ÉCOLE DOCTORALE
DES SCIENCES POUR L'INGÉNIEUR

Modeling the transition towards a circular economy: production, collection, and treatment of food waste

Modélisation de la transition vers l'économie circulaire : production, collecte et traitement des déchets alimentaires

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Financement : ADEME Agence de l'Environnement et de la Maîtrise de l'Energie; clermont auvergne métropole

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Outline

1. Introduction and Background

2. Literature Review

3. Methodology

4. Results

6. Discussion Conclusion

1. Introduction, Background :

- **PhD Start**: September 2023
- **Funded by**: ADEME (BEECOME 2*) & Clermont-Auvergne Métropole
- **Objective**: Transition toward a circular food system

(***B**io-**E**conomy and Circular **E**conomy for a **CO**operative **M**anagement of **E**co-Systems, Phase 2 (BEECOME 2)

Problem

of food waste in EU happens at household level

- Each year, ➔ more than 10 million tons of food are either lost or wasted in the country and most percentage happened at the consumer level.
- financial cost, ➔ 16 billion euros annually.
- Per capita, this translates to approximately 150 kg of food waste per person each year.

ADEME
AGENCE DE LA TRANSITION ÉCOLOGIQUE

What is the bio-waste?

Biowaste is any waste that can be recycled (valorised) organically.

- In France, around 30% of household waste is bio-waste
  - ➢ Large quantities to consider
  - ➢ They represent a cost for local authorities

What and how to manage biowaste?

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

- Biowaste management ➤ Complex system

- System dynamics models ➤ Complex systems over time.

- Developing a system dynamics model

2. Literature Review

Engineering Models

Babalola, 2019
Kollikkathara, Feng, et Yu (2010)

Social Models

Zheng et al., 2020; Knickmeyer, 2020; Scalco et al., 2017 ..etc

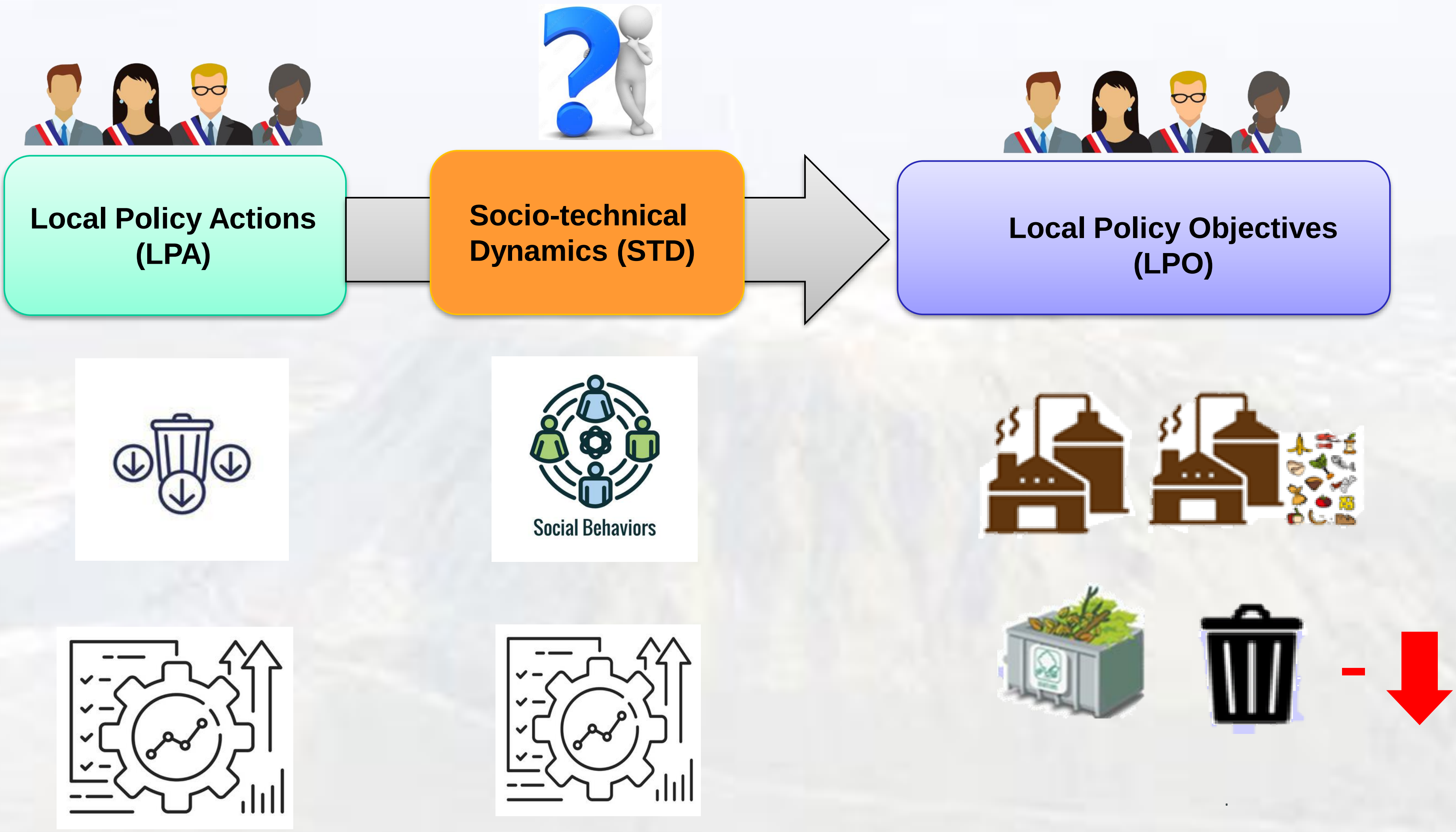
Incomplete understanding

Socio-Technical Model

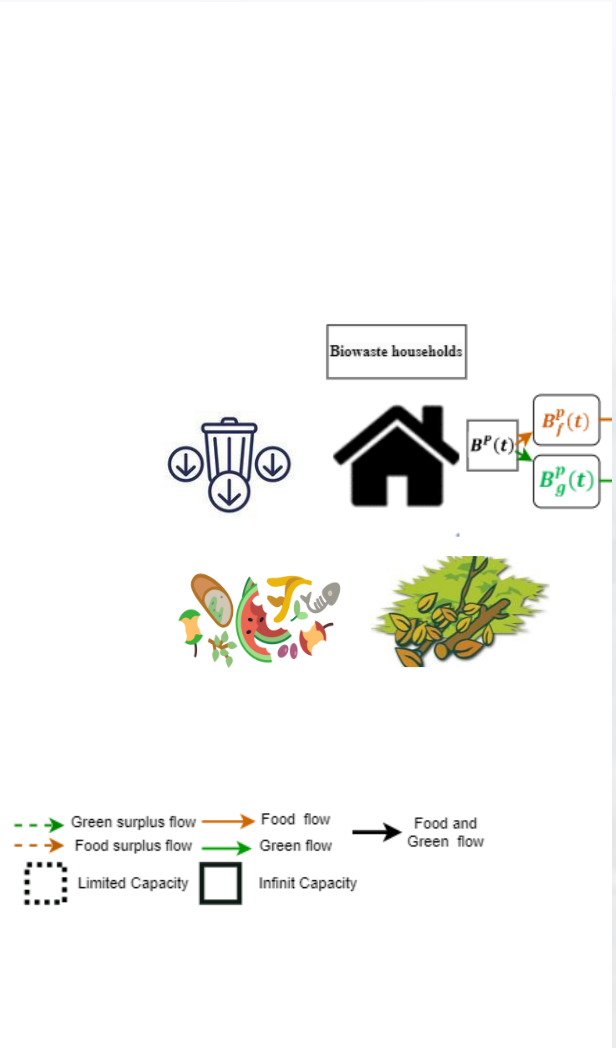
Incomplete understanding

What can be understood of this integration approach related to biowaste management

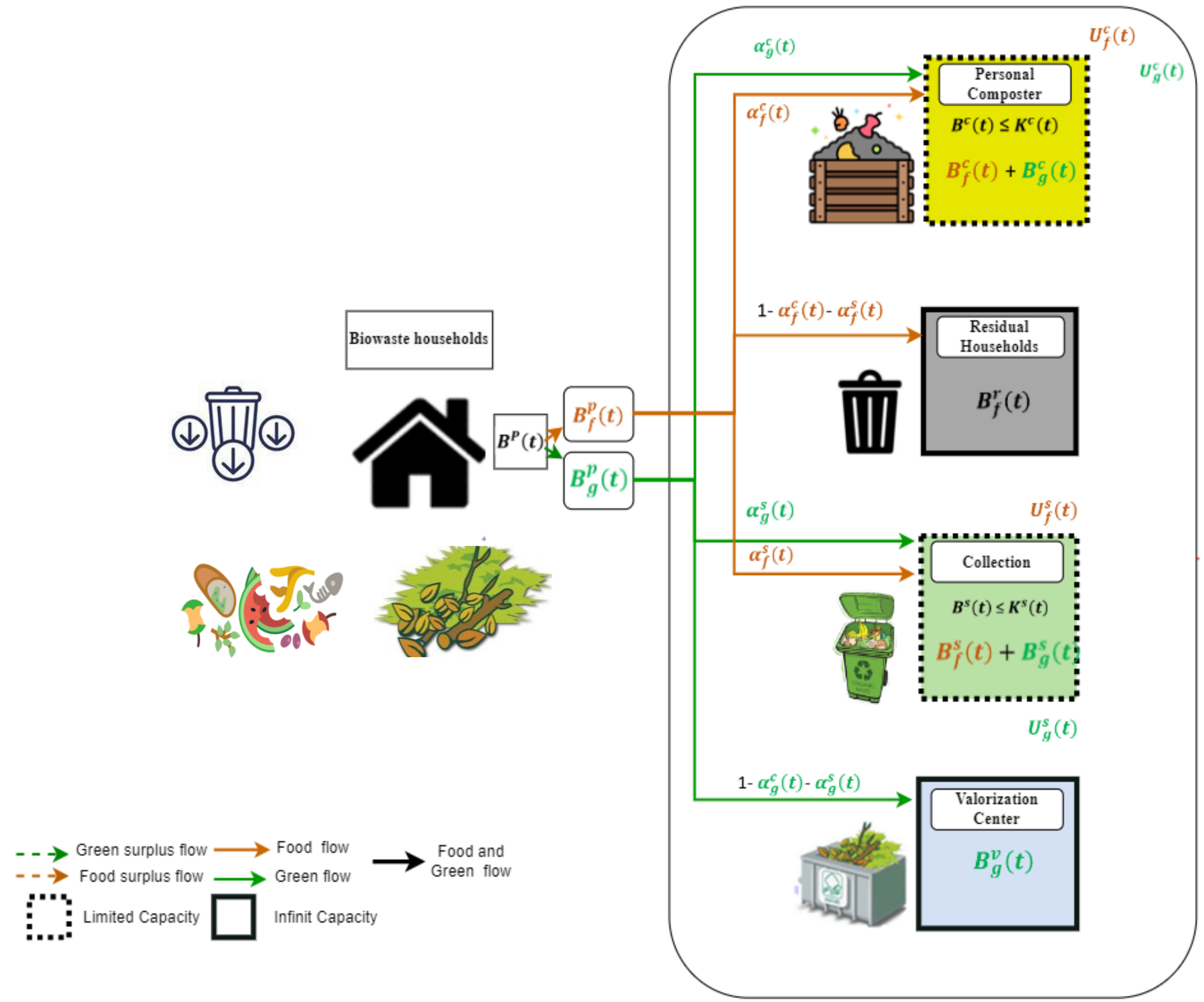
3. Methodology: General approach



3. Methodology: Model Structure and Dynamics



Households' Biowaste Behaviour And Proximity equipment



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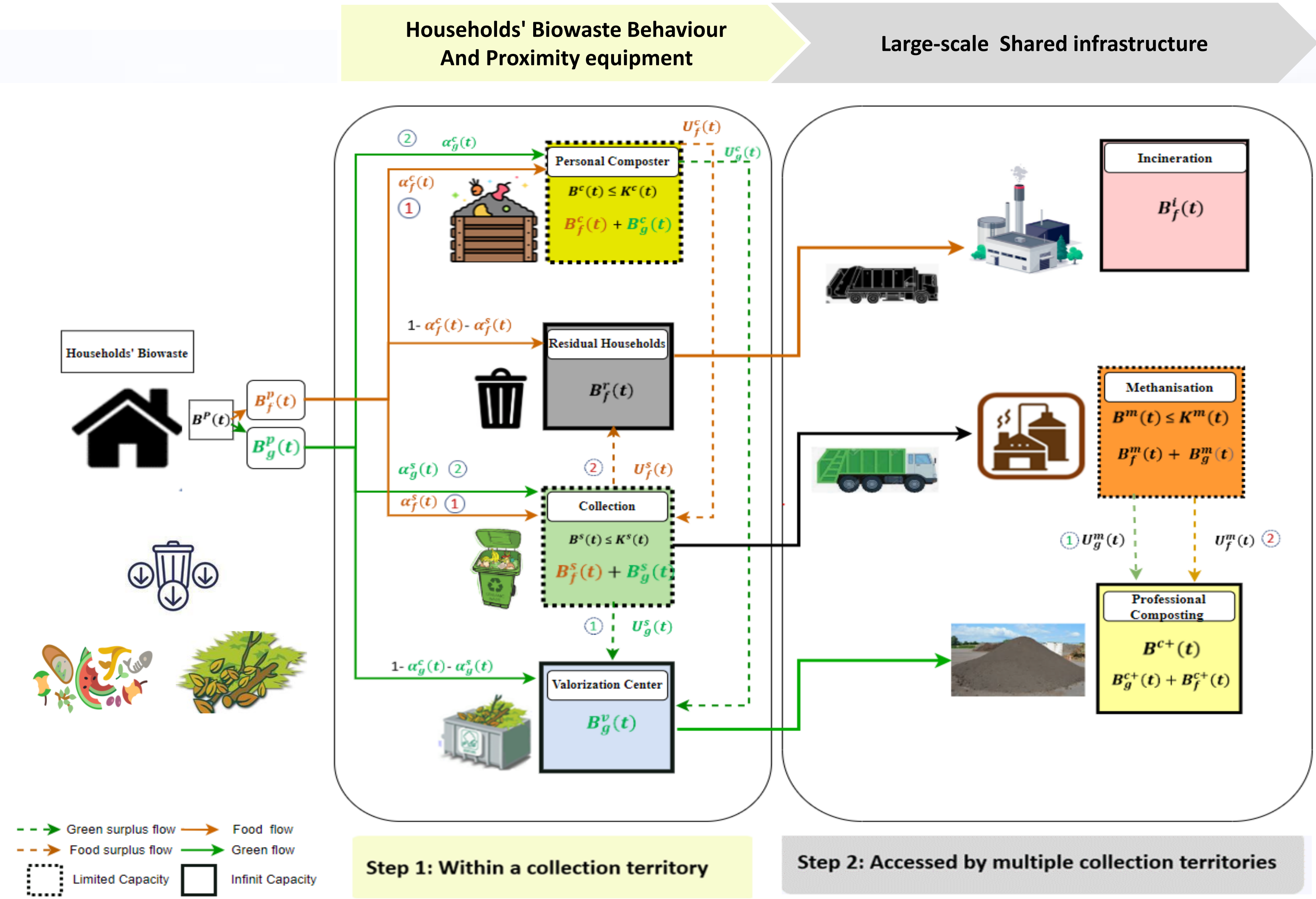
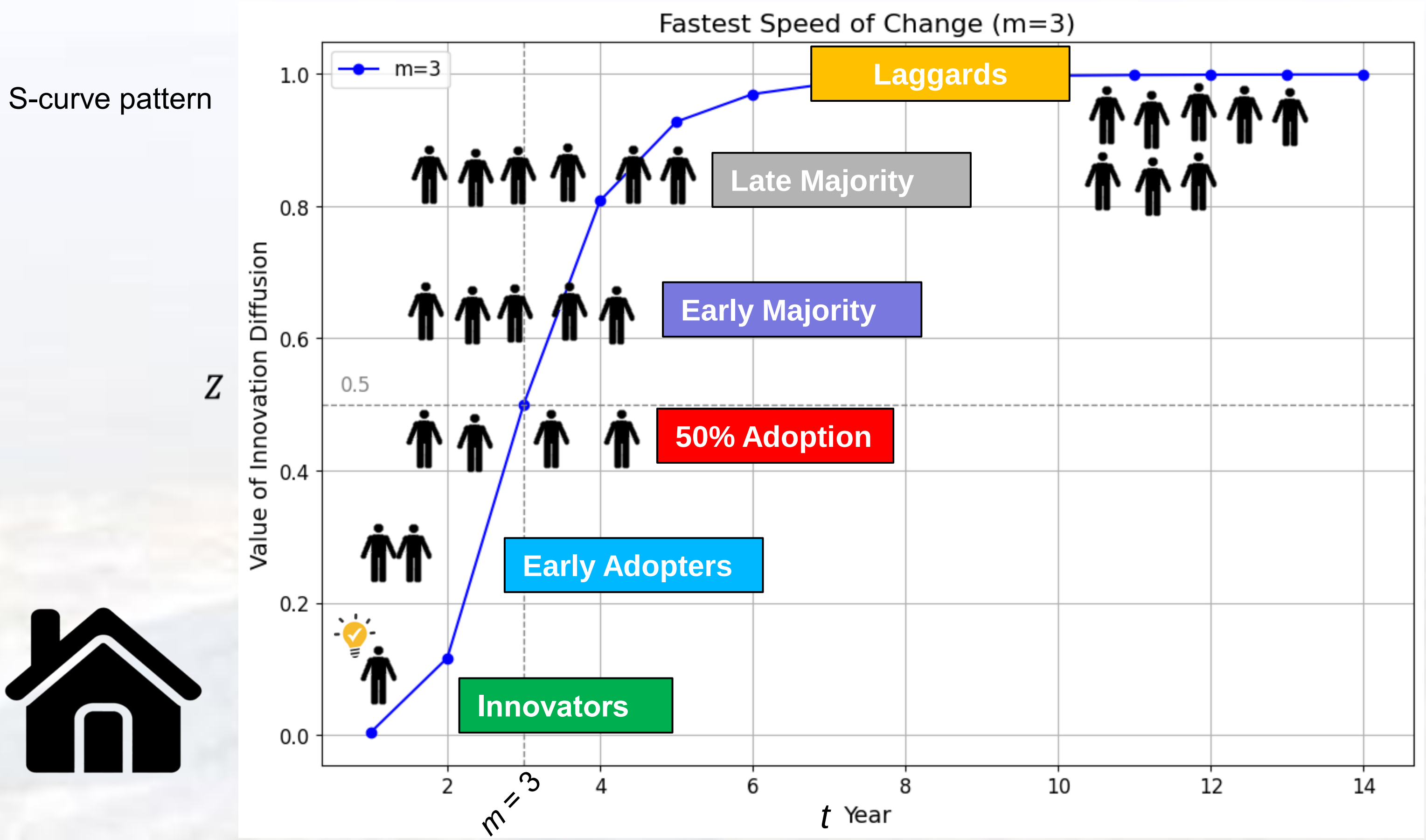


Generic simulation stock and flow model for biowaste management

3. Methodology: The innovation diffusion for modelling households biowaste behavioural changes

S-curve pattern

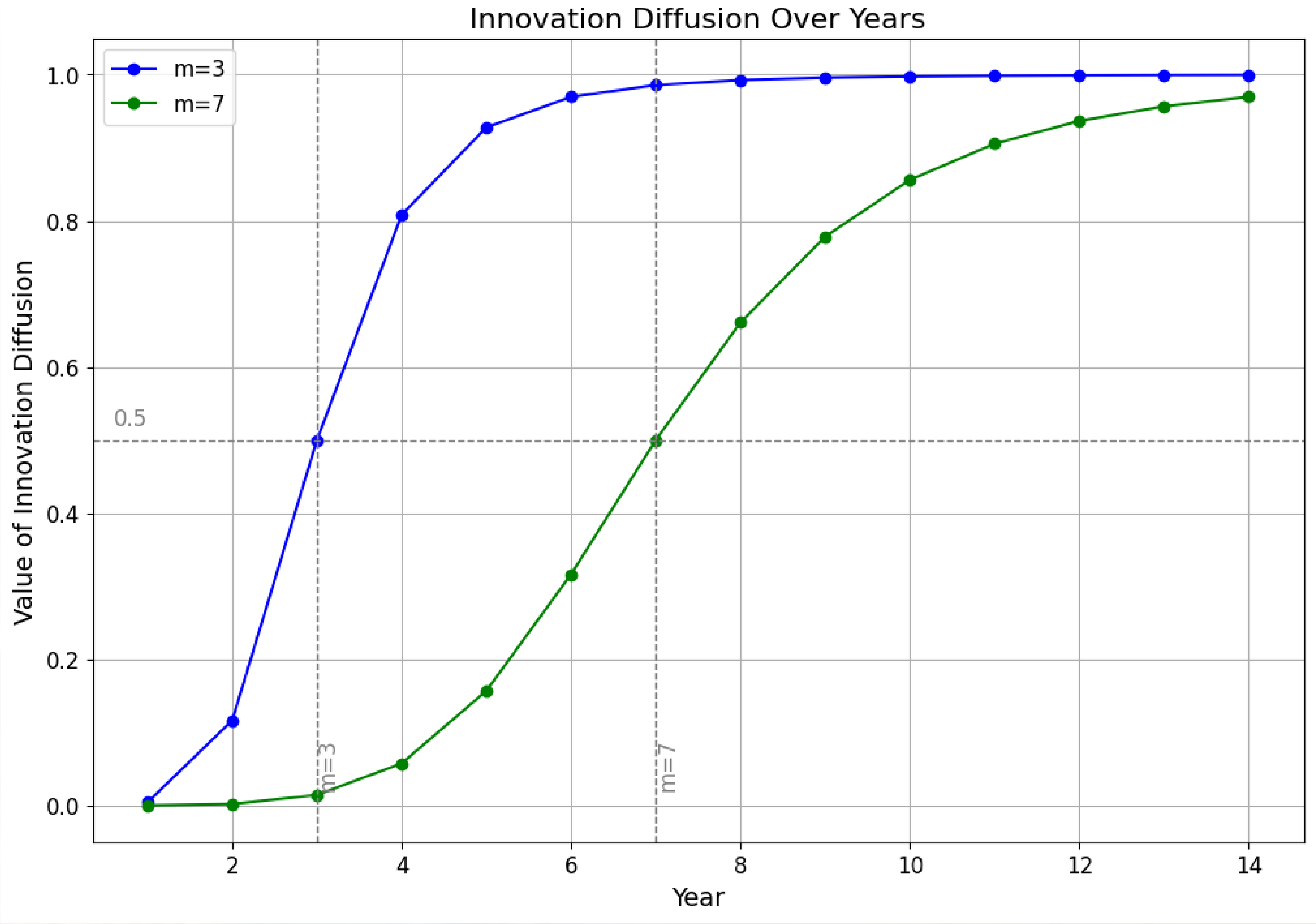


$$Z = \frac{t^5}{(t^5+m^5)}$$

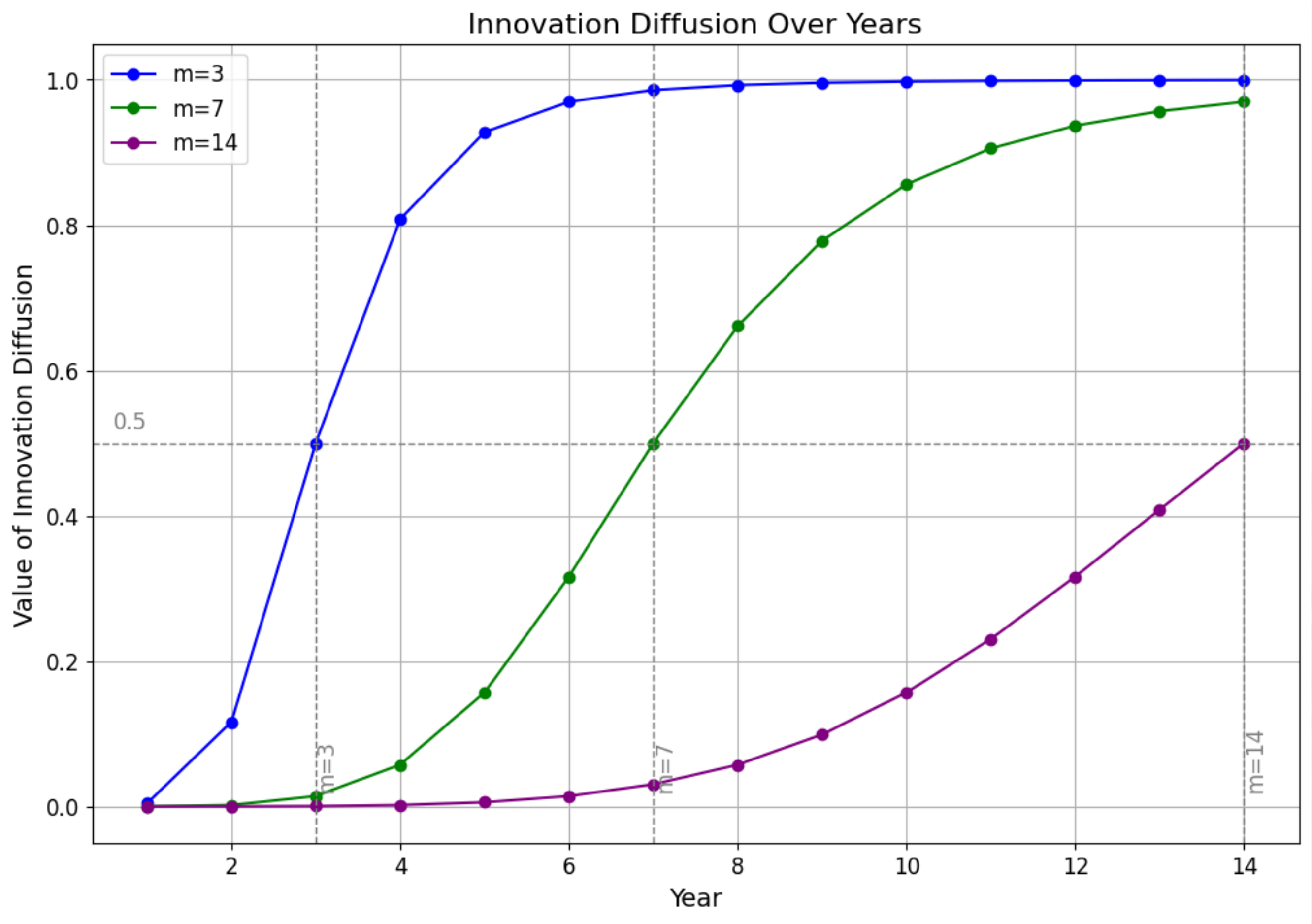
m: indicating how quickly the population reaches the midpoint of adoption intention.

- Ryan et Gross 1943

3. Methodology: The innovation diffusion for modelling households biowaste behavioural changes

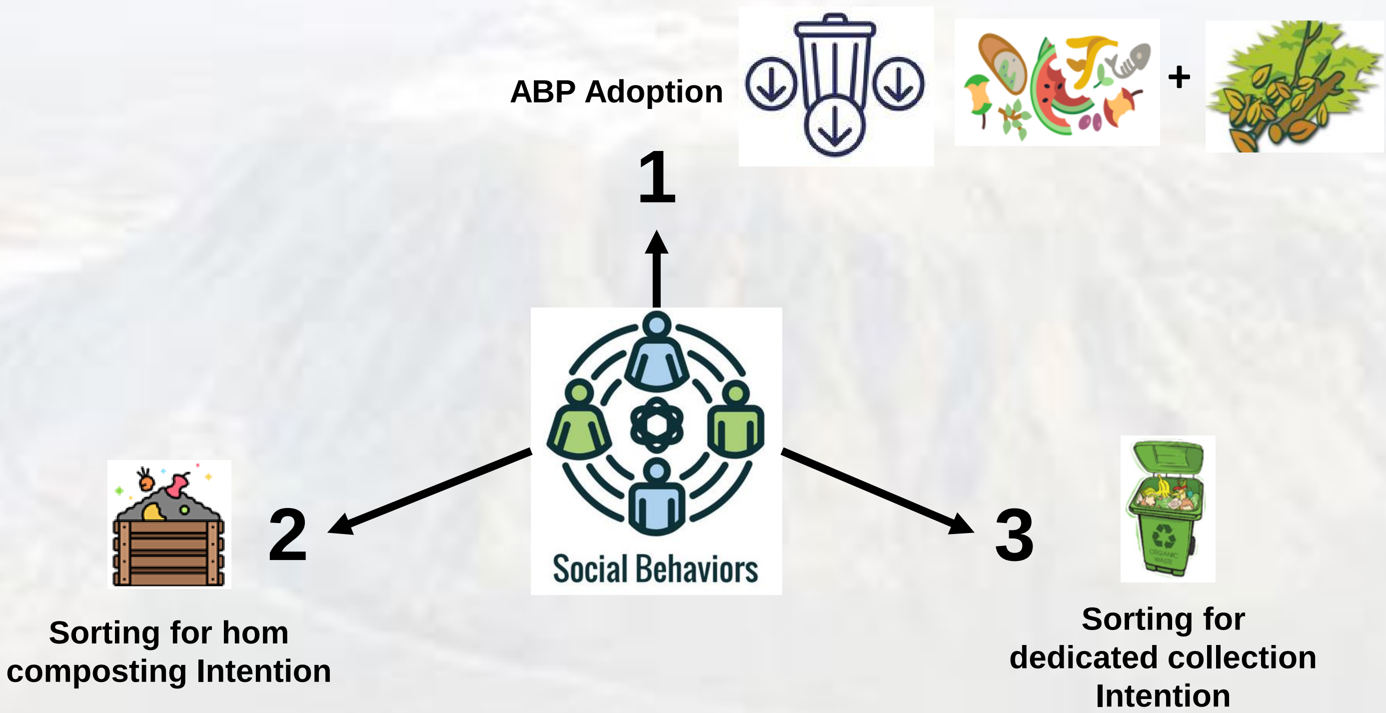


3. Methodology: The innovation diffusion for modelling households biowaste behavioural changes



3. Methodology: The innovation diffusion for modelling households biowaste behavioural changes

In our model, we have three social behaviours that can be ruled regarding their speed by *m* value to represent different aspects of behavioral intentions:



3. Methodology: Changing the capacity of infrastructure according to the local policy action:

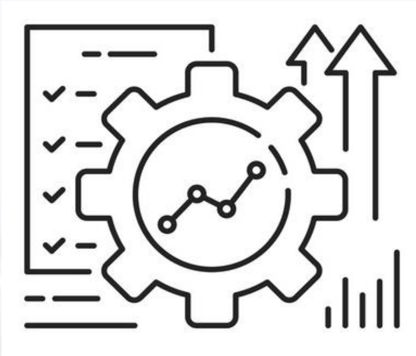
Capacity evolution

Initial Capacity

Planned Capacity

Linear function

$$K(t) = K(0) + \left(a(\tau) - K(0)\right)\frac{t}{d}$$

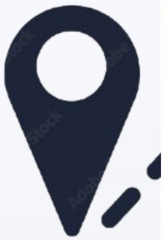


collection

Compostage local

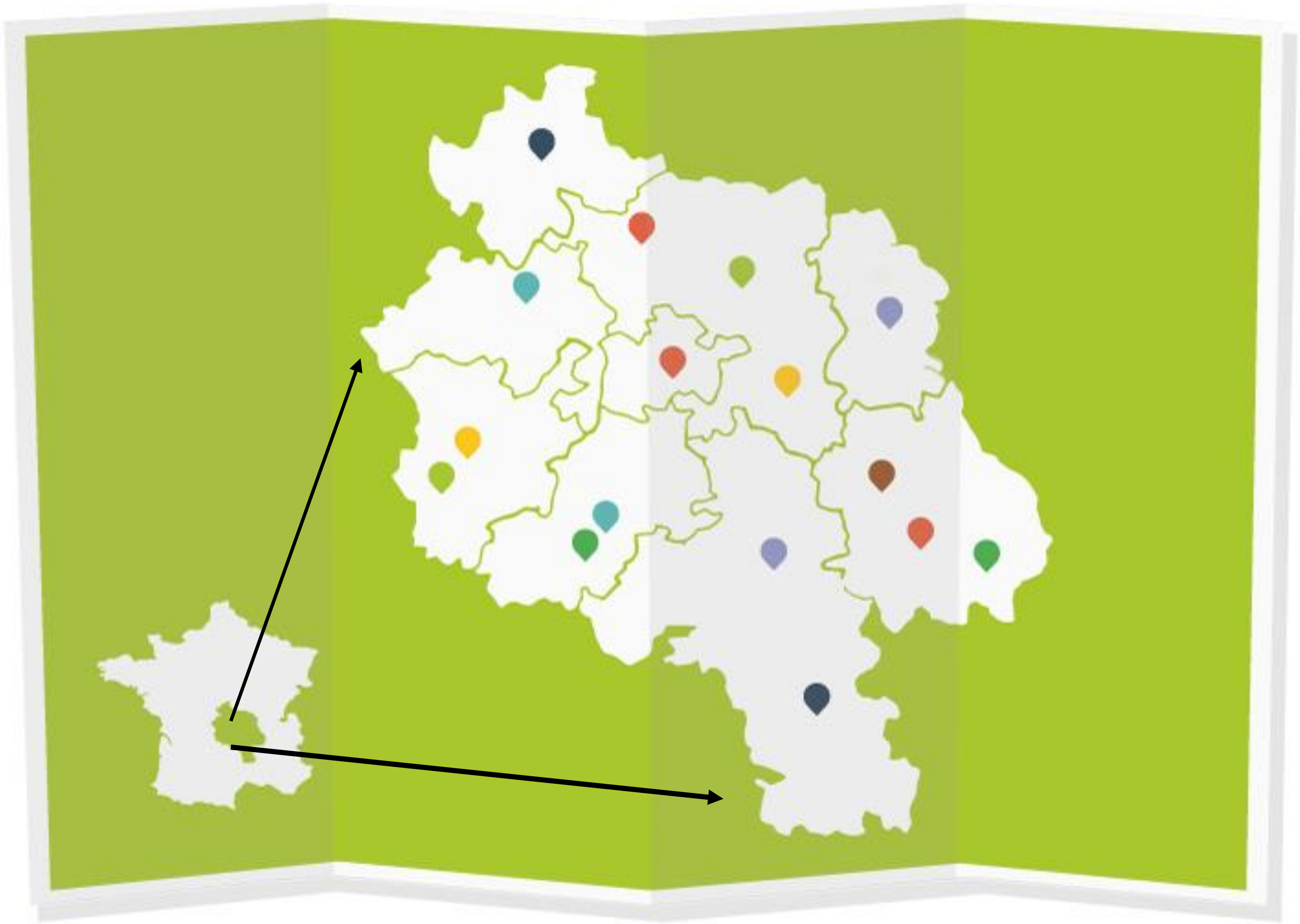
Méthanisation

3. Methodology : The use case of Valtom territory:



Puy-de-Dôme

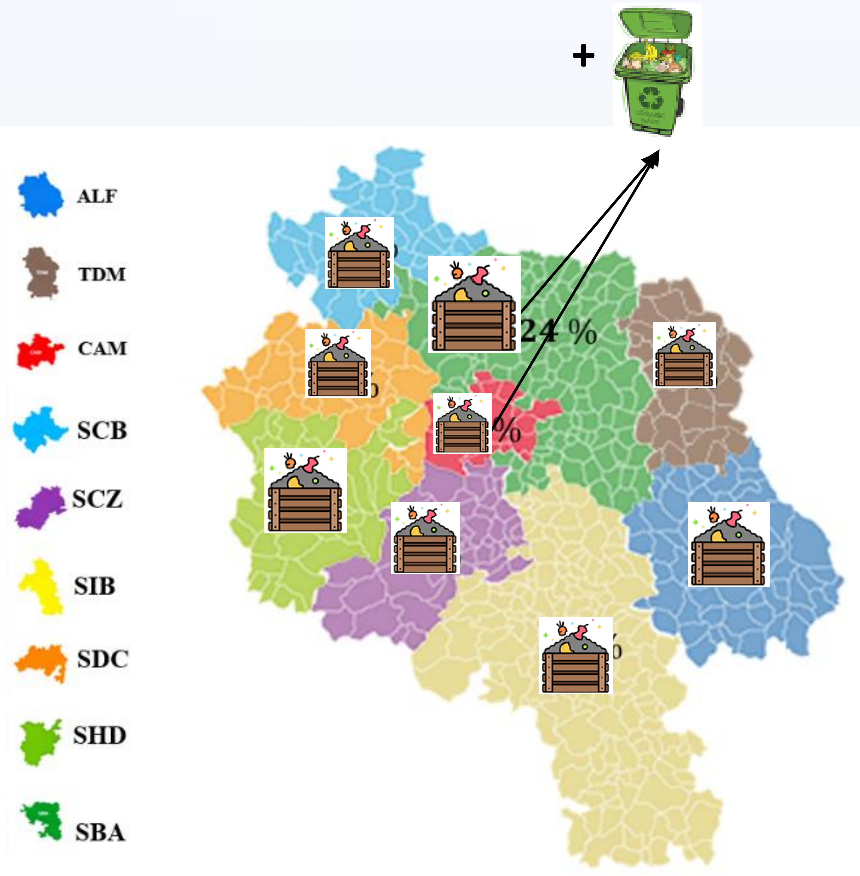
Northern Haute-Loire departments



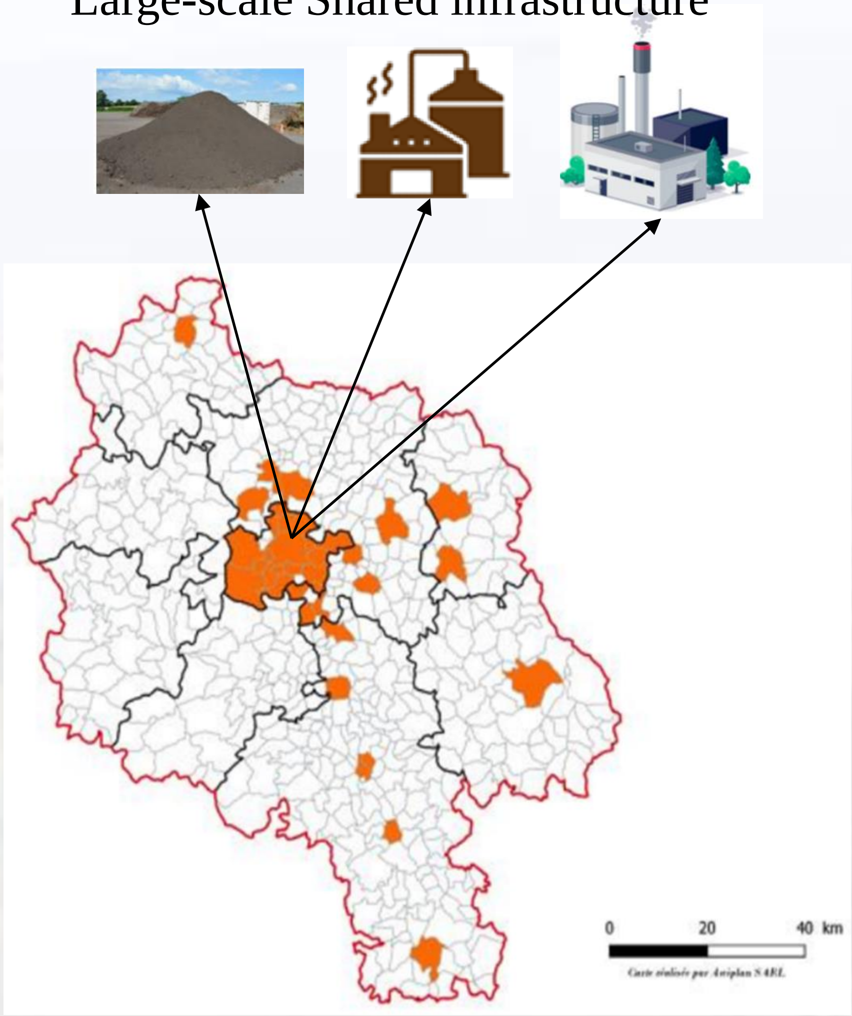
3. Methodology: Nine collection territories in Puy-de-Dôme and northern Haute-Loire departments

INRAE

Small-scale (proximity equipment)



Large-scale Shared infrastructure



700 000

9 collection territory 2 of them provided with collection infrastructure

3. Methodology : 4 Policy objectives for 2024

1. Reducing food waste in residual households by 50%.

$$\sum_{j=1}^{n} B_{f,j}^{r}(2024) \leq 0.50 \sum_{j=1}^{n} B_{f,j}^{r}(2017)$$

2. Reducing green waste in valorization centers by 12%.

$$\sum_{j=1}^{n} B_{g,j}^{v}(2024) \leq 0.88 \sum_{j=1}^{n} B_{g,j}^{v}(2017)$$

3. Increasing digested food waste in methanization units to at least 5,700 tons.

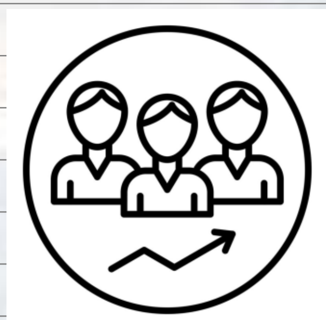
$$B_{f}^{m}(2024) \geq 5700 \text{ tons}$$

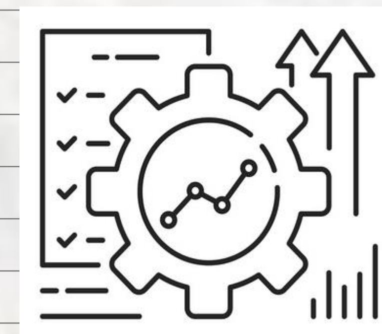
4. Increasing total biowaste in methanization units to at least 12,000 tons.

$$B^{m}(2024) \geq 12000 \text{ tons}$$

3. Methodology : Initialization and Parameterization

Collection territories	Demographic parameters		Initial per capita waste production in Kg/year		The initial intention expressed in % (composting and Sorting)				Infrastructure capacities (composter and Collection)	
	P	r	b_g^p	b_f^p	α_g^c	α_f^c	α_g^s	α_f^s	K^c	K^s
SBA										
CAM										
TDM										
ALF										
SCZ										
SIB										
SCB										
SDC										
SHD										



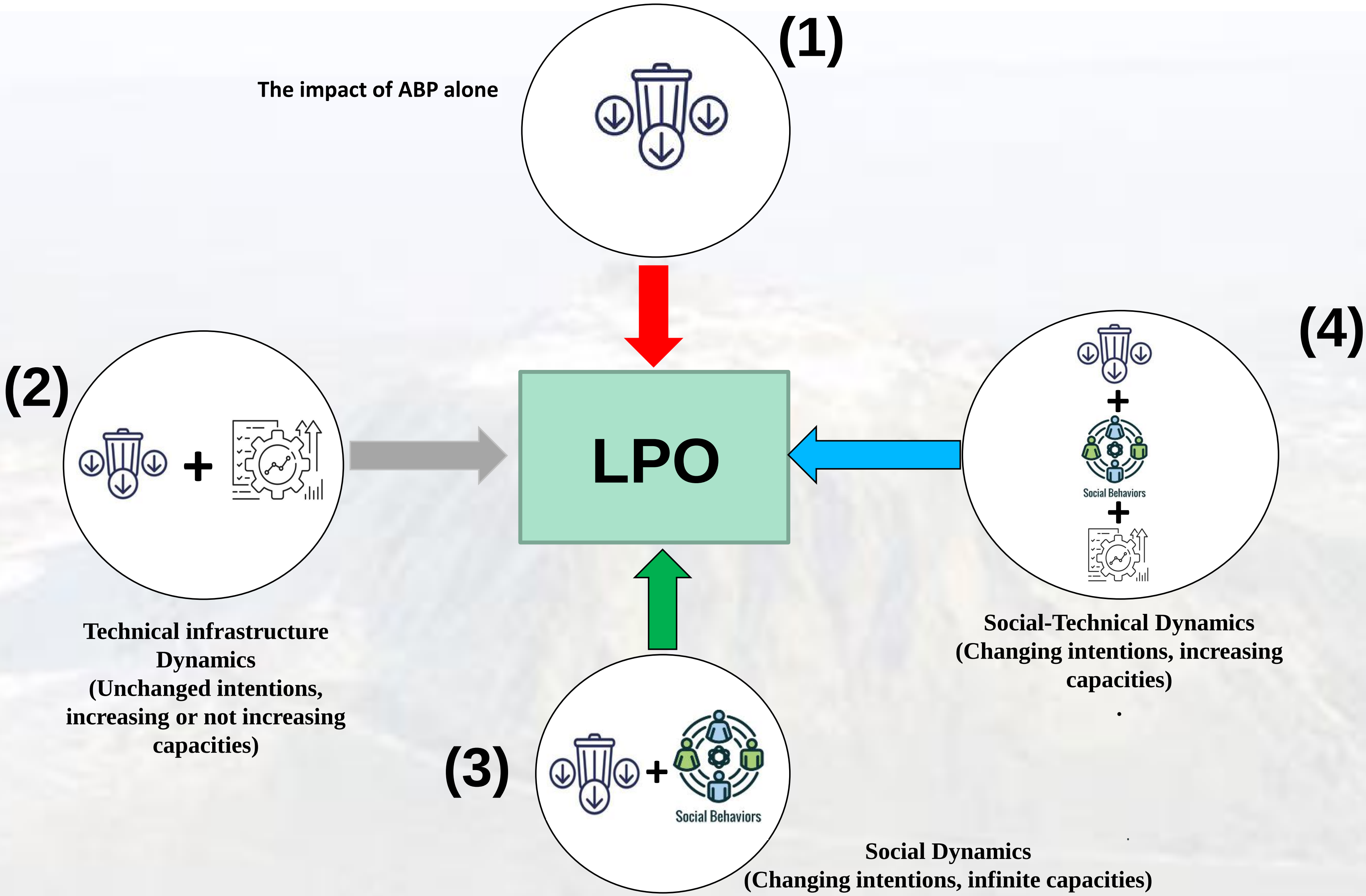


Valtom. (2018, 2019a, 2019b) Réalisation d'un « Schéma Territorial de Gestion des Déchets Organiques » (STGDO) sur le territoire du VALTOM - Phase 1 - Phase 2 - Phase 3. validation du projet. 19.

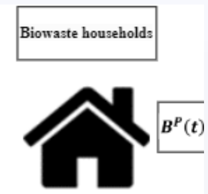
3. Methodology : The fixed parameters are

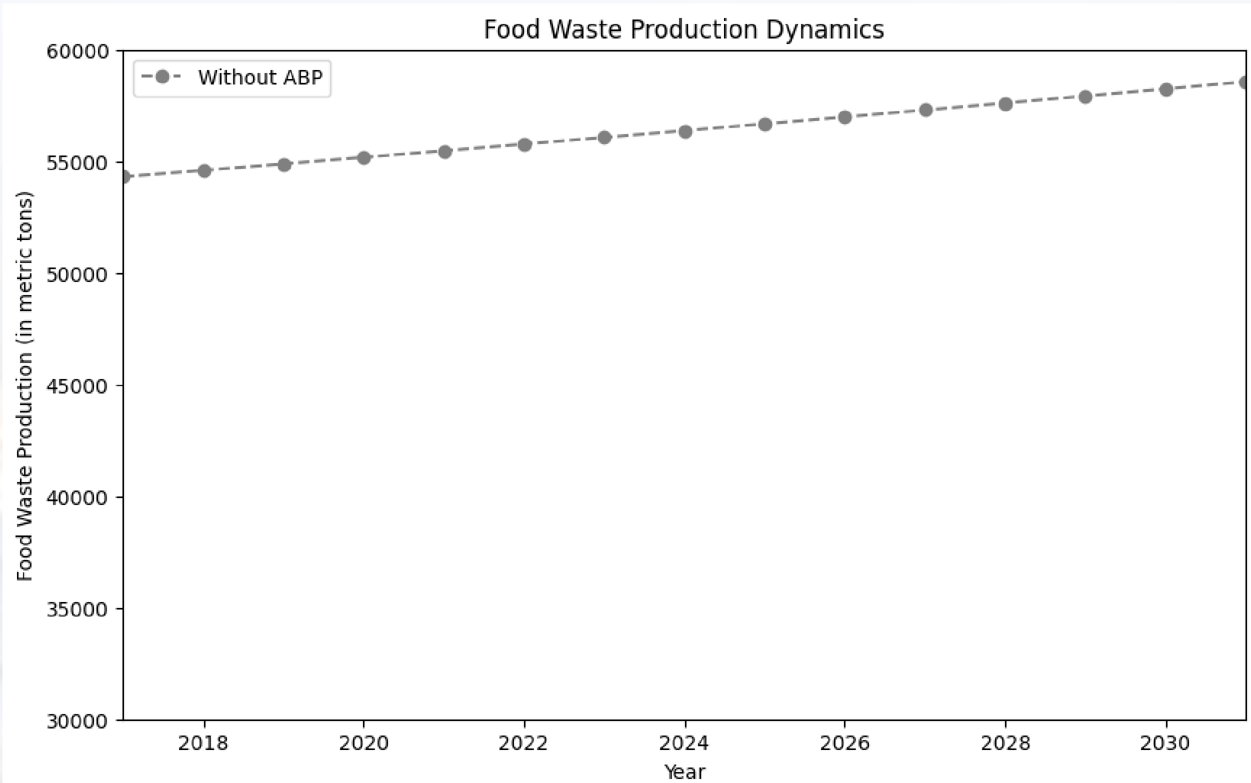
Collection territories Anti-biowaste characteristics	Anti-biowaste production ABP		
	Policy action of food reduction's values	Policy action of green reduction's values	Intention diffusion half-time (green and food) years
	a_f^p	a_g^p	m_f^p & m_g^p
SBA			
CAM			
TDM			
ALF			
SCZ			
SIB			
SCB			
SDC			
SHD			

3. Methodology : The experimental design 4 scenarios



4. Results: The impact of ABP alone

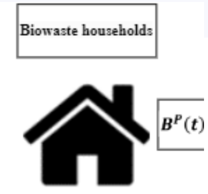


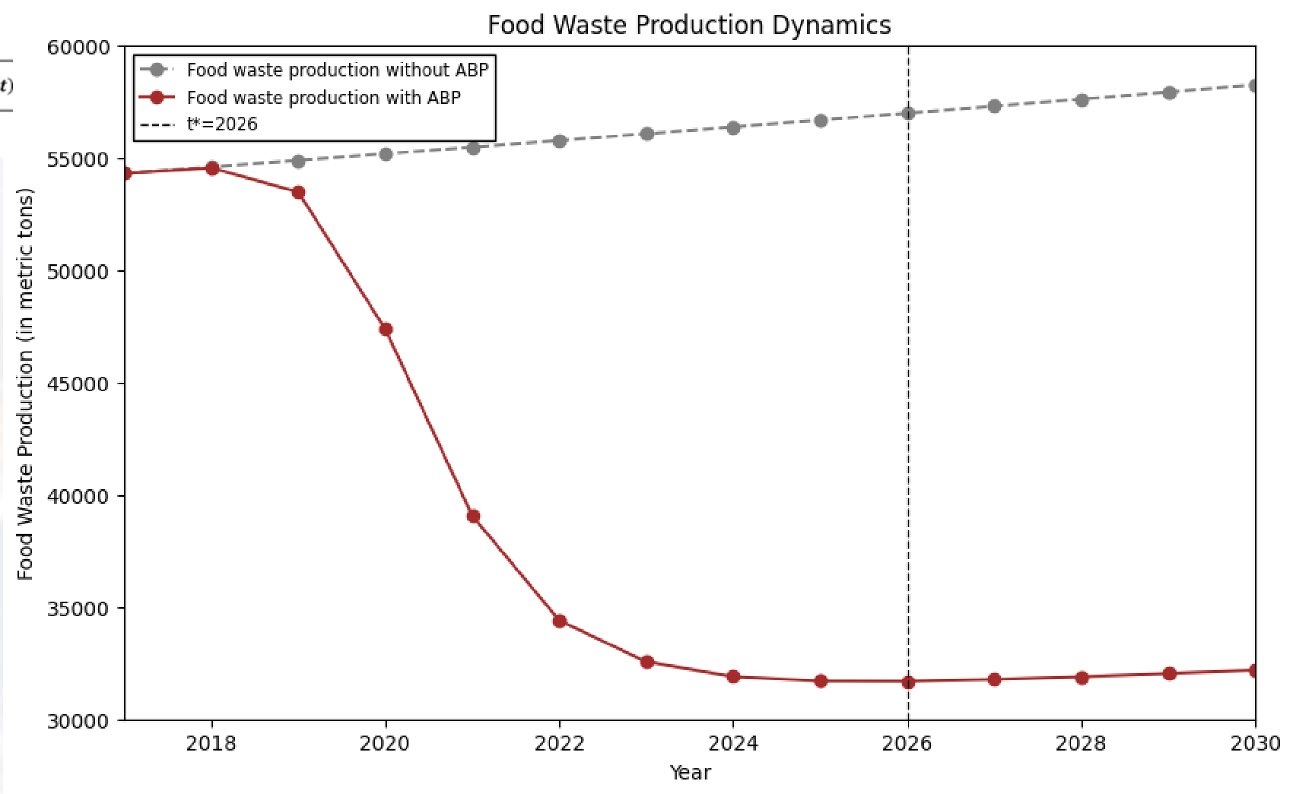


(a) food waste dynamics

(0)

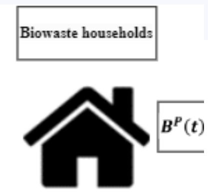
4. Results: The impact of ABP alone





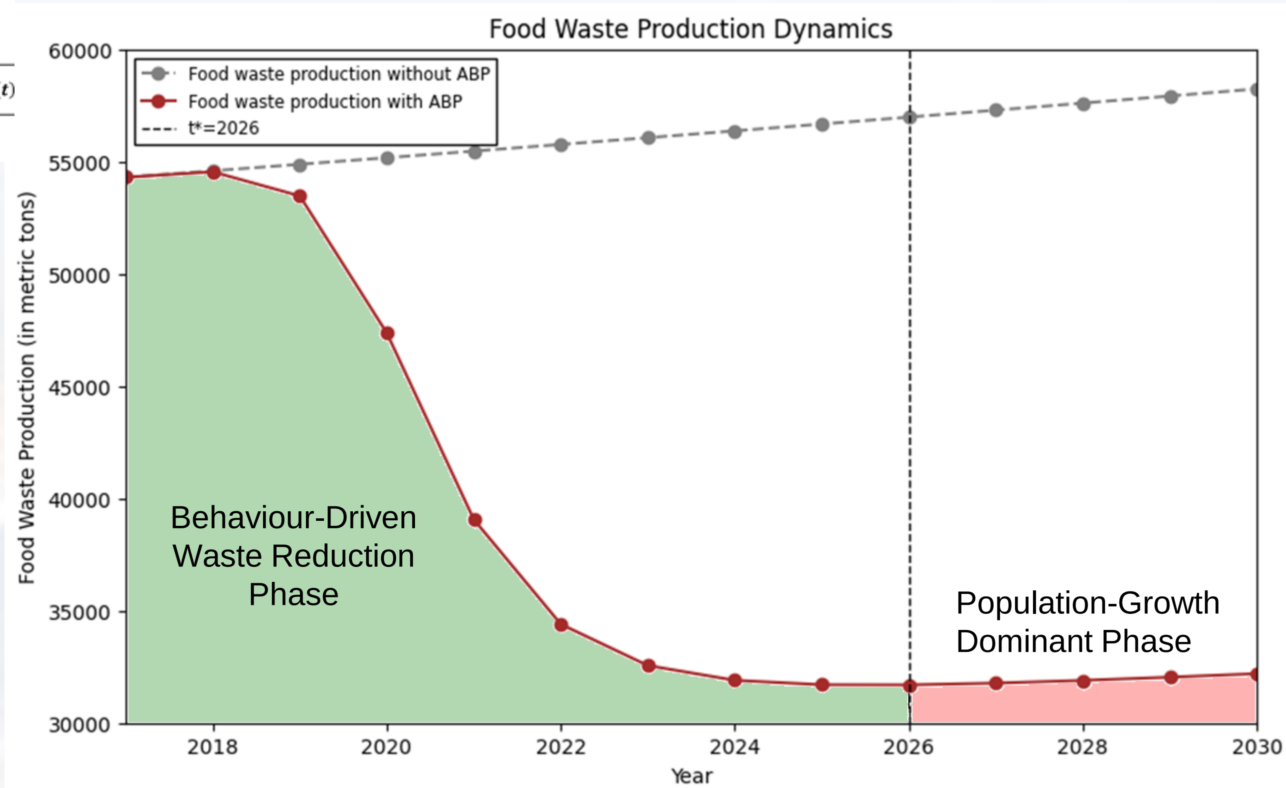
(1)

4. Results: The impact of ABP alone



Change of behaviour **>** population growth

Change of behaviour **<** population growth



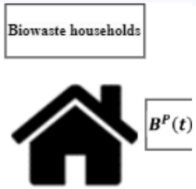
(1)

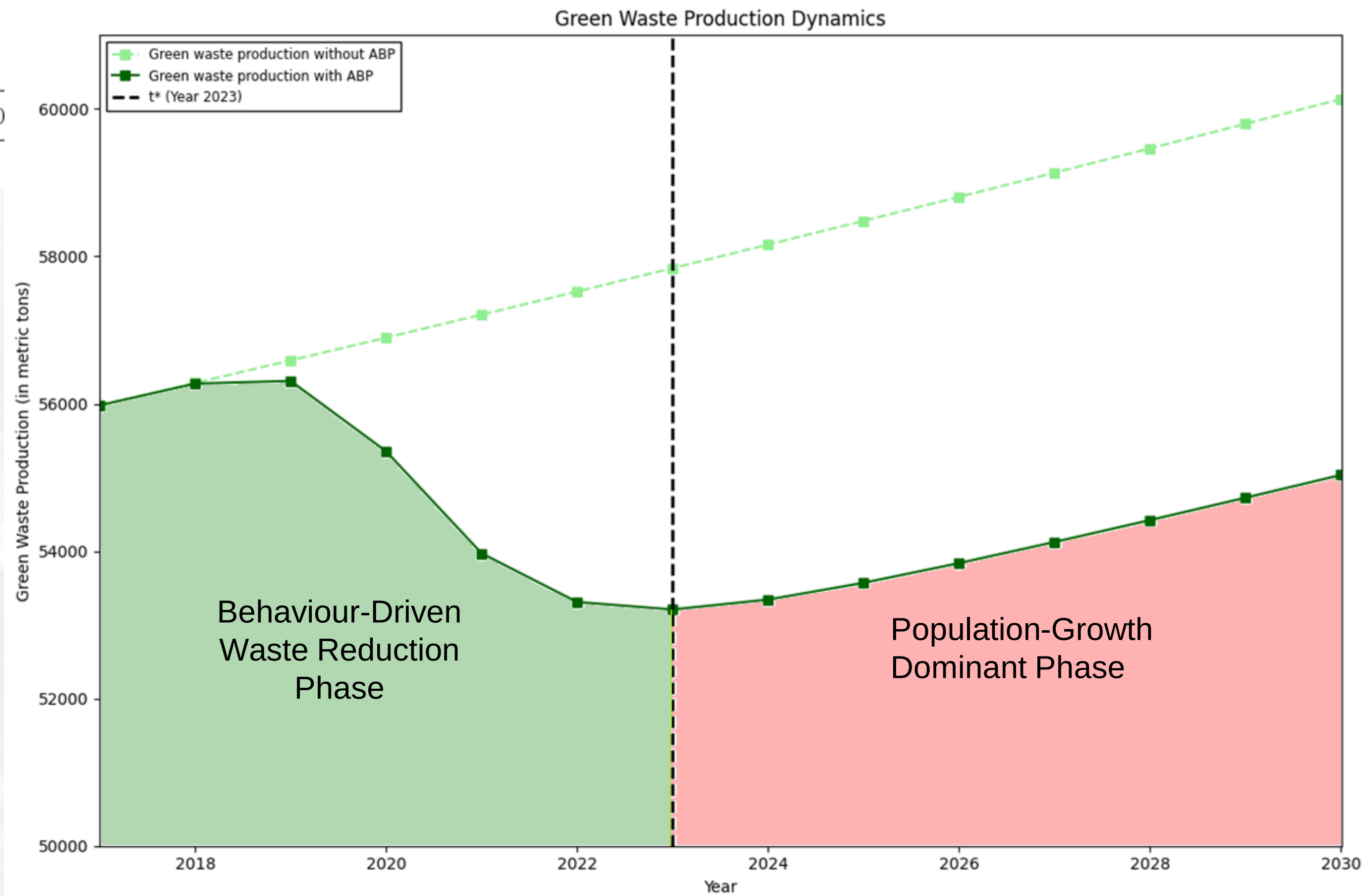
4. Results: The impact of ABP alone

(1)

Change of behaviour **>** *population growth*

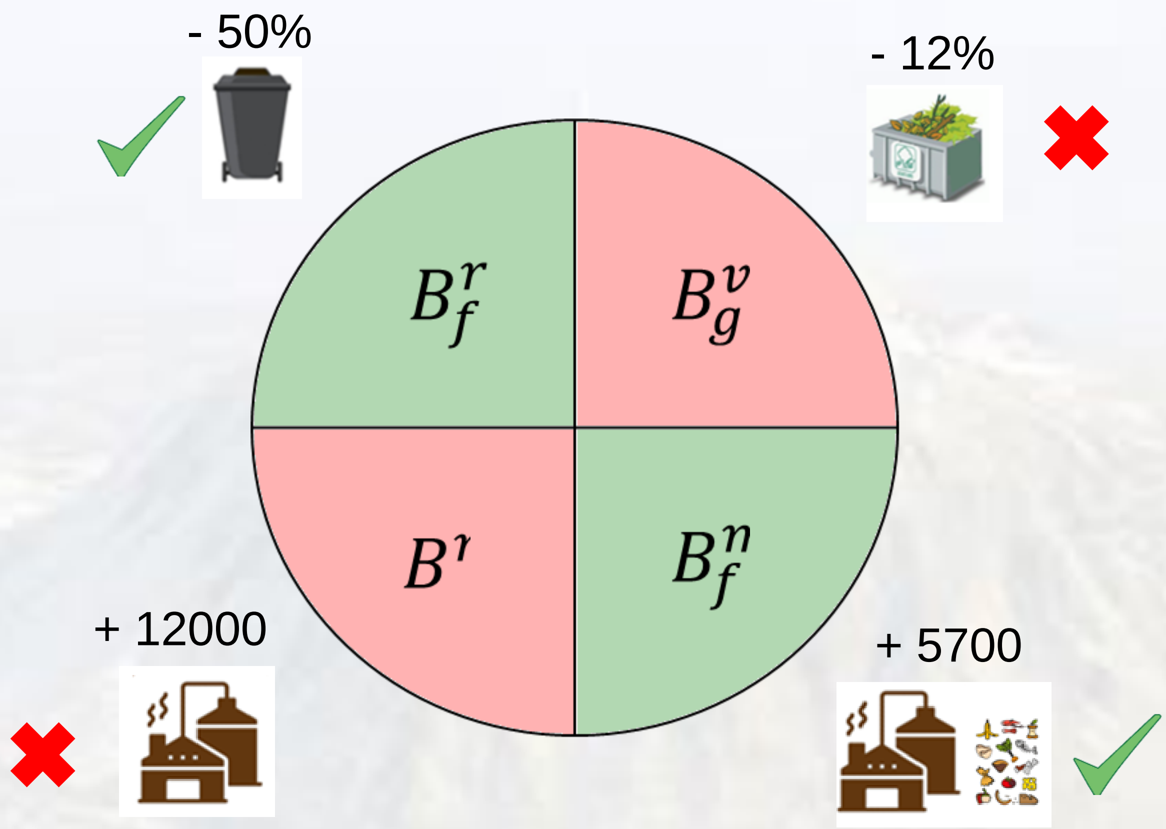
Change of behaviour **<** *population growth*





(b) green waste dynamics

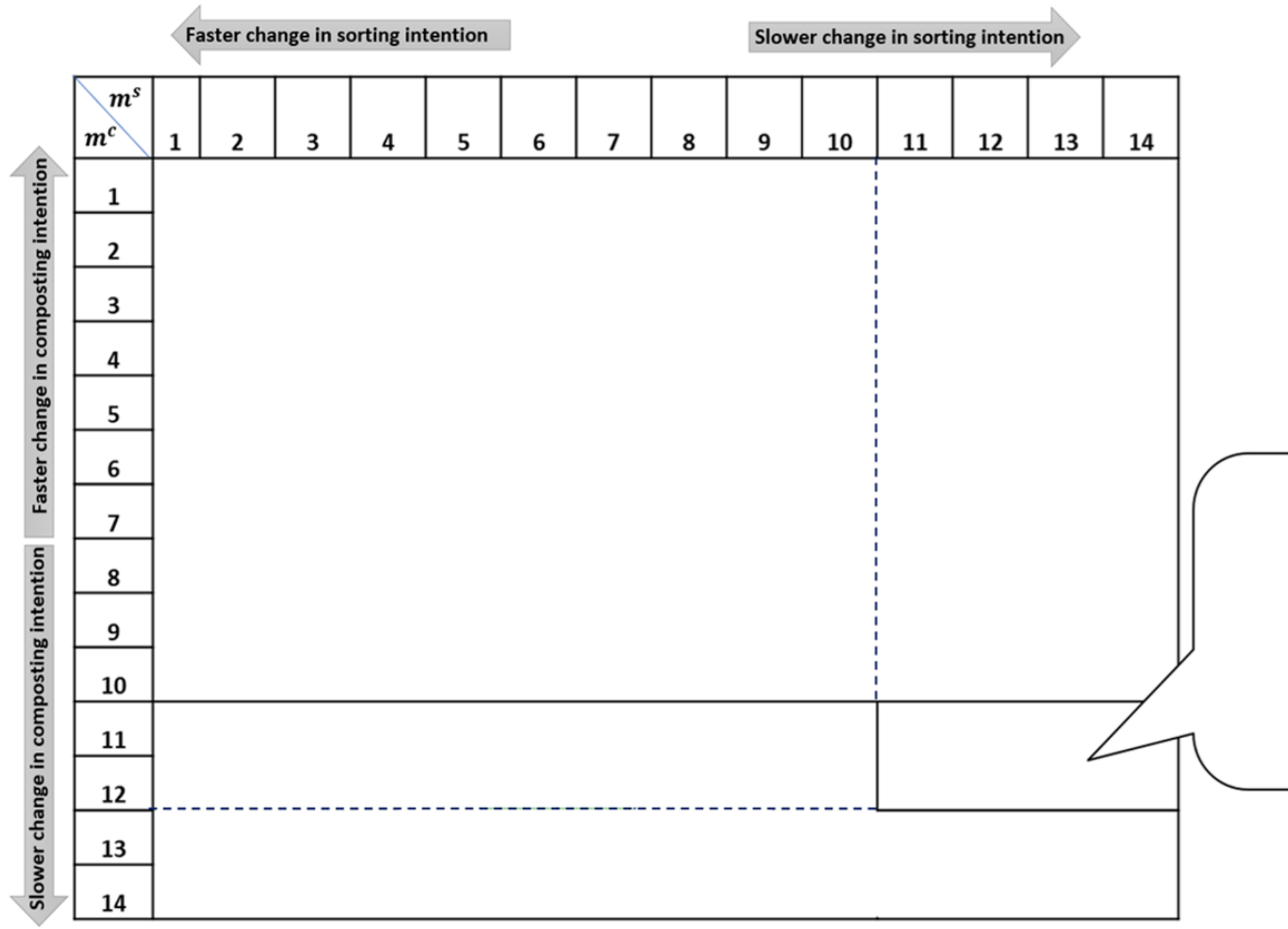
4. Results: Influence of social dynamics: exploring behaviour change without infrastructure limitations



Two LPOs are achieved (green colour)

Influence of sorting for home compositing and sorting for dedicated collection intention on achieving Local Policy Objectives (LPO) in 2024.

(3)



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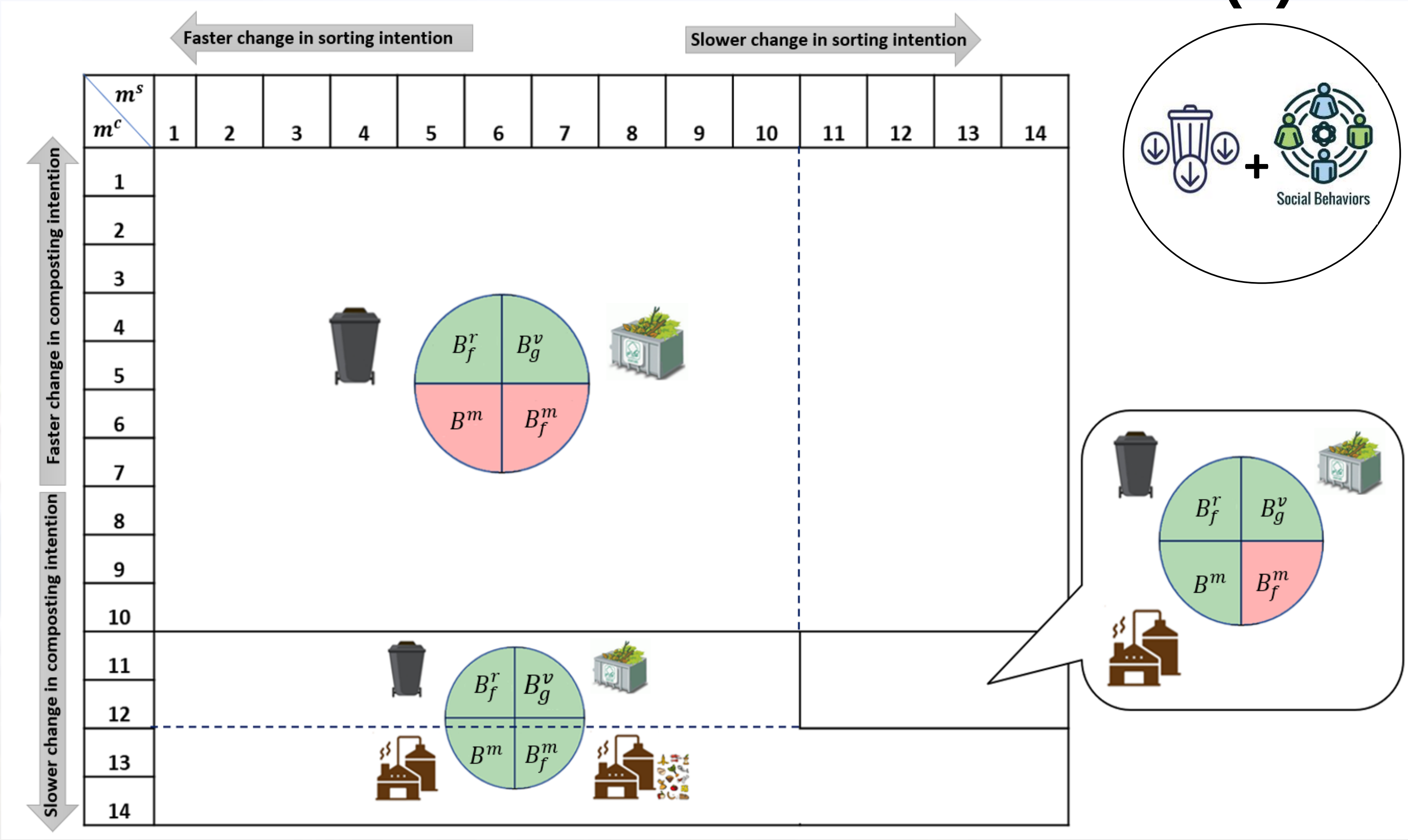
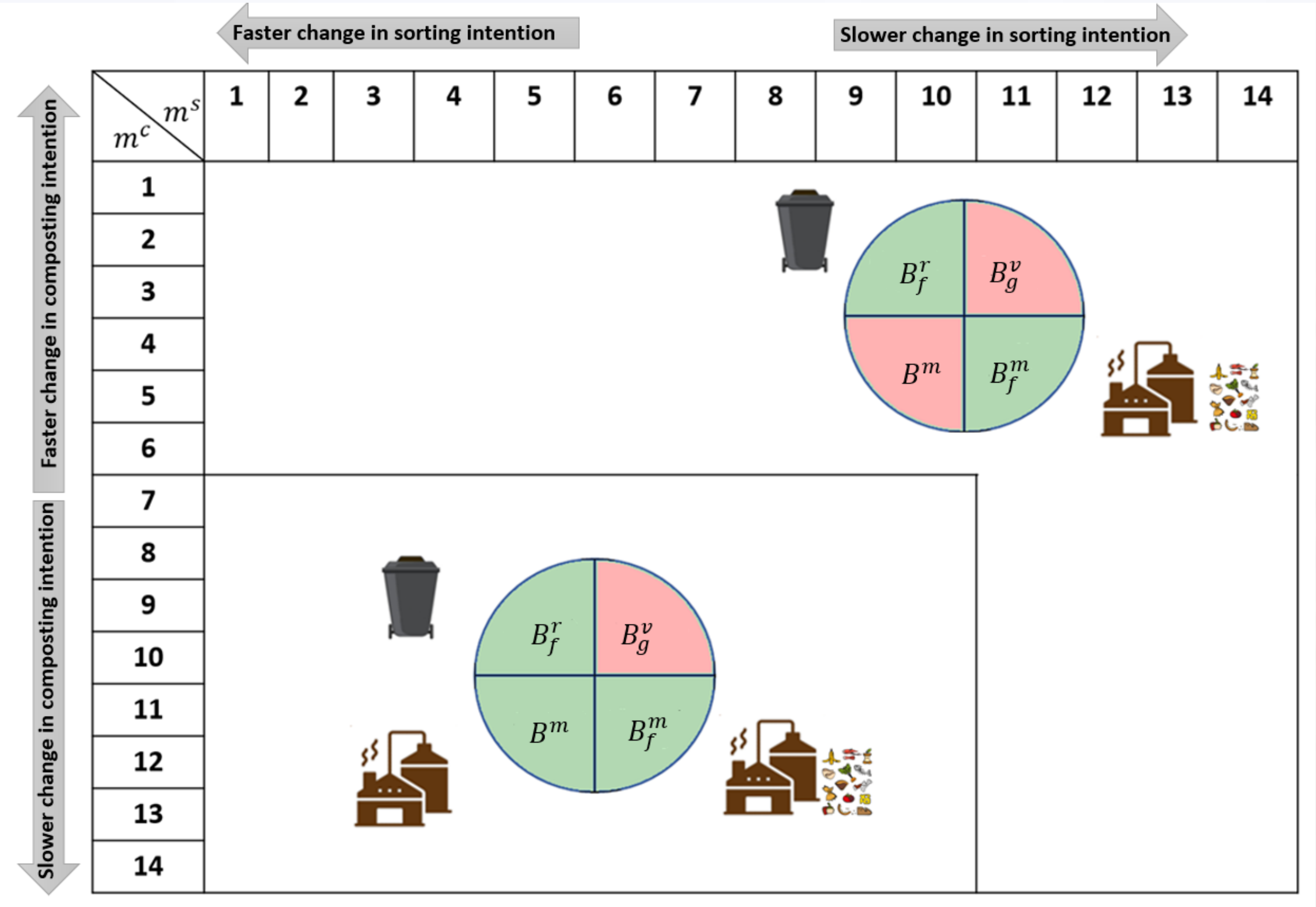
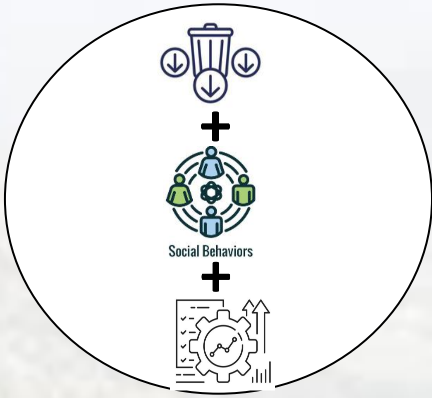


Influence of sorting for home compositing and sorting for dedicated collection intention on achieving Local Policy Objectives (LPO) in 2024.



(4)



4. Results: Synthesis of Influential Factors on achieving policy objectives for biowaste management

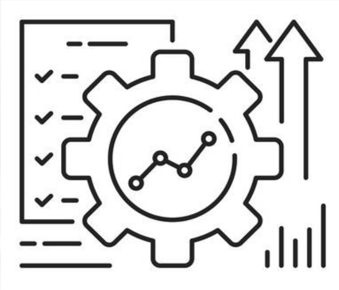
Table 5. Impact of various processes and/or scenarios on the LPOs

Factors / *LPOs.*		+	+ Social Behaviors	Social Behaviors +
	Negative impact Not achieved	Not achieved	Can be achieved	Achieved
	Negative impact Not achieved	Not achieved	Can be achieved	Can be achieved
	Positive impact Not achieved	Not achieved	Achieved	Not achieved
	Positive impact Not achieved	Not achieved	Achieved	Achieved

[1]Intentions are composting and sorting intentions $\alpha_f^c(t), \alpha_f^s(t), \alpha_g^c(t), \alpha_g^s(t)$, while [2] 'capacity' relates to the size in tons of the composters and collection technical infrastructure $K^c(t), K^s(t)$.

Conclusion about our Developed system dynamic model

The model highlights the complex interplay between the **infrastructure capacity** , **behavioural intentions**, and **demographic** trends in biowaste management transition .



It underscores the need for a detailed approach to policy implementation considering territory specific characteristics and potential trade-offs between different waste management strategies

Limitations of Current Study (Key Simplifying Assumptions) and Future Research

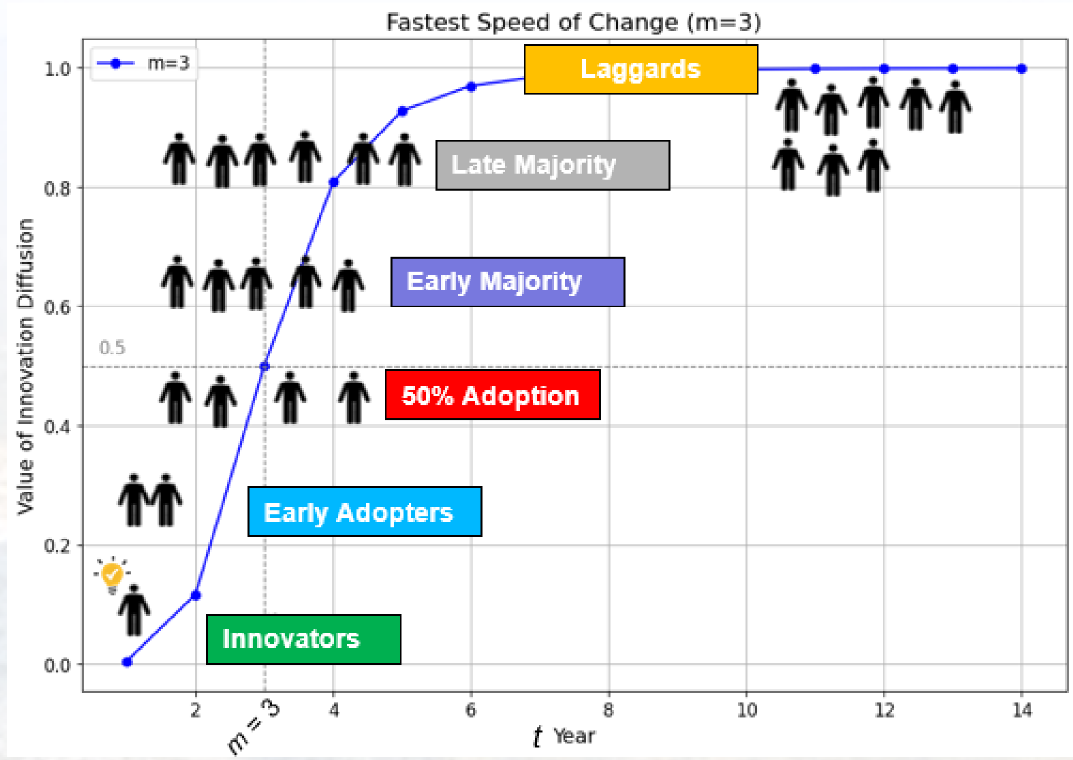
- **Simple model**

- **Simplified Behavioral Model:**

1. Homogeneous Intentions:

2. Behavior Independence

Z



•Ryan et Gross 1943

3. Methodology: Model Structure and Dynamics

Limitations of Current Study (Key Simplifying Assumptions) and Future Research

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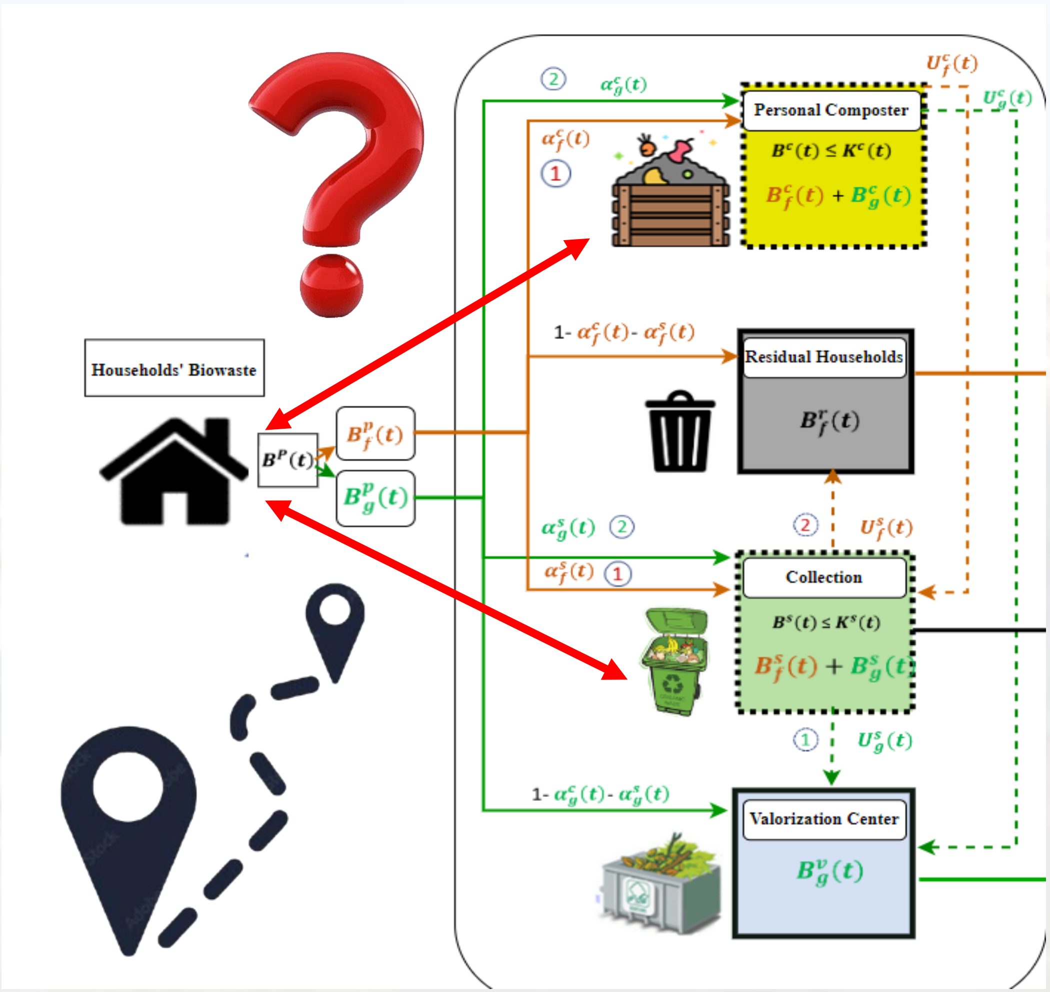
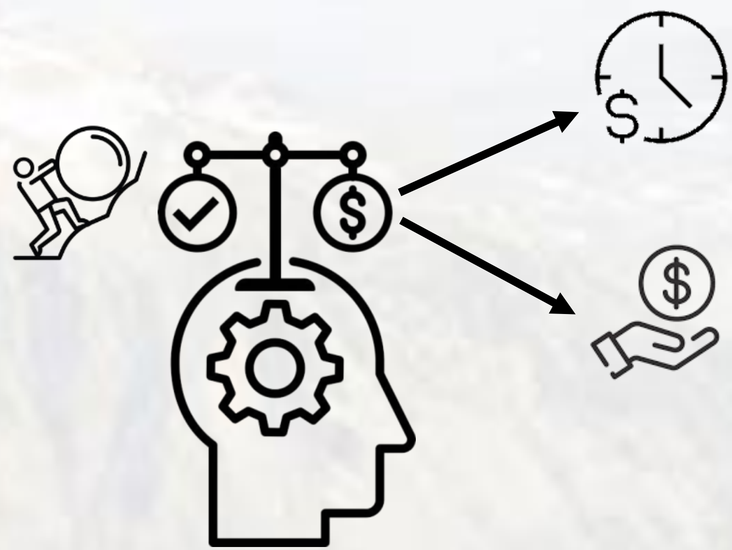
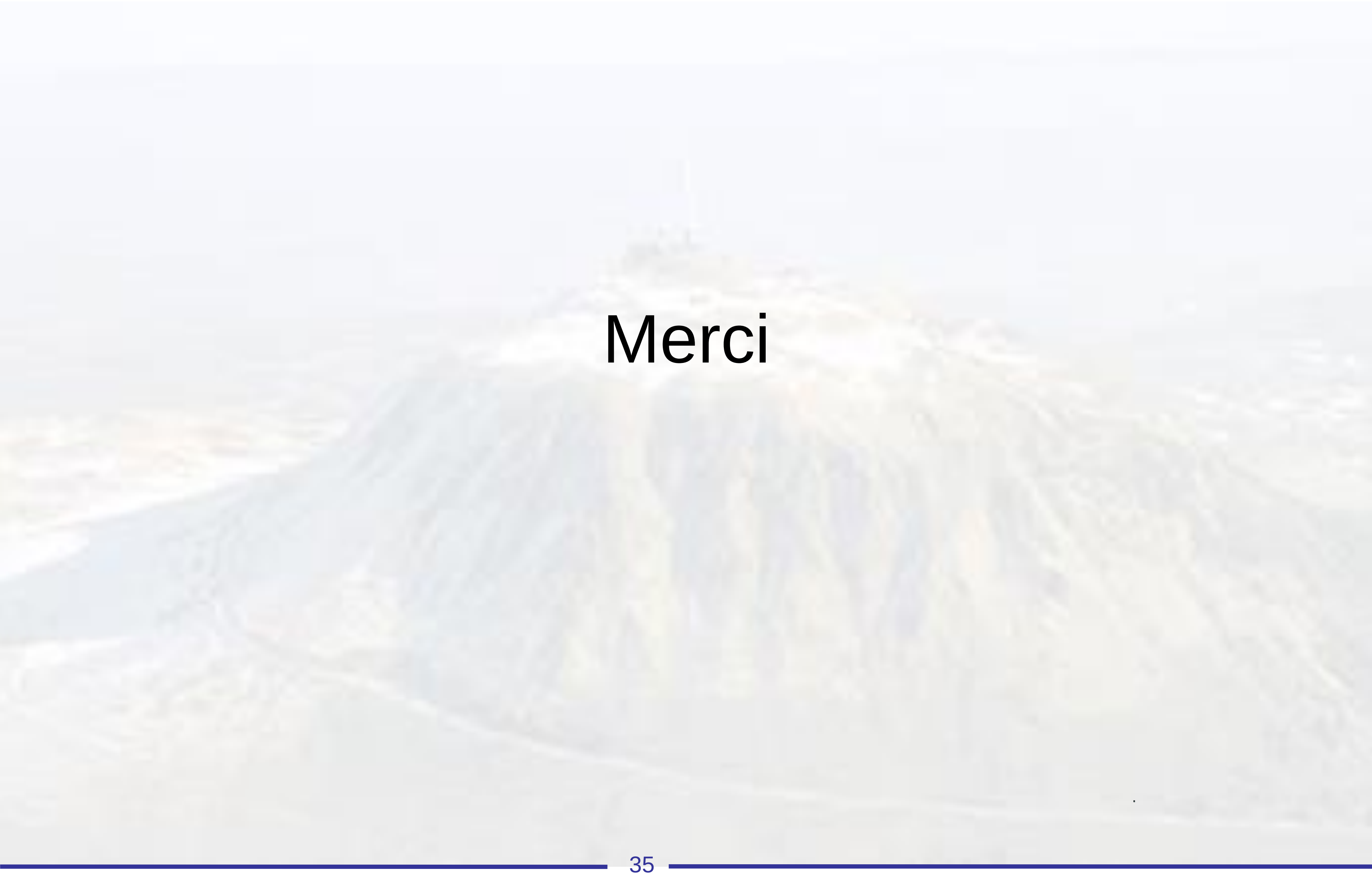




Psychological Factors

Physical Factor



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