Peer-reviewed version available at Resources 2017, 6, 8; doi:10.3390/resources6010008

Article

The Impact of Pay-As-You-Throw Schemes in the Management of Municipal Solid Waste: The Case of the County of Aschaffenburg, Germany

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Abstract: The "Pay-as-you-throw" scheme, PAYT, is an economic instrument of waste management that implements the "polluter pays" principle by charging inhabitants of municipalities according to the amount of residual, organic and bulky waste they send for third-party waste management. When combined with well-developed infrastructure to collect the different waste fractions (residual waste, paper and cardboard, plastics, bio waste, green cuttings, many recyclables) as well as with a good level of citizen's awareness, its performance has frequently been linked to high collection rates of recyclables. However, the establishment and operation of PAYT systems can require significant resource inputs from municipalities. In this paper, PAYT is analysed through a case study from the German County of Aschaffenburg, covering nearly 20 years of implementation across 173,000 inhabitants. Key performance indicators applied include temporal trends in the county's recyclables collection rate, waste treatment fees for residents and municipal waste management costs, benchmarked against German municipalities not implementing PAYT.

Keywords: waste management; economic instruments; pay-as-you-throw; municipal solid waste; recycling; environmental management

1. Introduction

1.1. Fundamentals of Pay-As-You-Throw

In the context of municipal solid waste management, the "Pay-As-You-Throw" (PAYT) approach, also known as unit pricing [1], differential and variables rates or variable fee charge systems [2, 3], is an economic instrument that implements the *polluter pays* principle by charging inhabitants according to the amount of waste they generate and send for third party management [4]. For such a system, the technical implementation of a PAYT approach is based on the following three pillars: identification of the waste generator, measurement of the amount of waste, and unit pricing e.g. per kg and/or per emptying. However, the experience gained so far revealed that the waste fee should not only be dependent on the single component per amount of waste generated, but should best consist of basic and variable (service-based) fees [5]. On the one hand, this reflects the cost structure of waste disposal, which consists of fixed and variable costs [6], and on the other hand, the inclusion of a fixed (basic) fee helps to avoid illegal disposal practices which can increase in case the fee is only charged for the amount of waste collected [7, 8]. Figure 1 shows the conventional structure of the components of a waste fee.

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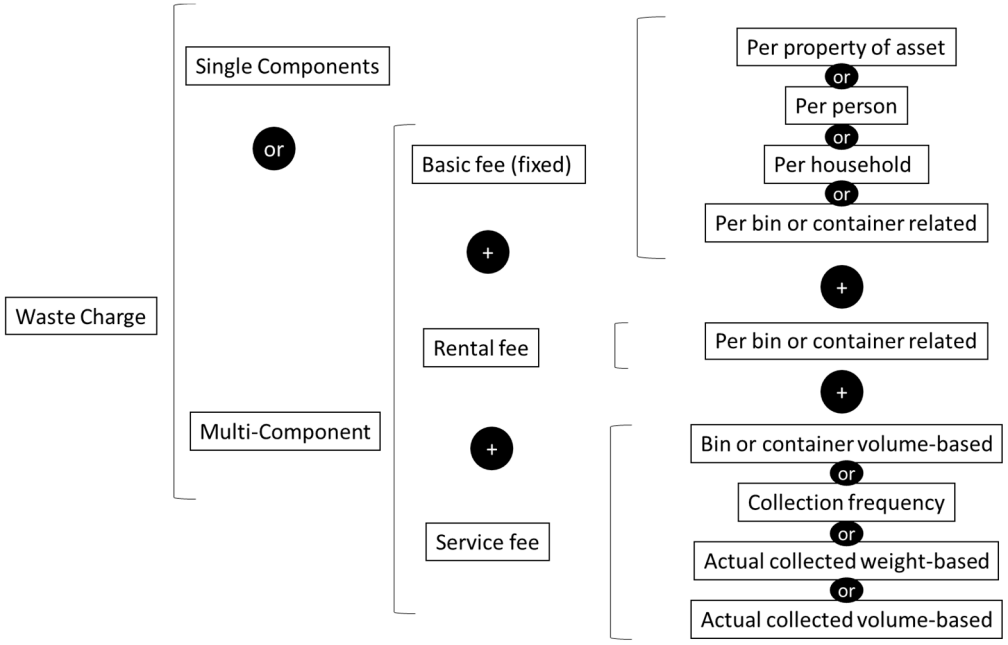

Figure 1. Different suitable components for the design of waste fees (adapted from [5])

The PAYT approach means that a substantial part of the overall fee is allocated to the amount of waste generated in order to stimulate waste prevention and recovery. Against this background, the PAYT approach can be implemented in different ways [7] depending on the waste accounting method:

- Per user identifier:
  - Volume-based accounting
  - Weight-based accounting
- Per bin identifier (individually or collectively assigned bins)
  - Volume-based accounting (identification system)
  - Weight-based accounting
- Pre-paid systems
  - Pre-paid sack
  - Tag, sticker or token

The pre-paid sack system is commonly considered to belong to the volume-based systems, but its differentiation lays on the fact that the volume of a sack directly correlates with its weight and the fee has to be paid for each sack, while common volume-based schemes are based on the container size for which the citizens pay. In this case, containers can be collected partially filled and hence volume may not correlate to weight. PAYT schemes with high rate of implementation [9] are: volume-based schemes (choice of container size); sack-based schemes (number of sacks set out for collection); weight-based schemes (the weight of the waste collected in a given container); and frequency-based schemes (the frequency with which a container is set out for collection – this approach can be combined with volume- and weight-based schemes).

1.2. The County of Aschaffenburg

The County of Aschaffenburg has about 173,000 inhabitants and a population density of 247 inhabitants per km². Until the early 1990ies, the total untreated waste was landfilled. As the landfill was close to exhaustion, a site for a new landfill seemed to be needed. The public acceptance of a new landfill was very low resulting in heavy protests. As a consequence, the county was forced to develop new options to secure waste disposal and introduced the separate collection of plastic waste in 1990, the incineration of residual waste in a neighbor county and the separate collection of waste wood in

1994, the reduction of the quantity of commercial waste due to higher fees, the reduction of collection frequency for bulky waste to two times a year and the introduction of separate bio waste collection in 1994 – 1995 as a first trial in the municipality of Stockstadt [10]. Thus, the county switched from waste disposal by landfilling to waste management with the target to prevent waste and to recycle it as much as possible. So, after trials from 1994 – 1996 in the municipality of Stockstadt, in 1997 the county started a PAYT system, which has been working ever since. Today, the municipalities and cities of the County of Aschaffenburg have one of the highest recyclables collection rate, 86 %, while their residual waste is around 50 kg per capita and year, one of the lowest observed. The success of the system in the County of Aschaffenburg and its performance is proven in other current examples such as from Germany (County of Landsberg am Lech, County of Schweinfurt, County of Calw, County of Heidenheim, about 75 % of the municipalities in the County of Wetterau), from Italy [11-13], and from Belgium [14} but its early implementation and successful performance makes the County of Aschaffenburg an excellent case study of PAYT to benchmark the operation of similar systems, as discussed in this paper.

2. Materials and Methods

2.1. PAYT as a best environmental management practice

A *best environmental management practice*, BEMP, is defined by the European Commission Regulation EC No. 1221/2009, on Eco-Audit and Management Schemes, as the *most effective way to implement the environmental management system by organisations in a relevant sector and that can result in best environmental performance under given economic and technical conditions*. Therefore, a best environmental management practice should achieve outstanding performance and minimise the environmental impact of organisational operations in a technically feasible and economically viable manner that is widely applicable across relevant organisations [15]. In this context *benchmark of excellence* is defined as the performance of frontrunners implementing best practices, whereas *key performance indicators* are used to report the performance of BEMPs and to quantify *benchmarks of excellence*. In the case of PAYT schemes, two main environmental performance indicators are essential to measure its impact:

- Collection rate of recyclable materials, %. This indicator is frequently reported as "recycling rate", but given the amount of rejects from existing sorting and recycling plants, the term *recyclables collection rate* is preferred to avoid its misinterpretation. PAYT schemes are designed to increase the amount of recovered recyclable materials from municipal solid waste, so their implementation should aim to increase this indicator.
- Residual waste, kg per person and year. This is the amount of waste that the system user disposes in the residual waste bin. This definition excludes the amount of waste rejected in recycling or sorting plants from the recyclable waste fraction or illegally disposed of.

During the elaboration of a background report for the European Commission on best environmental management practices for the waste management sector in Europe [16], we concluded that PAYT is a definite BEMP, and that the performance of the system in Aschaffenburg represented a *benchmark of excellence*. In general, BEMP is a PAYT system with weight-based door-to-door collection for residual, organic and bulky waste. The successful implementation of an efficient PAYT system also requires a well-developed infrastructure to collect different fractions of recyclable waste by individual bins (paper/cardboard/board, organic waste, eventually waste plastic and organic waste), glass containers and recycling facilities for ferrous metals, non-ferrous metals, end-of-life electrical and electronic equipment, refrigerators and other white goods, waste plastic, pure waste polystyrene, waste wood, green cuttings, non-commercial construction and demolition waste, waste tyres, exhausted printer cartridges, waste vegetable fat, waste textiles and shoes, cork, CDs, etc. in order to offer the citizens a comfortable way to get rid of materials which they do not need anymore. In addition, awareness raising is also a key element for effective PAYT implementation; informed citizens understand and support the scheme.

The experience shows that pre-paid sack schemes achieve good performance [2]. However, volume-based systems give the weakest incentive for waste prevention and recycling [2, 9]. In contrast, highest recycling rates and lowest residual waste quantities respectively are achieved with weight-based systems accompanied with well-developed infrastructure and citizens with high awareness. This is the case of Aschaffenburg, which is reported in this paper with detail.

2.2. Implementation and operation of PAYT in Aschaffenburg

In the County of Aschaffenburg, the system implemented is a weight-based waste collection of residual waste, bio waste and bulky waste as well as separate collection of paper from all households, the operation of collection centres (also called 'container parks' or 'civic amenity sites') and composting of green cuttings (or incineration of woody fraction in a biomass-fired power plant) in nearly all municipalities and disposal of the residual waste in an incineration plant according to BAT standards, anaerobic digestion of bio waste, subsidies for composting on household level, for the use of re-usable nappies, and for families with incontinent persons.

The motivation for introducing a weighing system for residual and bio waste conconsidered aspects such as the missing fairness of fees, the non-permitted use of the disposal system by commercial and industrial enterprises, the need to introduce new bins with wheels due to the manual handling of loads according to the Directive 90/269/EEC, the central billing by the county (until 1994, the billing of waste was carried out by the municipalities), the need to reduce the quantity of residual waste due to high incineration costs and the shift of recyclables from residual waste to more cost effective recycling options, the need to reduce the quantity of bio waste due to the limited capacity of the compost plant at that time and ecological considerations such as the prevention of the incineration or landfilling of recyclables and bio waste.

Starting the implementation of the Aschaffenburg PAYT system requires considerable effort to acquire and process data for billing, accounting and system optimisation purposes. The principal data collection and processing scheme employed is illustrated in Figure 2. All bins and containers need to be coded and the collection truck should be equipped with a reading device and a weighing measurement device. Data are transferred to a central facility via telemetry just-in-time, where processing, accounting and billing of end users occurs. Aschaffenburg also uses the collected data to measure the economic efficiency of the system and to optimise the logistics of the system.

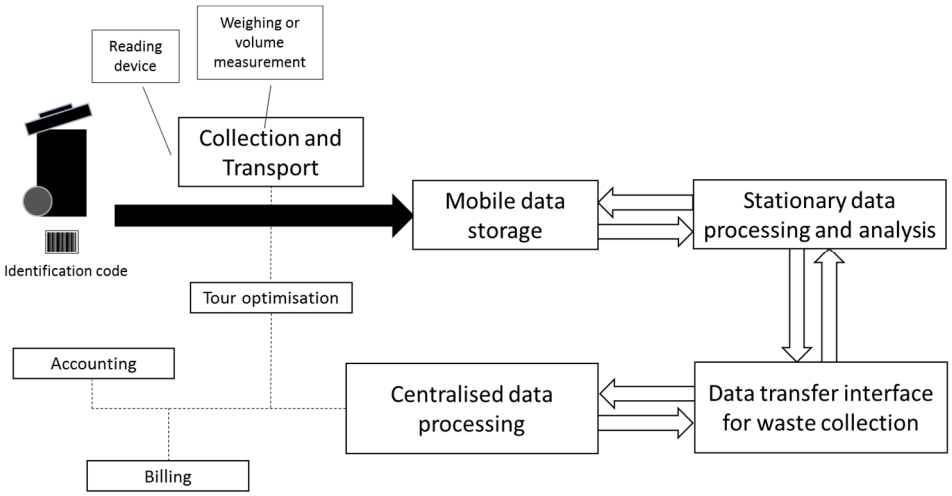

Figure 2. Process chart for the electronic identification and data transfer in a bin identification scheme (adapted from [4])

All the waste bins are equipped with a chip and a bar code that can be read by a transponder whereas the bar code reader (see Figure 3) is only for the delivery and take back of the bins. An example of a bar code is given in Figure 3 and examples for chips are shown in Figure 4. For densely

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populated areas and high-rise buildings, container systems are in use to which only assigned people have access.

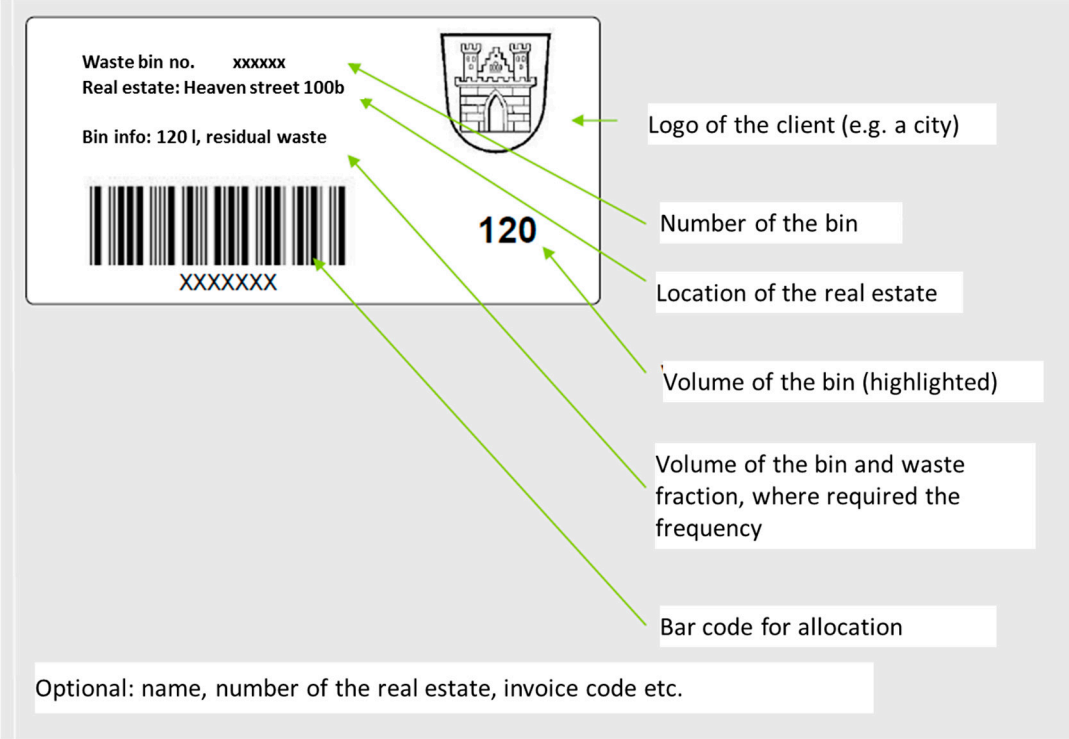

Figure 3. Example for the information automatically read by an identification system, taken from [16, 17]

a) Standard chip for new bins b) Chips for the retrofit of existing bins

Figure 4. Examples for chips for (a) new bins, and (b) for retrofitting existing bins [16, 17]

Figure 5 shows a waste collection truck which is equipped with a waste identification system and a weighing system. The weight-based system requires higher efforts to maintain and to calibrate the scales, due to the continuous vibrations of the truck.

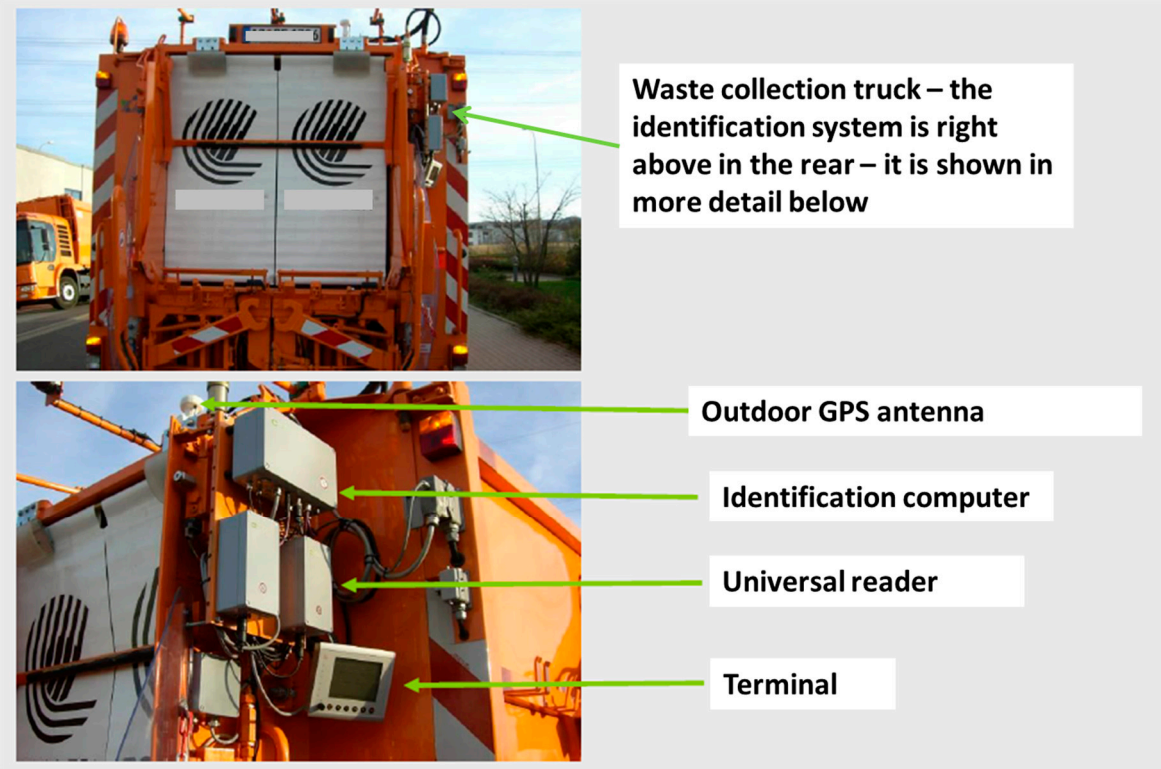

Figure 5. Waste collection truck which is equipped with a waste identification system [16, 17]

Where the infrastructure to separately collect and to process the different fractions, such as residual waste, glass, paper/cardboard, plastics, organic waste, green cuttings, demolition waste, bulky waste, is well established and functioning, a framework condition in Germany, the reduction of residual waste arising owing to implementation of the weight-based system can be estimated. In this case, illegal dumping is negligible [18] but can be higher in case of not well-developed infrastructure and less environmental awareness of citizens.

3. Results

3.1. Environmental performance

When the PAYT system with identification and weighing of the waste, collected door-to-door, was introduced in 1997 in the County of Aschaffenburg, a subsequent increase in the collection of recyclable waste and a decrease in disposed waste were obvious. The county achieved collection rates of recyclables of up to 86 % [19], which is a significant improvement against the average performance of PAYT systems, with typical recycling rates of around 70 % [7]. The performance of Aschaffenburg is considered a *benchmark of excellence* for the waste management sector. The main differentiating factors in this specific case are:

- the use of a weighing system;
- an existing and efficient infrastructure for the collection of recyclable waste streams, and
- a high level of environmental awareness and active support from the citizens.

Table 1 provides the annual quantities of the different waste fractions from 1989 – 2015. The drastic reduction of household-type commercial waste after 1994 was a consequence of a new regulation at that time and the significantly increased costs for incinerating the residual waste.

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Table 1. Quantity of the different waste fractions of the County of Aschaffenburg from 1989 – 2015; the quantities are given in [kg/cap x yr] [19]

Year	Waste glass	Waste paper	Scrap metal	Waste tyres	Waste plastic	Textiles	Shoes	Green Cuttings	Biowaste	Waste wood	Windows / flat glass	Aluminium	Waste Cable	Cork	Construction and Demolition wastes	Waste of Electric and Electronic Equipment	Other Reycyclables	Residual Waste	Bulky waste	Hazardous waste	Commercial waste (MSW like)	Total waste
1989	17	37	17	*N/A*	*N/A*	1.7	*N/A*	5	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	191	26	N/A	444	*N/A*
1990	19	38	18	*N/A*	4.6	2	*N/A*	18	*N/A*	0.1	*N/A*		*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
1991	24	65	22	*N/A*	6.6	2.2	*N/A*	27	*N/A*	1.2	*N/A*	0	*N/A*	*N/A*	1.6	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
1992	30	74	21	*N/A*	7.2	2.5	*N/A*	27	*N/A*	3.1	*N/A*	0	*N/A*	*N/A*	6.2	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
1993	31	83	20	*N/A*	12	2.4	*N/A*	35	*N/A*	3.1	*N/A*	0.2	*N/A*	0	16	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
1994	31	81	23	*N/A*	14	3	*N/A*	53	1.9	18	0.1	0.2	0	0	20	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
1995	34	80	21	*N/A*	14	2.6	*N/A*	75	4	24	0.3	0.2	0	0	28	*N/A*	*N/A*	134	27	1.5	67	*N/A*
1996	34	82	22	*N/A*	13	5.3	0.1	79	2.4	19	0.4	0.4	0	0	27	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
1997	33	89	22	*N/A*	17	3.2	0.1	81	25	25	0.6	0.7	0.1	0.1	41	*N/A*	*N/A*	68	27	1.6	28	463
1998	34	98	22	*N/A*	16	3.2	0.1	63	24	31	1.1	0.9	0.1	0.1	42	*N/A*	*N/A*	45	36	1.4	21	437
1999	33	97	17	*N/A*	20	2	0.1	59	24	17	1.4	0.9	0.1	0.1	50	*N/A*	*N/A*	48	1.8	1.1	14	387
2000	32	101	20	*N/A*	21	2.3	0.1	74	24	20	2.6	0.1	0	0.1	45	*N/A*	*N/A*	49	2.7	0.6	10	404
2001	31	100	20	*N/A*	22	3.2	0.1	80	24	23	2.3	0.1	0	0.1	47	*N/A*	*N/A*	48	1.3	0.9	9.6	411
2002	29	99	20	*N/A*	23	3.1	0.1	81	24	23	2.5	0.1	0	0.1	54	*N/A*	*N/A*	47	0.8	0.6	8.7	417
2003	27	95	19	*N/A*	22	3.5	0.1	83	24	23	2.6	0.1	0	0.1	51	*N/A*	0.2	46	0.7	0.7	8	379
2004	25	84	15	*N/A*	22	3.8	0.1	85	26	23	2.6	0.1	0	0.1	51	*N/A*	0.3	48	0.7	0.8	6.9	395
2005	29	89	14	*N/A*	22	4.8	0.1	83	26	24	1.8	0.6	0.1	0.1	50	*N/A*	0.2	48	0.9	0.8	9.1	403
2006	29	93	14	*N/A*	22	6.6	0.1	84	27	23	5.9	0.6	0.2	0.1	50	5.5	0.1	49	1.1	0.9	11	422
2007	28	94	11	*N/A*	24	5.5	0.1	76	27	25	6.6	0.1	0.2	0.1	47	4.9	0.1	50	1.2	0.8	7.9	411
2008	26	94	12	*N/A*	25	2.9	0.1	72	27	26	7.6	0.1	0.1	0.1	47	5.7	0.1	50	1.5	0.8	8.3	408
2009	18	93	14	*N/A*	26	3.7	0.1	51	28	28	8.2	0.1	0.2	0	50	6.1	0.1	52	1.5	0.9	9	389
2010	27	92	13	*N/A*	27	5.6	0.1	90	28	29	8.5	0.1	0.2	0.1	50	5.7	0.1	52	1.7	1	9.7	440
2011	27	92	12	*N/A*	27	6.1	0.1	94	29	30	9.4	0.1	0.1	0	56	5.5	0.1	53	1.5	1	11	459
2012	27	92	11	0.2	24	5.4	0.1	98	29	30	9.8	0.1	0.1	0	53	5.6	0.2	52	1.6	1	9.1	449
2013	27	90	11	0.1	26	7	0.1	130	30	30	10	0.1	0.1	0.1	53	5.6	0.2	53	1.8	0.9	11	488
2014	27	91	12	0.1	26	9.9	0.1	148	31	29	11	0.1	0.1	0	54	5.4	0.2	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
2015	27	88	12	0.1	27	7	0.1	123	31	28	11	0.1	0.1	0	54	5	0.2	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*

The numbers clearly reflect the drastic change of the waste management system of the county. The quantity of residual waste drastically decreased and the quantities of recyclables sharply increased.

Figure 6 visualises the development of the quantities per capita for the total waste, the disposed and the recycled waste from 1995 to 2013 for the County of Aschaffenburg and for Germany. As observed, the implementation of the PAYT scheme in Aschaffenburg had a high impact on the amount of residual waste. In 2013, the amount of residual waste is 56 kg per person per year (reduced from 162 kg in 1995), while in Germany average residual waste quantity is reported at around 220 kg per capita and year (reduced from 380 kg in 1995), which is usually disposed through incineration. Therefore, it can be concluded that PAYT is an economic instrument with high impact on the amount of recyclables materials collected from waste.

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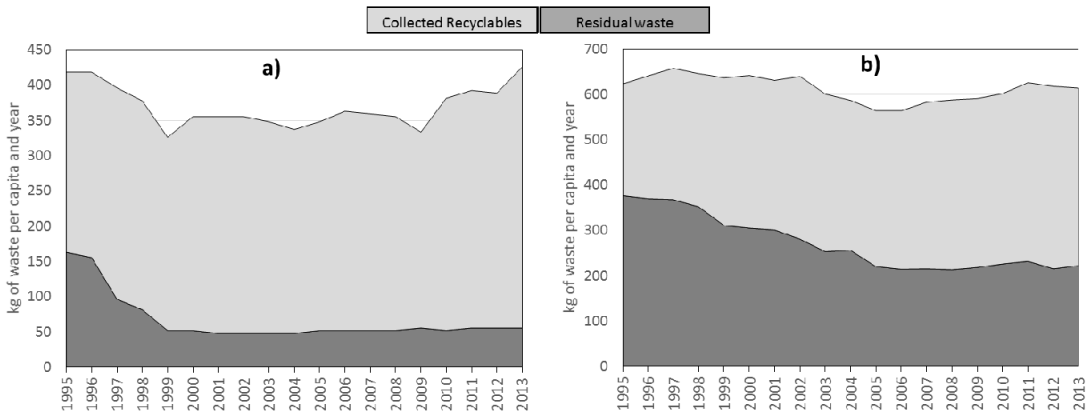

Figure 6. Development of the quantities of residual waste and recyclables collection from municipal solid waste for 1995 – 2013 of (a) the County of Aschaffenburg [19] and (b) Germany

The very low residual waste quantities associated with PAYT implementation in Aschaffenburg mean that less municipal solid waste (just 55 kg per person per year) ends up being incinerated. Essentially, waste streams are diverted from incineration towards recycling, anaerobic digestion (food waste), composting (green waste) and combustion for energy (woody waste) – with avoidance of primary material extraction for recycled materials. In order to estimate the reduction in GHG emissions arising from lower residual waste quantities achieved in Aschaffenburg compared with the German average, the diversion of specific fractions from the 220 kg/capita/yr that typically goes to incineration in Germany was considered. Therefore, the composition of this 220 kg was estimated using data for EU28 average waste composition [20] and residual waste composition recorded by the German waste management organisation AZV Suedniedersachsen [21] (Table 2). In order to calculate product replacement for "nappies and sanitary waste", this waste fraction was assumed to include 30% plastics by weight, whilst the "other waste" fraction was represented as a weighted average of defined waste fractions. It was assumed that nappies remain in the residual waste stream in Aschaffenburg, but that other main fractions are recycled in higher proportions to reduce residual waste from 220 to 55 kg/cap/yr (Table 2). Compared with the German average, waste management in Aschaffenburg leads to a 111 kg per person per year reduction in primary material demand ("recycling" options for organic waste fractions still require material replacement).

Table 2. Estimated composition of residual waste for Germany (derived from [20, 21]) and Aschaffenburg

	German average	Aschaffenburg
	kg/cap/yr	
MSW Incineration	220.0	55.0
Additional recycling*	0.0	165.0
Aluminium	2.3	0.3
Paper & cardboard	40.9	3.4
Mixed plastics	31.7	3.5
Packaging glass	11.4	1.3
Steel & iron	4.5	0.7
Food waste	56.8	53.2
Green waste	5.7	6.8
Woody waste	5.7	6.8
Textiles	9.1	1.8
Nappies	14.76	14.8
Other	82.6	16.2

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Figure 7 presents the GHG balance of managing the baseline 220 kg/capita/yr residual waste according to typical German practice (incineration), and for the same quantity of waste handled in Aschaffenburg. A GHG credit was attributed to avoidance of grid electricity via incineration with energy recovery, assuming a lower heating value (LHV) of 10 MJ/kg for MSW at 65% dry matter, 30% net energy conversion efficiency, and a German electricity GHG intensity of 0.65 kg CO_2e per kWh [22]. The GHG cost of replacing primary materials removed from the economy following incineration (or anaerobic digestion or combustion for organic wastes) was calculated based on embodied GHG emissions for products reported by [23]. GHG burdens for recycling were also taken from [23], whilst the GHG credits for energy recovery from anaerobic digestion and combustion of woody wastes were calculated based on a net electricity output of 0.21 MJ/kg food waste following anaerobic digestion [24] and the German average GHG intensity of electricity generation reported above, and assuming that 85% of the LHV of wood at 50% dry matter (8.2 MJ/kg) is converted into useful heat that replaces oil heating with a GHG intensity of 0.0874 kg CO_2e/MJ [22]. Considering all these factors for the 220 kg of MSW that typically goes to incineration in Germany, net GHG emissions for waste management and primary material replacement are 665 and 326 kg CO_2e per person per year for Germany and Aschaffenburg, respectively (Figure 7). Thus, the additional recycling achieved in Aschaffenburg saves 39,594 tonnes CO_2e per year from the municipality (173,000 inhabitants) when compared against German average waste management performance.

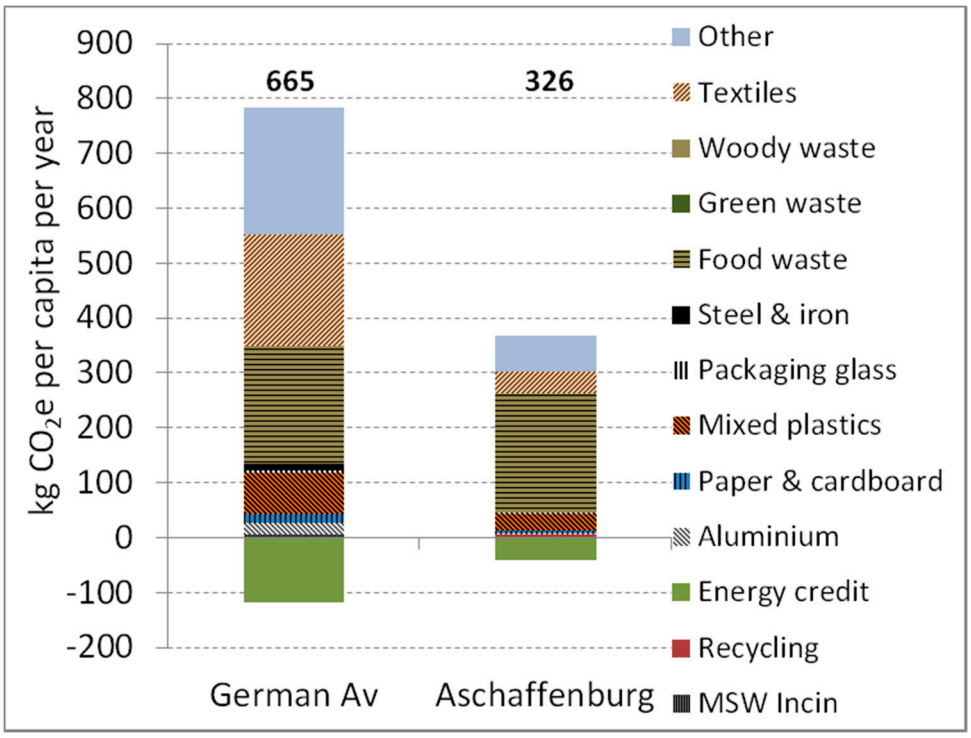

Figure 7. GHG balance of incineration with energy recovery and raw material replacement for the 220 kg residual waste representative of the German average, and the estimated fate of the same 220 kg waste generated in Aschaffenburg, expressed per person and per year (net values in text above bars)

When considering the implementation of PAYT, there is the argument that illegal dumping in the countryside or littering in the cities may increase. This is not the case where the infrastructure for the collection of waste is well-developed and easy to use and where citizens have an adequate environmental awareness. As a consequence, public awareness campaigns are very much required when introducing a PAYT system.

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3.2. Economic implications

The calculations of the fee just before and just after introducing the weight-based system in Aschaffenburg are publicly available [19, 25]. As a result, in 2013, the waste management fee in the County of Aschaffenburg was lower than the fee in the initial situation before 1997 (Table 3).

Although the manifold additional activities (separate collection of the different fractions, erection of facilities to recycle or to recover waste streams, etc.) the fee significantly decreased after the change, proving that the weight-based system is not a significantly more expensive waste management option than others, contrary to some studies [26]. However, waste management costs vary massively from one municipality to another and over time based on a wide range of temporally variable factors. After the change in Aschaffenburg from 1994-1997, due to the sharp decrease of residual waste the disposal cost decreased by 46 % although the residual waste was incinerated and the incineration costs were high at that time (EUR 232/t in 1997). The latter decreased to EUR 103.60/t in 2014. In 1999, the fee had to be increased by 10 %, as the management costs until that time had not considered the whole county. In 2000, there was another increase by 10 % due to sanitation measures on the landfill. But from 2002 to 2013, the fee significantly decreased by about 23 %, even though the county further invested in anaerobic digestion of the bio waste, in collection centres, optimisation of green cuttings collection and its weighing and other measures. In 2015, the waste fee again decreased by 10 %.

Table 3. Development of the waste fees in the County of Aschaffenburg from 1997 (the year the PAYT system for residual waste was implemented) to 2015 for an average four persons household (average values), columns 1-4 provide the figures for the case where the household has no bin for organic waste and column 5 gives the total fee where the household also has a bin for organic waste [25]

Year	1. Annual basic fee for a 120 l bin	2. Fee for the weight of the waste	3. Fee to collect the waste (emptying the bins)	4. Total annual fee (without a bin for organic waste	5. Total annual fee (with a bin for organic waste)
	[EUR]	[EUR]	[EUR]	[EUR]	[EUR]
1994-95				171.80 / 245.40[1]	
1996-97				158.00 / 225.50[1]	
After the introduction of the weight-based system mid-June 2007					
1997	50.31	44.54	21.47	116.33	148.67
1998	50.31	47.92	18.41	116.64	148.97
1999	55.22	53.87	20.25	129.34	165.52
2000	62.58	59.93	21.47	143.99	184.91
2001	62.58	59.30	21.47	143.36	182.05
2002	63.00	46.22	21.60	130.82	162.90
2003	63.00	45.80	21.60	130.40	162.70
2004	63.00	48.50	21.60	133.10	168.33
2005	60.00	40.04	19.60	119.64	147.76
2006	60.00	40.13	19.60	119.73	148.20
2007	60.00	40.66	19.60	120.26	149.49
2008	54.00	37.28	19.60	110.88	138.72
2009	54.00	37.76	19.60	110.36	139.50
2010	54.00	37.20	19.60	110.80	138.65
2011	54.00	38.32	19.60	111.92	140.94
2012	54.00	37.68	19.60	111.28	140.14
2013	54.00	37.60	19.60	111.20	140.38
2014	48.60	33.84	17.50	99.94	126.20
2015	48.60	35.14	17.50	101.24	129.25

[1]lower figure for a 35 litre bin, higher figure for a 50 litre bin

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The fee after the introduction of the weight-based system represents an average value as all the bills are individual due to the variable fee for the weight.

The fee in the County of Aschaffenburg consists of the basic fee, the collection fee (to empty the bins) and the weight fee. In 1997 and in 2012, the average fee breakdown changed as shown in Table 4.

Table 4. Waste treatment fee breakdown in the County of Aschaffenburg for the example of Table 3 [19]

Type of fee	1997	2012
Basic fee	32 %	47.0 %
Collection fee	17 %	18.5 %
Weight fee	51 %	34.5 %

The percentage for the weight part decreased but it still appears sufficient to motivate waste prevention/recycling. Figure 8 shows an example of the annual bill of the County of Aschaffenburg indicating the basic fee, the service charge to collect the waste (collection fee) with a certain frequency and the weight fee, separately for the bio waste, for which the basic fee is zero, and the residual waste.

Landkreis Aschaffenburg
- Müllgebührenstelle -

Öffnungszeiten Müllgebührenstelle
Mo.-Mi. 8.00-16.00
Do. 08.00-17.00, Fr. 08.00-12.00
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DE7610000000010338
Müllsonderkonto des Landkreises:
SPK Aschaffenburg-Alzenau BLZ 79550000 Kto.Nr. 60954
IBAN DE04 7955 0000 0000 0609 54 BIC BYLADEM1ASA
Mandatsreferenznummer
PK33458/1KD13442-21-A-0
(bei Überweisung unbedingt angeben!)
Bescheidnummer 2900929 vom 09.01.2015

Note on the waste disposal fee

1. Determination for the estate
BEISPIELSTR. 21 A, WALDASCHAFF

Final bill for 2014 173,01 EUR

2. Fee calculation
For the time period 01.01.2014 – 31.12.2014

										Fee	Sum
Biowaste	60 L, bin no. 101625, 01.01.2014 – 31.12.2014										
a)	Basic fee esidual waste	12 months			x	0.00	EUR	=	0.00	EUR	
b)	Collection fee	collect. frequ. per yr	25		x	0.45	EUR	=	11.25	EUR	
c)	Weight fee	weight	343.0	kg	x	0.18	EUR	=	61.74	EUR	72.99 EUR
Residual waste	120 L, bin no. 604576, 01.01.2014 – 31.12.2014 014										
a)	Basic fee esidual waste	12 months			x	4.05	EUR	=	48.60	EUR	
b)	Collection fee	collect. frequ. per yr	12		x	2.50	EUR	=	30.00	EUR	
c)	Weight fee	weight	119.0	kg	x	0.18	EUR	=	21.42	EUR	100.02 EUR

Final billing 173.01 EUR
Already paid amount 153.72 EUR
Remaining amount to be paid 19.29 EUR

Please check your bin number! Residual waste: 604576 Bio waste: 101625 Paper: 732590

3. Remaining amount 2014
The remaining amount mentioned under no 2 for the year 2014 is payable on:
16.03.2015: 19.29 EUR

Figure 8. County of Aschaffenburg – example of the annual bill for the waste fee of a four-person household having separate bins for residual waste (120 l), bio waste (60 l) and paper/cardboard

When comparing the cost figures with other municipalities or cities, it is best to compare the so-called uncovered costs which are the difference between the total costs and the revenues. They are usually covered by the annual waste fee charged to the citizens of the municipality.
Thereby, in the evaluation of total costs, the following costs are usually considered:

- costs for collecting the different waste fractions (e.g. residual waste, bio waste, paper);
- costs for the treatment/disposal of residual waste (e.g. incineration) and recycling/energy recovery of waste fractions with distinction between municipality-owned plants and third-party plants;
- costs for operation, closure and management of closed landfills (leachate treatment, recultivation, etc.);
- costs for staff and administration related to waste management;
- miscellaneous costs.

In addition, the total costs can also include costs for services provided:

- by private waste management companies on behalf of the municipality;
- by the municipality itself;
- by municipalities providing services for another municipality.

In the evaluation of revenues from recycling/recovery activities, the following ones can be considered:

- selling electricity or/and heat from incineration of refuse derived fuels, residual waste, biogas from anaerobic digestion of bio waste or landfill gas;
- selling biogas from anaerobic digestion;
- selling separately collected or separated paper/cardboard;
- selling separately collected packaging;
- selling separately collected or separated scrap metal;
- selling compost;
- fees charged to businesses for waste collection and disposal.

After the considerable efforts and measures practiced by the County of Aschaffenburg, the uncovered costs are kept relatively low. Compared to other counties and cities, with 44.5 EUR/cap/2013, the uncovered costs are on a low level (Figure 9) from a benchmarking exercise with other German counties [27], where data is anonymised. Thus, high environmental performance is not necessarily associated with high uncovered costs.

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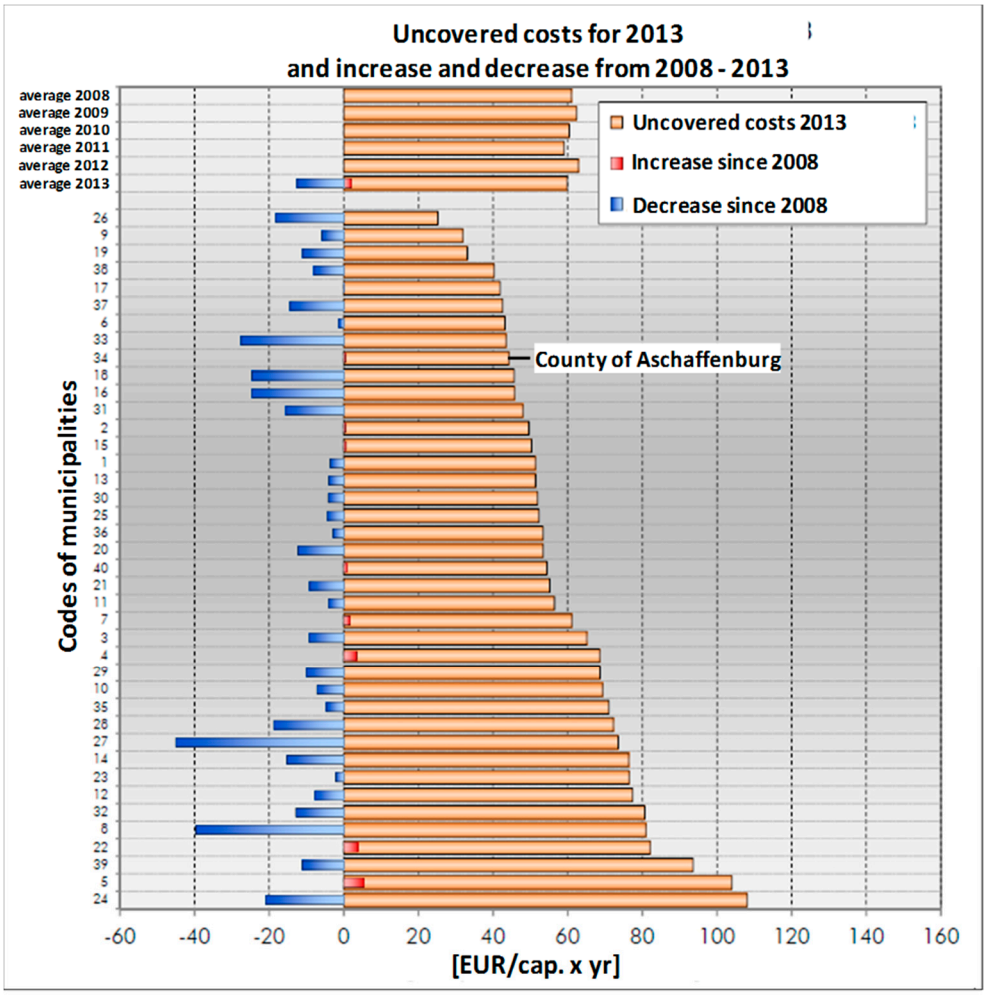

Figure 9. Increases and decreases of uncovered costs in 33 counties and 11 cities in Germany from 2008 – 2013, based on [27]

4. Discussion

The implementation of PAYT in the County of Aschaffenburg is representative of a *best environmental management practice*, as the weight-based system produced particularly high collection rates of recyclable materials. Improving the efficiency of separated waste stream and recyclables collection is a priority for Member States of the European Union to comply with overarching targets to recycle 65 % of municipal waste and 75 % of packaging waste by 2030, according to new objectives in the proposed directive on waste [28]. The implementation of PAYT schemes, along with the development of appropriate infrastructure, awareness raising and other Circular Economy policies, would help to achieve such demanding objectives. However, previous reports on weight-based PAYT systems have indicated varying levels of recycling performance owing to different levels of development of waste collection infrastructure and public awareness – suggesting that PAYT schemes are most effective when implemented as part of a holistic waste management strategy.

Some recent examples of PAYT implementation in Italy have been reported to have achieved high recycling rates and low residual waste quantities. In the Treviso region, a residual waste quantity of only 55 kg residual waste per capita and year was reported for 2015 [11, 12], and in the municipality of Trento a residual waste quantity of 102 kg per capita and year was also reported [13]. In Flanders, Belgium, pre-paid sacks were used in a simplified weight-based PAYT system, significantly increasing the recycling rate up to 71 %, and reducing the residual waste quantity down to 149 kg/capita x yr [14]. Pre-paid sack systems show a significant decrease in the quantity of residual

waste, but the achievable figures are lower compared to optimum weight-based systems such as implemented in Aschaffenburg: i.e. 53.5 % in Switzerland, 44 % in Belgium and 38 % in Spain [2]. The applicability of PAYT is likely to be affected by geographical considerations. For instance, in a country with a hot climate, the collection frequency for bio waste will need to be higher for hygiene reasons, which may be associated with higher collection costs. However, in that case, if a high degree of bio waste separation is achieved, the collection frequency for residual waste would be lower, compensating partially the increase of costs.

Under certain circumstances, the legislative framework is not compatible with the development of PAYT schemes. This particular case arises in the United Kingdom, where a debate continues about the applicability of PAYT at local level [29]. A well-studied alternative to PAYT in the UK that avoids legal barriers is the implementation of recycling incentive schemes. They consist of payments or rewards given to users to encourage people to recycle more, typically consisting of vouchers paid to individuals or communities, or waste management fee refunds paid back to individuals. The behavioural aspect is important here: while PAYT addresses a whole range of citizens, with different awareness levels, recycling incentive schemes have most impact on users with a high level of awareness who are responsive and increase their recyclables collection rate accordingly [9]. The experience gained with recycling incentive schemes shows that they can be considered a BEMP, due to their performance and costs, but cannot be benchmarked against PAYT due to their different scope and applicability.

Finally, in the example of the County of Aschaffenburg, it is remarkable that despite the very low quantities of residual waste achieved, implementation of PAYT appeared to have no significant effect on the total amount of waste generated and managed by the county. This has been recorded previously for other examples of PAYT. In other words, waste prevention cannot be achieved through PAYT implementation, but requires of other policies developed at national or regional level (e.g. product policies and waste prevention plans) and more targeted actions at the local level such as awareness raising campaigns, reuse initiatives, second hand markets, repair cafés, etc.

Acknowledgments: The Joint Research Centre of the European Commission is acknowledged for the funding received through the contract 154367 2014 A08 DE.

Author Contributions: J. Morlok is responsible for municipal waste management in the County of Aschaffenburg and has provided the data shown in the paper, and provided feedback on the text. H. Schoenberger, D. Styles and J.L. Galvez-Martos have drafted the text, performed the analysis of the received data and the literature review. B. Zeschmar-Lahl has coordinated and led the work, contributed to the text, provided feedback and proof-read the article before submission.

Conflicts of Interest: The authors declare no conflict of interest.

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