3: Selective collection of bio-waste (France)[51]

- Municipality of 150 000 inhabitants
- 58% of households live in multi storey houses
- 13.8% of households have a home composter in place
- 70 800 tonnes (+/- 470 kg/cap/y) of household waste generated
- Home composting diverts 996 tonnes of bio-waste (7 kg/hhld or 70 kg/hhld with home composter)
- 6 724 tonnes (45 kg/cap/y) of green waste brought to recycling centres
- 11 720 tonnes (71 kg/cap/y) of bio-waste collected selectively
- 16 645 tonnes of bio-waste sent to compost plant, of which 8% sent for biomass and only 0.1% refuse
- Collection costs: green waste drop off in recycling centres at €75t, selective collection of bio-waste at €118/t or an average of €103/t
- Treatment costs: €35/t
- Overall cost: €138/t

Case 4: Green Bin Program for bio-waste diversion in the Nanaimo region (Canada)[52]

- 150 000 inhabitants, of which 85 500 in the city of Nanaimo
- Mixture of urban and rural lands, 34 500 single-family houses
- Composition analysis: food waste & compostable paper: +/- 50% of household waste
- Home composting program in place
- Green Bin Program started in October 2010 for 52 000 households
- Food waste is collected weekly, recyclables and residuals collection alternates every two weeks
- Average household diverted +/- 2.5 kg of food waste and soiled paper per week or 130 kg/hhld/y or 6 700 t/y
- Containers may be lined with newspaper, paper bags or certified compostable bags, or loose
- Food waste collected with 'split-packers' and brought to an 'in-vessel' composting plant
- Finished products (compost) meets 'Organic Matter Regulation'
- Communication program cost: €3.5/hhld
- Program costs: €90/hhld including collection and treatment of residual waste, recyclables and bio-waste

[51] *Indicateurs de coûts et de performance de la gestion des déchets organiques – exemples de schémas de gestion*
[52] *Rolling out residential SSO collection in Nanaimo region, Biocycle, October 2011*

Case 5: Bio-waste collection in Djerba (Tunisia)

- Djerba is a large island and popular tourist destination off the coast of Tunisia with a surface of 500 km^2 and 140 000 inhabitants
- Municipal solid waste collection is 50 000 tonnes, whereof 20 000 tonnes are generated by the tourism sector
- The bio-waste fraction corresponds to 70% and has a humidity of 70 to 80%
- Bio-waste progressively collected separately from households (10 000 inhabitants) and hotels
- Collection frequency of bio-waste is 3x/week interspersed with packaging waste (1x/week) and residual waste (1x/week)
- Current small scale composting plant with forced aeration to be replaced by state-of-the-art 'in-vessel' composting plant

Case 6: Boadella I Les Escaulus decentralised composting (Spain)

- Public initiative since 2006
- 180 tonnes of kitchen and canteen waste treated per year from source separated collection (door-to-door in 10 l buckets)
- Small truck used for collection; transport distance to composting plant less than 1 km
- Composting plant with a surface of 250 m^2
- 4 windrows of 5 m^3 each turned with a front loader
- Bio-waste mixed with wood, tree and bush cuttings (bulking/complementary materials) at a rate of 1/1.5 (vol/vol)
- Total treatment cost per ton = €51.1 (investment costs of €18.9 + operational costs of €32.2)

Technical challenges

It takes time to educate residents when starting with such a program. During the initial period of source-separated household bio-waste collection programs, there will be some contamination that has to be dealt with at the composting facility.

Residents sometimes complain that their bio-waste containers become more odorous than regular mixed trash containers. This is more likely to be a problem for households that have a relatively small portion of non-food compostables, such as green waste, in the bio-waste container. This is also especially true for residents who have less than weekly collection for the bio-waste stream. Due to concerns about odour and health, programs that include food waste should consider collecting these materials more often, especially in warmer climates.

Although food waste does not tend to exhibit observable seasonality, except in Mediterranean areas where consumption of fruits and some vegetables increases significantly during summer time, the variable pattern in garden waste generation has implications for the treatment systems operated. This is especially the case where food and garden waste are collected together. Seasonal garden waste generation will mean that the relative concentration of food to garden waste will vary throughout the year. This can make it difficult to optimise the treatment system and will have a potentially negative impact on treatment economics. When collected for centralised management, food waste containing products from animal origin is subject to the EU Animal By-Products Regulation (1774/2002).

This regulation attempts to mitigate the risks associated with animal by-products re-entering the food chain. Garden waste (when collected separately or together with only fruit and vegetable waste) does not fall within this regulation and is routinely treated in simple open air composting facilities which tend to have low infrastructure and operating costs. Household food waste (that includes or potentially includes waste from animal origin) is subject to the rules affecting catering waste under the EU Regulation.

Applicable portion of the bio-waste stream diverted

Household bio-waste collected separately has strong potential to contribute to the diversion of food waste. Separate food (intensive scheme) and green waste (less intensive) collection are considered a better option than a combined bio-waste collection. Food waste collected separately will be treated either in 'in-vessel' plants or in anaerobic digestion plants. Therefore theoretically 100% of the food waste generated by the household sector can be collected and treated centrally. In case food waste is collected with green waste, the animal residues have to be avoided so as to comply with the animal by-product regulation, specifically when the bio-waste is further treated in windrows. For the sake of this report, and based on an Irish study[53] and a US EPA study[54], we assume households account for 50% of municipal food waste. Table 10 shows the applicable portion of food and green waste that can be diverted through separate collection systems.

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[53] *Statement of Regulatory Impact Analysis, Indecon study on behalf of the Irish Department of Environment, Community & Local Government, June 2012*
[54] *Organic Materials Management strategies, US EPA, 1999*

Table 9: Potential (P) and current (C) household bio-waste and food waste available for household source-separated bio-waste and food waste in kg/hhld/y

	Bio-waste	Food waste
	kg/hhld/y	kg/hhld/y
Europe (averages)	100 - 300[55] (P) 345[56] (P)	
UK (North Lincolnshire)	225 (C)	
Spain	47 – 103 kg/cap/y[57]	
Finland[58]		60 – 70 (C)
Germany[59] [60]	>200 (C) 60 (multi-unit buildings) 120 (single-unit buildings)	
Italy[61] (2)		188 (C)
Applicable portion range	**25 – 145 kg/cap/y**	**25 – 80 kg/cap/y**

(1) Areas with high proportions of detached and semi-detached houses
(2) Currently collected in one specific district

Again, a household source-separated bio-waste collection scheme should preferably be combined with a home & community composting program, hereby reducing the collection and treatment costs.

Costs per tonne diverted

The choice of operational options, as highlighted in the strategy description, will influence the cost of a household bio-waste source-separated collection scheme. The operational options such as material types collected (e.g. green waste, food waste, cardboard), collection system, container options (e.g. bins, buckets, paper sacks, kitchen caddies, etc), coverage, frequency of collections, and finally vehicle options (e.g. compacting or non-compacting trucks, load size) as well as the possible use of transfer stations play a key role in the final costs of such a strategy. One of the issues with costing collection systems is that whether or not the system increases the cost of collection (and the system) depends upon the choice of system.

Systems which include the free collection of green waste tend to be more costly than those which target food waste only (see strategy: municipal green waste collection & centralized composting). In general, systems collecting green waste free of charge, or green waste and food waste together, on a fortnightly basis are more expensive than systems collecting food waste only on a weekly basis. The key reason for this is that additional waste is being pulled into the formal waste collection system through the provision of a service which is free at the

[55] *'Etat de l'art de la collecte séparée et de la gestion de proximité des bio-déchets, Partie 1: analyse comparative, AWIPLAN, Juin 2013*
[56] *Study report on end-of-waste criteria for biodegradable waste subjected to biological treatment, draft final report, July 2013, IPTS Seville, Spain*
[57] *Gestion de Biorresiduos de Competencia Municiapl, Guia Para la Implantacion de la Recogida Separada y Traitamiento de la Fraccion Organica – Ministerio de l'Agricultura, Alimentacion y Medio Ambiente, Madrid 2013*
[58] *Food waste volume and composition in the Finnish supply chain: special focus on food service sector, K. Silvennoinen, November 2012*
[59] *Separate collection of organic waste – how does it work in Germany, Dr. Bergs, Claus-Grehard, BMU, Bonn, 2005*
[60] *Modeling bio-waste flows for life-cycle assessment – calculation of the potential and collected weight of kitchen and garden waste, Sonja Schmidt and Claudia Pahl-Wostl, 2007*
[61] *Managing bio-waste from households in the UK: applying Life-cycle Thinking in the framework of Cost-benefit Analysis, a final report for WRAP, May 2007*

point of provision. In terms of financial costs, separate collection systems which target food wastes are likely to be the most cost-effective.[62] The research in this report could not however provide evidence for this statement.

Table 10: Program costs per tonne diverted for household source separated composting

	Collection costs (€/t) as part of municipal waste collection	Composting costs (in-vessel) (€/t)	Total costs (€/t)
Costs range	40 - 178	39 - 94	79 - 272
Median costs	**82**	**70**	**152**

4.6 Mixed waste composting at centralized processing facilities

Strategy summary

Strategy Description	Mixed waste composting facilities separate MSW into component streams for composting, recycling, and refuse disposal
Technical Challenges	Odour problems have plagued mixed waste composting facilities, and odour mitigation initiatives have raised mixed waste composting costs. Emissions of harmful airborne fungi also have been reported. The compost produced by these facilities is often contaminated by metals and other materials present in MSW, which reduces its range of application and its value.
Applicable Portion of the Waste Stream Diverted	In theory, this strategy could divert all municipal bio-waste (as part of the residual waste) for treatment. However, ideally the residual fraction, including the remaining bio-waste fraction (up to 50% of the residual fraction), to be treated in MBT plants should not exceed 20 to 30% of total municipal waste or 52 – 80 kg/cap/y.
Costs Per Tonne Diverted	Costs (collection + treatment) per tonne diverted range between €140/t and €197/t, the median value being €162/t.

Strategy description

Mechanical-Biological Treatment (MBT) can be an interesting technology, only if it intervenes at the end of pipe and not as a pre-treatment, this is to say after upstream measures such as separate collection of recyclables, bio-waste and hazardous waste have been taken, thus dealing only with the remaining 20 to 30% of municipal waste. However, nowadays most MBT facilities are rather used for various forms of pre-treatment carried out before landfill disposal. An MBT plant is not a fixed technology and combines mechanical processes to separate out the dry recyclables such as glass and metals, with biological processes to drive out moisture and to handle the bio-waste of the incoming waste. In practice two distinct

[62] *Dealing with food waste in the UK, Eunomia, Dr Dominic Hogg, 2007*

technologies are used, both having different aims[63]: MBT to produce a landfillable or combustible fraction with a minimum of unstable bio-waste, NOT destined for agriculture, or MBT to produce a stabilized bio-waste fraction that can be recycled, e.g. in agriculture, with an acceptable maximum level of pollutants and physical impurities (only allowed in certain Member States).

MBT can, in optimal conditions, reduce the volume of waste to be disposed of in landfills by around half. In addition to the separation of dry recyclables from the incoming waste stream, the plant can be designed for:

- production of an energy-rich refuse-derived fuel (RDF) that can be combusted in waste-to-energy plants or in dedicated industrial furnaces
- diversion of bio-waste going to landfills by reducing the dry mass or reducing the biodegradability prior to landfill
- stabilization into a compost-like output (CLO)[64] for use on land
- conversion into a combustible biogas for energy recovery

A MBT facility is typically large in scale (from 10 000 t/y up to 200 000 t/y). MBTs treating the bio-waste fraction include basic pre-processing equipment such as trommels, shear shredders, or other size reduction equipment. Composting technology ranges from relatively simple windrows to capital-intensive in-vessel systems to anaerobic digestion. This range of technologies exists to accommodate the need for more process control (in terms of odour control), finished product quality, and composting speed in order to maximize throughput for a given facility size.

[63] Study report on end-of-waste criteria for biodegradable waste subjected to biological treatment, draft final report, July 2013, IPTS Seville, Spain
[64] Compost-like Output (CLO) is also sometimes referred to as 'stabilised bio-waste' or a soil conditioner, it is not the same as a source-separated waste derived 'compost' or 'soil improver' that will contain much less contamination and has a wider range of end uses.

Case studies

Several full-scale schemes are described below:

Case 1: New Earth solutions, Avonmouth MBT facility (UK)

- 200 000 t/y facility (2011) treats residual household waste as well as commercial assimilated waste from the West of England partnership
- The facility extracts metals and plastics and produces a CLO from the organic waste fraction
- The CLO is used in remediation projects, such as the capping of former landfill sites
- The facility is currently performing to landfill diversion levels in excess of 95%
- The non-recyclable fraction is turned into a refuse-derived fuel product (RDF) that will be treated into the patented New Earth Advanced Thermal (NEAT) energy recovery technology

Case 2: MBT and MBS (MBT-like process) program in Germany[65]

- From 8 plants in 2000 to 43 plants in 2013
- Capacity of 4.5 million tonnes (10% of MSW in Germany)
- MBT process: step 1: mechanical separation of light dry recyclables followed by the production of RDF; step 2: biological treatment of bio-waste through composting or anaerobic digestion (minority) with a view to stabilization compost residues for landfilling
- MBS process: drying of the waste upon receiving it (using the gas from the anaerobic digestion process) before mechanical treatment (production of RDF). Biological treatment process produces stabilized residues but less than MBTs
- Material recovery is low as compared to input
- MBTs and MBSs do not produce compost
- Costs are comparable to Waste-to-Energy plants
- Average performance of 43 plants: 24% landfilled, 6% material recovery, 37% RDF, 8% other (landfill cover) and 25% losses (water, gas,..)
- Several steps needed in waste handling with an increased risk of occurrence of problems.

Case 3: MBT program in France[66]

- Example of a municipality in France with 100 000 inhabitants with the following characteristics: 4.8% multi-storey flats, 6.3% of households practicing home composting
- 43 660 tonnes (435 kg/cap/y) of municipal waste produced annually, of which 8 217 tonnes (82 kg/cap/y) of green waste selectively collected through recycling centres and 5 268 tonnes (53 kg/cap/y) of packaging materials selectively collected
- The remaining 29 995 tonnes (300 kg/cap/y) is collected as residual waste and sent to a MBT facility
- The MBT produces the following: 17.5% compost, 3.5% residues for WtE plant, 67% residues to landfill, 1% material recycling and 11% losses
- Collection cost of residual waste fraction is €85/t
- Treatment cost (including the management of residues) is €76/t

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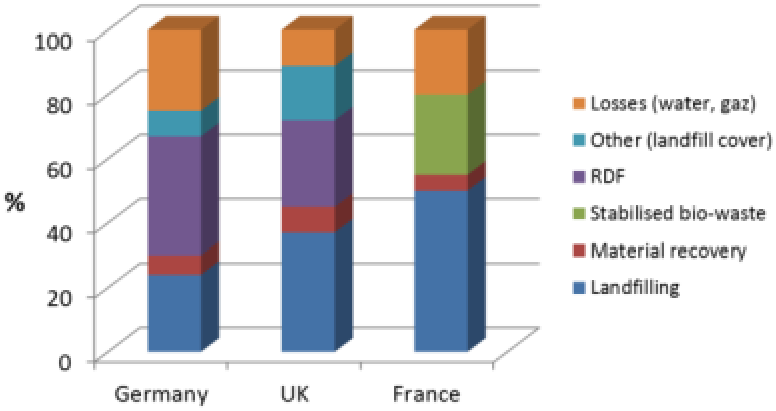
[65] *Les centres de traitement Mécano-Biologiques (TMB) – des outils flexibles en réponse aux contraintes locales, FNADE et ADEME, avril 2009*

[66] *Indicateurs de coûts et de performance de la gestion des déchets organiques – exemples de schémas de gestion, AMORCE, Octobre 2011*

Performances[67]

Figure 9 shows the average performance of MBT plants with for 3 studied countries: Germany, UK and France



The study refers to the production of 25% compost for France. However, it is better to call this a ‘Compost-Like Output (CLO)’ as discussed in the strategy description. Most likely the ‘other’ in the figure above for Germany and the UK refers to the stabilized, dried bio-waste fraction that is used as landfill cover.

Technical challenges

There remain a number of obstacles and uncertainties which are currently restricting the use of MBT. These include uncertainty regarding the strength of markets for MBT end-products such as refuse-derived fuel (RDF) and biologically stabilized products for application to land. The certainty of these markets is far from guaranteed with legislative hurdles facing the use of RDFs in industrial furnaces and better quality composts available from elsewhere competing on the soil improver side.

Depending on the nature of the individual facility, the health effects of MBT facilities might be expected to be comparable to those of in-vessel composting facilities (with an external maturation process), related to bio-aerosol emissions. Some bio-aerosols can cause health problems, notably *‘Aspergillus Fumigatus’*, but also some other fungal spores and bacteria.
Any waste management operation can give rise to dust and odours. The control of odour from waste reception areas and from any composting component of MBT facilities needs careful consideration.

Odours are controlled by a combination of facility enclosure, material handling procedures, processing technologies, competent process control, and end-of-pipe odour control technologies. Remediation technologies have improved, but this has substantially increased the cost of mixed waste composting. The odour control technologies most often used at mixed waste composting facilities are bio filters.

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[67] *Les centres de traitement Mécano-Biologiques (TMB): des outils flexibles en réponse aux contraintes locales, FNADE et ADEME, 2009*

Another potential concern with mixed waste composting is the quality of the finished compost. Chemical contamination, due to the heavy metals and organic chemicals found in batteries, consumer electronics, household hazardous waste, and other components of the waste stream, concerns potential end-users. Physical contaminants, such as pieces of glass and plastic, even if not regulated, can reduce the marketability of the product. The optical separators do not allow for the separation of glass, stones, metals and black materials from the municipal waste stream. These are important factors to consider when preparing a concept of a technological process and when designing the installation.

Applicable portion of the bio-waste stream diverted

In theory, this strategy could divert all bio-waste (as part of the residual waste) for composting. However, given the obstacles (costs, marketing end-products,…) mentioned in the technical challenges, preferably only the bio-waste remaining in the residual waste after selective collection of dry and wet recyclables should be treated in MBTs. Ideally, the residual fraction, including the remaining bio-waste fraction (up to 50% of the residual fraction) to be treated in MBT plants, should not exceed 20 to 30% of total municipal waste.

Costs per tonne diverted

Major cost elements for mixed waste composting facilities include siting, capital expenditures for equipment and odour control devices, and operating costs. Mixed waste composting facilities use much higher levels of technology than other bio-waste diversion strategies in order to sort recyclables and compostables. Facilities have dramatically different capital costs depending on the level of technology employed and the reliance upon low-skilled labour for sorting. Capital costs for MBT facilities are relatively high and have been estimated at around 60 to 150 million euro for MBT facilities in the capacity range 80 000 to 225 000 t/y[68]. Odour control technologies also have associated design, construction, and operating costs that vary widely from project to project. Operating costs include labour, operation and maintenance, utilities, and residuals disposal. The technology used will determine labour requirements. Residuals disposal can be a very large cost item depending on compost quality, the corresponding degree of contaminant removal, and the cost of disposal.

In addition to facility costs, mixed waste composting involves collection costs. Unlike other bio-waste strategies, however, mixed waste composting does not require a separate collection system. There is therefore no additional collection cost for a community that changes from hauling its waste to a landfill to hauling its waste to a mixed waste composting facility.

The economic viability of MBT projects depends heavily on the existence of stable, long term opportunities for outputs (products and energy). Financial balance might be delicate as the income generated from compost might be very low. Additionally, there is a risk of producing compost not meeting the standards, causing supplementary costs for storing and disposal. Finally, the treatment of the RDF generates costs (recovery costs by cement facilities or Waste-to-Energy plants) only partially compensated by the sale of energy.

[68] *Mechanical Biological Treatment of Municipal Solid Waste, DEFRA, February 2013*

The following table presents the costs associated to the collection and treatment of residual waste in MBT plants.

Table 11: Program costs per tonne diverted for collection and bio-waste treatment

	Capacity (t/y)	Collection costs (€/t) (1)	Treatment cost (€/t) (2)	Total costs (€/t)
Europe[69]		67	75 – 126 Average 100	142 – 193 Average 167
France[70] Case city	+/-30 000	85	76 100 - 110[71]	161
Germany	100 000	67	100 – 130 Average 115	167 – 197 Average 182
Italy		75	70 – 100 Average 85	145 – 175 Average 160
FNADE study		60	80 – 125 Average 102.5	140 – 185 Average 162.5
Applicable portion range	**€140 – 197/t**			

(1) See Table A2-& Annex 2
(2) Residual waste management (incineration and landfilling) included

Some information on costs is presented above, but perhaps more so with MBT than other treatment options, there is little sense in reporting costs without knowing a) what the plant seeks to achieve, b) the fate of the materials and the terms upon which they are accepted (is a gate fee paid to combustion facilities to have RDF treated, or is revenue received for the delivery of the calorific value), and c) the destination of any residuals (and as seen from earlier in this section, the residual waste treatments themselves vary in cost across countries). Based on the figures presented in Table 9 it can be assumed that the total costs (collection + treatment) per tonne ranges between €140/t and €197/t, the median value being €162/t.

5. Summarizing the 6 strategies

Midrange compost strategy costs

Building on the analyses and information in the previous chapters, this section addresses the potential cost impacts of compost strategies. Strategy costs (i.e. midrange compost strategy costs derived from Chapter 4) and midrange applicable portion of the waste stream are shown in Table 12.

[69] *Zeschmar-Lahl et al. (2000) Mechanisch-Biologische Abfallbehandlung in Europa, Berlin: Blackwell Wissenschafts-Verlag GmbH,*
[70] *Indicateurs de coûts et de performance de la gestion des déchets organiques, exemples de schémas de gestion, Amorce, Octobre 2011*
[71] *Acte du colloque ADEME déchets et territoires – Juin 2013*

Table 12: Summary of compost strategy costs

Strategy	Materials targeted	Midrange cost per tonne (€/t)	Cost per tonne range (€/t)	Applicable portion - range
Home composting (HC) and community composting (CC)	Household bio-waste	32 (HC) 93 (CC)	26 – 38 (HC) 54 – 145 (CC)	50 - 162 kg/cap/y 22 – 73 kg/cap/y
Green waste composting	Municipal green waste	52	36 - 70	60 – 160 kg/cap/y
On-site institutional composting	Institutional bio-waste	94 (1)	55 - 237	0.3 – 3 t/employee/y (2) 110 – 800 t/y (3)
Off-site commercial composting	Commercial food waste	152 (1)	79 - 272	0.3 – 3 t/employee/y (2) 110 – 800 t/y (3)
Household source-separated bio-waste	Household bio-waste	152 (1)	79 - 272	25 - 145 kg/cap/y bio-waste 25 – 80 kg/cap/y food waste
Mixed waste composting	All municipal waste	162 (1)	140 - 197	52 – 80 kg/cap/y (4)

(1) Median values
(2) Restaurants
(3) Retailers
(4) Ideally 20-30% of the municipal waste (525 kg/cap/y in EU-15) of which 50% is bio-waste.

Applicable portion of (bio) waste stream

The data presented hereunder are extracted from Annex 3 and correspond to calculation based on EU-15 data. It is assumed that the overall municipal waste stream generates +/- 525 kg/cap/y of which 37% or 200 kg/cap/y is bio-waste. The ratio food waste / green waste, based on data presented in Chapter 3, is considered 50%/50%. Another refinement can be done by estimating the food waste and green waste by households and by the assimilated waste producers (businesses, institutions,…). The ratio household/assimilated waste producers for food waste is considered 50%/50% while the ratio for green waste is considered 80%/20%. All these figures are presented in Annex 3 including calculations made for EU-13 + Balkan countries as well as MENA countries.

More than 80% (+/- 160 kg/cap/y) of the applicable portion of the bio-waste stream (200 kg/cap/y, see above) could be composted at a net benefit to society through a combination of home & community composting, on-site institutional composting, green waste composting, off-site commercial composting, and household source-separated bio-waste.
On-site institutional composting and home and community composting (including additional closed loop gardening techniques) programs could potentially target about 50% (100 kg/cap/y) of the applicable bio-waste stream at the greatest net benefit to society. Some of the bio-waste targeted by home and community composting programs could also be captured by green waste composting programs. Off-site commercial composting could

capture another 25% (50 kg/cap/y) of the bio-waste stream at a net benefit. Composting the remaining 20 to 25% (50 kg/cap/y) of the bio-waste stream could be accomplished through more costly mixed waste composting or residential source-separated composting strategies.

Midrange savings of Bio-waste Management Strategies

Table 13 provides an estimate of the savings of individual compost strategies. The table is divided into five columns. Strategy costs (i.e. midrange/median program costs per tonne - Chapter 4) are combined with benefits (i.e. revenues as well as collection and disposal savings) in order to derive a 'net cost' per tonne diverted and are presented in Table 13. The collection and disposal costs saved per tonne presented in Table 13 are calculations based on European averages but can also be calculated per country based on country data presented in Annex 2.

Table 13: Midrange savings per tonne diverted for compost strategies

Strategy	Midrange/ Median program costs per tonne (A)	Collection and disposal costs for MSW per tonne (B)	Average revenues per input tonne (C)	Midrange savings per tonne (D= (B-A)+C)
Home composting	32	175	0	142
Community composting	93	175	0	82
Green waste composting	52	175	10	133
On-site institutional composting	94	175	0	81
Off-site commercial composting	152	175	5	28
Household source-separated bio-waste	152	175	5	28
Mixed waste composting	162	175	2	15

Column A, Midrange/median program costs per ton, presents strategy costs: see Table 12.

Column B, Collection and disposal costs saved per tonne, shows the avoided collection and disposal cost per ton. These figures are based on weighted average costs for EU-15 collection of residual waste (€67/t) and landfilling (€108/t).

Column C, Revenues per input tonne, uses average end-product revenue per tonne from Table 15 as a proxy for revenue received for finished compost products. Even though this technical report highlights composting strategies only it has to be mentioned that revenues may also be generated when selling energy from anaerobic digestion plants. Despite the avoided fertilizer cost and other benefits of home & community composting and on-site institutional composting, no euro value is assigned for end-product revenues for these strategies. Similarly, conservative bulk revenue values are assigned to all other strategies.

Finally, **Column D**, Savings per tonne, shows the savings per tonne diverted for each strategy. Costs were calculated by subtracting the midrange program costs from the collection and disposal costs and adding the revenues (B-(A+C)). Assuming midrange costs for the studied compost strategies, all of the composting strategies would result in a net benefit when the value of avoided collection and disposal and revenues are taken into account. It is worthwhile mentioning that no externalities are considered here. Should externalities be considered, results would be even more satisfactory.

The net savings for home, community and on-site composting strategies are obvious since all the bio-waste is processed on site needing no further collection and or treatment. The net savings registered for off-site commercial composting, green waste collection strategies and household source separated composting strategies might be less obvious since it is often stated that introducing a separate collection and treatment system will increase overall municipal waste management costs. The box hereunder however explains that a well-designed, optimised collection system does not necessarily increase these overall costs.

Overall costs for municipal waste management do not necessarily increase when introducing source separated bio-waste collection strategies[72]

Research carried out by the Scuola Agraria del Parco Di Monza shows that source segregation of food waste with door-to-door schemes can be run with no substantial increase in overall costs, and sometimes costs are even lower than with traditional collection (no segregation of food waste) or with food.

To understand the unexpected outcomes of the survey, it must be underlined that if source separation of food waste is added to that of commingled municipal waste, with no modification in the pre-existing scheme for MSW collection, total costs are likely to rise.

This actually tends to happen with the segregation of food waste by means of road containers. But this does not necessarily happen when food waste collection is introduced in such a way that the overall collection system is optimised. The key point is that intensive door-to-door schemes for food waste – when made "comfortable" for households - yield high captures. This sharply reduces the percentage of food waste in residual waste, which can then be collected less frequently with fewer complaints regarding odours.

This approach might be considered likely to be especially effective in municipalities where households are charged on the basis of frequency of residual waste collection.

A similar study carried out by ENT Environment and Management, Barcelona based on the empirical analysis of 80 municipalities in Catalonia came to the same conclusions.

As a reminder it should be stated that bio-waste management will always be a mixture of different strategies allowing thus for municipalities to choose for optimized solutions at reasonable costs.

[72] *Strategies and practices for the management of bio-waste: in the light of EU waste policy and environmental drivers, Enzo Faviono, Scuola Agraria del Parco di Monza, 2005*

6. Potential markets for diverted bio-waste

Compost markets and product value

Review of benefits associated with compost end-users

The demand for finished compost helps divert an increasing amount of bio-waste from landfills. In addition, the use and application of finished compost result in a multitude of benefits, such as enhancing the physical, chemical, and biological properties of soils, which in turn results in various environmental and economic benefits. The suitable uses of compost depend on source material type and compost class and quality. Application areas like agriculture just require standard quality. Landscaping and, even more so, the growing media sector need an upgraded and more specialized product. Here, further customer requirements have to be met and it is up to the marketing strategy of the compost plant to decide whether to enter into this market segment. Compost producers often face difficulties in marketing because they lack understanding of the potential use sectors such as landscaping and horticulture (e.g. knowledge of plant growing and the related technical language). Advertisement and marketing are not always of a standard comparable with that of competing products.

Overview of compost markets, applications, and constraints

Finished compost can be used in a variety of applications. The potential demand for compost is substantially greater than the compost that would be available if the entire applicable bio-waste stream were composted. The following market segments can be identified including the distribution thereof for selected countries[73].

Table 14: Applications of finished compost for selected countries, in %

<table>
<tr><th></th><th>AT (2003)</th><th>BE (Fl) (2009)</th><th>DE (2005)</th><th>ES (2006)</th><th>HU (2005)</th><th>IT (2003)</th><th>NL (2005)</th><th>UK (2005)</th></tr>
<tr><td>Agriculture</td><td>40</td><td rowspan="2">11</td><td>53.4</td><td>88</td><td>55</td><td>51</td><td>74.8</td><td>30</td></tr>
<tr><td>Horticulture</td><td>10</td><td>3.9</td><td>8</td><td>15</td><td>-</td><td></td><td>13</td></tr>
<tr><td>Landscaping</td><td>15</td><td>38</td><td>15.9</td><td>4</td><td>10</td><td>6</td><td>3.6</td><td>14</td></tr>
<tr><td>Blends</td><td>15</td><td rowspan="3">44</td><td>13.6</td><td>-</td><td>-</td><td>-</td><td>15</td><td>2</td></tr>
<tr><td>Hobby gardening</td><td>15</td><td>11.9</td><td>-</td><td>5</td><td>27</td><td>1.1</td><td>25</td></tr>
<tr><td>Land restoration & landfill cover</td><td>2</td><td>-</td><td>-</td><td>15</td><td>2</td><td>-</td><td>16</td></tr>
</table>

In Europe, more than 50 % of the compost goes to mass markets which require standard quantities. 20 – 30% of the market volumes are used in higher specialized market areas which require an upgrade and mixing of the compost in order to meet specific customer requirements.

[73] *Study report on End-of-Waste criteria for Biodegradable waste subjected to biological treatment – Draft final report, IPTS Seville, Spain, July 2013*

Compost[74] product quality

Compost end-product quality is highly variable depending on the type of bio-waste and the processing method used. Compost-related national regulations as well as compost quality certification schemes usually include minimum product quality requirements for ensuring the usefulness of compost and for achieving the desired levels of health and environment protection.

The EU is in the process of setting the product quality requirements that need to be respected for possible end-of-waste status for compost and digestate[75]. These direct quality criteria on compost/digestate could include the following parameters:

1. Quantitative minimum limits of elements providing a soil improvement/fertilising function, such as organic matter content or nutrient (N, P, K, Mg) content.
2. Quantitative maximum limits on elements potentially toxic to human health or ecotoxic, such as heavy metals or persistent organic pollutants.
3. Quantitative maximum limits on macroscopic foreign materials (e.g. glass, plastics, metals)
4. Limited content of pathogens (if appropriate through quantitative maximum limits)
5. Limited presence of viable weeds (if appropriate through quantitative maximum limits)
6. Minimum stability (if appropriate through quantitative maximum limits)

Further requirements are often included as specifications for certain uses and application areas.

For instance, there are a number of compost standards and specifications for using compost in growing media and potting soil or for use in landscaping. Legal limits on heavy metal concentrations are in place everywhere that compost plays a role today. Limits are usually set at a national level and differ from country to country. In some countries, limits have been set for a number of different compost classes.

Potential market value of compost

The market value of compost is influenced by a variety of factors including the demand for soil organic matter, availability of competing products, compost quality, and the effectiveness of the producer's marketing strategy. The extent of pre- and post-processing (e.g. curing, screening, bagging, and mixing) of compost feed stocks also has a direct effect on the market value of compost.

Compost market value is also affected by the type and quality of the bio-waste (or feed stocks) diverted by a given compost program. Source-separated food waste compost (typically collected in commercial, institutional, and residential source-separation compost programs) will generally have high nutrient values and low contamination. Green waste compost will have somewhat lower nutrient values as well as low contamination. Mixed

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[74] ***Compost****: compost is the solid particulate material which has been sanitised and stabilised by a biological treatment process of which the last step is an aerobic composting step. Composting is a process of controlled decomposition of biodegradable materials under managed conditions, which are predominantly aerobic and which allow the development of temperatures suitable for thermophilic bacteria as a result of biologically produced heat.*

[75] *End-of-waste documents from the JRC-IPTS are available from http://susproc.jrc.ec.europa.eu/activities/waste/. See in particular the operational procedure guidelines of Figure 5 in the "End-of-Waste Criteria" report.*

waste compost will usually have moderate nutrient values with higher levels of contamination. Table 15 shows reported revenues received from bulk sales of compost end-products. The table organizes revenue information by type of compost program subject to available data. The price of bulk compost for use as an organic fertiliser or soil improver is much lower than the 'production costs', i.e. the costs of treating biological wastes in a composting plant. The prices achieved for compost for agricultural use in Central Europe are rarely higher than €5/t of compost and, in most cases, lower. Often, the compost is actually given away to farmers free of charge. Compost produced by home & community composting is used by the home/flat owners. Similarly, on-site institutional composting facilities often use the compost they produce in their own landscaping operations. While no money is exchanged in these cases, the end-users are likely to realize economic benefits in the form of reduced fertilizer and/or soil amendment costs.

Table 15: Revenues from bulk sales of compost end-products for selected countries in €/t[76]

	Average compost Sales	Green waste compost sale	Mixed waste Compost sale	Highest quality compost sale
Europe	5 (1)			
France		0 to 10 – 12 (2)	0 to 2 – 3 (3)	
Austria				12.5 (4)
Denmark		8 - 9		
Italy	3 - 10			

(1) Often, compost is actually given away to farmers free of charge
(2) €0 in most cases, €10-12 includes the cost for transport and spreading,
(3) €0 in most cases, €2-3 includes the spreading
(4) Used in organic farming

[76] *Study report on End-of-Waste criteria for Biodegradable waste subjected to biological treatment – Draft final report, IPTS Seville, Spain, July 2013*

Conclusions

This technical report reveals several important findings for the future development of composting:

- Approximately 37% (or 200 kg/cap/y) of the EU-15, 42% of the EU-13 + Balkan and 59% of the MENA region Municipal Solid Waste (MSW) stream is available for composting using existing strategies and technologies.
- Bio-waste reduction programs, on-site institutional composting, and home & community composting (including closed loop gardening techniques), require much less public outlay (when compared to other composting alternatives) because we assume homeowners' labour is donated. As a result, operational costs are more than offset by avoided disposal costs. In combination, these strategies could target about 50% of the waste stream available for composting.
- About 80% of the applicable bio-waste stream could be targeted by a combination of home & community composting (including closed loop gardening techniques), green waste composting, on-site institutional composting, and commercial composting programs at a net benefit.
- Green waste composting programs are relatively well established and widespread compost strategies in Europe. These strategies target about 45% (leaves, grass, and prunings) of the applicable bio-waste stream.
- Household source-separated composting programs have been widely and successfully practiced in a few EU countries (Belgium, Austria, Germany, the Netherlands,…) whereby large quantities of bio-waste are treated according to high quality standards. Source-separated composting programs are probably the best option in combination with above described upstream strategies and can easily target up to 50% of the bio-waste stream.
- Mixed waste composting can be an interesting technology, only if it intervenes at the end of pipe and not as a pre-treatment. However, these facilities have experienced substantial setbacks in the past few years. Public opposition and technical difficulties have been troublesome for mixed waste composting facilities.
- The potential market for finished compost is much larger than the potentially available supply. If all applicable materials addressed in this report ((200 kg/cap/y) x (~400 million inhabitants – EU-15) = ~80 million tonnes) were captured for composting, approximately 25 to 30 million tonnes of finished compost would be created to be used for agriculture, horticulture, blending, and landscaping purposes.
- Higher technology does not necessarily yield a more efficient or cost-effective system. In many cases a low-technology method, such as windrow composting, might be more cost-effective in terms of compost sales and reduced tipping fees than a high-technology counterpart such as an in-vessel system. Countries and municipalities should use the level of technology that fits their needs.

While this report reflects European average statistics, the basic assumptions are easily translatable to national and regional level, provided basic data as presented in this report are available. On a basic level, the message of this report is that composting is feasible on almost every scale, and it works. The key is choosing the most appropriate combination of strategies. The more municipal solid waste produced, the more bio-waste is available for composting. The economies of scale dictate that the more material available for composting, the lower the cost per tonne to operate whatever composting strategy is used. By their very nature, however, some composting strategies are more costly to operate than others. The most important part of a successful composting operation is choosing a strategy or combination of strategies that works for a particular situation.

Annex 1: Bio-waste treatment targets & performances

Table A1-1 Implementation mode and households served by selective bio-waste collection system[77]

Country	Implementation mode	Ratio of households served in 2010/2011
Ireland	Voluntary	-
Belgium (Flanders)	Voluntary	67%
Austria	Compulsory if no household management	70 – 80%
France	Voluntary	9% (of which 6% green waste)
Italy	Voluntary	41% (31% of Italian municipalities)
Spain	Voluntary	5 – 10%
Spain (Catalonia)	Compulsory	74% of the municipalities
Germany	2012 Voluntary Compulsory as from 2015	55 – 60%
England	Voluntary	53% (including green waste)
Canada	Voluntary	9%
US	Voluntary	Very little
Australia	Voluntary	41% (green waste)

Table A1-2 Targets and bio-waste treatment performances for selected countries[78]

Country	Bio-waste treatment targets	2010/2011 bio-waste treatment performances
Ireland	45% in 2020 50% in 2020	37%
Belgium	75% (2015)	70%
Austria	N/A	55%
France	45% (2015)	37%
Italy	65% separate collection (2012)	35.3%
Spain	40 to 60% of bio-waste	33%
Spain (Catalonia)	55%	41%
Germany	70% (2020)	56%
England	45% (2015) 50% (2020)	41%
Switzerland	N/A	51%
US	Variable (states)	34%
Australia	Variable (states)	40%

[77] *Etat de l'art de la collecte séparée et de la gestion de proximité des bio-déchets, partie 1 : analyse comparative, Juin 2013*
[78] *Etat de l'art de la collecte séparée et de la gestion de proximité des bio-déchets, partie 1 : analyse comparative, Juin 2013*

Annex 2: Collection and treatment costs

Residual collection and landfilling

Table A2-1: Average landfill gate fees, landfill taxes, total landfilling costs and residual waste collection costs for selected countries (source: EEA, Eurostat, MEDSTAT, 2007-2010)[79]

Country	Landfill gate fee[80] in €/t (1)	Landfill tax[81] in €/t (2) excl. VAT	Landfill charges (1+2) in €/t	Collection costs Residual waste (€/t)	TOTAL Landfilling + collection (€/t)
Austria	70	87*	157	70	**227**
Belgium (Wallonia)	40	65	105		
Bulgaria		7-15			
Czech republic	16	20	36		
Denmark	44	63	107	126	**233**
Estonia	40	12	52		
Finland	59	50	109		
France	60	9-30	80	60	**140**
Germany		-	140	67	**207**
Greece		-	23	30	**53**
Ireland	70	75	145	65	**210**
Italy	90	7-30	102	75	**177**
Latvia	16	22	38		
Netherlands	25	107	132	100	**232**
Poland	70	27	97	45*	**142**
Portugal	11	4	15		
Slovenia	105	19*	124		
Spain (Catalonia)	41.7	12.4	54.1	50	**118**
Sweden	106	47	153		
United Kingdom	27	80 (2012) 100 (2014)	91	42	**133**
United States	36	-	36		
Australia	110	4 of the 6 states	110		
Canada		16	40-60		
Morocco			6.25	40	**46.25**
Tunisia			8	21.5	**29.5**
Jordan			3	25.4	**28.7**
Palestine			5	31	**36**

(*) Taxes for bio-waste only

(**) Estimate

[79] *Etat de l'art de la collecte séparée et de la gestion de proximité des bio déchets, Partie 1: analyse comparative, ADEME, 2013*

[80] *Gate fees: charges set by the operators of the landfills for the provision of the service (i.e. waste disposal) and which are designed to cover their costs and profit. This type of fee is subject to variation according to the landfill site used, and to other factors such as available landfill capacity and market variations. Gate fees do not always cover an operators' cost due to the market situation at a given time. In this report, the term 'gate fees' refers to the costs before the application of landfill taxes.*

[81] *Taxes: a levy charged by public authorities (in most cases at national level, although is some cases (e.g. Italy, Spain) regional) for the disposal of waste in a landfill site, usually with an environmental purpose in mind, and where the revenue is accruing to the body responsible for the levy;*

Summary table

Region	Collection costs (€/t) (1)	Landfilling costs (€/t) (2)	Total costs (€/t) (1+2)
EU-28 cost variations	30 - 126	23 - 157	53 - 233
EU-28 median	*67*	*108*	*175*
Balkan, Turkey and MENA costs variations	21 - 40	3 - 8	24 - 48
Balkan, Turkey and MENA median	*28*	*5.5*	*33.5*

Selective collection and centralized composting

Table A2-2: Comparative costs of selectively collected bio-waste in different Member States[82]

Country	Frequency	Estimated cost (€/t)
Austria	Weekly summer, every two weeks outside summer	€82/t
Belgium (Flanders)	Weekly summer, every two weeks outside summer Green waste	€111/t (average) €38/t
Finland	Weekly summer, every two weeks outside summer	€63/t
France	Urban, twice weekly (split-bodied)	€36-45/t
Germany	Weekly summer, every two weeks outside summer	€100/t (average)
Italy	Weekly summer, every two weeks outside summer	€54-302/t*
Spain (Cat)	3-4x/week DtD and 3-7x/week for road containers	€100/t

Table A2-3: Comparative costs of composting strategies in selected countries[83] [84]

Country	Process	Cost
Austria	High specification plant for bio-waste On farm composting Green waste (1) Green waste confined treatment (1)	€94/t at 20 000 t/y €45-58/t at 5 000 – 20 000 t/y €15-55/t €45-65/t
Belgium	Green waste composting VFG waste composting Windrow composting (1)	€25-37/t €62-74/t €35/t
Denmark	Garden waste Kitchen waste	€0-30/t €73-77/t at 10 000 t/y
Finland	Drum reactor for bio-waste Drum and tunnel reactor for bio-waste	€47/t at 6 000 t/y €189/t at 1 300 t/y €68-76/t at 7 000 t/y

[82] *Costs for Municipal Waste Management in the EU, Eunomia research & consulting Ltd,*
[83] *Costs for Municipal Waste Management in the EU, Eunomia research & consulting Ltd*
[84] *Etat de l'art de la collecte séparée et de la gestion de proximité des biodéchets – Partie 1 : analyse comparative, Juin 2013*

	Tunnel reactor	€37-54/t at 20 000 t/y
France	Green waste (open air windrow) Kitchen waste (open air windrow) Kitchen waste (open air, forced aeration, no odour treatment) Kitchen waste (enclosed, forced aeration) with bio filter Green waste (1) Confined composting (1)	€50-85/t at 6 000 t/y €34-57/t at 12 000 t/y €63-95/t at 6 000 t/y € €41-68/t at 12 000 t/y €50-91/t at 22 000 t/y €15-40/t €50-90/t
Germany	Kitchen and garden waste, enclosed with odour treatment etc.	€62/t at 40 000 t/y €56/t at 60 000 t/y
Ireland	Food and Green waste composting Green waste Green waste	€16/t at 6 000 t/y €25/t at 5 000 t/y €23/t at 10 000 t/y
Italy	Kitchen and garden waste Green waste Green waste (1) Food waste (1)	€53/t at 20 000 t/y €34/t at 20 000 t/y €20-40/t €70-90/t
Netherlands	Open-air compost (green waste) Enclosed bio-waste compost Enclosed bio-waste compost Buhler systems GICOM systems VAR system VAM system	€30/t €80/t at 10 000 t/y €30-60/t at 50 000 t/y €50-59/t €34-55/t €38-45/t €38-41/t
Spain		€18-30/t
Sweden		€73/t at 3 000 t/y €30-45/t at 20 000 t/y
United Kingdom	Garden waste, open air windrow In-vessel batch tunnel (bio-waste) In vessel batch container (bio-waste) In vessel VCU (bio-waste) Green waste (1) Confined composting	€22/t at 18 000 t/y €40/t at 20 000 t/y €47/t at 18 000 t/y €31/t at 20 000 t/y €7.5-63.5/t €36-102/t
Australia	Green waste Bio-waste + Green waste	€40/t €65/t

(1) Based on the report 'Etat de l'art de la collecte séparée et de la gestion de proximité des bio-déchets, Partie 1: analyse comparative, AWIPLAN, Juin 2013

Summary table

Region	Collection costs (€/tonne) (1)	Composting costs (€/tonne) (2)	Total costs (€/tonne) (1+2)
EU-28 cost variations, bio-waste	40 - 178	39 - 94	79 - 272
EU-28 median costs, bio-waste	*82*	*70*	*125*
EU-28 cost variations, green waste	38-40	22 – 67.5	60 – 117.5
EU-28 median costs, green waste	*39*	*31*	*70*

Annex 3: Bio-waste potential

Table A3-1: Total bio-waste generation, bio-waste generation in kg/cap/y and bio-waste as a % of MSW for the 3 main regions targeted in this report (source: EEA, Eurostat, MEDSTAT, 2007-2010)

	EU-15	EU-13 + Balkan	MENA
Population	397 000 000	110 000 000	190 000 000
Waste generation in tonnes	214 380 000	36 300 000	53 770 000
Waste generation in kg/cap/y	540	330	283
Total bio-waste generated in tonnes	79 400 000	15 246 000	31 730 000
Bio-waste generation in kg/cap/y	200	138.6	167
Bio-waste generation as % of MSW	37%	42%	59%

Table A3-2: Potential bio-waste generation, assumptions for ratio food waste / green waste, and calculated food waste and green waste for selected geographical regions expressed in tonnes and kg/cap/y (source: EEA, Eurostat, MEDSTAT, 2007-2010)

	EU-15		EU-13 + Balkan		MENA	
	tonnes	kg/cap/y	tonnes	kg/cap/y	tonnes	kg/cap/y
Bio-waste	79 400 000	200	15 246 000	138	31 730 000	167
Ratio food/ green waste	50%/50%		40%/60%		80%/20%	
Food waste	39 700 000	100	6 098 400	55.2	25 384 000	134
Green waste	39 700 000	100	9 147 600	82.8	6 346 000	33

Table A3-3: Potential food waste generation, assumptions for ratio household/assimilated food waste and calculated household food waste and assimilated food waste for selected geographical regions expressed in tonnes and kg/cap/y (source: EEA, Eurostat, MEDSTAT, 2007-2010)

	EU-15		EU-13 + Balkan		MENA	
	tonnes	kg/cap/y	tonnes	kg/cap/y	tonnes	kg/cap/y
Food waste	39 700 000	100	6 098 400	55.2	25 384 000	134
Ratio Hhld/ Assimilated food waste	50%/50%		50%/50%		50%/50%	
Household food waste	19 850 000	50	3 049 200	27.6	12 692 000	67
Assimilated food waste	19 850 000	50	3 049 200	27.6	12 962 000	67

Table A3-4 : Potential green waste generation, assumptions for ratio household/assimilated green waste and calculated household green waste and assimilated green waste for selected geographical regions expressed in tonnes and kg/cap/y (source: EEA, Eurostat, MEDSTAT, 2007-2010)

	EU-15		EU-13 + Balkan		MENA	
	tonnes	kg/cap/y	tonnes	kg/cap/y	tonnes	kg/cap/y
Green waste	39 700 000	100	9 147 600	82.8	6 346 000	33
Ratio Hhld/ Assimilated Green waste	80%/20%		80%/20%		80%/20%	
Household green waste	31 760 000	80	7 318 080	66.24	5 076 800	26.4
Assimilated green waste	7 940 000	20	1 829 520	16.56	1 269 200	6.6

Annex 4: Tools and lessons from some EU projects

ACR+ has been involved in several European projects in which partners shared their expertise in the field of bio-waste prevention or management, in particular:

- The **European Week for Waste Reduction** (EWWR): a LIFE+ project running from 2009 with the aim of raising awareness on waste reduction, product reuse and materials recycling during a single week. www.ewwr.eu
- **Pre-waste**: an INTERREG IV C project (2010-2013) aiming to provide cities and regions with good practices, guidelines and monitoring tools to develop and follow their waste prevention strategies. www.prewaste.eu
- **Miniwaste**: a LIFE+ project (2010-2012) with the objective of helping local and regional authorities to minimise organic waste thanks to good practices, guidelines and monitoring tools. www.miniwaste.eu
- **Regions for Recycling** (R4R): an INTERREG IV C project (2012-2014) aiming to provide a local and regional contribution to the European Recycling Society. www.regions4recycling.eu

Guidance documents

The Pre-waste methodology highlights 5 key elements that will make local waste prevention strategies a success: assessing the situation, setting priorities and objectives, involving stakeholders, feeding and implementing the plan, monitoring the results. The Miniwaste guide provides detailed information in particular on the various bio-waste prevention strategies and their key factors of success (partnership, targeted communication, and support to participants). Miniwaste also provided protocols on compost quantitative and qualitative assessment.

Good practices

The Pre-waste and Miniwaste projects delivered many examples of good practices on the implementation of home and community composting schemes and of initiatives fighting against food waste (at school, in restaurants or at home). Additionally, the EWWR highlighted many successful communication activities on bio-waste prevention, some of them rewarded at EU level for their originality or efficiency, such as a communication action on composting in the Barcelona Zoo (2012) or some contests in Scottish, Swedish or Italian schools. The R4R project identified good experiences to implement bio-waste collection schemes. ACR+ also developed a database of waste prevention actions (including bio-waste prevention) showing quantitative results (www.acrplus.org).

Decision-making and monitoring tools

The Miniwaste, Pre-waste and R4R projects propose some online or offline tools aiming to help decision makers conduct a territory analysis and collect relevant data, to provide them with advice on strategies relevant to their situation and to help them monitor the implementation of their actions. Each of these tools has its specificities and advantages, depending on the user's needs.