Separate collection of bio-waste by local authorities in the framework of multimunicipal waste management systems – the case study of Aveiro

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Abstract

Separate collection of bio-waste represents in Portugal only 2% of total collected bio-wasted. The majority of Mechanical and Biological (MBT) treatment facilities produce compost from unsorted waste and in case future European legislation restricts input materials this compost would have limited applications. This work studies the viability of implementing bio-waste collection targeting restaurants and canteens in the center of Aveiro city (Portugal). Bio-waste producers were identified and the collection potential was estimated through door-to-door surveys to 36% of these producers. The MBT and a private composting company were the destinations considered, and possible constrains and limitations of each option are discussed. Collection routes were defined using specific software and costs were calculated (comprising vehicle, fuel, containers, labor, gate fees and landfilling taxes) and compared with the baseline. This works show that a source-separated collection of bio-waste targeting canteens and restaurants in the city center can be implemented by local authorities without additional costs, the major constrain being the destination of these wastes. Even though composting bio-wastes is feasible when targeting specific groups and small volumes, for larger cities, such as Aveiro, other larger-scale solutions

must be found involving inter- and multi-municipal systems (IMS), and therefore a better articulation between local authorities and these IMS must be pursued.

Key words

Bio-waste, municipal solid waste, MSW, Waste Management, Portugal, compost quality.

1. Introduction

In European Union up to 138 Mt of bio-waste are produced each year (JRC, 2013). Bio-waste includes biodegradable garden and park waste, food and kitchen waste (from households, restaurants, caterers and retail premises) and comparable waste from food processing plants (EC, 2008). Aiming at limiting greenhouse gas emissions, proper management of bio-waste is necessary. The European Directive on the landfill of wastes (1999/31/EC) establishes that in 2016 landfilled biodegradable waste should not exceed 35% of the amount of biodegradable waste produced in 1995. This deadline can be postponed until 2020 for countries that strongly depended on landfilling in 1995. European countries have used different approaches to divert biodegradable wastes from landfills and achieve the goals set in the Landfill Directive. For instance in Austria there is a legal obligation to separately collect biodegradable waste, while in Denmark all municipal waste that can be incinerated must be sent to incineration (JRC, 2013). Currently in Portugal, 59% of biodegradable MSW is still being landfilled (APA, 2013). The remaining is incinerated (20%), organic valorized (15%) and recycled (paper, 6%). Back in 1980's each one of the 279 municipalities in Portugal had their own landfill/dump place, where more than 90% of all municipal waste was placed, and there is historically a close proximity between waste production and disposal/treatment. Nowadays, there are 23 large, inter- and multi-municipal systems (IMS), of regional influence. The scale-economy and a strong investment allowed building Mechanical and Biological Treatment facilities (MBT) and an array of other waste-related infrastructures (e.g. landfills and transfer

stations) to handle waste at regional level. In this new framework municipalities remained in charge of collecting unsorted wastes, and to forward these to the large IMS for further treatment and disposal, while separate collection schemes are the responsibility of IMS.

The great majority of IMS in Portugal have not opted for bio-waste collection schemes, and this waste is currently recovered at MBT from unsorted municipal solid waste. Recovered bio-waste is then either anaerobically digested or composted, or both. While this option is in line with the Landfill Directive, source-sorting of bio-waste is most suitable for obtaining a high quality organic fraction, with minimum levels of contaminants (such as heavy metals and organic compounds), and macroscopic impurities, and consequently a high quality compost. One of the policy measures currently under discussion in the EU is the implementation of compost quality standards, either in the form of criteria for compost or restrictions on the input materials. In the later there is a strong possibility that only source-separated bio-waste could be used to produce compost (Arcadis, 2010; JRC, 2013). Since in Portugal only 2% of bio-waste is source-separated, any future European legislation on compost restricting input materials would mean that compost produced at MBT would have only very limited applications.

In this work the economic framework for the implementation of source-separated bio-waste collection in Aveiro (Portugal) is presented, envisioning the participation of medium and large producers of food and kitchen waste. The aims are to provide an insight on the feasibility of implementing food and kitchen waste collection and discuss constrains and solutions that can be adopted by municipalities throughout Portugal.

2. Materials and methods

This section describes the municipal waste collection and treatment currently implemented at Aveiro city and the methodologies used to assess the scenario of separate bio-waste collection from restaurants and canteens.

2.1 Case study

The study area (Figure 1) comprises the center of Aveiro City (Portugal), characterized in table 1. The district (UF Glória e Vera Cruz) represents 22,9% of the area and 23,9% of the population of the municipality.

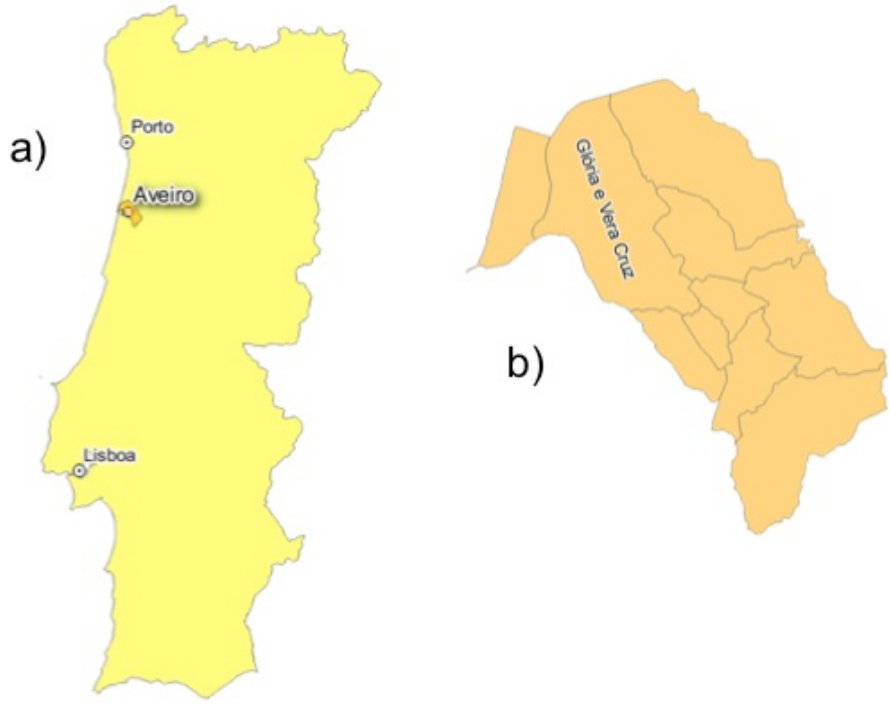

Figure 1: Study-area: (a) Portugal; (b) District of UF Glória e Vera Cruz, Municipality of Aveiro (adapted from DGT, 2013).

Unsorted MSW collection is under the responsibility of local authorities (Aveiro City Council) and collected waste is delivered at ERSUC, S.A. This company has the concession, in exclusivity until 2030, to valorize and dispose unsorted MSW from the multi-municipal system "Litoral Centro", comprising 36 municipalities and approximately one million inhabitants (ERSUC, 2014). ERSUC, S.A. is a partnership between the municipalities (42,5% of the capital) and EGF - Empresa Geral do Fomento (51,5%), a public company currently on the verge of privatization, with the remaining 6% hold by two private companies (ERSUC, 2014). Under the contract signed with the Portuguese State, ERSUC, S.A. is also responsible for the separate collection of MSW, and the currently implemented streams comprise packaging waste (paper and cardboard, plastic and metal).

The Integrated Center for Treatment and Recovery of MSW of Aveiro, managed by ERSUC, comprises a Mechanical and Biological Treatment Facility (MBT) for the treatment of unsorted municipal solid waste; an Automated Screening Station for treatment of recyclable waste from separate collection; a Unit for the preparation of Refuse Derived Fuel (RDF) for the fraction with calorific value recovered at the MBT; a Unit for Energy Recovery from the biogas produced at the MBT; and a refuse landfill.
The organic fraction currently separated at the MBT is first treated by anaerobic digestion, and then composted to produce "FERTISUC", an agricultural organic amendment with 51% organic matter.

2.2 Identification of bio-waste producers

This work targets service and commerce producers of kitchen waste that are currently collected by the municipality together with household waste. This excludes residential households, but includes local restaurants, hotel restaurants, public schools and university, nurseries and kinder gardens, rest homes (including day care, house support), military barrack and prison. Snack-bars and coffee shops were excluded due to the small volume of bio-waste produced. Large companies having their own

arrangements for waste management are also excluded, such as large chain supermarkets and food chains, central hospitals, and catering corporations. A comprehensive list of such producers was put up based on:

- Public schools in the study area were selected from the Municipal Registry;
- Restaurants and coffees in the city center (district of UF Glória e Vera Cruz) were selected from a list supplied by Aveiro Trade Association;
- Public and private kinder gardens, nurseries and rest homes were identified from Social Charter online (GEP, 2014);
- Other specific producers were identified through field knowledge and previous contracts with City Council related to waste services.

Table 1 – Characterization of the study area and management of unsorted MSW in 2013. Adapted from SMA (2014) and ERSUC (2014). (a) Data based on the whole municipality

District / Municipality / Country	UF Gloria e Vera Cruz /Aveiro / Portugal
GPS coordinates (center of district) (*Datum* WGS 84)	40,640384,-8,653632
Population (inhabitants)	18.756
Area (km^2)	45,32
Production of MSW	
Unsorted MSW ($t.year^{-1}$)	9.807,98
Unsorted MSW ($kg.person^{-1}. year^{-1}$)	523
Collection of unsorted MSW	
Containers with 800 liters volume	493
Collection vehicles	2
Collection frequency	Daily (except Sundays and holidays)
Treatment/elimination at MBT Facilities of ERSUC in Aveiro and Coimbra	
Total of MSW received at MBT Facilities (t)	348.745
Recovered from unsorted waste to be sent to material recycling and valorization (t)	17.274
RDF (refuse derived fuel) potential (t)	100.624
Refuse to Landfill (t) (% of total received)	159.330 (45,7%)

2.3 Waste Collection potential

Door-to-door surveys were carried out in April 2014 amongst a selected set of producers in order to assess (a) the daily amount of bio-waste per producer (b) the bio-waste per meal, (c) management options, (d) the willingness of producers to participate in a bio-waste collection scheme, and (e) the preferred collection frequency and time of day. The enquiry consisted in 11 fast-reply questions, aiming at an interview time of 15-20 minutes. The amount of waste was estimated based on the number and volume of available waste containers at the producer, combined with how often these are emptied.

2.4 Collection routes

The collection routes were based on the number and location of producers willing to participate in source-separation of food and kitchen waste, obtained through the inquiries. The routes were planned using a specific on-line application for multiple addresses (Myrouteonline, 2014) and considering the following parameters: service time of 5 minutes; route optimization to minimize distance; no limitation imposed on time nor on maximum number of stops per route. The starting point for the collection route is the City Council garage, located approximately 6 km from the city center. Two scenarios were considered for the collected bio-wastes. In scenario 1 the bio-waste is delivered at ERSUC, S.A. for treatment whilst in scenario 2 a private licensed waste operator receives and composts the source-separated bio-waste.

3. Results and discussion

3.1 Bio-waste production

A total of 132 producers were inventoried in the study area (Table 2) and 48 inquiries were carried out, corresponding to 36% of the producers identified.

Total bio-waste generated by the producers inquired adds up to 13,73 m^3 d^{-1}. The individual amount for each producer is represented in Figure 2-a. The largest producers are, by far, the University canteens, with 9,60 m^3 d^{-1} (almost 70% of the total bio-waste). Since the 3 canteens belong to the same entity only the

total is shown. The remaining units produce between 5 and 260 L d^{-1} and can be divided in small-scale producers (<30 L d^{-1}), medium sized (between 30 and 100 L d^{-1}) and large producers (>100 L d^{-1}).

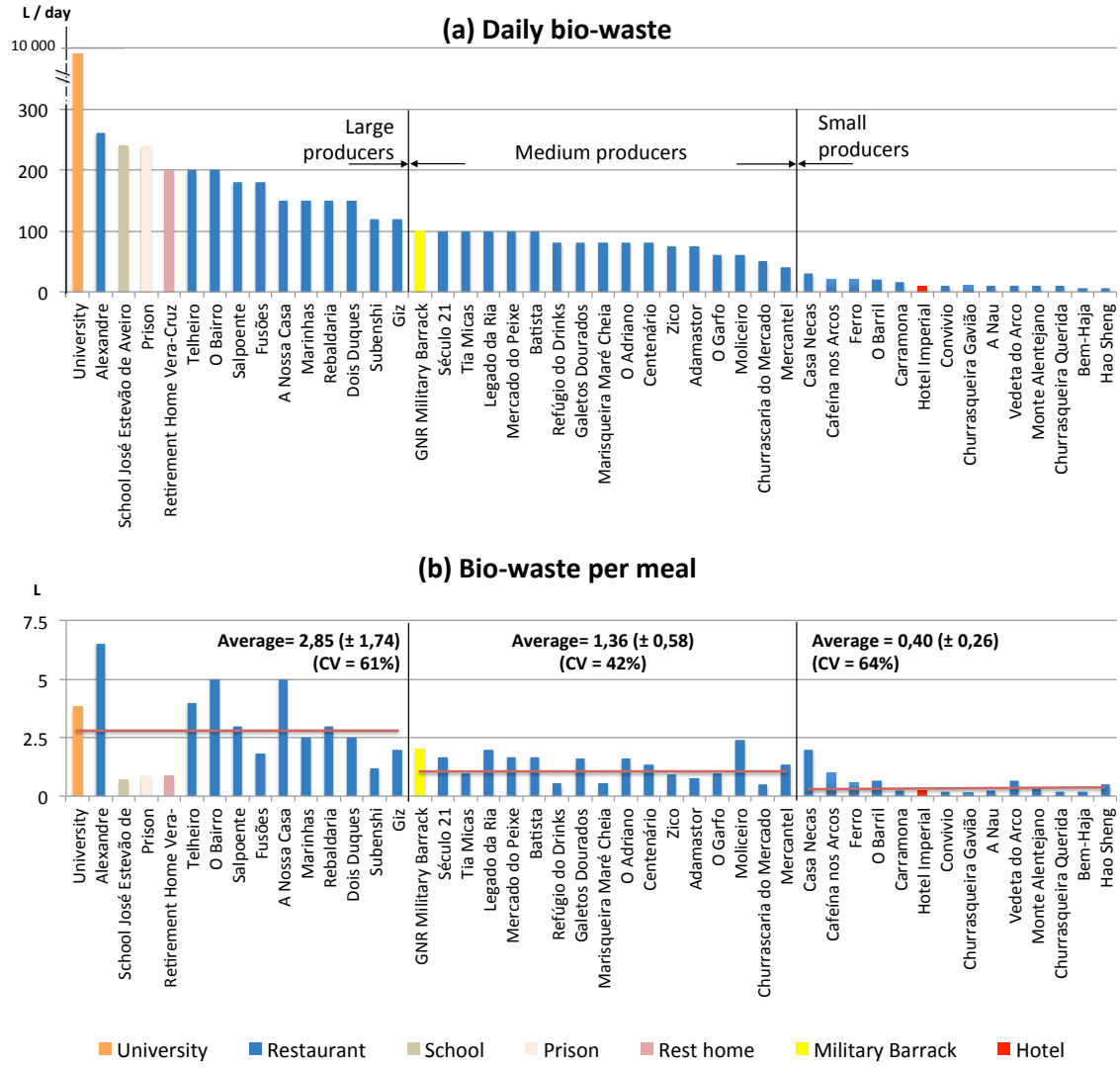

Figure 2: Bio-waste generation in the study area (inquired producers) (a) Daily production and (b) Amount of bio-waste per meal served for individual producers and average in each group (CV - coefficient of variation).

Table 2 – Kitchen- and food waste producers in the study area

Type of Producer	Units	Notes
Schools	7	4 primary schools (6-9 years-old); 1 preparatory school (10-11 years old); 2 high-schools (12-17 years old); (Each having its own canteen and kitchen)
Kindergarden/nursery	8	Children and babies (less than 6 years-old)
Rest homes	5	Rest homes (full pension), day care (lunch) and home assistance (lunch and dinner).
Local restaurants	105	Snack-bars and coffee-shops not included
Military barrack	1	Canteen serving meals to 50 military guards
Prison ward	1	Approximately 270 meals per day
University	3	Canteens serving approx. 2500 meals per day
Hotel	2	Only hotels with restaurant were considered
TOTAL	132	

Bio-waste produced per meal (shown in Figure 2-b) is widely variable, ranging from 0,17 to 6,5 $L.meal^{-1}$. The difference of almost 2 orders of magnitude between the smallest and the largest values is too big, considering that the activity is similar (food preparation), and is probably due to the difficulty in estimating very high or very low volumes of bio-waste with this methodology. This is supported by the higher coefficients of variation (CV) found for both large and small-scale producers (61% and 64%, respectively), compared to medium scale producers (CV = 42%).

The average amount of waste generated per meal in the 3 groups of producers indicate that, contrary to what was expected, there was no scale-economy, and small producers seem to be able to better manage the amount of leftovers and to reduce the generation of bio-waste.

3.2. Final destination

Two different options were considered for the collected bio-wastes. In the first case the bio-waste is delivered at ERSUC, S.A. for treatment. This entity currently produces compost (named “FERTISUC”) from unsorted waste, and therefore questions related to possible contamination and safety can arise. Nevertheless, due to its high organic matter content (51%) it is classified as “fertilizer” and is currently used as organic amendment in agriculture.

In case source-separation of bio-waste is implemented, this waste should be handled separately from unsorted waste at the TMB, so that high quality compost with market value could be produced. This would allow for nitrogen and phosphorus recycling into the productive cycle, with additional safety guarantees regarding contaminants. However it would require the adaptation of the facility, probably with significant investments costs, and would additionally mean less income to the facility, since the amount of unsorted waste would decrease. Even though ERSUC detains the exclusivity to carry out source-separation collection of materials this is only valid from the date this entity can maximize the valorization potential of MSW according to the best practice of waste management (as stated in the contract between ERSUC and the Portuguese State. At this moment ERSUC, S.A. does not have this capacity and no intentions to implement source-separated bio-waste collection are set forward in the "future perspectives" chapter of their annual report (ERSUC, 2014). This opens the legal possibility for local authorities to implement source-separated collection of bio-waste.

So a second scenario was envisaged, in which source-collected bio-waste is sent to a private licensed waste operator to produce compost. Compliance with the specific provisions of EC Regulation Nr 1069/2009 (EC, 2009) with regard to hygienisation, transport and use of compost containing animal by-products is required. It is also advisable that the waste operator is located within 50 km from the producers to prevent high transportation costs and to reduce transport-related environmental impacts. Based on the requirements defined above one private company was identified (in case of future implementation a thorough benchmarking is required, as other companies may also comply with requirements). This company receives mainly forestry waste for composting, which can be mixed with food and kitchen waste to adjust relevant operational composting parameters. For instance forestry waste could help increasing C:N ratio and porosity, and reduce water content. In addition, this private company

is also licensed to handle animal by-products, allowing to guarantee the specific provisions of Regulation (EC) No 1069/2009.

3.3 Collection circuit

According to the inquiry results, 67% of the producers are willing to join a separate collection scheme for bio-waste. Producers not willing to join such a circuit are all private restaurants, and the reasons presented are not having enough space for bio-waste containers or that bio-waste is taken home by employees at the end of the day (Figure 3-a) to be fed to farm animals. According to Regulation (EC) No 1069/2009 (EC, 2009), bio-waste containing animal-derived waste (such as is the case of food and kitchen waste) should not be used in feed for farmed animals. However, this is a deep-rooted practice in Portugal, and even though the study area is markedly urban, some districts in the municipality of Aveiro have a strong rural character.

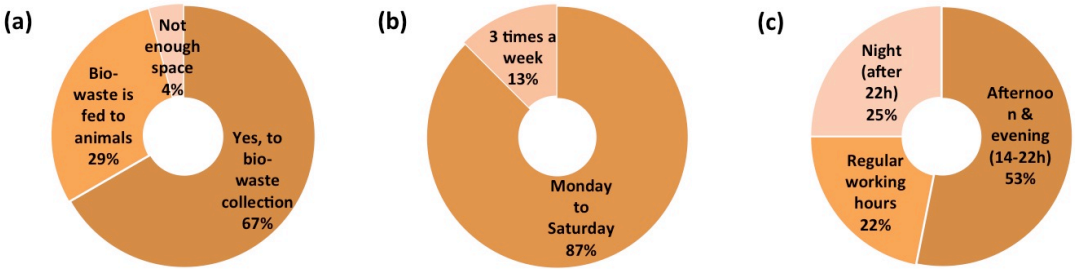

Figure 3: Bio-waste producers' answers to the enquiry: (a) interest in participating in source-separated bio-waste collection; (b) preference of frequency of collection; and (c) preference of collection period.

The circuits were established considering producers willing to join the circuit, and include 34 points (32 collection points at the producer; 1 starting location; 1 destination location). It is considered that after disposal the vehicle returns to the City Council garage. The collection vehicle is compact, leak-proof,

with 5-cubic meter capacity, with a tipping body and a rear mounted bin lift, suitable to drive in narrow streets. Due to the smaller size, two intermediate journeys will be required to the disposal site during the collection circuit, and extra kilometers and time were added to circuits 1 and 2, accordingly. The routes obtained for scenarios 1 and 2 are summarized in table 3 and the map with the collections points and start location is shown in figure 4.

Table 3: Description of baseline and alternative scenarios for bio-waste collection in the study area regarding route distance and time and cost.

Scenario	**Baseline** (bio-waste is not source separated)	**1** (bio-waste to MTB, ERSUC)	**2** (bio-waste to composting company)	**3** (equal to Scenario 2, but collection and transport carried out by a private company)
Route distance	**-**	**117,8 km** **23%** Between collection points **76%** to and from garage/disposal site	**169,8 km** **16%** Between collection points **84%** to and from garage/disposal site	**108,57 km**
Route duration	**-**	**6:06** **73%** Between collection points (including service time) **27%** to and from garage/ disposal site	**6:38** **66%** Between collection points (including service time) **34%** to and from garage/disposal site	**5:45**
Cost	**80,77 (€ ton^{-1})** **62%** Collection and transport (inclusive containers) **38%** Treatment and disposal	**99,92 (€ ton^{-1})** **70%** Collection and transport (44% Labor; 18% Vehicle; 6% Fuel; 2% Containers) **30%** Treatment and disposal	**96,54 (€ ton^{-1})** **78%** Collection and transport (49% Labor; 19% Vehicle; 8% Fuel; 2% Containers) **22%** Treatment and disposal	**53 (€ ton^{-1})** **60%** Collection and transport (inclusive containers) **40%** Treatment and disposal

The routes are similar regarding the number and order of stops. The main difference is the distance to disposal point, which in route 1 is 16 km, whilst increasing to 21 km in route 2. This rises the route time and distance by approximately half an hour and 52 km, respectively.

Figure 4: Route for bio-waste collection in the study area, considering the City Council garage as the starting point (point 1) and 32 collection points (points 2-33) (final destination is not included in the visualization) (adapted from Myrouteonline, 2014).

3.4 Costs

This section shows the costs associated with bio-waste collection, transport, treatment and disposal for the baseline (bio-wastes are part of unsorted waste) and for three alternative scenarios, in which bio-waste from selected producers in the study area is separately collected.

3.4.1 Baseline

The City Council is currently paying a private company 39,28 € t^{-1} to collect unsorted waste and 8,00 € t^{1} for container rental, totaling (in 2013) 50,12 € t^{-1} (47,28+6%VAT). Unsorted waste is delivered at the MTB (ERSUC, S.A.) and the gate fee is 27,00 €.t^{-1} plus a landfilling tax of 4,29 €.t^{-1} (over an average of

52,42 % of total amount of waste received). In 2013 Aveiro City Council paid 28,92 €.t^{-1} + 6%VAT for treatment of unsorted MSW on MBT. This adds up to **80,77 € t^{-1}** (inclusive 6% VAT), which represents the total cost for the City Council with MSW management.

3.4.2 Alternative scenarios

When implementing the source-separation of bio-wastes it is necessary to consider costs with the collection vehicle (including insurance and maintenance), labor, fuel, containers and treatment/disposal fees. Each parameter is detailed next.

Vehicle: Collection and transport to final destination is carried out using a specialized vehicle (described in section 3.3). To avoid huge investment costs (not compatible with current constrains on municipal funding) this vehicle is rented and monthly rent and maintenance fee is 1500 € m^{-1} and insurance is 170 € $year^{-1}$.

Labor: the annual cost for one person comprises the base salary (750€) multiplied by 14 months/year, as well as all taxes, insurances and contributions paid by the institution. Collection is carried out daily (Monday to Saturday, except holidays), from 14h to 22h, in line with producers' preferences (figures 3-b and 3-c). A supplement of 20% for working shifts is therefore included. The cost per person amounts to 16303,64 € $year^{-1}$, or 1358,64 € $month^{-1}$. Considering 2 teams of 2 workers (one driver and one professional garbage remover), replacement during vacations and the percentage of time dedicated to the collection route, the total cost with labor is **4489 € m^{-1}** for route 1 and **4882 € m^{-1}** for route 2.

Fuel cost was computed by considering an average fuel consumption of 15L/100km, the current fuel price (1,2938 € L^{-1}) and the total number of kilometers driven in a certain time interval, amounting to a total cost with fuel of 588 € m^{-1} for route 1, and 823 € m^{-1} for route 2.

Containers: according to the volume of daily bio-waste produced (see figure 2-a), 18 containers of 120 L (47,74 € $unit^{-1}$), 12 containers of 240 L (59,85 € $unit^{-1}$) and 12 containers of 800 L (463 € $unit^{-1}$) are required. To account for losses and maintenance, 15% extra is added to the base price, as well as 23%VAT, and the total amount was divided by 60 months (assuming 5-year life-time for containers), totaling 168,17 € m^{-1}.

Treatment & Disposal: the gate fee for the MTB (ERSUC, S.A.) is 29,25 €.t^{-1} (expected value for 2014), the same as for unsorted MSW (see section 3.4.1), whereas the price charged by the private composting company for receiving this bio-waste is 20,00 €.$^{t-1}$. To both values 6% VAT was added, amounting to **30,01 € t^{-1}** for scenario 1 and **21,20 € t^{-1}** for scenario 2.

A market consultation was carried out in which private companies were provided with the collection points and the expected bio-waste volume, and asked for a quotation for the service (collection and transport, including containers). The price obtained ranged between 30 and 100 € ton^{-1}. An additional option (scenario 3) was therefore also included, in which the private company with the lowest price carries out the collection and transport. In this option the start and end points are the address of the company. The smaller distance and time required in scenario 3 when compared to scenarios 1 and 2 is explained by the larger volume of bio-waste transported by the vehicle, and therefore no intermediate journeys to the disposal site are required.

3.4.3 Total costs

Total cost for the baseline and the 3 alternative scenarios are shown in Table 3, as well as the cost distribution. Comparing scenarios 1 and 2, where collection is carried out by the City Council, labor costs are the most significant item, whereas containers represent the lowest value (2% of total). Even though the distance and route duration in scenario 2 are higher, the total cost of one ton of collected bio-waste is approximately 5€ lower than in scenario 1, mainly because of lower treatment/disposal costs of the composting unit, when compared to MTB. However, it is option 3 that turns out to be the most economically advantageous of all the alternatives, probably because the specialized waste collection company can make full use of already existing equipment and optimize resources. This option has also a lower cost per ton of bio-waste than the baseline, meaning that implementing a separate bio-waste collection for the city center of Aveiro (study area) would not represent any added cost for the City Council, being in fact cheaper than the current waste management solution.

4. Conclusion

This works show that source-separated collection of bio-waste targeting canteens and restaurants in the center of Aveiro city can be implemented by local authorities without additional costs. The major constrain is to where this bio-waste can be directed to.

ERSUC, S.A. is the most obvious entity to receive source-separated bio-waste, as it has gained the concession (in exclusivity) to collect and valorize both source separated, as well as unsorted waste, in the study area. This entity already has the equipment, facilities and field experience which would bring an added value to bio-waste valorization. However, it has not so far put forward any plans to implement the valorization of source-separated bio-waste, and its facilities are not prepared to handle and valorize this waste separately from unsorted waste. Adaptation of facilities would mean additional costs and probably this will not happen unless there are external incentives or some regulation. EGF, the state company

holding more than 51% of the ERSUC's shares is currently being privatized, so there are a lot of uncertainties about what will happen in general.

As an alternative, bio-waste can end up in a private composting company (scenario 3). Economic advantages are clear compared to either the baseline or to scenario 1, as gate fee is reduced from 27 at the TMB to 20 € ton^{-1} and the additional landfilling tax is also avoided. These savings largely exceed the extra cost with the collection and the longer distances to the disposal site, and the total price per ton of bio-waste is 27,77 € lower in scenario 3 than the baseline. The compost produced would also be of higher quality than, since source-separation reduces the level of contaminants, and therefore recycling of valuable nitrogen and phosphorus would be possible. The only visible drawback is that it would no longer be possible to valorize the waste energetically (production of biogas).

The study area comprises only one district, and approximately 1/3 of food and kitchen waste producers were inquired. Even so, it was found economically possible to implement the source-separate collection of bio-waste, and to find alternatives that can be implemented, despite legal constrains. For small cities, composting food and kitchen wastes with garden and park organic waste can probably be a good alternative, especially if other producers also join in, such as wholesale markets or vegetable markets.

However, for larger cities, such as Aveiro, due to the larger amounts and concentration of organic waste other larger-scale solutions must be found, necessarily involving inter- and multi-municipal waste management systems. And even though the conversion of existing infrastructures to comprise an extra waste stream for bio-waste is not viable for such systems in the short term and without huge costs, a better articulation between local authorities and these systems must be actively pursued.

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