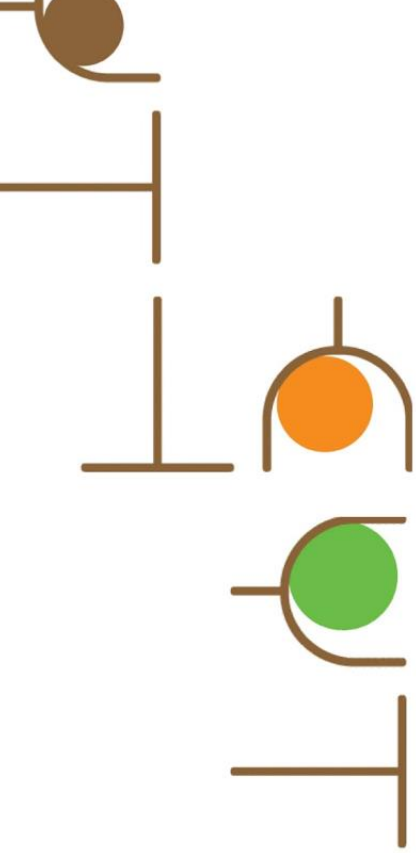

# Costs and benefits resulting from the implementation of PAYT schemes

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Politécnico de Coimbra

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**CONTENTS**

# 1. INTRODUCTION

Several literatures have already applied a waste full cost accountability (FCA) methodology in the evaluation of PAYT solutions. The handbook of FCA for Municipal Solid Waste Management (MSWM) from United States Environmental Protection Agency (USEPA) proposes that FCA should focus on the flow of economic resources (assets) and costs, since MSWM may induce a considerable economic-financial effort both before and after operating life of management facilities, “focusing solely on the use of current financial resources misrepresents the costs of MSW management and can be misleading”.

D’Onza et al. (2015) applies the FCA method to analyse a separated waste collection efficiency. So that, they propose a standard cost and actual quantities to calculate the collection costs of separate and undifferentiated waste. Karagiannidis et al. (2008), in a PAYT experience in Panorama Municipality, Greece, considers a FCA analysis to evaluate all available alternative, in terms of environmental, economic and social impacts, in order to provide adequate information to the decision makers.

The handbook on the implementation of Pay-as-you-throw as a tool for urban waste management emphasises that “introducing PAYT has far-reaching implications on the development of costs and financial flows related to the waste management service as well as on the waste disposal logistics” (Reichenbach et al. 2004).

In this scope, our analysis follows FCA in order to evaluate the impact of the implementation of a sustainable waste management and the potential application of PAYT schemes in a wider scale. This framework requires the consideration of tangible and intangible costs/benefits of the LIFE PAYT project from the different municipalities and their solid waste management process. Thus, carrying out this methodology we are proposing a standard cost benefit analysis that can be

replicated in other similar communities and municipalities with a PAYT waste management implementation.

The main goal of this work is to identify advantages and disadvantages of each system applied in the different municipalities: Aveiro, Condeixa-a-Nova, Vrilissia and Larnaka. Thus, we've created four models for a "theoretical municipality", where we tested different collection systems and technical solutions, based on data generated by the LIFE PAYT project.

## 2. METHODOLOGY

A “theoretical” municipality” was modelled and different technical PAYT solutions were tested. The following table shows the main characteristics of this municipality, in terms of population and the amount of solid waste production (before PAYT system implementation).

**Table 1:** Characterization of the “theoretical municipality”

| **Population** | **100 000 inhabitants** |
|---|---|
| **Total Solid Waste** | 47 757 t |
| **Waste/capita** | 0,47 t per capita |
| **Number of non-domestic waste producer** | 4 006 producers |
| **Recycling rate of municipal waste** | 9,2% |
| **Waste collection (before PAYT)** | |
| **Unsorted** | Kerbside collective containers for unsorted waste (units/hab) |
| **Recyclables** | Bring-banks for recyclables (Units/ hab) – cost not included (not responsibility of the municipality) |

In this context, we’ve created four models to test the PAYT solutions that the LIFE PAYT project put into practice, both for domestic and non-domestic producers, as well as for collection schemes based on volume or weight, with conditioned access collective containers or door-to-door collection with bags. Table 2 summarizes the models created, considering the pilots of Aveiro, Condeixa-a-Nova, Vrilissia and Larnaka:

**Table 2:** PAYT solutions tested in the "Theoretical municipality"

| Model | PAYT solution | Waste producer targeted | Data source |
|---|---|---|---|
| **Model 1** | Change all Kerbside open access collective containers to closed access container, opening with RFID (volume based) | Domestic + non-domestic | Based on LIFE PAYT Aveiro pilot. |
| **Model 2** | Equal to scenario 1, but weight based | Domestic + non-domestic | Based on LIFE PAYT Vrillissia pilot. |
| **Model 3** | Door-to door with bags | Domestic + non-domestic | Based on LIFE PAYT Larnaka pilot. |
| **Model 4** | Door-to-door with identified containers | Non-domestic | Based on LIFE PAYT Condeixa-a-Nova pilot. |

Initially, historical data (from 2017 to 2020) was collected regarding costs and revenues from the different Municipal Solid Waste Management (MSWM) and the LIFE PAYT investments were extrapolated from the 4 pilots.

Here, the year of 2022 is considered the year of the investment, costs and benefits were estimated for ten years (from 2022 to 2032), taking into account annual population growth rate, annual solid waste growth rate, MSW collection, treatment, taxes and administrative costs and tariff revenues estimations. The main PAYT benefits recognised in the literature were also estimated in this exercise concerning the reduction of amounts of residual waste and the increase of source separated recyclables in the long run (Reichenbach et al. 2004).

The difference between those cashflows generated by the annual cost and benefit estimations enabled us to calculate the net present value (NPV) of this project, applying a discount rate that could be earn in alternative investments

during the selected period of analysis. So that, this indicator gave us the information about the profitability and feasibility of the PAYT solution for the different models.

Our cost and benefit analysis follows a methodology based in the calculation of tangible costs and benefits throughout the consideration of assumptions according to the different typology of investment in current (OPEX) and noncurrent assets (CAPEX) for MSWM.

**Comparing Scenarios:**

For the four models, our analysis considers three different scenarios of investment:

1 – PAYT and Biowaste investment,
2 – Only PAYT investment,
3 – Business-as-Usual (BAU).

The first scenario is the basis scenario, that considers the investment of a PAYT solution for the entire Municipality – CAPEX and OPEX -, and the consideration of a Biowaste investment plan. These scenarios allow us to compare tariffs per household that waste producers will face in the long run, as well as comparing the economic and financial indicators for the MSWM, providing information if we should invest or not in a PAYT system.

**Costs Estimation:**

In the four models, the estimation for MSW collection cost assumed the contract terms of Aveiro Municipality firmed with a MSW collection company for the next

years. In 2022, the cost per tons is 26,59€/t and the following years should be updated by the annual inflation rate. Similarly, the MSW treatment cost considers 46,68€/t in the year of 2022, imposed by the management entity for the Aveiro Municipality. The estimation of Taxes follows the current Portuguese Legislation for MSWM: 22€/t in 2022, 25€/t in 2023, 30€/t in 2024 and 35€/t for 2025 and following years.

In terms of CAPEX, we assume that initial investment in PAYT are related to closed access containers with RFID technology, volume based (model 1) or weight based (model 2), telemetry (model 2 and 4), monitoring and tracking software (for all models) and other equipment needed for the different PAYT schemes.

In terms of OPEX, the maintenance costs reflect the cost of containers cleaning, software maintenance, biowaste and door-to-door paper bags, insurance, taxes and inspection costs, consulting and technical support costs during PAYT implementation. All these costs are updated by the annual inflation rate.

The public education campaign estimation cost was calculated considering the “Fundo Ambiental” (Portuguese Governmental Entity for Environmental Funds management) estimation tool for biowaste awareness campaigns costs. So that, we use it as a proxy for this PAYT solution.

Administrative costs were calculated considering personnel cost allocated to administrative tasks in the MSWM, adding an incremental cost on hiring workers that will be necessary to handle with the new data generated in the PAYT system, such as data supplied for accounting and individual billing process based on the individual waste measurements.

The following table sums up the cost assumptions.

**Table 3:** Cost Assumptions

| Estimation | Assessment factor | Assets | Assumptions |
|---|---|---|---|
| Up-Front Costs | Investment | Equipment | **Containers:** closed access containers with RFID technology, volume based (model 1) or weight based (model 2).<br><br>**Other Equipment:** LIFE PAYT prototype costs |
| | | Software | Telemetry (model 2 and 4), monitoring and tracking software (for all models). |
| | Operation Costs | Collection Cost | In 2022, is 26,59€/t and the following years updated by the annual inflation rate. |
| | | Treatment Cost | In 2022, is 46,68€/t and the following years. |
| | | Tax | 22€/t in 2022, 25€/t in 2023, 30€/t in 2024 and 35€/t for 2025 and following years. |
| | | Public Education Campaigns | Proxy - Fundo Ambiental Estimation for BioWaste Investments |
| | | Equipment Maintenance | We use a market benchmarking unit costs (54€/container). |
| | | Other Costs | LIFE PAYT prototype costs.<br>Cost of door-to-door collection based on market survey (PT) 60€. |
| | | Administrative wages, salaries and benefits | Incremental cost in hiring workers that will be necessary to handle with the new data generated in the PAYT system. |

**Benefits Estimation:**

Tariff revenues covers 100% of operating costs subtracted from avoided costs and investment deducted from co-funding component, to compare annually the evolution of tariffs per household/establishment within the three scenarios for each model. Co-funding is an investment incentive component that municipalities are eligible in several funding programs. Typically, this type of financing could reach 60% (occasionally non-refundable) and covers investment in equipment, technology, innovation, software, consulting services and awareness campaigns.

Several Literature refers that the main goal of PAYT is the reduction of the total amount of household waste and the increase of source separated recyclables. So that, we've measured a composing three effects annual reduction rate due to PAYT and Biowaste implementation, to calculate PAYT Benefits or the so-called Avoided Costs.

The first effect considers a reduction of unsorted waste due to diversion of recyclable materials to separate collection (% of unsorted MSW). This effect will

be produced through the monitoring actions and awareness campaigns that a PAYT project induces. It is estimated that the impact of these actions on waste reduction is between 13.7% and 29.2%, with a greater impact on models with door-to-door collection (models 3 and 4).

The second effect calculates a reduction of unsorted waste due to prevention (% of unsorted MSW). Once again, this effect will be produced through the monitoring actions and awareness campaigns induce by PAYT. It is estimated that the impact of these actions on waste reduction is between 1% and 5%.

The third effect considers a reduction of unsorted waste due to diversion of biowaste to separate collection (% of unsorted MSW). We consider that the implementation of PAYT solutions will encourage and boost biowaste collection actions. This impact could amount to a reduction of total waste, between 11.3%-18.1% per year.

The following table sums up the benefits assumption:

**Table 4:** Benefit Assumptions

| Estimation | Assessment factor | Indicators | Assumptions |
|---|---|---|---|
| Benefits | **Tariff Revenue** | Tariff per Household/establishment | Tariff revenues covers 100% of operating costs subtracted from avoided costs and investment deducted from co-funding component |
| | **Co-Funding** | % of co-funding investment and public education campaigns | Covers 60% of the investment |
| | **Avoided Costs**<br>% Total waste reduction due to PAYT implementation + Biowaste separate collection | Reduction of unsorted waste due to diversion of recyclable materials to separate collection (% of unsorted MSW) | Monitorisation of waste generation + Awareness campaigns + Door-to-door collection [13,7%-29,2%] |
| | | Reduction of unsorted waste due to prevention (% of unsorted MSW) | Monitorisation of waste generation + Awareness campaigns [1% - 5%] |
| | | Reduction of unsorted waste due to diversion of biowaste to separate collection (% of unsorted MSW) | Biowaste collection [11,3% - 18,1%] |

## 3. RESULTS

We've predicted an average annual population growth rate of 0,319%. Therefore, the number of households and the total amount of solid waste will also increase. We assume that after the year of investment (2022), the Municipality will cover the total amount of solid waste within the PAYT solution. The following table shows this evolution in detail:

**Table 5:** Evolution of Population, Households and Solid Waste

| Socio Demographic Indicators | | 2022 | 2023 | 2024 | .... | 2031 | 2032 |
|---|---|---|---|---|---|---|---|
| Resident Population | nº | 100000 | 100 319 | 100 640 | .... | 102 911 | 103 239 |
| Annual population growth rate | % | 1,197% | 0,319% | 0,319% | .... | 0,319% | 0,319% |
| Households / Establishments with contracts | nº | 47 124 | 47 275 | 47 426 | .... | 48 496 | 48 651 |
| Total Solid Waste (unsorted + sorted collection) | | | | | …. | | |
| Total amount of solid waste collected | t | 47 757 | 47 910 | 48 063 | .... | 49 147 | 49 304 |
| Total amount of unsorted solid waste + Biowaste | t | 44 658 | 44 800 | 44 943 | .... | 45 957 | 46 104 |
| PAYT Coverage Rate | % | 0% | 100% | 100% | ..... | 100% | 100% |

The majority of the investment is allocated to the acquisition, installation and configuration of equipment and software. Public Education campaigns and equipment maintenance correspond to the majority of the OPEX fraction. In terms of cash flows, we incorporate the annual amortization of investments, according to the type of investment: 8 years for conditioned access containers, 10 years for vehicles, 6 years for other equipment and 4 years for software.

In the following table we detailed the investment assets for PAYT and Biowaste investments:

**Table 6:** Investment Cost (€)

| | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| Total Investment | 2 253 826 € | 2 305 171 € | 1 102 708 € | 316 188 € |
| PAYT | 1 614 914 € | 1 666 259 € | 463 796 € | 181 139 € |
| Containers | 1 576 800 € | 1 576 800 € | 0 € | 44 325 € |
| Vehicles | 0 € | 0 € | 0 € | 0 € |
| Other Equipment | 38 114 € | 45 185 € | 459 232 € | 105 954 € |
| Software | 0 € | 44 274 € | 4 565 € | 30 860 € |
| BioWaste | 638 912 € | 638 912 € | 638 912 € | 135 049 € |
| Containers | 575 600 € | 575 600 € | 575 600 € | 69 265 € |
| Vehicles | 0 € | 0 € | 0 € | 0 € |
| Other Equipment | 357 € | 357 € | 357 € | 2 829 € |
| Software | 62 955 € | 62 955 € | 62 955 € | 62 955 € |

In table 7, below, we summarize the cash flows of each model in terms of benefits and costs. In terms of benefits, the domestic sector models (models 1 to 3) are very similar. The tariff per household/establishment are comparable and show a decreasing trend if we invest in a scenario with PAYT solution and biowaste strategy (scenario 1).

Models 1 and 2 correspond to a collective waste collection, despite having different technologies in terms of volume (model 1) and weight (model 2). The door-to-door collection created in the model 3 offers a less investment effort, but at a higher operating cost, due to the acquisition of a considerable number of bags needed to the respective number of households and establishments. Though, at the end of the period, the tariff is very similar to the other domestic models.

Model 4 created for the **non-domestic** sector is not comparable with the previous ones. However, we show that also in this sector it is reliable to invest on PAYT schemes to achieve sustainable trajectories in MSWM.

The key element of this comparison lies on the observation of the avoided costs induced by the PAYT system. If these effects will not be observed, this solution may be compromised. The second important component, in terms of cash flows for municipalities, is the possibility of their investments being subsidized by co-funding programs available in the various states of the European Union.

**Table 7:** Cashflows for PAYT & Biowaste implementation 2022 – 2032

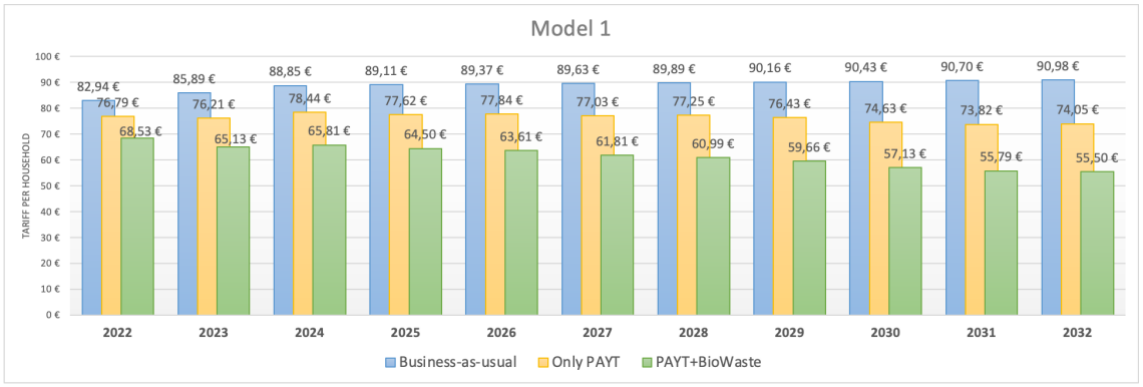
| Model 1 | 2022 | 2023 | 2024 | 2025 | .... | 2031 | 2032 |
|---|---|---|---|---|---|---|---|
| **Total Investment** | **291 201 €** | **291 201 €** | **291 201 €** | **291 201 €** | | **0 €** | **0 €** |
| **Benefits** | **4 783 651 €** | **4 540 600 €** | **4 695 213 €** | **4 721 903 €** | **....** | **4 596 253 €** | **4 624 775 €** |
| Tariff Income | 3 229 299 € | 3 078 844 € | 3 121 148 € | 3 068 480 € | .... | 2 705 813 € | 2 700 200 € |
| Co-Funding | 410 788 € | 210 997 € | 211 113 € | 211 229 € | .... | 37 214 € | 37 333 € |
| Avoided Costs | 1 143 564 € | 1 250 758 € | 1 362 952 € | 1 442 194 € | .... | 1 853 226 € | 1 887 243 € |
| **Operating Costs** | **4 492 451 €** | **4 249 399 €** | **4 404 013 €** | **4 430 703 €** | **....** | **4 596 253 €** | **4 624 775 €** |
| **Tariff per household/establishment** | **69 €** | **65 €** | **66 €** | **64 €** | **....** | **56 €** | **56 €** |

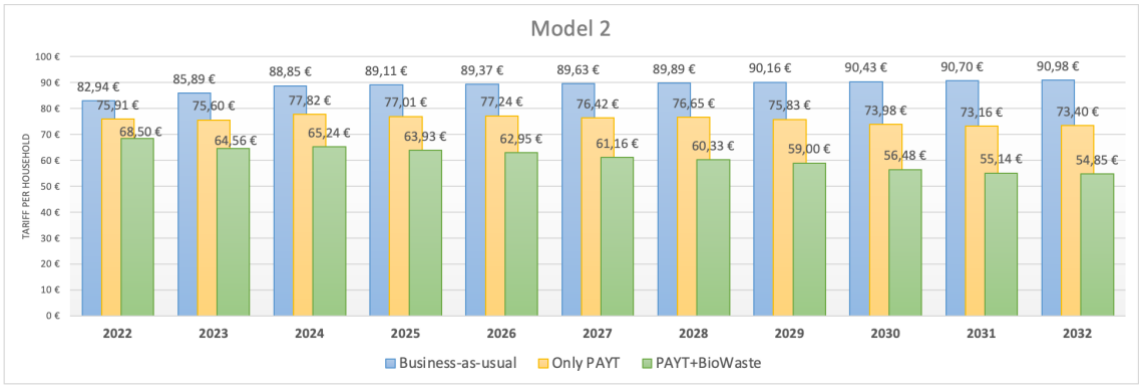
| Model 2 | 2022 | 2023 | 2024 | 2025 | .... | 2031 | 2032 |
|---|---|---|---|---|---|---|---|
| **Total Investment** | **303 448 €** | **303 448 €** | **303 448 €** | **303 448 €** | | **0 €** | **0 €** |
| **Benefits** | **4 789 892 €** | **4 520 998 €** | **4 675 611 €** | **4 702 302 €** | **....** | **4 564 405 €** | **4 592 927 €** |
| Tariff Income | 3 228 192 € | 3 051 894 € | 3 094 198 € | 3 041 530 € | .... | 2 673 965 € | 2 668 351 € |
| Co-Funding | 418 136 € | 218 346 € | 218 461 € | 218 578 € | .... | 37 214 € | 37 333 € |
| Avoided Costs | 1 143 564 € | 1 250 758 € | 1 362 952 € | 1 442 194 € | .... | 1 853 226 € | 1 887 243 € |
| **Operating Costs** | **4 486 445 €** | **4 217 550 €** | **4 372 164 €** | **4 398 854 €** | **....** | **4 452 995 €** | **4 480 452 €** |
| **Tariff per household/establishment** | **69 €** | **65 €** | **65 €** | **64 €** | **....** | **61 €** | **60 €** |

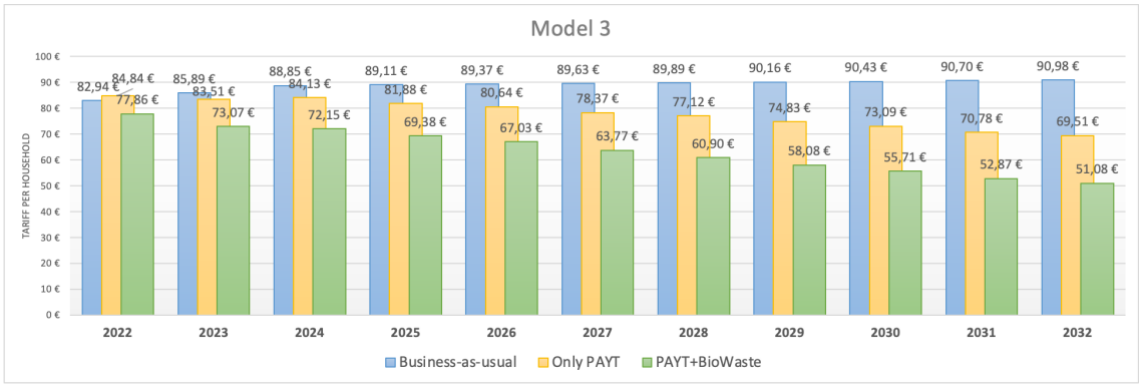
| Model 3 | 2022 | 2023 | 2024 | 2025 | .... | 2031 | 2032 |
|---|---|---|---|---|---|---|---|
| **Total Investment** | **165 428 €** | **165 428 €** | **165 428 €** | **165 428 €** | | **0 €** | **0 €** |
| **Benefits** | **5 239 240 €** | **4 998 848 €** | **5 152 745 €** | **5 178 712 €** | **....** | **5 174 337 €** | **5 202 083 €** |
| Tariff Income | 3 669 286 € | 3 454 129 € | 3 421 574 € | 3 300 936 € | .... | 2 564 170 € | 2 484 956 € |
| Co-Funding | 335 325 € | 135 534 € | 135 650 € | 135 766 € | .... | 37 214 € | 37 333 € |
| Avoided Costs | 1 234 629 € | 1 409 186 € | 1 595 521 € | 1 742 010 € | .... | 2 572 953 € | 2 679 794 € |
| **Operating Costs** | **5 073 812 €** | **4 833 420 €** | **4 987 317 €** | **5 013 284 €** | **....** | **5 065 955 €** | **5 092 666 €** |
| **Tariff per household/establishment** | **78 €** | **73 €** | **72 €** | **69 €** | **....** | **64 €** | **61 €** |

| Model 4 | 2022 | 2023 | 2024 | 2025 | .... | 2031 | 2032 |
|---|---|---|---|---|---|---|---|
| **Total Investment** | **55 783 €** | **55 783 €** | **55 783 €** | **55 783 €** | | **0 €** | **0 €** |
| **Benefits** | **953 188 €** | **896 377 €** | **924 743 €** | **930 327 €** | **....** | **909 185 €** | **915 155 €** |
| Tariff Income | 676 412 € | 615 794 € | 615 619 € | 595 597 € | .... | 474 822 € | 462 198 € |
| Co-Funding | 60 717 € | 37 657 € | 37 670 € | 37 684 € | .... | 4 295 € | 4 309 € |
| Avoided Costs | 216 060 € | 242 926 € | 271 455 € | 297 046 € | .... | 430 068 € | 448 648 € |
| **Operating Costs** | **897 405 €** | **840 594 €** | **868 961 €** | **874 544 €** | **....** | **885 871 €** | **891 616 €** |
| **Tariff per household/establishment** | **169 €** | **153 €** | **153 €** | **147 €** | **....** | **136 €** | **131 €** |

In figure 1, we demonstrate that the worst-case scenario is not to invest, since it will achieve unsustainable growth of tariffs if the Theoretical Municipality maintain its business-as-usual modus operandi, with heavy impacts in environmental and social costs, in the long run. In annexes 2 to 5, we show the investment and cost shares in the total amount of the tariffs per household/establishment.



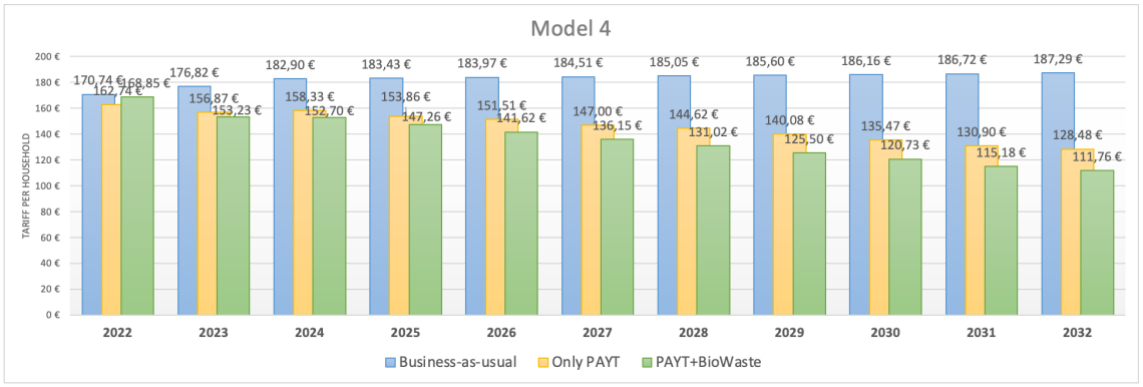




**Figure 1:** Tariff per household comparison

## 4. CONCLUDING REMARKS AND FURTHER DISCUSSION

In this study, we've developed an analysis for a Theoretical Municipality evaluating the economic and financial impact in investing in a PAYT solution and considering a biowaste strategy, focusing on the estimation of their cost structure in the following years. We've created a tool that can be replicated in similar experiences with PAYT implementation. Our results must be interpreted considering our assumptions, described in the methodology chapter.

Our findings suggest that if population will grow, the total amount of solid waste will also increase. At the same time, the municipality will face greater operating costs, due to expected rising collection, treatment costs and taxes, in the BAU scenario.

We demonstrate that all PAYT system models introduce a sustainable MSWM in the long run. It will generate avoided costs concerning the reduction of the total amount of household/establishment waste and the increase of source separated recyclables. Otherwise, with no PAYT investment, the Municipality will face unsustainable MSWM path.

Notwithstanding, we demonstrate that rising operating costs must be contradicted by reducing the total solid waste and consider new tariff revenues strategies using PAYT schemes and follow a biowaste strategy. If nothing changes in the next years, we will face severe impacts on the degradation of the environment, social cohesion, and economic-financial instability in the MSWM.

For further discussion and consider our limitations in this analysis, on one hand, we can improve our model introducing intangible benefits and costs, as well as follow a wider benchmarking analysis for the investment cost, among other PAYT projects, that will allow us to calculate economic and financial indicators more accurately. On other hand, we can introduce a case sensitivity analysis to determine statistically significant scenarios of occurring.

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# 6. ANNEXES

## ANNEX 1: COST AND BENEFIT TOOL /SIMULATOR FOR PAYT SOLUTIONS

Model 1 - Simulador_PAYT_Biowaste_Aveiro_vfinal.xls

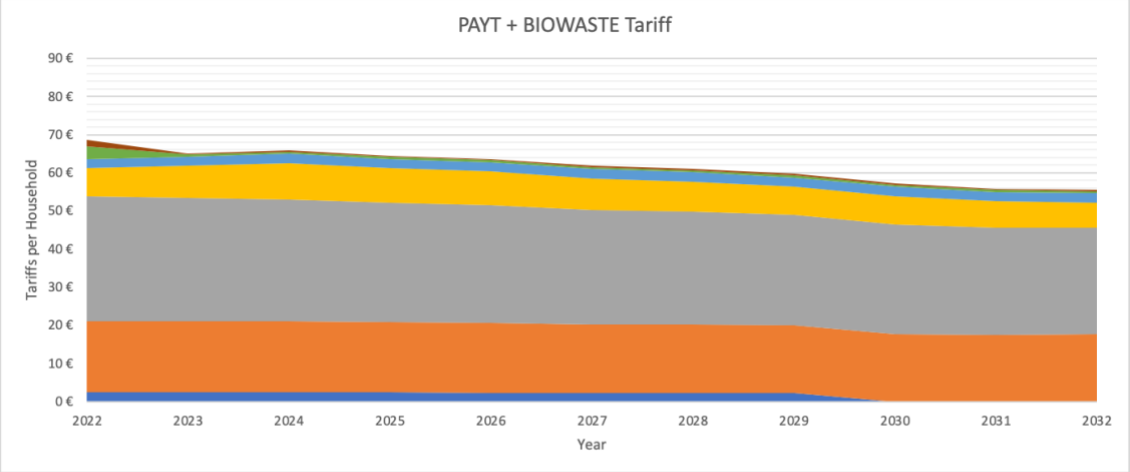
Model 2 - Simulador_PAYT_Biowaste_Vrillissia_vfinal.xls

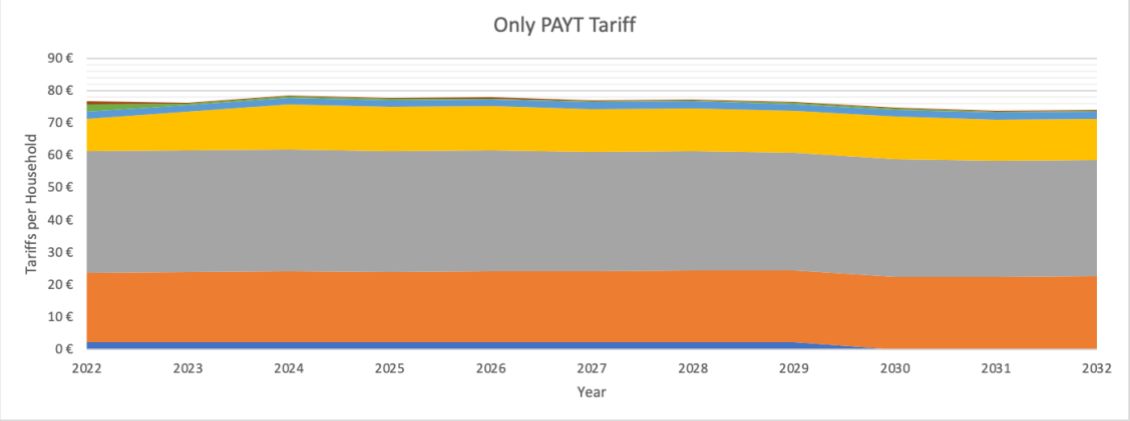
Model 3 - Simulador_PAYT_Biowaste_Larnaka_vfinal.xls

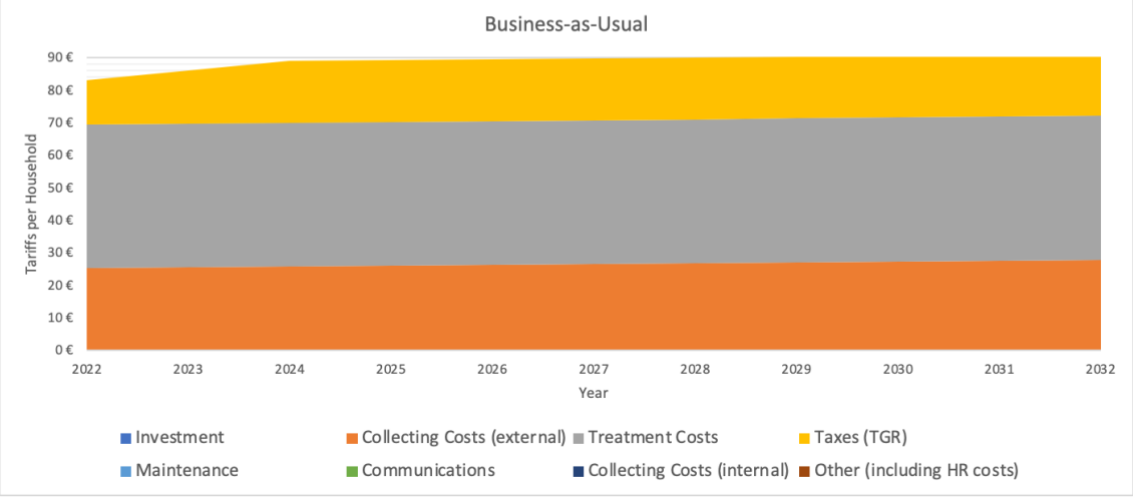
Model 4 - Simulador_PAYT_Biowaste_Condeixa_vfinal.xls

# ANNEX 2: DETAILED TARIFF PER HOUSEHOLD AND PER SCENARIO

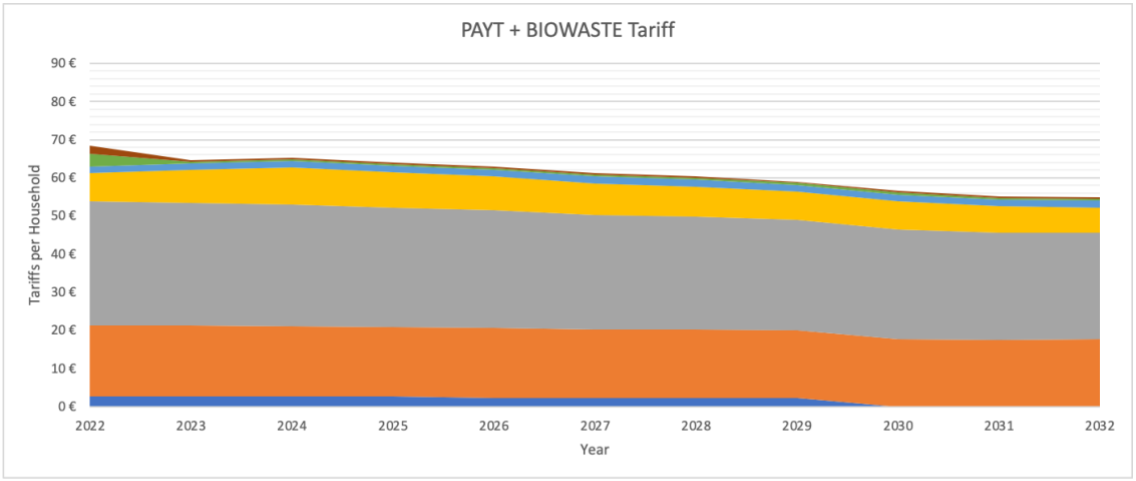
## Model 1 - Detailed Tariff per household and per Scenario (Aveiro)

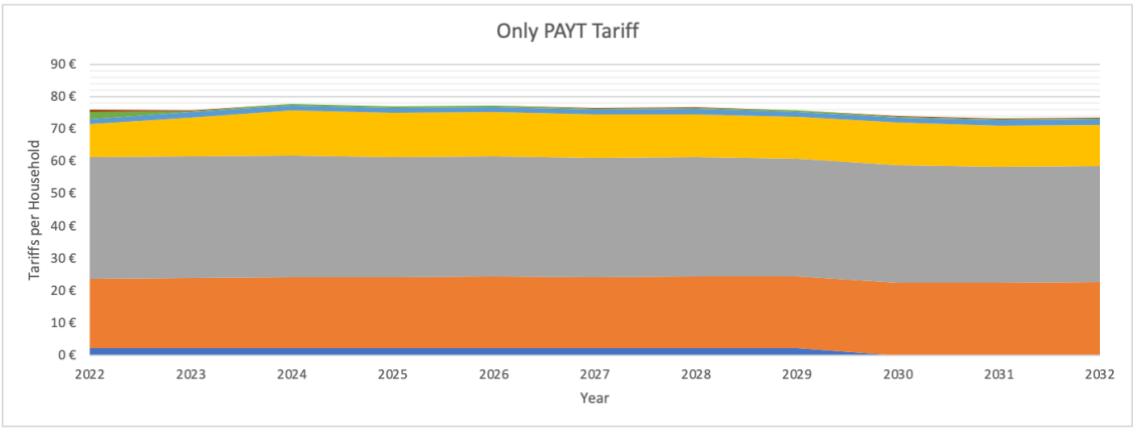


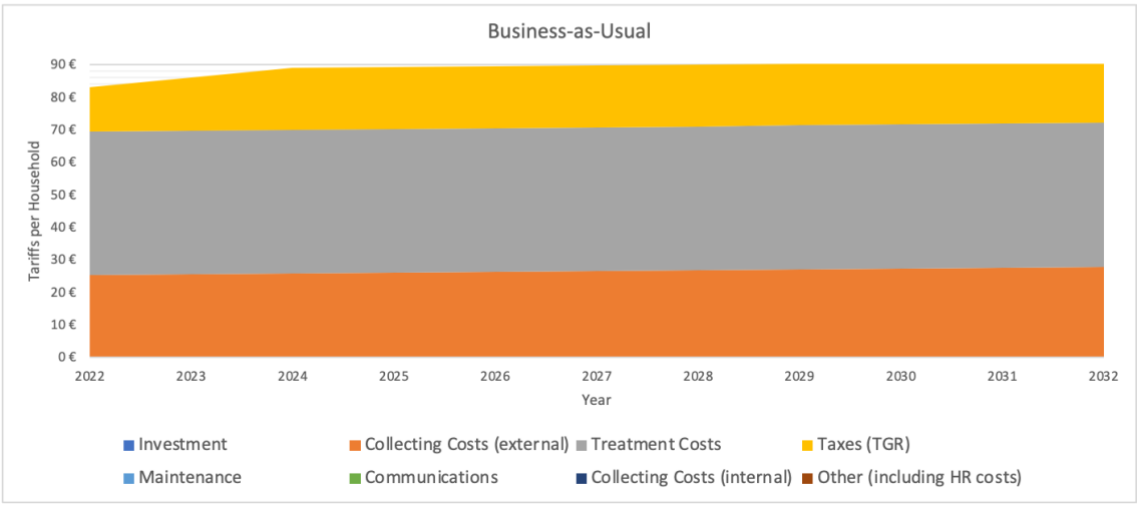



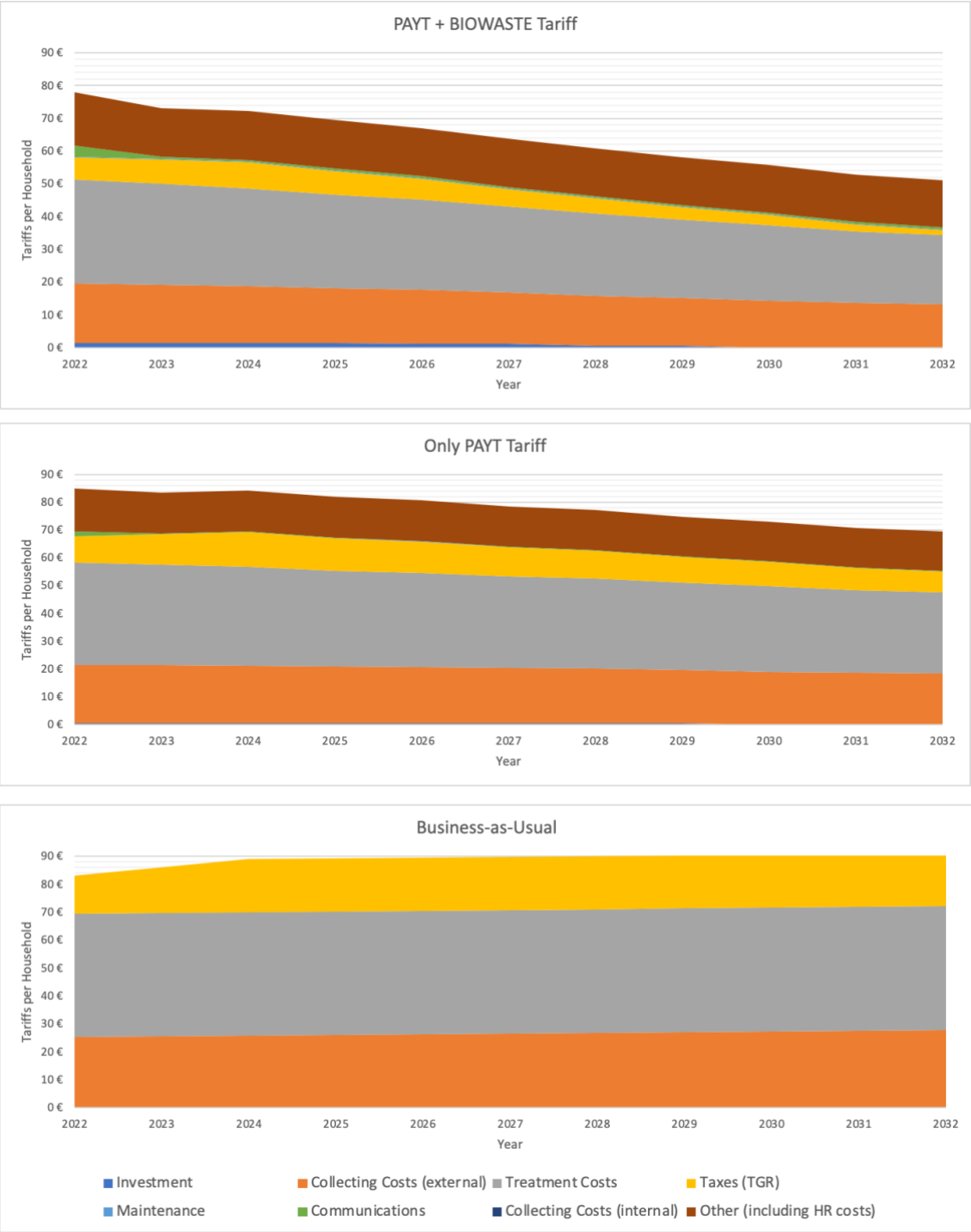
Model 2 - Detailed Tariff per household and per Scenario (Vrilissia)



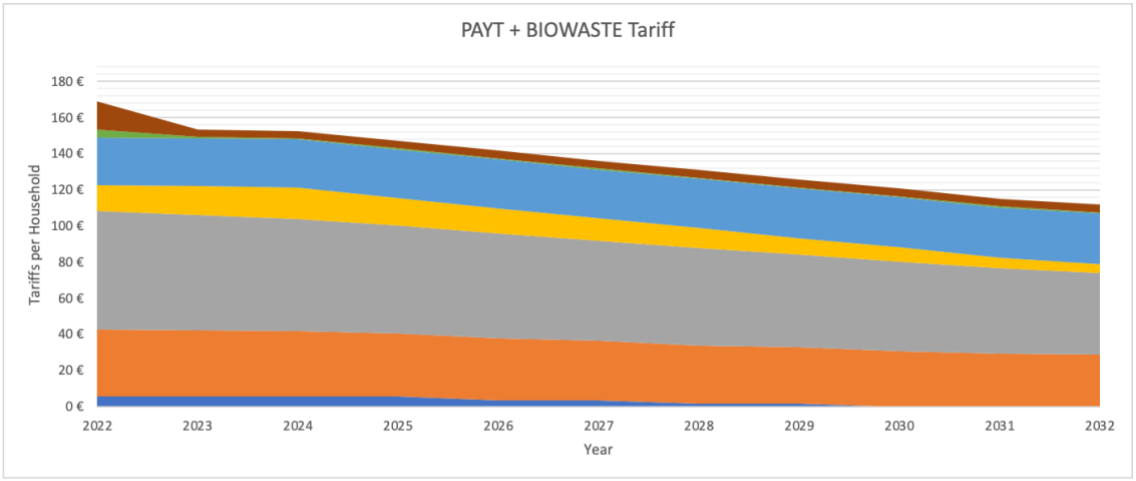



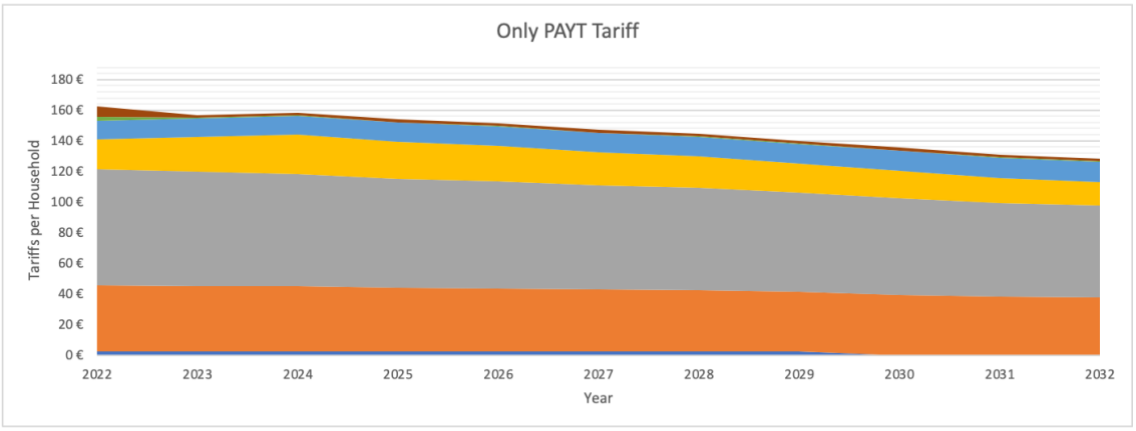



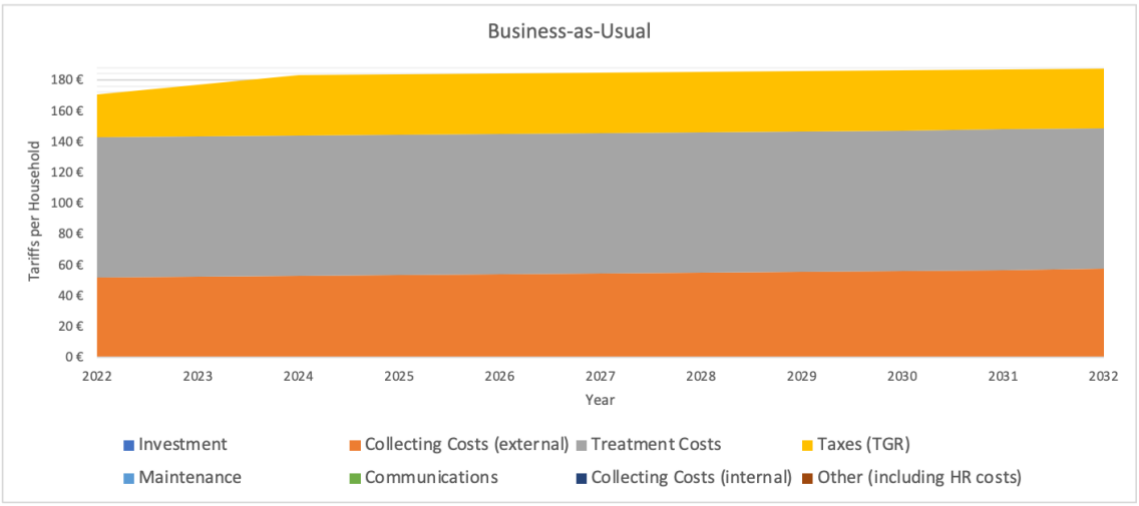
Model 3 - Detailed Tariff per household and per Scenario (Larnaka)



Model 4 - Detailed Tariff per household and per Scenario (Condeixa)



# Tool to reduce waste in South Europe

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