How do human behaviour and infrastructure interact in achieving biowaste policy objectives?

Extended Abstract

1. Introduction

The increase in household biowaste, driven by urbanisation and increased consumption, presents significant environmental challenges, straining waste management systems. Effective biowaste management is crucial for achieving carbon neutrality and supplying renewable energy. In response, many countries have developed specific policies. For example, the European Union has prioritised waste prevention strategies and mandated Member States to provide citizens with viable biowaste sorting solutions, as outlined in directives like 2018/851.

The complexity of biowaste management arises from its dual nature, encompassing both technical aspects, such as infrastructure development, and social aspects, such as behavioural dynamics. Addressing this issue requires an approach that captures the dynamic interactions between demographics, social behaviours, local policy, and infrastructure developments, providing insights into the potential outcomes of various designs.

This study aims to understand the impact of socio-technical dynamics on achieving policy objectives related to biowaste management. We propose a generic dynamic approach that integrates both technical and social aspects, using a system dynamics model with a stock-and-flow approach. Our model visualises biowaste accumulation and processing within a defined system boundary, offering a better representation of the system's current and potential future states.

2. Literature Review

While waste management systems have been extensively studied through dynamic modelling, few dynamic models have specifically addressed household biowaste management systems. Most existing models have primarily focused on infrastructure development or social behaviour change in isolation, often oversimplifying human behaviour or treating it as a static factor. More sophisticated models that integrate behavioural dynamics with infrastructural development are crucial for accurately predicting biowaste management outcomes. Current models typically compare simulation results across a limited number of scenarios, ranging from 2 to 7, which may not be sufficient to understand the key considerations and trade-offs involved in designing infrastructure for biowaste management. Our work proposes a novel modelling approach that integrates socio-technical dynamics into a stock-and-flow model for biowaste management. By incorporating both infrastructure development and social behaviour change, and applying socio-technical systems theory, our approach addresses the limitations of existing models and provides a better understanding of the complex interactions that shape the performance of biowaste management systems.

3. Methodology

Our generic model is structured into three main components:

1. Local Policy Actions (LPA): These actions represent practical measures decided by policy-makers, such as the Anti-Biowaste Plan (ABP) and investments in technical infrastructure capacities.
2. Socio-technical dynamics (STD): This component captures the dynamic interplay between household behavioural intentions (for sorting and/or composting) and infrastructure capacities (composters and collection systems).
3. Local Policy Objectives for biowaste management (LPO): These objectives are derived from collaborative policy-making over a given time horizon.

The model is designed to analyse households' biowaste management within a multi-territorial context composed of n territories. Each territory manages its biowaste, but they may share infrastructures to ensure efficient common valorisation of their biowaste.

Key features of the model include:

1. Demographics: The model incorporates population dynamics, including growth rates, which influence biowaste production across different collection territories.
2. Behaviours: The model considers three types of behaviours, modelled based on innovation diffusion theory: Anti-Biowaste Behaviour, and Valorisation Behaviors (composting and sorting intentions).
3. Infrastructure: The model uses a linear update principle to represent the evolution of infrastructure capacity.

4. Case Study: Valtom Territory, France

To demonstrate the applicability of our model, we examine the Valtom territory in France as a case study. Valtom is a syndicate responsible for the valorisation and treatment of household and similar waste, overseeing nine collection territories in the Puy-de-Dôme and northern Haute-Loire departments. Each of these collection territories is characterized by its unique demographics, behaviours, and infrastructure.

The local policy objectives considered in this case study are:

- Lower food waste in residual households
- Lower green waste in the valorisation centre
- More digested food waste in the methanisation units
- More total biowaste in the methanisation units

5. Key Findings

Our system dynamics model reveals several important insights:

1. Anti-Biowaste Plan (ABP) Effectiveness: The Anti-biowaste Plan (ABP) contributes to an overall reduction of food and green waste, but its effectiveness interacts critically with demographic trends and specific local political objectives. The ABP's impact is limited by population growth in the medium term. If population growth exceeds the reduction induced by the ABP before the target year (2024), some objectives become less likely to be achieved. This highlights the need to tailor ABP objectives and

implementation schedules to each collection territory's unique demographic characteristics and future population growth projections.

2. Infrastructure Limitations: Relying solely on improvements in technical infrastructure is insufficient to achieve the objectives. The effect of increased capacity in composters and collection infrastructures can be limited by initial behavioural intentions (as of 2018). When these intentions generate a waste flow less than or equal to infrastructure capacity, technical improvements have no impact. Conversely, when initial behaviour is limited by infrastructure capacity, forcing people to redirect waste to alternative infrastructures (e.g., grey bins), infrastructure improvements can help achieve objectives.
3. Capacity Constraints: The "STDGO infrastructure" and "without infrastructure capacity limitation" scenarios highlight the crucial role of capacity constraints. While some objectives, like food waste reduction, are systematically achieved in both scenarios, others are significantly affected by infrastructure capacity limitations.
4. Composting vs. Sorting Trade-offs: Rapid adoption of composting can hinder the achievement of objectives related to methanisation volumes by limiting the development of sorting intentions. This is due to the model's assumption that prioritizes composting over sorting when the two behaviours are incompatible.
5. Green Waste Management Challenges: With infrastructure limitations, achieving the objective of reducing green waste in recovery centres (Dechetrie) becomes a major challenge. The rapid adoption of composting, while initially beneficial, can lead to reaching infrastructure capacity limits, causing excess green waste to be redirected to waste recovery centres.
6. Methanisation Objectives: The achievement of food waste methanisation objectives is influenced by the interplay between composting and sorting behaviours. Paradoxically, infrastructure limitations can sometimes aid in achieving methanisation objectives, as surplus compostable food waste from saturated composting infrastructures is redirected to collection infrastructure and then to methanisation units.

6. Conclusion and Implications

This study highlights the complex interactions between demographics, policies, infrastructure, and social behaviour in biowaste management. Our findings demonstrate that achieving sustainable biowaste management requires an integrated approach that considers:

1. The dynamic interplay between waste reduction initiatives (like the ABP) and demographic trends.

2. The limitations of infrastructure improvements without corresponding behavioural changes.

3. The potential trade-offs between different waste management strategies (e.g., composting vs. sorting for methanisation).

4. The crucial role of infrastructure capacity constraints in shaping waste management outcomes.

These insights can guide decision-makers in designing more effective interventions for sustainable biowaste management. For instance, policymakers should:

- Regularly review and adjust waste reduction initiatives in light of demographic projections.

- Consider the existing behavioural intentions when planning infrastructure improvements.

- Carefully balance the promotion of different waste management behaviours to avoid unintended consequences.

- Plan for potential redirections of waste flows when infrastructure capacities are reached.

Our model demonstrates the value of exploring these complex interactions through dynamic simulation. However, it's important to note the model's limitations, including several simplifying assumptions regarding behaviours, including infrastructure independence, behaviour independence, and homogeneous intentions within collection territories. These limitations point to avenues for future research, potentially involving the development of an Agent-Based Model (ABM) to capture the heterogeneity of individual situations and behaviours.

In conclusion, achieving sustainable biowaste management requires a better understanding of the complex socio-technical system dynamics at play, particularly the interactions between demographics, infrastructure, policy initiatives, and social behaviours. By providing a system dynamics model to explore these intricate relationships, our research contributes to a better understanding of biowaste management strategies. This approach can aid policymakers and waste management practitioners in anticipating challenges, identifying potential trade-offs, and considering interventions that account for the multifaceted nature of biowaste systems.

Keywords: computational simulation, system dynamics, behavioural change, socio-technical systems, biowaste management, infrastructure capacity.

Note to organisers: While I have selected an oral presentation as my preferred option, I also have a poster prepared for this work and would be willing to present both an oral presentation and a poster if the opportunity is available. Please let me know if this is possible.

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