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EVALUATION OF THE IMPACT OF SEPARATE COLLECTION AND RECYCLING ON THE EFFICIENCY OF WASTE MANAGEMENT SERVICES IN SPANISH MUNICIPALITIES

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OUTLINE

1. CONTEXT
2. OBJECTIVES
3. METHODOLOGY
4. EMPIRICAL APPLICATION
5. RESULTS
6. CONCLUSIONS

1. CONTEXT

Sustainable Development Goals 2030

- ✓ Reduction and recycling waste to minimize the impact of cities on the global climate system.
- ✓ By 2030, reduce the negative environmental impact per capita of cities, including paying particular attention to air quality and municipal waste management.
- ✓ By 2030, significantly reduce the generation of waste through prevention, reduction, recycling, and reuse activities.

1. CONTEXT

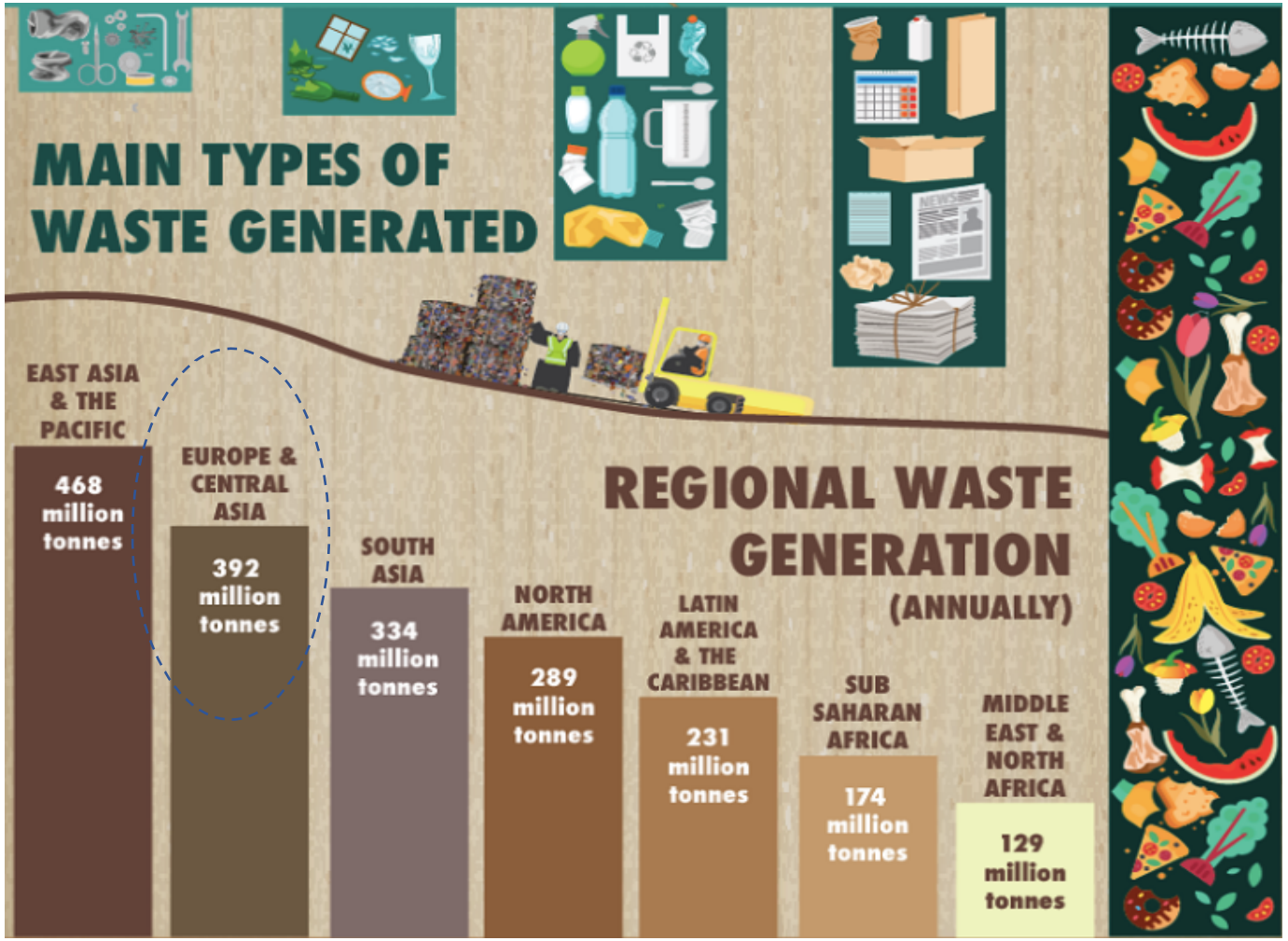


Figure 1. World Bank Infographics (2018): What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050

1. CONTEXT

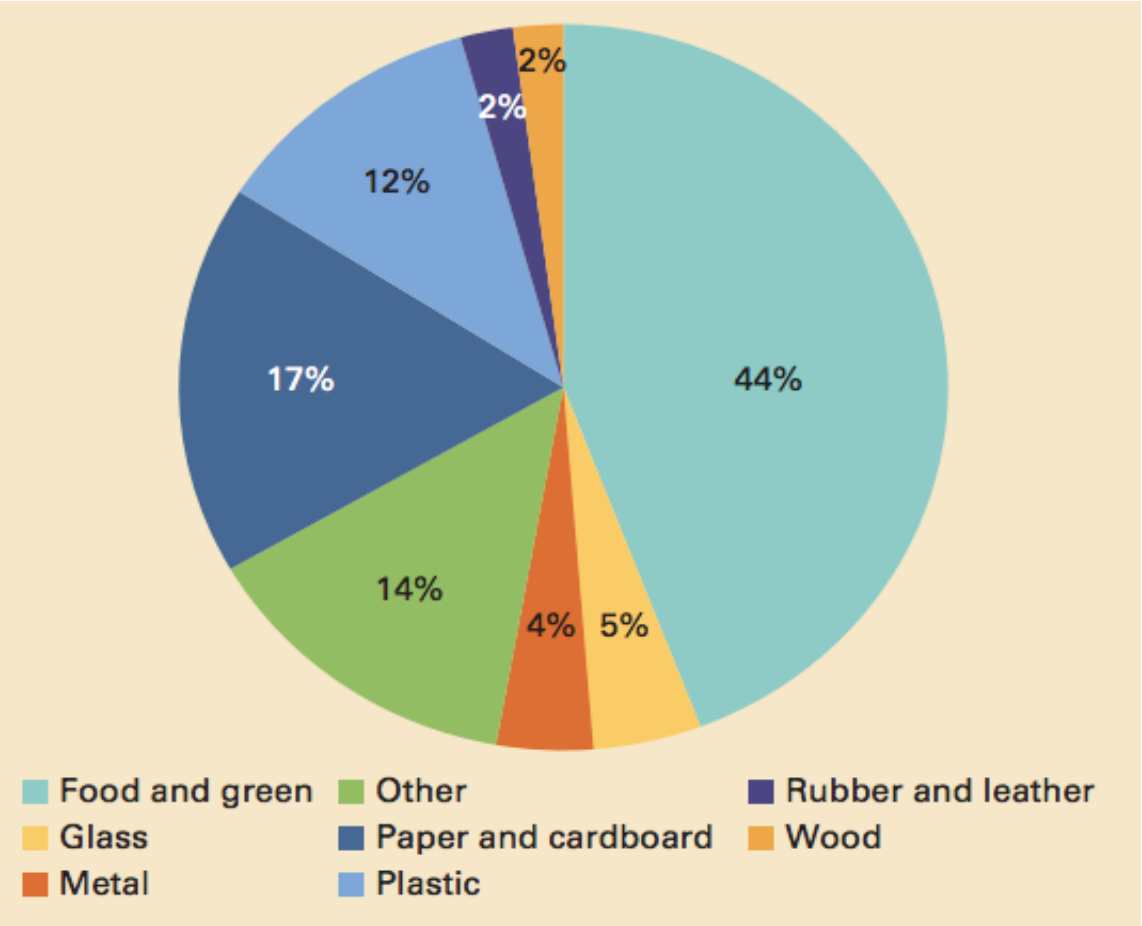


Figure 2. Global Waste Composition percent: What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050

1. CONTEXT

	2016 Average	Min	Max
Sub-Saharan Africa	0.46	0.11	1.57
East Asia and Pacific	0.56	0.14	3.72
South Asia	0.52	0.17	1.44
Middle East and North Africa	0.81	0.44	1.83
Latin America and Caribbean	0.99	0.41	4.46
Europe and Central Asia	**1.18**	**0.27**	**4.45**
North America	2.21	1.94	4.54

Table 1. Ranges of Average National Waste Generation by Region kg/capita/day. Adaptation of What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050

1. CONTEXT

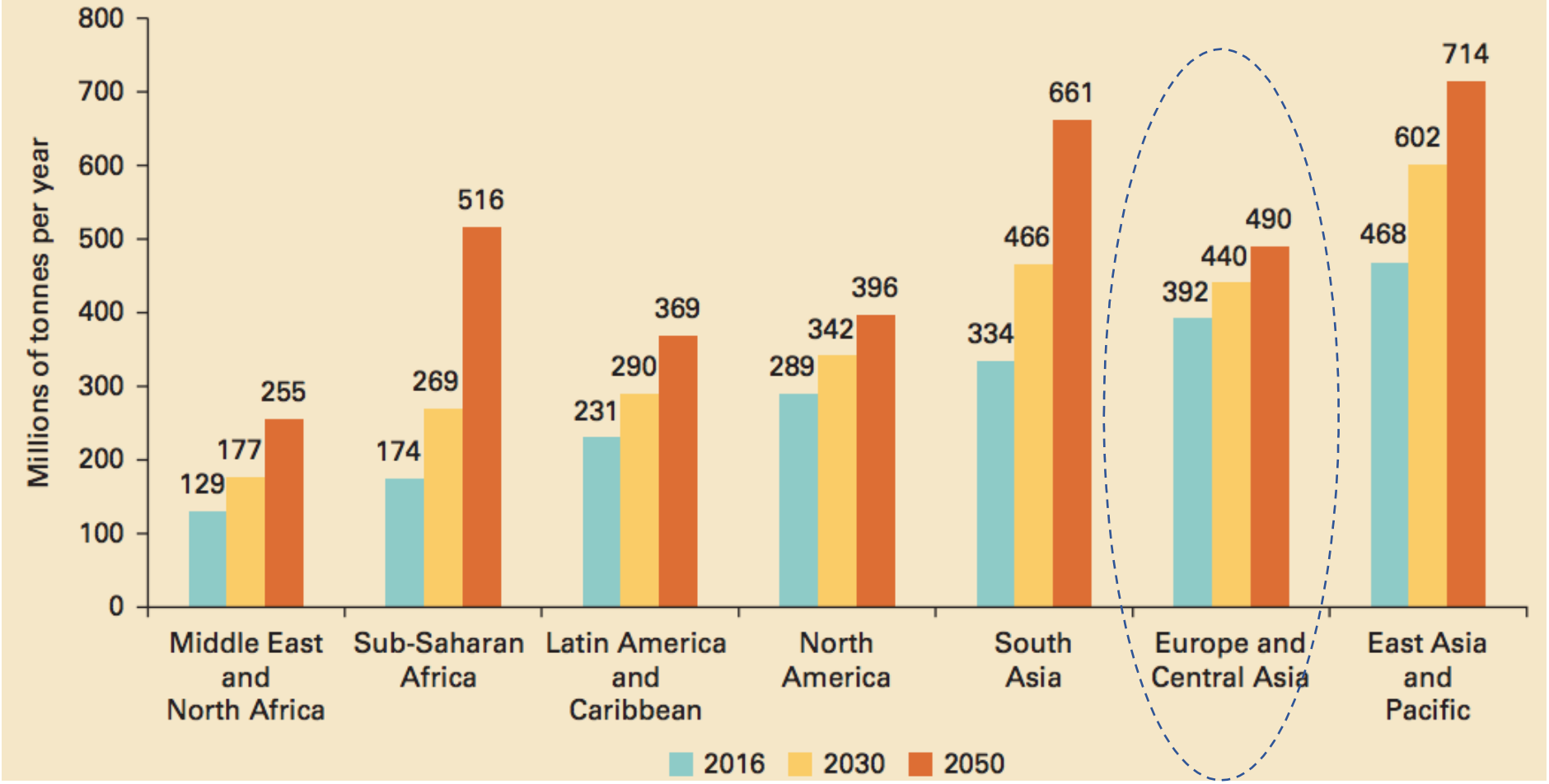
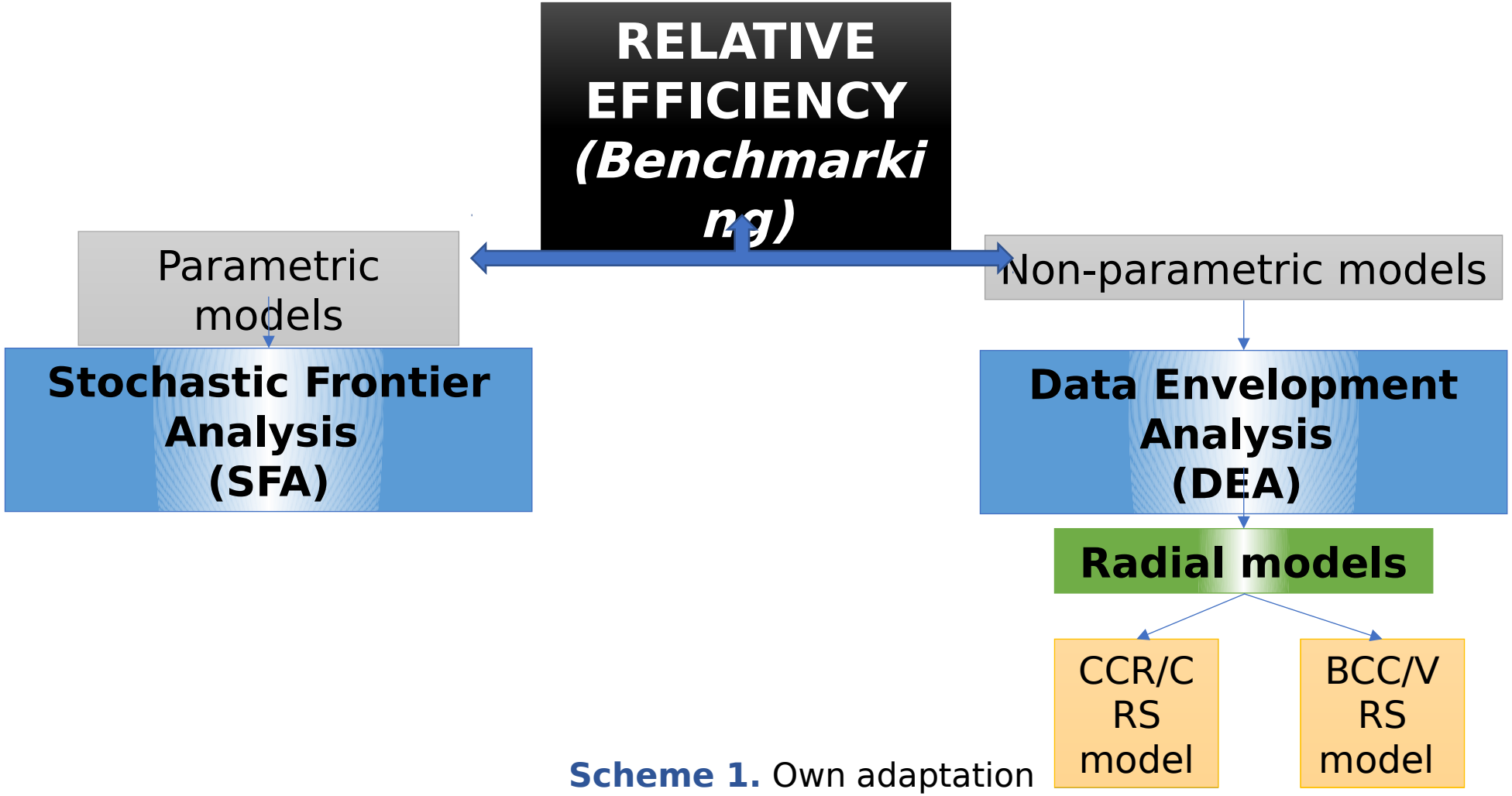


Figure 3. Total projected waste generation by Region: What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050

2. OBJECTIVE

- ✓ Evaluate the impact of the separately collection and recycling of waste in the performance of waste service provision by Spanish municipalities estimating two synthetic indexes namely: efficiency and eco-efficiency.

3. METHODOLOGY



Scheme 1. Own adaptation

3. METHODOLOGY

DEA: It is a non-parametric methodology based on linear programming, proposed for the first time by Charnes et al. (1978), to evaluate the efficiency of a series of decision-making units (DMU), based on linking inputs to outputs via efficiency frontier.

3. METHODOLOGY

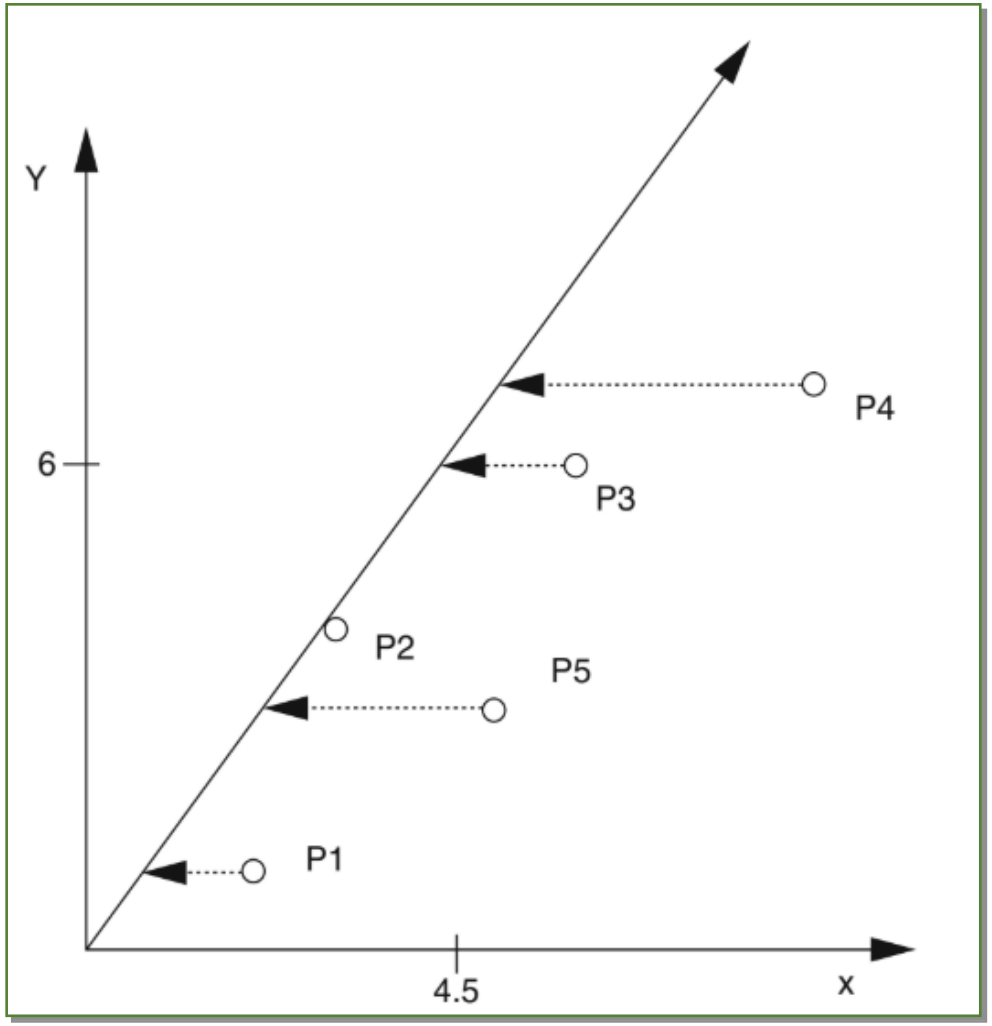


Figure 4. Projection to frontier for the input-oriented CCR model.

W.W. Cooper et al. 2011. *Handbook on Data Envelopment Analysis*.

3. METHODOLOGY

ESTIMATION OF EFFICIENCY SCORES

$$
\begin{aligned}
&Min\ \theta \\
&s.t. \\
&\textstyle\sum_{j=1}^{N} \lambda_j x_{ij} \leq \theta x_{i0} && 1 \leq i \leq M \\
&\textstyle\sum_{j=1}^{N} \lambda_j y_{rj} \geq y_{r0} && 1 \leq r \leq S \\
&\textstyle\sum_{j=1}^{N} \lambda_j = 1 \\
&\lambda_j \geq 0 && 1 \leq k \leq N
\end{aligned}
$$

Where,

θ: Indicates the efficiency of the municipality evaluated,

***M*:** Is the number of inputs used,

***S*:** Is the number of desirable outputs generated,

N: Is the number of DMUs analyzed, and

***λj*:** Is a set of intensity variables which represent the weighting of each analyzed municipalities

***j*:** Composition of the efficient frontier

$\theta \in (0, 1;$ a unit (municipalities) is efficient if its efficiency score (θ) equals unity, whereas it is inefficient if $0 \leq \theta < 1$.

3. METHODOLOGY

ESTIMATION OF ECO-EFFICIENCY SCORES

$$
\begin{aligned}
&Min\ \theta^* \\
&s.t. \\
&\textstyle\sum_{j=1}^{N} \lambda_j x_{ij} \leq \theta^* x_{i0} && 1 \leq i \leq M \\
&\textstyle\sum_{j=1}^{N} \lambda_j y_{rj} \geq y_{r0} && 1 \leq r \leq S \\
&\textstyle\sum_{j=1}^{N} \lambda_j b_{zj} = b_{z0} && 1 \leq z \leq H \\
&\textstyle\sum_{j=1}^{N} \lambda_j = 1 \\
&\lambda_j \geq 0 && 1 \leq k \leq N
\end{aligned}
$$

Where,

θ* **:** Indicates the eco-efficiency score of the municipalities evaluated,

M **:** Is the number of inputs used;

S **:** Is the number of desirable outputs generated,

H **:** Is the number of undesirable outputs involved in the assessment;

N **:** Is the number of municipalities analyzed, and

λj **:** Is a set of intensity variables which represent the weighting of each analyzed municipalities *j* in the composition of the efficient frontier.

$\theta^* \in (0, 1$ and a municipality is efficient if θ^* equals unity, whereas it is inefficient if $0 \leq \theta^* < 1$

4. EMPIRICAL APPLICATION

SAMPLE

	Efficiency assessment	Eco-efficiency assessment
INPUT	i) Total costs of MSW collection and disposal (€/year); ii) Total number of containers.	i) Total costs of MSW collection and disposal (€/year); ii) Total number of containers.
DESIRABLE OUTPUT	i) Quantity of MSW collected and disposed (ton/year).	i) Quantity of paper collected and recycled (ton/year); ii) Quantity of glass collected and recycled (ton/year); iii) Quantity of plastic collected and recycled (ton/year).
UNDESIRABLE OUTPUT		i) Unsorted waste (ton/year).

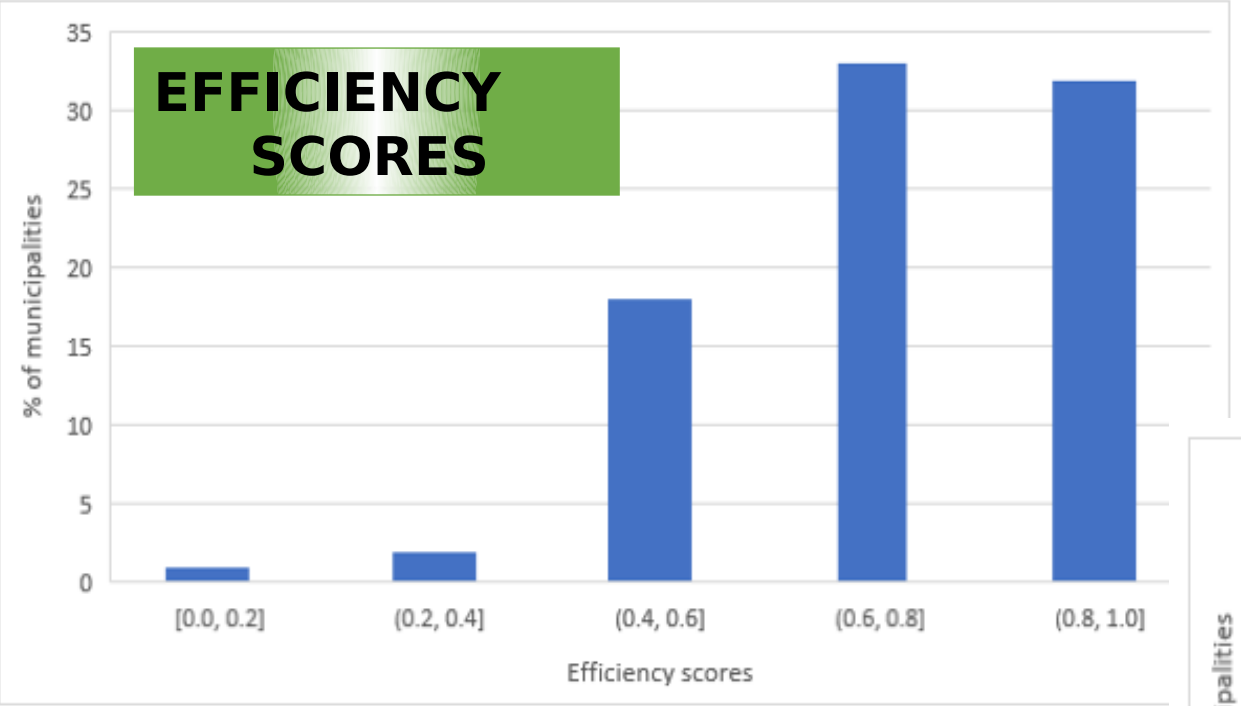
Table 2. Description of variables. An empirical application, case study 85 Spanish municipalities.

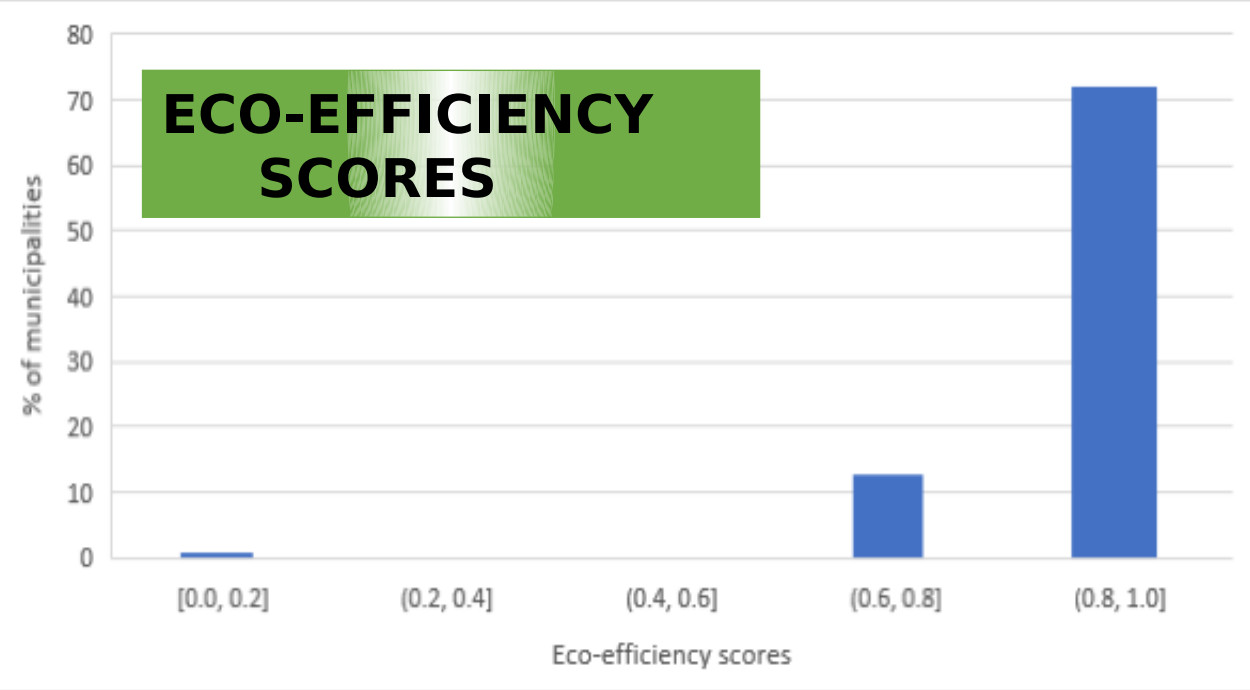
5. RESULTS

	Efficiency score (θ)	Eco-efficiency score (θ*)
Average	0.75	0.92
SD	0.19	0.10
Maximum	1.00	1.00
Minimum	0.20	0.63
Percentage of efficient municipalities	18.8%	45.9%

Table 4. Main statistics of the efficiency and eco-efficiency scores of municipalities evaluated

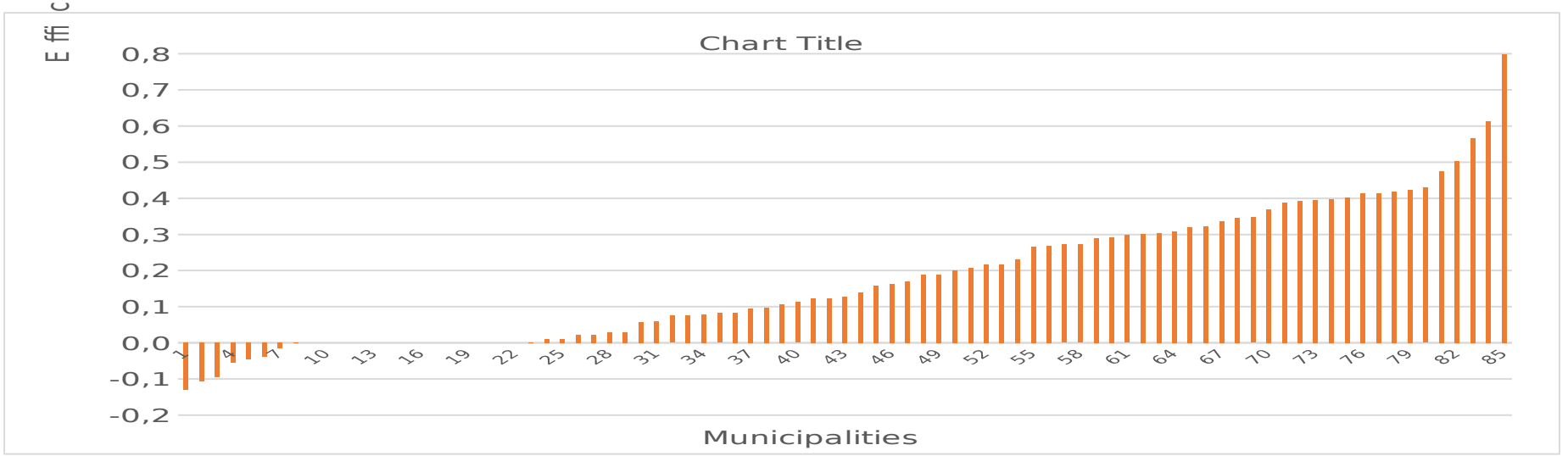
5. RESULTS


EFFICIENCY SCORES
% of municipalities
35
30
25
20
15
10
5
0
[0.0, 0.2]
(0.2, 0.4]
(0.4, 0.6]
(0.6, 0.8]
(0.8, 1.0]
Efficiency scores


ECO-EFFICIENCY SCORES
% of municipalities
80
70
60
50
40
30
20
10
0
[0.0, 0.2]
(0.2, 0.4]
(0.4, 0.6]
(0.6, 0.8]
(0.8, 1.0]
Eco-efficiency scores

5. RESULTS

Differences in efficiency and eco-efficiency scores Spanish municipalities evaluated



6. CONCLUSIONS

- ✓ The importance of urban solid waste management is that it is an essential service, which must be addressed in an interdisciplinary manner.
- ✓ In this work efficiency and eco-efficiency scores were computed for a sample of Spanish municipalities using the DEA method assuming variable returns to scale input orientation. Among the variables selected for this study, it is highlighted that glass, plastic and paper collected and recycled were integrated as desirable outputs and unsorted waste as undesirable output.

6. CONCLUSIONS

- ✓ Results evidenced a large percentage of inefficiency in the separation and non-separation of waste. This 51.8% inefficiency reveals that the municipalities where it is possible to improve their management.
- ✓ It should also be taken into account that within the results of the efficiency and eco-efficiency score obtained; there is 52% of the municipalities that are inefficient in both models studied.

National Technical University of Athens

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Differences between DEA and SFA methods

	DEA	SFA
Advantage	✓ No need to define its functional form	
Disadvantages	✓ It is a deterministic method, sensitive data outliers	✓ If need to define your functional form

Table 2. Own adaptation, Schiltz, F. (2018)

ANEXXES

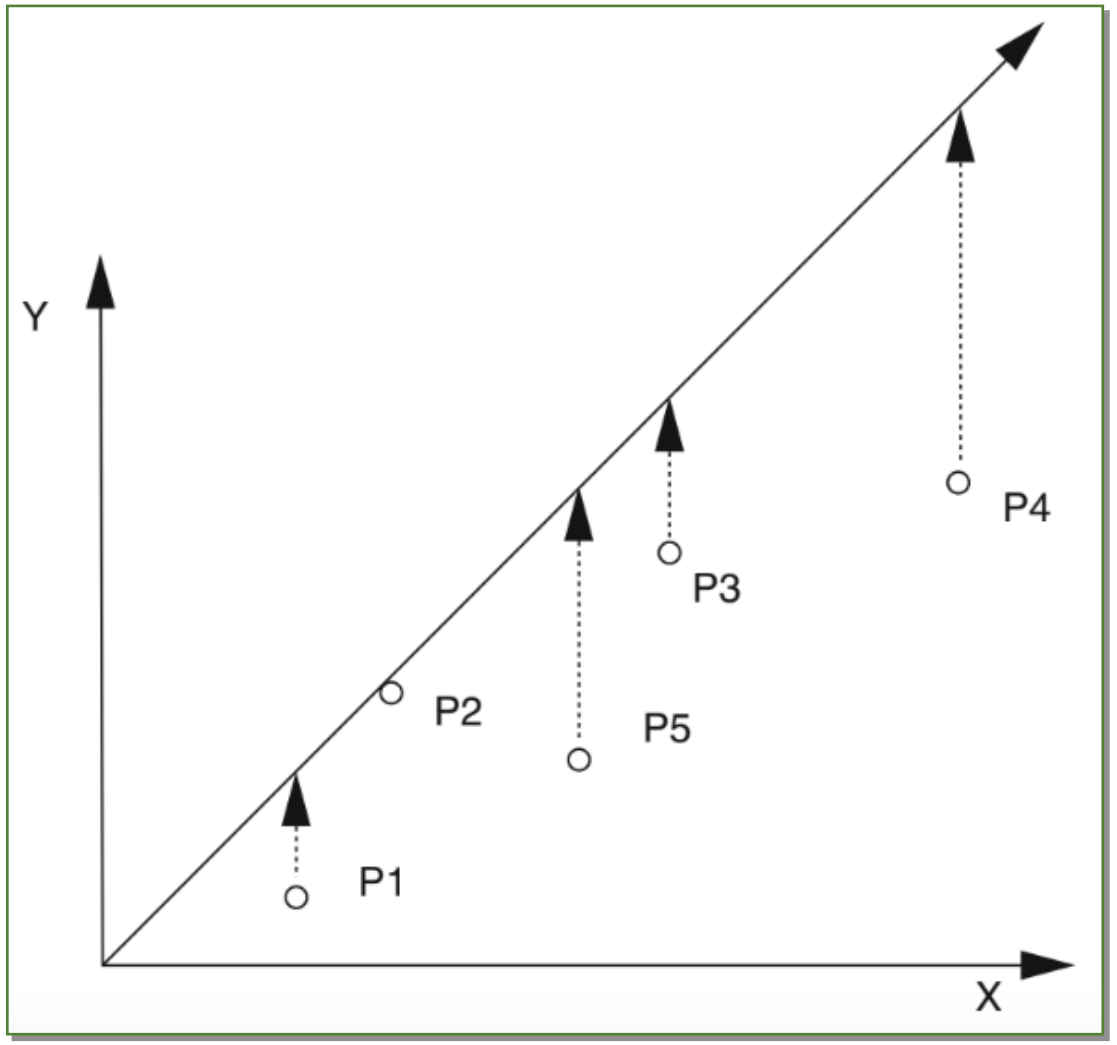

Figure. Projection to frontier for the output-oriented CCR model.

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