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*Supplementary Materials*

# Sustainability and Environmental Performance in Selective Collection of Residual Materials: Impact of Modulating Citizen Participation Through Policy and Incentive Implementation

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In this supplementary section, we provide additional details and data supporting the findings presented in the main scientific article. Below, we delve into further analyses, methodologies, and results to offer a comprehensive understanding of the research conducted on bulk density variations in mixed materials.

The bulk density distribution of various waste materials serves as crucial input data for the agent-based model (ABM), facilitating the accurate simulation of waste management scenarios. Incorporating such detailed representations of waste material properties enables our ABM to simulate waste generation, sorting, and collection processes with enhanced realism and precision.

The methodology employed by Tanguay-Rioux [1] is used to represent the raw material density ($\rho_m$) for each material "m" and the bulk density ($\rho_{bulk,m}$). The data provided by the author are however revised to better represent the variability of waste materials.

Figure S1 illustrates the bulk density distributions utilized within our model. These distributions are derived from comprehensive literature reviews and empirical data [1–3], ensuring their relevance and accuracy in the context of waste management simulations. From each source, the appropriate category of waste was selected and transformed into the same unit of measure. Please refer to the cited sources within the main text for further details on the derivation and validation of these density distributions.

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### Fibers

The composition of fibers has a discernible effect on the bulk density of the material. As evidenced by Tanguay-Rioux [1], newspapers, cardboards, and desk papers exhibit varying densities. While the mean fibers bulk density in Table S1 appears consistent across the references, the standard deviation provided by Tanguay-Rioux is extended to better represent the possible values.

### Glass

Table 1 indicates two sources reporting bulk densities for glass at 225 kg/m³ [4] and 276±16 kg/m³ [2], whereas Tanguay-Rioux [1] has noted a value of 597 kg/m³ when considering voids. Given the readily available $\rho_m$ value for glass, the disparity likely stems from variations in void content, influenced by factors such as the presence of broken glass or product type. Both density ranges were evaluated within the agent-based model. A lower value was necessary to ensure calibration convergence. Therefore, the void fraction is corrected to 0.903.

### Metal

While literature offers $\rho_m$ data for various metal types, bulk density is contingent upon material composition. Incorporating more aluminum can significantly reduce metal density. A volume-weighted average is computed to reflect metal averages, leveraging insights from recycling waste characterization studies [5]. This necessitates a departure from previous methodologies [1] reliant on weight-based averages. The standard deviation is expanded to encompass the range of data presented in Table S2.

**Plastic**

The plastic category was adapted in mean and standard deviation values to include all the data presented in Table S1. This choice was made since this category depends on the chosen plastic material mix, and all the references had similar values.

**Non-recyclable Material**

For paper, glass, and plastic, the density of the materials was estimated to be similar to that of recyclable ones. Depending on the material mix, this might not be completely accurate. However, the impact on the model is judged negligible since the wastes are considered similar enough to be mistaken by citizens when sorting their waste.

Non-recyclable metals are often non-ferrous metals. Therefore, the values presented by Tanguay-Rioux [1] are used for this category.

**Organic waste and other waste**

Organic waste is subject to high variation caused by the availability of certain heavy food items as a function of seasons and the presence of yard waste. The average values representing the best annual average food-to-yard waste ratio, as evaluated by the waste characterization [5,6], were chosen.

The average bulk density found for the mixed material bin is 131 ± 47 kg/m$^3$. By knowing the characterization of materials in the territory and that of the province [5,6], it is possible to deduce from the set of previously determined bulk densities that materials considered as "other" have a bulk density of 150 ± 47 kg/m$^3$. This value includes some wood and residential construction materials. While not the focus of the mixed waste stream those materials are found in this stream on the territory.

**Table S1.** Bulk density in kg/m3 information adapted and integrated from various sources.

| **Integrated value** | | **[1] (kg/m$^3$)** | | | | **[4] (kg/m$^3$)** | | | | **[2] (kg/m$^3$)** | | | | **[3] (kg/m$^3$)** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Void** | **Mean** | **STD** | **Min** | **Max** | **Mean** | **STD** | **Min** | **Max** | **Mean** | **STD** | **Min** | **Max** | **Mean** | **STD** | **Min** | **Max** |
| Fiber | 0.87 | 130 | 13 | 117 | 143 | 145 | 80 | 65 | 225 | 112 | 84 | 28 | 195 | | | | |
| Glass | 0.769 | 597 | 46 | 551 | 642 | 225 | 0 | 225 | 225 | 276 | 16 | 256 | 287 | | | | |
| Metal | 0.987 | 91 | 7 | 85 | 98 | 66 | 38 | 27 | 104 | 40 | 6 | 34 | 46 | | | | |
| Non-recyclable Metal | 0.978 | 43 | 6 | 37 | 49 | | | | | | | | | | | | |
| Plastic | 0.966 | 26 | 2 | 24 | 28 | 20 | 4 | 15 | 24 | 24 | 10 | 14 | 33 | | | | |
| Organic waste | | | | | | 341 | 184 | 275 | 407 | 246 | 138 | 108 | 384 | 262 | 17 | 245 | 280 |
| Other waste | | | | | | 163 | 15 | 148 | 178 | | | | | 99 | 16 | 84 | 115 |
| Recycling waste mix | | | | | | 75 | 9 | 56 | 75 | 84 | 34 | 50 | 118 | 36 | 5 | 31 | 41 |
| Mixed waste mix | | | | | | 163 | 15 | 148 | 178 | | | | | 99 | 16 | 84 | 115 |

**Table S2.** Mean of Table 1 results for bulk and material density in kg/m3 (*Adapted for calibration convergence).

| **Integrated value** | **$\rho_{bulk,m}$ (kg/m³)** | | | | | **$\rho_m$ (kg/m³)** | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Mean** | **STD** | **Min** | **Max** | **Void** | **Mean** | **STD** | **Min** | **Max** |
| Fiber | 129 | 99 | 28 | 225 | 0.870 | 993 | 759 | 215 | 1734 |
| Glass | 251 | 31 | 225 | 287* | 0.903* | 2584 | 317 | 2323 | 2958 |
| Metal | 66 | 38 | 27 | 104 | 0.987 | 5050 | 2944 | 2099 | 7986 |
| Non-recyclable Metal | 43 | 6 | 37 | 49 | 0.978 | 1957 | 290 | 1667 | 2247 |
| Plastic | 23 | 10 | 14 | 33 | 0.967 | 703 | 289 | 426 | 1004 |
| Organic waste | 283 | 150 | 108 | 407 | | | | | |
| Other waste | 150 | 47 | 103 | 197 | | | | | |
| Recycling waste mix | 65 | 22 | 31 | 75 | | | | | |
| Mixed waste mix | 131 | 47 | 84 | 178 | | | | | |

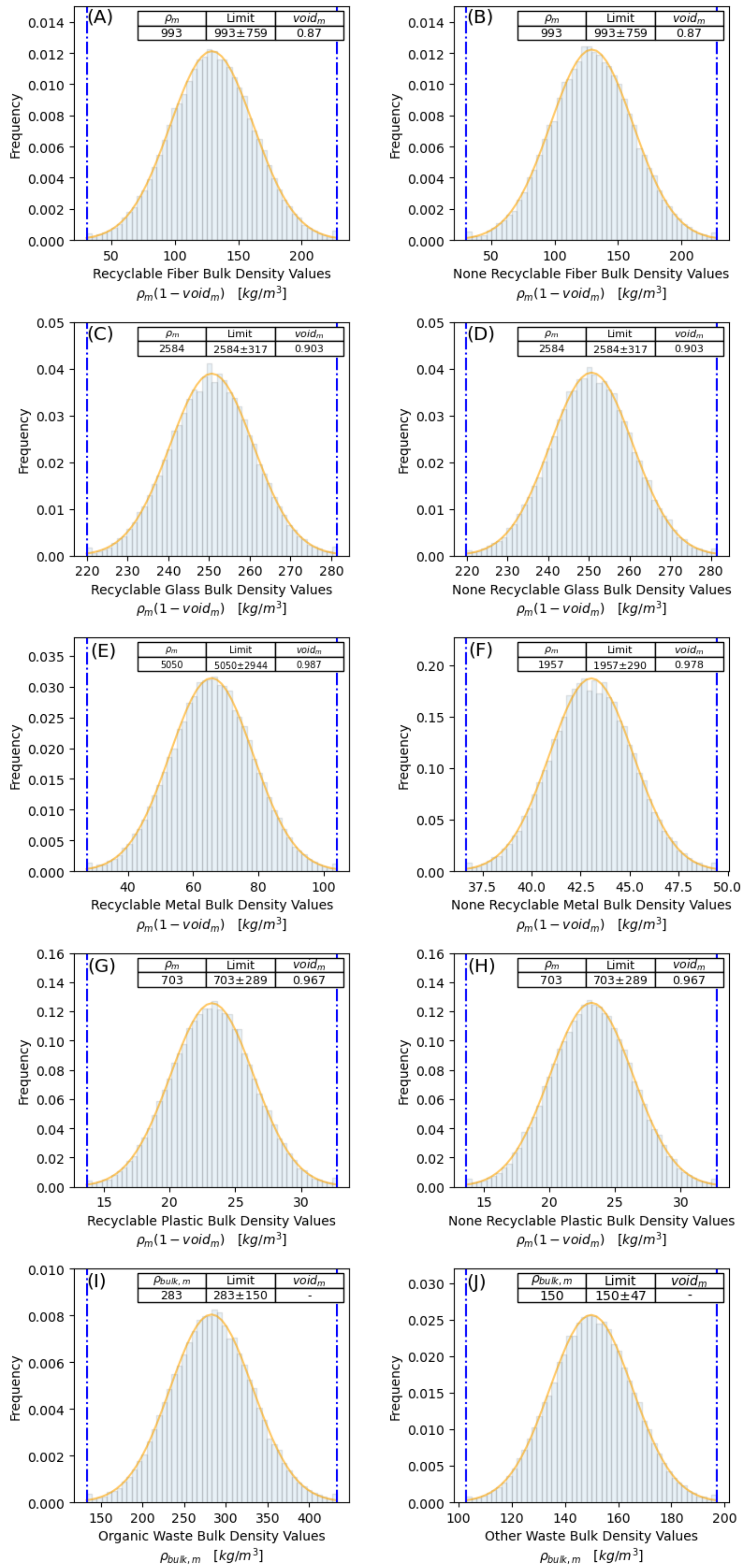


**Figure S1.** Density distribution per material in kg/m3.

## References


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