detritus | Multidisciplinary Journal for Circular Economy and Sustainable Management of Residues

CISA

FOOD WASTE COLLECTION VERSUS FOOD WASTE DISPOSERS: A CASE STUDY OF A PORTUGUESE CITY

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Article Info:
Received:
5 September 2023
Revised:
1 December 2023
Accepted:
13 December 2023
Available online:
31 December 2023

Keywords:
Wastewater treatment plant
Food waste
Disposers
Economic aspects
Environmental aspects

ABSTRACT

The European Union (EU) prioritises sustainable development and aims to achieve climate neutrality by 2050 through investments in green technologies and a legislative climate framework. Waste collection and treatment systems, including biowaste like food waste, protect natural capital and citizens' well-being. Directive 2008/98/EC defines biowaste and sets the stage for exploring alternative solutions. This study focuses on the city of Guarda (Portugal) and analyses the use of disposers for food waste treatment. By comparing storage/collection systems with disposers regarding environmental and economic costs and benefits, the study aims to determine the most effective solution for collecting food waste. The analysis utilises a simulator provided by the Portuguese Fundo Ambiental®. The results show that while operating costs are higher for food waste collection systems, disposers require a more significant initial investment. Nevertheless, the cost-benefit ratio favours disposers, while the net present value analysis suggests that the food waste collection system is more favourable. Additionally, food waste collection systems contribute to higher greenhouse gas (GHG) emissions per tonne of food waste compared to using disposers.

1. INTRODUCTION

Population growth and the development of society, coupled with rapid urbanisation, are projected to result in 68% of the world's population living in urban areas by 2050 (Ritchie & Roser, 2018). As a result, will be a significant escalation in the production of municipal solid waste (MSW). In many cases, the amount of solid waste generated should exceed the management capacity of municipal authorities, potentially causing adverse impacts on the environment, human health, and quality of life. Since land resources around urban centres are limited, finding environmentally safe and socially and politically acceptable sites for landfill construction has become a problem for technical and political decision-makers.

The European Union's (EU) growth strategy advocates investments in green technologies and presents a legislative climate framework that allows society to achieve climate neutrality by 2050. The protection, conservation, and enhancement of the natural capital of the EU and the defence of the health and well-being of the citizens against risks and impacts related to the environment are one of the EU's priorities. The existence of waste collection and treatment systems, including biowaste, particularly food waste, is another example of the search for sustainable development to improve living conditions and preserve the environment (Mehta et al., 2018; Laso et al., 2019). Also, Directive 2008/98/EC of the European Parliament and the Council of November 19th, 2008, defines biowaste as: "biodegradable garden waste, food and kitchen waste from homes, restaurants, catering and retail units and similar waste from food processing plants". Unlike Europe, Central Asia, and North America, which tend to generate more significant amounts of dry waste, most regions produce around 50% or more organic waste on average (Kaza et al., 2018).

Until now, in Portugal, the organic fraction has been collected in an undifferentiated model. However, starting January 1st, 2024, the organic fraction will be collected separately through a door-to-door system, public road collection, or treatment and recovery at the source, such as home or community composting, or a combination of these solutions. In the door-to-door collection system, households are encouraged to separate their organic waste from other types of waste, such as recyclables or non-biodegradable items. Residents use specific bins (typically of brown colour). These receptacles are designed to prevent odours and facilitate easy handling. Waste collection personnel visit residential areas on a scheduled basis and collect organic waste directly from each household. After the collection procedure, the organic waste is processed through composting or anaerobic digestion to ultimately obtain a

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https://doi.org/10.31025/2611-4135/2023.18326

duly stabilised fertiliser that can be incorporated into the soil. When collecting on the public roads system, the objective is the same. However, instead of each house having a container, one or more containers with greater capacity are distributed on public roads and serve a wide range of homes. The concept of home or community composting is a decentralised approach to composting organic waste that takes place in the yards, balconies, or designated spaces. The basic idea is to convert kitchen scraps and garden waste into nutrient-rich compost, which can then be used to enrich soil and promote plant growth. Home or community composting is a sustainable waste management practice that empowers individuals and communities to actively reduce organic waste, promote environmentally friendly habits, and avoid waste collection vehicles. The alternative to minimising waste at the source is using food waste disposers. These devices allow the separation of a significant fraction of food waste from the entire MSW stream by grinding the waste with mechanical means and adding tap water, allowing mixing in the drainage. As a result, recycling at the source can be diverted from the waste collection system by introducing a food waste disposer that directs the flow of food waste to the wastewater collection and treatment system (Iacovidou et al., 2012; Zan et al., 2022).

In this scope, based on the case study of the Portuguese city of Guarda, this paper analyses the possibility of using disposers send solid food waste to wastewater treatment plants (WWTP) but not about the subsequent treatment there. What municipalities do with food waste frequently harms the environment and public health. For example, food waste is sometimes stored inside buildings, piled in bags on sidewalks, collected in trucks and shipped to distant landfills, generating leachate and greenhouse gases (GHG) emissions. This process is not cheap, hygienic, environmentally friendly, or sustainable. Contrariwise, the food waste disposers reduce the incidence of vector attraction by decreasing the amount of MSW garbage collection, promoting a healthier municipal solid waste environment, and reducing truck collection costs and greenhouse emissions. Thus, the comparative study between food solid waste storage/collection and food waste disposers, in a context of environmental and economic costs-benefits, applied to the Portuguese city of Guarda, aims to analyse whether food waste disposers are the best environmental and economic solution to implement, ensuring that the food waste is sent adequately for treatment and recovery for this type of waste. Using the simulator provided by the Fundo Ambiental (Department of the Portuguese Ministry of Environment and Climate Action), two scenarios were conducted to evaluate the most appropriate solution for the city of Guarda (Portugal), considering the analysis period from 2023 to 2030. One scenario considers food waste collection on public roads, door-to-door and recycling at source and another contemplates using food waste disposers.

Therefore, the structure of the research is organised as follows. Section 2 focuses on the food waste disposers' history and features. Section 3 presents the solution for food waste, presenting the technical parameters and the simulation developed. Section 4, centred on results and discussion, sets out the capture rate of the food waste, collected and disposers, and their future potential. Section 5 summarises the main findings and presents the conclusions.

2. FOOD WASTE DISPOSERS

2.1 History

Food waste disposers were first introduced in the United States of America (USA) in the 1930s and have since become prevalent, with over 94% of all cities and nearly half of all American households using them as standard items (Kelemen & Furlong, 2020). After the 2nd World War, with the real estate boom, the effectiveness of disposers was evaluated by municipalities as an alternative to solid waste collection and treatment systems. They conducted thorough evaluations to determine their effectiveness. However, their use faced scepticism in some large cities, such as New York, which banned their use due to concerns about the city's old sewer infrastructure's ability to handle the additional load. It was not until 1995 when the city was forced to address waste disposal concerns after the closure of its main landfill, that it commissioned an extensive pilot project to study the impact of food disposers on sewage. The study yielded positive results, and the city lifted the ban and legalised installing food waste disposers in residential buildings in 1997 (Shure, 2021). Towards the end of the 20th century, disposers became ubiquitous in American kitchens. Today, approximately 50 countries, including England, Ireland, Italy, Spain, Japan, Canada, Mexico, and Australia, sell food waste disposers to homes with limited or no restrictions. France also banned food waste disposers, but it was lifted in 1986 following an in-depth investigation by French authorities (Nilsson et al., 1990). With growing concerns about the environmental impact of depositing food waste in landfills and increasing interest in finding sustainable alternatives, food waste disposers are gaining global acceptance.

Although food waste disposers help divert organic waste from the solid waste stream and reduce associated management costs, their use raises questions about the additional energy required to operate the units, the amount of additional tap water needed for the transfer of particulates in the sewer, the alteration of sewer quality due to the addition of suspended solids (SS) and organic substances, and the additional loads in the sewer network and sewage treatment plants. Several studies have been conducted to investigate these issues. The increasing international acceptance of food waste disposers is a response to the significant concern of diverting organic food waste from landfills and finding beneficial uses, such as land application. Traditional municipal methods of managing food waste, such as storing it inside buildings (even refrigerated), piling it up in bags on sidewalks, collecting it in trucks, and sending it to distant landfills, be harmful to the environment. This process is not cost-effective, hygienic, ecological, or sustainable.

2.2 Features of food waste disposers

Food waste disposers, also known as garbage disposals or waste disposers, serve as kitchen appliances designed to efficiently grind food scraps and other kitchen waste for easy disposal with water. Typically installed beneath the kitchen sink, these devices connect seamlessly to the plumbing system. At the core of the food waste disposer lies an electric motor, carefully sealed to prevent water damage. The grinding chamber constitutes the primary space where food waste accumulates and undergoes the grinding process. This chamber is constructed from robust materials such as stainless steel and ensures durability throughout the grinding operation. The grinding mechanism employs a shredder ring or grinding wheel featuring sharp blades that rotate at high speeds, effectively transforming food waste into fine particles. It is crucial to emphasize that not all types of waste are suitable for disposal in the unit. Items like bones, fibrous vegetables, and non-food materials have the potential to cause damage and should be avoided.

Numerous studies have examined the operational, economic, and environmental aspects of using disposers to treat the organic fraction of domestic MSW by diverting food waste to wastewater treatment systems and sludge. Based on the available literature, the benefits of implementing this approach outweigh the drawbacks. The literature highlights several advantages of food waste disposers, including reduced noise, improved traffic flow due to the absence of collection vehicles, lower GHG emissions, and transport costs. Additionally, waste disposers are a less complicated, more hygienic, and sustainable system compared to other waste-collected disposal methods (Saraiva et al., 2016). It also reduces the frequency and amount of MSW collection (Sahu, 2020) and eliminates the need for storing food waste at home or on public roads, which helps reduce disease vectors, contributing to public health.

Compared to other waste disposal methods, disposers and sending food waste through the drainage system is a natural way of disposing of organic waste. Since food waste is mostly made up of water, the WWTP is the most natural system for processing food waste (Battistoni et al., 2007; Trabold & Nair, 2018). Additionally, the high carbon content of food waste improves the nitrogen and phosphorus nutrient removal process in WWTP (Tang et al., 2019; Feng et al., 2021). Grinding food waste also enables energy recovery using biogas resulting from anaerobic digestion (Caffaz et al., 2008; Morelli et al., 2020). The use of food waste disposers (FWD) can significantly reduce the potential for uncontrolled biochemical processes in landfills, lower the generation of leachates, and decrease the contamination of groundwater (Battistoni et al., 2007; Iacovidou et al., 2012). This is particularly beneficial in small towns and decentralized areas, where FWD can be integrated with the management of municipal wastewater and household organic waste (Battistoni et al., 2007). However, the impact of FWD on the wastewater system, particularly in terms of chemical oxygen demand (COD), biological oxygen demand (BOD), and suspended solids, needs further investigation (Thomas, 2011). Additionally, the recycling of nutrients from organic residues, such as the sludge resulting from treatment at WWTP, through composting and application to the soil, can further enhance the environmental benefits of FWD (Nowak, 2006).

Although food waste disposers can divert organic waste from the solid waste stream and reduce associated management costs, their usage raises several concerns. These include the additional energy required to operate the units, the amount of extra tap water needed to transfer particles in the sewer, changes to sewer quality due to the introduction of suspended solids and organic substances, and the added strain on sewer networks and treatment plants. Extra water use due to disposers is negligible, averaging 4.3 L/person.day and representing only 2.2% of total domestic water use. Additionally, the cost of electricity to run food disposers is relatively insignificant, with estimated consumption lower than that of a 75 W light bulb used for 10 minutes (Marashlian & El-Fadel, 2005; Iacovidou et al., 2012).

Disposers significantly change the amount of organic matter and suspended solids at the WWTP. In a study, Thomas (2011) reported that the largest impacts will be on COD, BOD and solids, with food waste adding an additional of 24%, 28% and 18%, respectively, compared with the design standard when a figure of 142g/person/day food waste is applied, or 48%, 59% and 39%, respectively, when a figure of 303g/person/day food waste is applied. Another study in Shurammar (Sweden) did not show increased BOD, nitrogen, or phosphorus (Evans et al., 2010).

In long-term tests assessing obstructions, Evans et al. (2010) demonstrated that the optimised use of disposers over 15 years did not present any operational problems within the drainage system. Regular inspections and annual network filming showed that outside sewer pipes worked well when using food disposers. In the WWTP, theoretical calculations have shown that using food disposers increases the amount of sludge by 57%, mainly affecting the biological stage and treatment of sludge (Thomas, 2011). Similar theoretical estimates by Galil and Yaacov (2001) reported that the contribution of food waste disposers increases the weight of raw sludge by about 60% in the case of biological treatment and 62% in the case of primary sedimentation followed by biological treatment. However, another study indicated an increase of only 18.1% in sludge production due to the introduction of food disposers (Marashlian & El-Fadel, 2005). Therefore, it is crucial to consider the specific characteristics of the region and its food waste generated, as there may be differences in the generation of sludge with possible environmental and economic implications depending on the location.

3. SOLUTION FOR THE FOOD WASTE

3.1 Technical parameters

The Portuguese Biowaste Collection Systems Simulator - Version 1.3, licenced by the Portuguese Fundo Ambiental®, allows the determination of the investment flows (tangible and intangible) and exploration flows (tariff income, avoidable costs, and other types of expenses) so that, in the end, it is possible to determine the economic-financial sustainability and environmental viability of the proposed solutions. In addition to the economic-financial and technical inputs, other global characterization data were necessary and obtained from various sources, such as AMCB (2021), APA (2020), EGF (2020), ERSAR (2020), CMG (2021), INE (2020), the following values were gathered for the year 2019 to construct scenarios for the collection of food waste on public road, door-to-door and recycling at the source, along with simulations involving the use of disposers in kitchens:

- The resident population in the city of Guarda is 26,446 inhabitants;
- The rate of change in the resident population according to projections for the central region of Portugal exhibits negative variations ranging from 0.077% to 0.504% until 2030;
- There are 14,619 accommodations, with an average of 1.8 inhabitants per accommodation;
- Non-domestic producers total 139, including 128 from the hotels and catering industry and 11 from other sectors;
- Urban waste collected varies between 15,908 tons and 15,312 tons in the period under review; undifferentiated waste varies between 13,818 tons and 8,309 tons; food waste varies between 4,249 tons and 464 tons; and green waste varies between 1,695 tons and 490 tons;
- The potential of biowaste ranges between 5,945 tons and 6,162 tons;
- Service reach 100% of the population and accommodation;
- Non-domestic producers are served at a 100%;
- The tariff charged to the Municipality for undifferentiated waste is €42.84 per ton;
- The Waste Management Fee related to the deposition of undifferentiated waste in landfills, is avoided, with an average amount of €32.2 charged to the Municipality;
- The percentage of undifferentiated waste sent to landfills is 87%;
- Operating income results from the application of fixed tariffs (€55.84), variable tariffs and auxiliary services (€4.73), for the provision of the selective biowaste management of service, by producer (domestic and non-domestic);
- The tariff charged to the Municipality by the high system related to the forwarding of biowaste, set at €0.00 per ton, has not yet been defined.

For the collection of food waste on public roads, door-to-door and recycling at source, the following parameters were considered:

- Annual value for awareness campaigns, proposed by the Simulator, amounts to €20,328.03 per year, from 2022 to 2030. An except is made for the year 2021, with a foreseen value of €135,520.22;
- 254 Containers of 770 litres each, with a unit price of €261.25;
- 2,961 Containers of 340 litres each, with a unit price of €88.28;
- 5,157 buckets of 7 litres, with a unit price of €3.70;
- 176 containers of 110 litres each, with a unit price of €56.09;
- A biocomposter (volume of 333 litre) with a unit price of €60,000.

Food waste will be collected three times a week, with an estimated annual diesel consumption of 8,300 litres. The estimated outsourcing value is €79,658. The planned acquisition of a container washing vehicle with a total value of €262,728, includes a frequency of 6 washings per year. The annual global cost of human resources is estimated at €40,824. Furthermore, for the simulation involving the use of a food waste disposer, the following base parameters were considered:

- The capture rate of household food waste is 90%;
- The capture rate of non-domestic food waste is 80%;
- The capture rate of domestic green waste is 70%;
- For non-domestic producers,139 food waste disposers were considered, with a unit price of €1,140.21;
- For domestic producers, 14,619 food waste disposers were considered, with a unit price of €320.

3.2 Simulations

Table 1 presents the food waste capture rate, categorised by producer type (domestic and non-domestic) and collection system (public road, door-to-door, and recycling at the source), as well as considering an alternative system of capturing food waste through disposers (considered equivalent to recycling at the source for model convenience). In an optimistic scenario representing selective collection or recycling at the source from 2021 to 2030, collection rates range between 38% and 57% for collection on public roads, 56% and 75% for door-to-door collection, and 70% for recycling at the source. An estimated increase in the global capture rate of biowaste from 2021 to 2030 is projected to reach 65.1%, with a domestic food waste at 65.2% and a non-domestic food waste at 63.4% by 2030.

Table 1 also presents results considering an alternative system of capturing food waste through disposers (considered equivalent to recycling at the source for model convenience). In this scenario, capture rates for recycling at the source are 90% for domestic food waste and 80% for non-domestic food waste. The higher rates in this context reflect the assumption that individuals are more likely to participate in a system where they do not need to separate and place waste in containers, whether on the public road, through door-to-door collection, or by using domestic or community composters. It should be noted that capture rates for public road collection and door-to-door collection are 0% in this alternative system. Globally, the estimated capture rate for food waste from 2021 to 2030 is approximately 89%.

Table 2 exhibits the potential for food waste collection from 2023 to 2030, considering two different systems: food waste collection and food waste disposers. In both scenarios, the potential amount of food waste decreases over the analysed period, from 4,468 tons in 2023 to 4,347 tons in 2030 (-2.7%). This decrease is attributed to the expected population decline until 2030 in the city of Guarda, following the trend observed in the central region of Portugal over the past decade.

Regarding the projection of the amount of food waste collected, an inverse trend is observed in both systems. In the food waste collection system, the amount collected

TABLE 1: Food waste capture rate (2021-2030).

		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Waste collection	Food waste (%)	50.2	51.8	53.5	55.2	56.8	58.5	60.1	61.8	63.5	65.1
	Domestic food waste (%)	50.0	51.7	53.4	55.1	56.8	58.5	60.2	61.9	63.6	65.2
	Public roads (%)	38.0	40.1	42.2	44.3	46.4	48.6	50.7	52.8	54.9	57.0
	Door-to-door (%)	56.0	58.1	60.2	62.3	64.4	66.6	68.7	70.8	72.9	75.0
	Recycling at source (%)	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0
	Non-domestic food waste (%)	52.5	53.7	55.0	56.2	57.4	58.6	59.8	61.0	62.2	63.4
	Public roads (%)	38.0	40.1	42.2	44.3	46.4	48.6	50.7	52.8	54.9	57.0
	Door-to-door (%)	56.0	58.1	60.2	62.3	64.4	66.6	68.7	70.8	72.9	75.0
	Recycling at source (%)	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0
Waste disposers	Food waste (%)	89.4	89.4	89.4	89.4	89.3	89.3	89.3	89.3	89.3	89.3
	Domestic food waste (%)	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0
	Public roads (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Door-to-door (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Recycling at source (%)	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0
	Non-domestic food waste (%)	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0
	Public roads (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Door-to-door (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Recycling at source (%)	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0

increased from 2,391 tons in 2023 to 2,831 tons in 2030 (+18.4%). Furthermore, the amount collected for the food waste disposer system varies from 3,992 tons in 2023 to 3,884 tons in 2030 (-2.7%).

4. RESULTS AND DISCUSSION

About the distribution of households, hotels and catering industry, and other entities served by two food waste management systems, i.e., the food waste collection system and the kitchen disposer system (here equivalent to recycling systems at the source, for simulation purposes only), both systems were assumed to have 100% coverage from the outset for the simulations conducted. In the food waste collection system, the distribution corresponds to 49% through the collection on public roads, 31% through door-to-door collection, and the remaining 20% through recycling at the source. Additionally, for the kitchen disposer system, the simulation assumes that all households in the city, the hotels and catering industry, and other entities are equipped with kitchen disposers to ensure complete population coverage.

Comparing the economic and financial sustainability between the collection of food waste and the use of disposers (Table 3) allows us to conclude that operating costs are substantially higher for collection systems (public road, door-to-door and recycling at source), with values in 2023 of €250,074 and €191,774 in 2030, while in the implementation of domestic disposers, the expected value for 2023 is €162,061 while for 2030 the value is reduced to €96,731. It is also possible to observe that the investment in implementing food waste disposers throughout the city is much higher. In 2023 the estimated value is €2,430,917 and €4,836,569 in 2030, while for the food waste collection system, the figures point to just €679,435 in 2023 and €679,435 in 2030. The food waste disposer system requires a much higher investment than implementing a collection system. However, the cost-benefit ratio is much more favourable for food waste disposal systems. In other words, the cost-benefit ratio for implementing a food waste disposal system is 372% in 2023 and 636% in 2030, while for the food waste collection system, it is 133% and 204%, respectively.

Additionally, the feasibility analysis of the two studied alternatives presented in Table 3 shows that the food waste collection system is more favourable by comparing the net present value (NPV), which considers the time value of money to assess investment viability. In 2030, it will reach a value of €1,456,277 and recover the initial capital investment in 5 years. Moreover, within the same time frame, the domestic waste crusher system amounts to €1,312,153 in 2030 with a capital recovery period of 8 years. Considering each pro-

TABLE 2: Potential for food waste collection and food waste disposers (2023-2030).

	Food waste collection			Food waste disposers		
	2023	2027	2030	2023	2027	2030
The potential amount of food waste (ton)	4,468	4,409	4,347	4,468	4,409	4,347
Amount of food waste selectively collected (ton)	2,391	2,652	2,831	3,992	3,939	3,884

TABLE 3: Decision support for food waste collection and disposers (2023-2030).

		Food waste collection			Food waste disposers		
		2023	2027	2030	2023	2027	2030
Economic and financial sustainability	Operating expenses (€)	250,074	202,482	191,774	162,061	138,188	96,731
	Benefit/cost (%)	133	182	204	372	444	636
	Investment (€)	679,435	679,435	679,435	2,430,917	4,836,569	4,836,569
Economic and financial sustainability	Net present value (€)	-281,517	625,804	1,456,277	-620,157	-543,680	1,312,153
	Payback invested capital (years)	I.N.C.	5	5	I.N.C.	I.N.C.	8
	Profitability Index (%)	-41	92	214	-26	-11	27
Economic and financial sustainability	Emission of greenhouse gases ($kgCO_2$/ton)	7.4	6,4	5,9	2.9	2.9	2.9

I.N.C. - Investment Not Covered

posed system's net present value and investment requirements, the profitability index favours the food waste collection system. In 2030, its profitability index stands at 214%, while the food waste shredding system only reaches 27%.

Table 3 also presents the forecasted GHG emissions per tonne of food waste for the two waste management systems: waste collection (including public road collection, door-to-door collection, and recycling at the source); and the shipping system through the basic sanitation system, using food waste disposers. In the latter case, the calculations are based on an average daily operation time of 10 minutes, with a power consumption of 75W, and considering the current energy mix in Portugal (APA, 2022). For the household waste collection system, the projected emissions in 2023 are expected to be 7.4 kg/tonne, decreasing to 5.9 kg/tonne by 2030. On the other hand, using food waste disposers is estimated to result in 2.9 kg/tonne emissions in 2023 and subsequent years. This value will likely decrease further due to the anticipated increase in renewable energy sources in the Portuguese energy mix in the coming years.

The results support the conclusion that collecting food waste through food waste disposers and subsequent treatment at WWTP through the sewage system is the most environmentally favourable solution. It should also be noted that considering the average increase in water consumption of 4.3 litres per person per day resulting from using food waste disposers and considering the population covered in the conducted simulation, the estimated daily increase in water consumption would be approximately 11.3 m^3.

5. CONCLUSIONS

Based on the provided results, a conclusion can be drawn regarding comparing food waste collection systems and using food waste disposers. The analysis, focused on economic and financial sustainability, feasibility, and GHG emissions, shows that the operating costs for food waste collection systems (public road, door-to-door, and recycling at source) are significantly higher compared to the use of disposers. Moreover, the investment required for implementing food waste disposers is considerably higher than for collection systems. However, the cost-benefit ratio favours the food waste disposal system, indicating higher economic efficiency.

The NPV analysis indicates that the food waste collection system is more favourable, reaching a higher value in 2030 and recovering the initial capital investment in 5 years. The food waste disposers have a lower NPV and a more extended capital recovery period, making them less financially feasible. Also, food waste collection systems result in higher GHG emissions per tonne of food waste than food waste disposers. The emissions associated with food waste disposers are lower and will potentially decrease further with the anticipated increase in renewable energy sources in the energy mix.

Based on the provided data, collecting food waste through food waste disposers and subsequent treatment at the WWTP via the sewage system offers the most environmentally favourable solution. While higher upfront costs are associated with implementing the disposer system, it demonstrates better cost-benefit ratios, lower operating costs, and reduced GHG emissions compared to food waste collection systems. Finally, to ensure the successful implementation of food waste collection through disposers, it is essential to approve new regulations in the licensing process for constructing and renovating buildings, which specifically mandate the installation of these devices to maximise their effectiveness, considering factors such as building size and type (residential, commercial, among others), contributing to sustainable waste management practices, and reducing the environmental impact of food waste.

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