Bin2Bean

From Bio-waste to Soil

Handbook of recommendations and good practices – a European perspective

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BIN2BEAN project

From Bio-waste to Soil – Handbook of recommendations and good practices

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Welcome!

to our **“From Bio-waste to Soil” Handbook**!

Are you looking for **“good to know” information** before embarking on the design or optimisation of a bio-waste management system? Are you **not** an expert on one or more of these questions?

→ What is bio-waste? Why recycle it into the soil? How to recycle it successfully?

Then, you are in the right place! Brace yourselves and join in the adventure!

START

- What is bio-waste?
- Why sorting bio-waste?
- Why recycling bio-waste in the soil?
- Who is concerned?

How to recycle bio-waste?

- Overview of existing systems
- Key principles and parameters

Separation at source

- How does it work?
- How to make it work?

Separate collection

- Door-to-door vs bring
- Good practices and recommendations

Transformation into soil improvers

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- Comparison across parameters

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- Compost or digestate?
- Recommendations and good practices
- A matter of Quality

Contents

Acronyms

Acronym	Meaning
AD	Anaerobic Digestion
EC	European Commission
ECN	European Compost Network
EEA	European Environmental Agency
FW	Food and kitchen Waste
GHG	Greenhouse Gas Emissions
GW	Green (garden and park) Waste
ISWA	International Solid Waste Association
JRC	Joint Research Center
PAYT	Pay As You Throw

Acknowledgments

Euroquality and Bin2Bean would like to sincerely thank all the different actors who participated to this study, either through the interviews (the list of people interviewed is available here) or by completing our surveys (for cities or for citizens). Apart from quotes, this document does not commit the opinions of interviewed or surveyed actors.

Summary

The goal of this report is to establish the status quo of existing knowledge, approaches and solutions on the entire value chain of **bio-waste** management, from separation at source and collection to the recycling process and the use of resulting soil improvers into soils. Good practices, results and concrete examples from cities, regions or areas with different local contexts will be presented.

This report aims to support any city, actor, researcher or citizen in getting a better overview of the bio-waste topic as a whole, with a **back-to-soil** objective in mind.

To compile this report,

- > 50 publications were analysed at national, EU or international levels, such as:
  - → European Environment Agency (2020): Bio-waste in Europe – Turning challenges into opportunities.
  - → Zero Waste Europe (2022): How to best collect bio-waste
  - → LIFE BIOBEST (2024): Guideline on the separate collection of bio-waste
  - → Joint Research Centre (2011): Supporting environmentally sound decisions for bio-waste management (LCT / LCA).
  - → ECN (2022): Overview of bio-waste Collection, Treatment & Markets Across Europe
  - → ISWA - ECN (2020): Benefits of compost and AD when applied to soil
  - → WRAP (2016): Digestate and compost use in agriculture - Good Practice Guide
  - → German Environment Agency (2017): Quality assurance of compost and digestate – Experiences from Germany
  - → ADEME (2022): Evaluation of the generalisation of source separation of bio-waste in France
  - → Reports from other EU projects: HOOP, SCALIBUR, WaysTUP!, DECISIVE, ValueWaste

NB: This handbook does not aim to overlap with existing reports and guidelines, but to highlight their key messages and insights in a visual way, along with new examples, good practices and quotes. For more technical details, check out the existing reports listed in 'To know more' or in here.

- 15 interviews were conducted with experts and solution providers at local, national and EU levels, *such as:*
  - → *The International Solid Waste Association (ISWA)*
  - → *The European Compost Network (ECN)*
  - → *Zero Waste Europe (ZWE)*
  - → *The French Agency for Ecological Transition (ADEME)*
  - → *The Finish Biocycle and Biogas Association*
  - → *Partners from other EU projects (LIFE BIOBEST, WaysTUP!, SCALIBUR)*

- 2 surveys were launched and analysed, respectively targeting EU:
  - → **Cities** (20 answers)
    - *Northern Europe: Amsterdam (The Netherlands), Düsseldorf, Hamburg, Münster (Germany), Mikkeli (Finland)*
    - *Southern Europe: Sevilla, Cardedeu (Spain), Albano Laziale (Italy), Porto (Portugal), Zagreb (Croatia), Ljubljana (Slovenia), Sarajevo (Bosnia- Herzegovina), Egaleo (Greece), Istanbul (Turkey)*
    - *Western Europe: Bordeaux, Nantes, Crozon (France)*
    - *Eastern Europe: Bratislava (Slovakia), Kyiv (Ukraine), Elbag (Poland)*
  - → **Citizens** (455 answers from 21 European countries)

Certain topics will not be addressed in this report:

- → Energy recovery solutions (e.g. biogas production) or other type of bioproducts (biorefinery, bioplastics, etc.), as Bin2Bean focuses on soil improvement,
- → Other organic waste streams that are not classified as bio-waste (sewage sludge, manure, etc).

→ New technological solutions that are not yet well-established or not yet fully demonstrated as performant, as this study focuses on existing, implemented solutions (some will be briefly mentioned).

Results:

The results of this study are manifold, but what stands out according to the authors are the following main steps, recommended to ensure the effectiveness of **biowaste-to-soil recycling systems**:

1. Map your local context and parameters, understand the **needs and barriers** of local actors.
2. Set ambitious objectives, both in terms of **quality** and quantity, aiming for **long-term viability,** respecting the **Waste Hierarchy**.
3. Design / optimise your bio-waste management system by ensuring that it is **user-friendly**, **trustful**, **reliable** and of the **highest quality**.
4. Design / optimise your **first communication and awareness raising campaign**, using different formats, explaining the sorting guidelines as clearly and visually as possible, adjusting to different population groups and including motivation incentives to engage people.
5. Launch your (designed or optimised) system first in a **pilot area** (previously studied in step 1):
   - Start with the awareness raising campaign,
   - Then, implement the collection system.
6. Ask for feedback: are there still some barriers? Needs? Levers? What worked? What didn't work? How many people sorted? How many did not? Why did they / didn't they? How did they with respect to quality?
7. Take into account all feedback into a **2nd, more tailored, awareness campaign**.
8. Launch that next campaign and **keep monitoring the impact**.
9. Once the system seems effective in this pilot area, restart the cycle & test with other areas, by basing on your first results while adjusting and optimising your approach to the new area and its characteristics (e.g. type of population, population density, housing density).
10. Once the system is proven effective in several pilot areas, with different characteristics, deploy it further at larger scale, by always:
    - monitoring, adjusting, optimising,
    - communicating, training, engaging and motivating.
11. When selecting your treatment system, if possible with regards to your local parameters, favour combining composting and Anaerobic Digestion, ideally on the same plant.

In short: it is key to adopt:

→ an iterative and long-term process that must be refined gradually, that should aim to:
- reach as many people as possible,
- collect / save as much bio-waste of good quality as possible,
- ensure as much as possible a safe and beneficial return to the soil.

→ an ecosystemic and cooperative approach across all the different actors concerned (similar to the *Living Lab Strategy*), that should enable to:
- Keep the dialogue flowing! Get the snowball rolling, multiply the effects.
- Consider the different perspectives and barriers of all actors.
- Empower them, give them a sense of ownership on this topic!

Moreover, while it is important to adapt to your local context, **do not start from scratch**! There are already a lot of good practices, recommendations, success stories of other municipalities to inspire you, and there are a lot of experts who could advise you. This handbook just represents a glimpse of it all.

Let's start from the same page:

According to the European Waste Framework Directive (2018), **bio-waste includes:**

→ Biodegradable garden and park waste (hereafter called "green waste"),

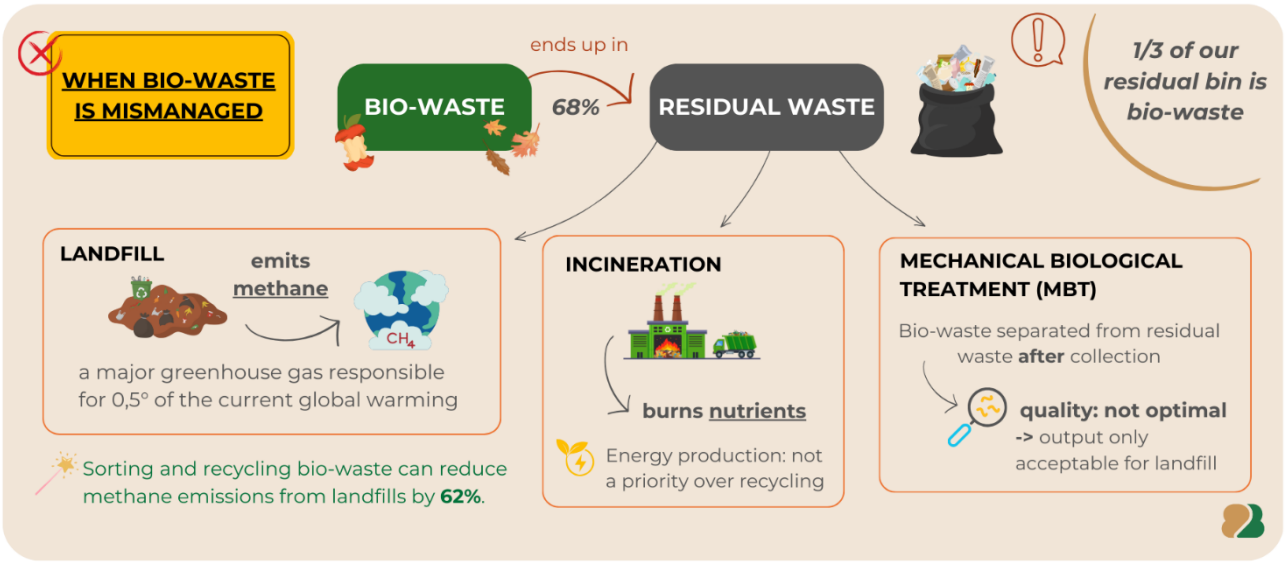
→ Food and kitchen waste (hereafter called "food waste"), from households, restaurants, caterers, retail premises and food processing plants.

It does not include: forestry and agriculture residues, manure, sewage sludge, or other biodegradable waste (natural textiles, paper, processed wood, etc).

→*Why sorting bio-waste?*

IMPACT OF BIO-WASTE MISMANAGEMENT

When bio-waste is not managed at source, i.e. not separated from other streams, it can have detrimental effects on the environment, on climate change and/or on resource efficiency:



Currently, a large proportion of the bio-waste produced in Europe ends up in the residual waste bin (about 68% [1]), and is therefore either incinerated, landfilled or sent to mechanical biological treatment (MBT) facilities (and ultimately landfilled) [+].

IMPACT OF LANDFILL

- → The decomposition of bio-waste in landfill emits **methane**, a major greenhouse gas which should not be overlooked, as it is responsible for approximately **0.5° of the current global warming** [2].
- → The separation, collection and treatment of bio-waste can reduce methane emissions from landfills by **62%** [3].

→ On the worldwide level, the waste sector is responsible for approximately 20% of anthropic **methane** emissions, and landfilled bio-waste is the major source.

IMPACT OF INCINERATION

→ Incinerating potentially reusable or recyclable waste **undermines resource efficiency**. It burns precious resources – usually produced at high environmental cost – that should be preserved as long as possible. In the case of bio-waste, it destroys carbon and nutrients that can be returned to the soil. [4]

50% of the waste currently incinerated could have been recycled or composted. (+)

Sorting bio-waste is thus beneficial for human, environmental and soil health

LEGAL OBLIGATION IN THE EU

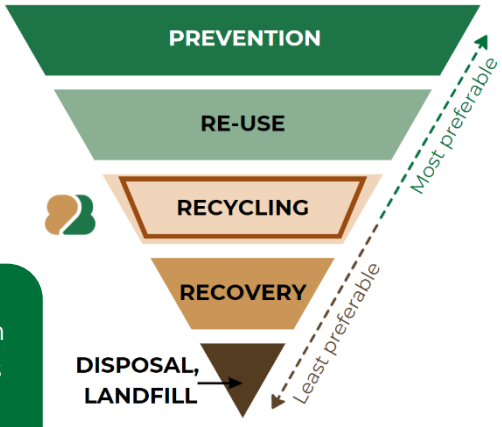
Since December 2023, proper bio-waste management and recycling has been a **legal obligation in the EU**, under the EU Waste Framework Directive [5]:

→ All **EU Member States (MS)** must ensure that bio-waste is either:
- → separated and recycled at source (e.g. through home or community composting) or
- → separately collected and not mixed with other types of waste (e.g. through door to door collection or bring systems).

Since 2008, this framework has also defined the "Waste Hierarchy", which represents the order of reference for waste management and disposal:

PREVENTION PREVAILS OVER RECYCLING

When designing or optimising a bio-waste management system, the waste hierarchy should always be considered. **Preventing bio-waste and/or re-using food surplus and by-products** should form the pillar of your strategy.



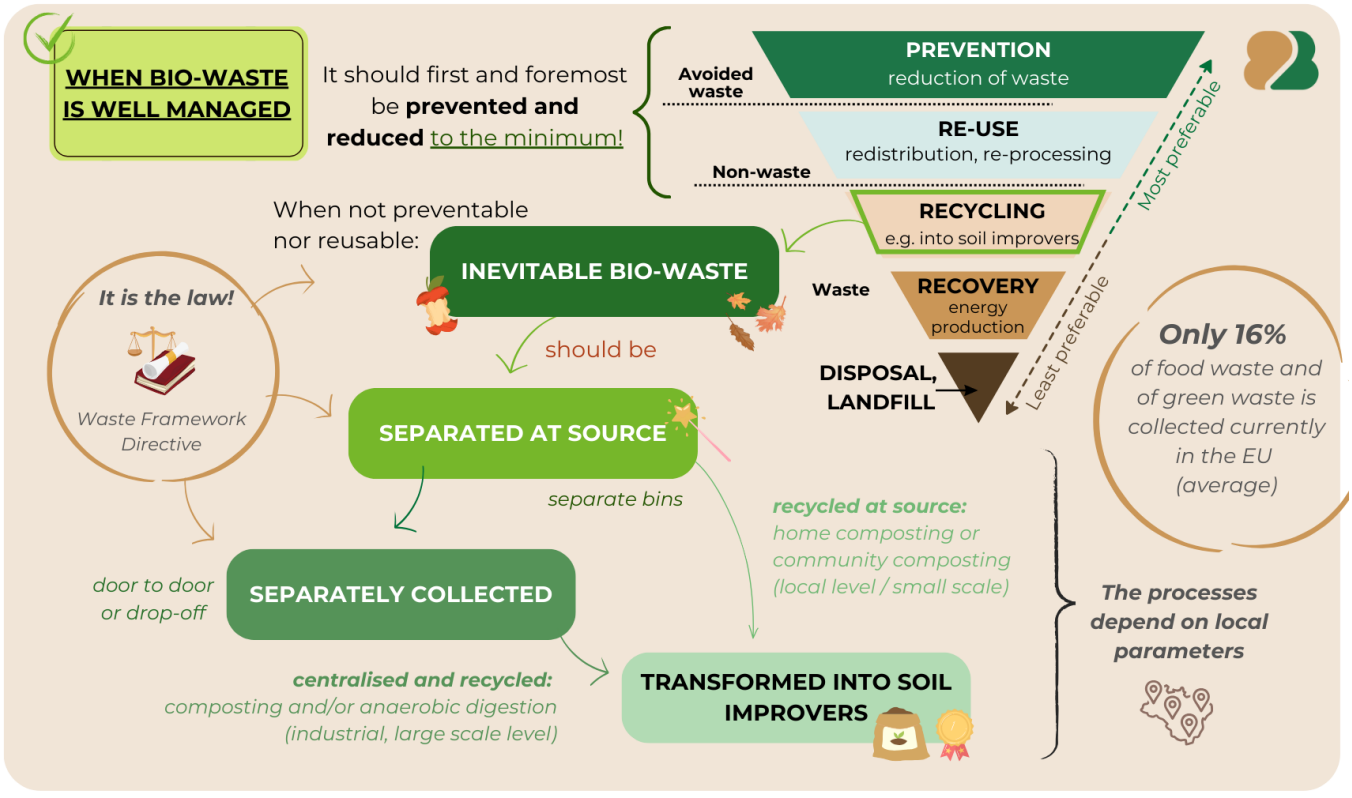
After all, what's the point of producing food, which uses precious resources (such as water) and emits greenhouse gases, if it is not eaten when edible?

→ **About 20% of all food produced in the EU is wasted every year [2].**

Prevention and re-use can be achieved through several cross-cutting measures around planification, communication, monitoring, redistribution and reprocessing.

→ The **EU Platform on Food losses and Food Waste:** supports in **preventing** food waste, with recommendations, good practices and communication materials.
→ Examples of solutions to **reduce** or better manage bio-waste: Article, Database.
→ Results of EU projects addressing food waste: e.g. Refresh, Fusions, Zero W, Sisters.
→ Data about food side streams for **re-use** in food production: FoodWaste EXplorer.

→ **Recycling** bio-waste should come third, for inevitable or inedible bio-waste mainly, such as unavoidable residues of food preparation (e.g. banana peels, eggshells).



There is still a long way to go, as currently **only 16%** of food waste and **32%** of bio-waste is collected in the EU (2020) [1,2]. Moreover, in order to guarantee a safe return to the soil, systems must be optimised to minimise the level of impurities.

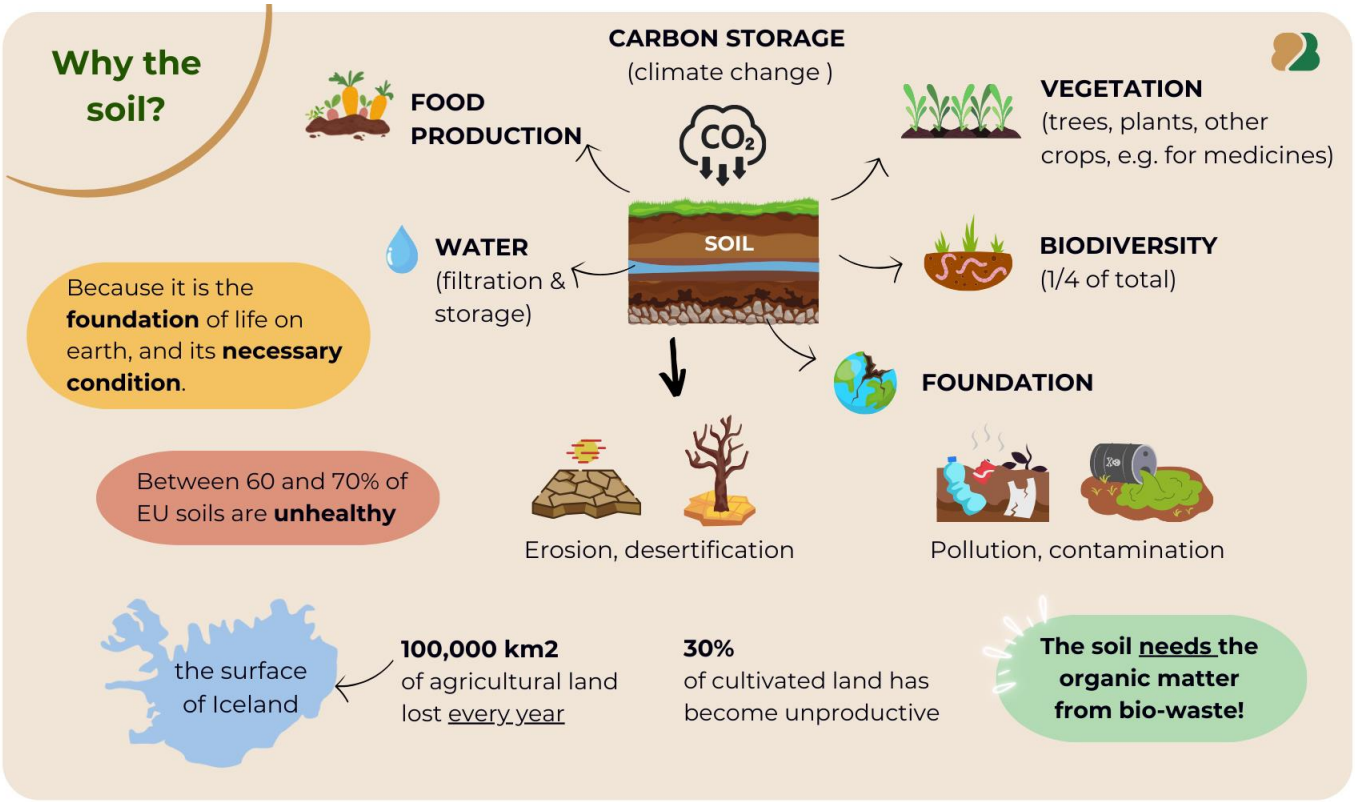
→ *Why recycling bio-waste into the soil?*

THE DEGRADATION OF SOILS, AN ECOLOGICAL CRISIS [6, 7, 8, 9] ...

Soils are essential to human life: they filter water, they are at the basis of our nutrition (95% of our food comes directly or indirectly from soils), they represent an incommensurable source of biodiversity and the second largest natural carbon sink after oceans.

However, like many other natural environments, soils are exposed to **major threats**, such as erosion, loss of organic matter, contamination, unsustainable management practices, degradation and desertification (+), among other factors. It is estimated that across the EU, between 60 and 70% of soils are unhealthy and that 45% of soils have a very **low organic matter content** [2].

Soil degradation in turn affects water pollution, biodiversity loss, climate change, as well as food security (+), and thus has cross-border and transverse effects on human health, natural ecosystems, climate and on the economy.



...TO WHICH BIO-WASTE IS A SOLUTION

There are several solutions to reduce soil degradation and restore soil health, and recycling bio-waste into soil improvers (compost) or fertilisers (digestate) is one of them [8].

A **soil improver** is a material added to the soil to:

- → maintain, improve and protect the soil:
  - physical or chemical properties,
  - structure or
  - biological activity,
- → thus increasing **soil fertility** and supporting **soil health**. [10]

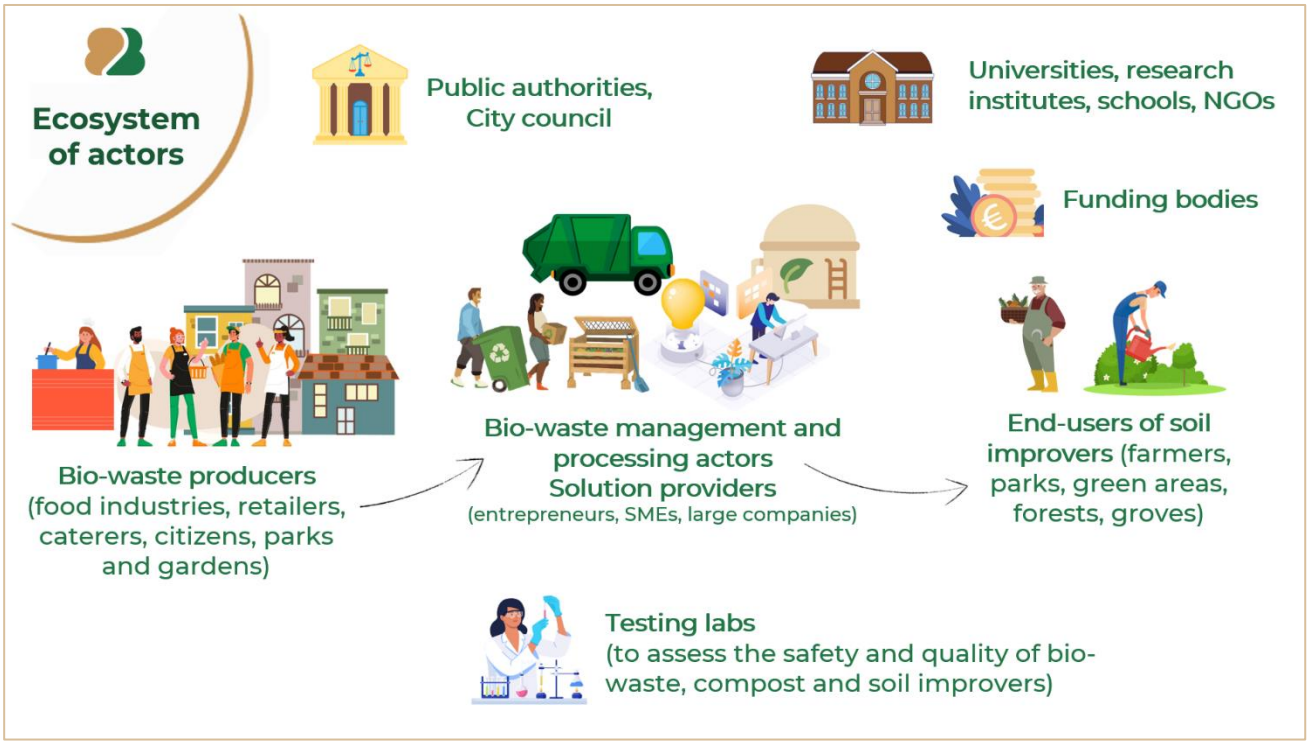
A **fertiliser** aims to feed crops and support plant growth.

- → A fertiliser is not necessarily a soil improver, and A soil improver is not necessarily a fertiliser. [11]

→ *Who is concerned?*

Everyone!

Qualitatively sorting, managing and recycling bio-waste & Safely using the resulting soil improvers requires the involvement of an **ecosystem of actors**.



How to engage actors?	Analyse their current state, needs and interests Co-define a common vision and clear objectives Enhance their sense of ownership on this topic

Take a look at the "Living Lab" strategy for concrete tips and good practices on stakeholder engagement: Bin2Bean Living Lab Toolbox.

How to recycle bio-waste into the soil?

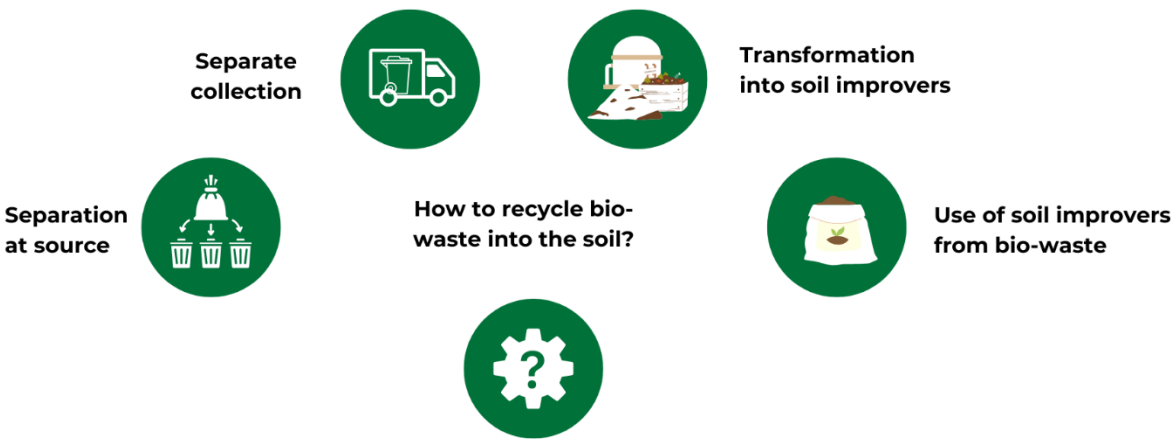
The selection, optimisation or implementation of a bio-waste management system can take on an algorithmic dimension:

- → there are many variables to take into account,
- → many conditions to test and
- → many "instructions to execute", or recommendations to follow,
- → in order to solve a problem (e.g. reducing bio-waste in the residual bin while minimising impurities).

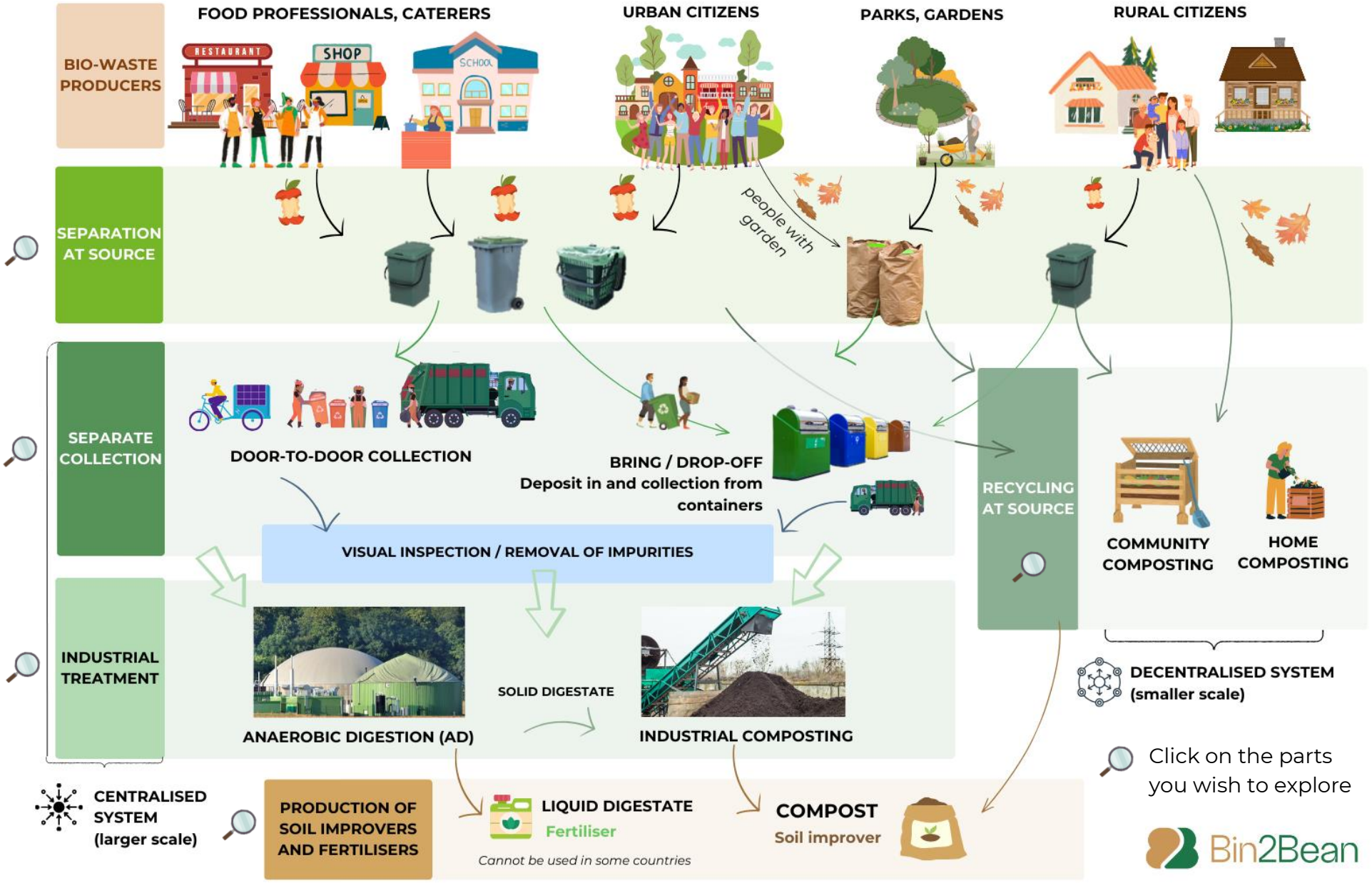
It can be visualised as interrelated decision trees, with many branches and possibilities.

Consequently, there is no universal or miracle solution that works for everyone or everywhere [12, 13, ITW]. But there are several recommendations that can guide the choices of decision makers or solution providers, based on various parameters that need to be **mapped, measured (if possible) and then monitored**.

The figure below gives a simplified overview of existing systems, approaches and possibilities, according to the type of bio-waste producers and throughout the different steps, from bio-waste to soil. A same territory can adopt several approaches.
Take a glimpse, more information on the parameters and steps will follow!



→ *An overview of existing systems*



→ *Key principles and parameters to consider*

MAP AND ADJUST TO YOUR LOCAL CONTEXT [12, 13, ITW]

Bio-waste management is a local undertaking, it must be adapted to numerous parameters and contextual factors, such as social, demographic, environmental, economic, geographical and pedoclimatic factors.

> **It is key to start by mapping the city, its rules, its possibilities, its inhabitants, its needs."** *Pablo Kroff – Suez*

KEY LOCAL PARAMETERS TO CONSIDER

TERRITORY CHARACTERIZATION

- **Population density and territory size**
- **Housing density and typology** (% of population with garden, in single houses, in high-rise buildings, in group housing...etc.)
- **Territory typology** (rural, semi-ural, peri-urban, urban, coastal, mountain area)
- Whether there are **seasonal changes**, for instance due to tourism.
- **Weather** conditions
- **Soil types and needs**, soil quality, land use, current use and quality of soil improvers / fertilisers

BIO-WASTE GENERATION + RECYCLING

- **Amount of total municipal waste and of bio-waste generated**
- **Distribution between food waste and green waste** which have different properties
- **Type and number of bio-waste producers:** households, restaurants, parks, etc.

- **Type of system in place (if any):** door-to-door, bring, composting, AD

- **Performance:** % impurities, quantity of bio-waste collected, frequency of collection, % of bio-waste ending up in the residual waste, nutrient recycling / substance flows, environmental impact

ECONOMIC VIABILITY

- **Costs optimisation, multi-annual budget planification,** costs of bio-waste management, e.g.. the costs of logistics, equipment, awareness-raising campaigns, staff, facilities, etc.
- **Financial incentives,** for waste in general or just for bio-waste, e.g. landfill tax, incineration tax, Pay As You Throw (PAYT), tax refund scheme or premium-penalty schemes

END-USERS

- **Stakeholders' current status:** habits, practices, experiences, knowledge, motivation, barriers, needs, solutions, behaviours
- **Stakeholders' perspectives:** individual or group versions of reality

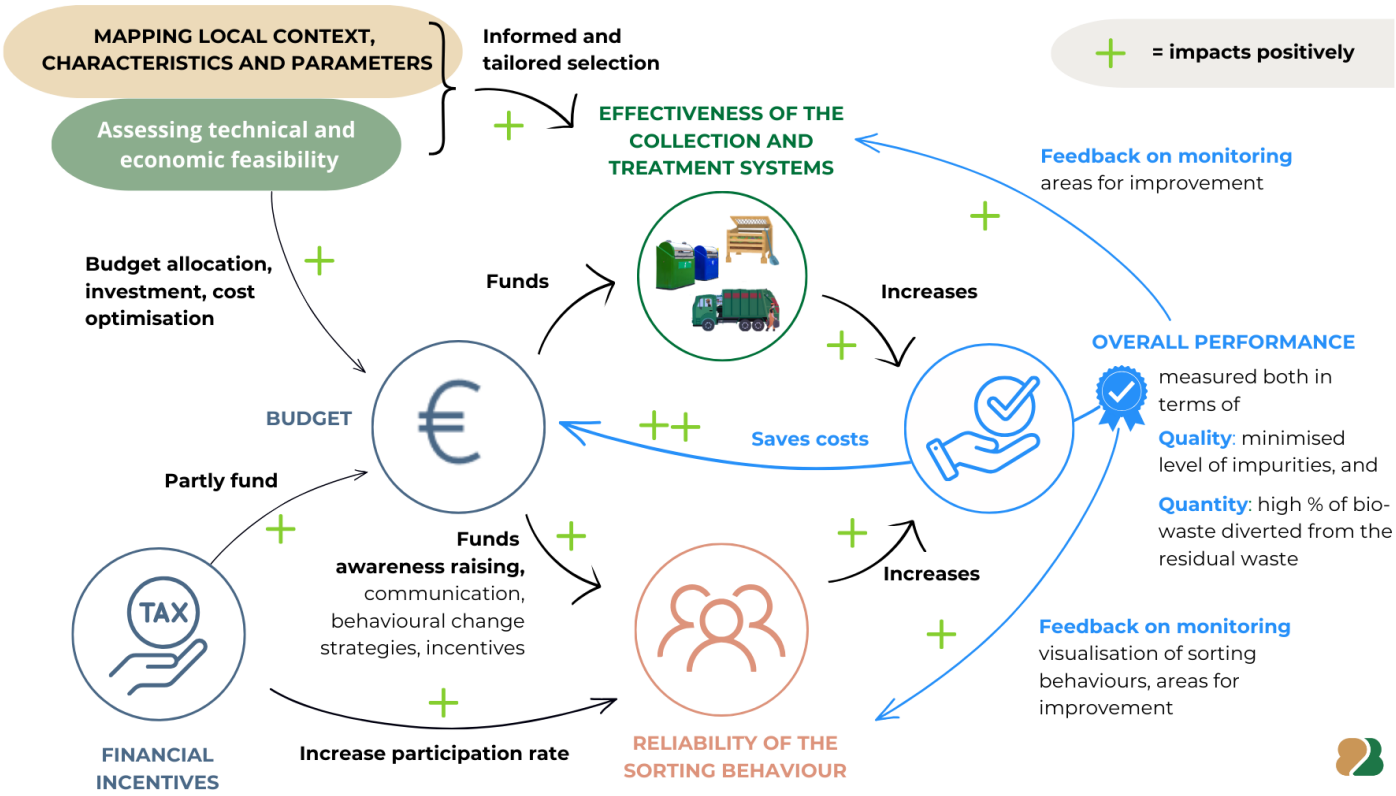
REGULATORY CONTEXT

- **National/regional/local policies** (e.g. binding targets, national versions of EU regulations such as the Waste Framework Directive)
- **Political will**

→ **All these parameters or variables** not only condition the selection or optimisation of a bio-waste management system beforehand, but they also impact the system effectiveness during its implementation. *The latter will be illustrated in the following sections.*

→ **Most of these parameters are interconnected.** For example, when zooming on the links between the following parameters, several positive interactions can be identified:

- economic viability (costs, financial incentives, grants)
- system (type(s) of system(s) in place, effectiveness, adjustment to the context)
- performance (quality and quantity of bio-waste collected)
- "user" (sorting behaviour)



This happens when applying transversal recommendations, such as:

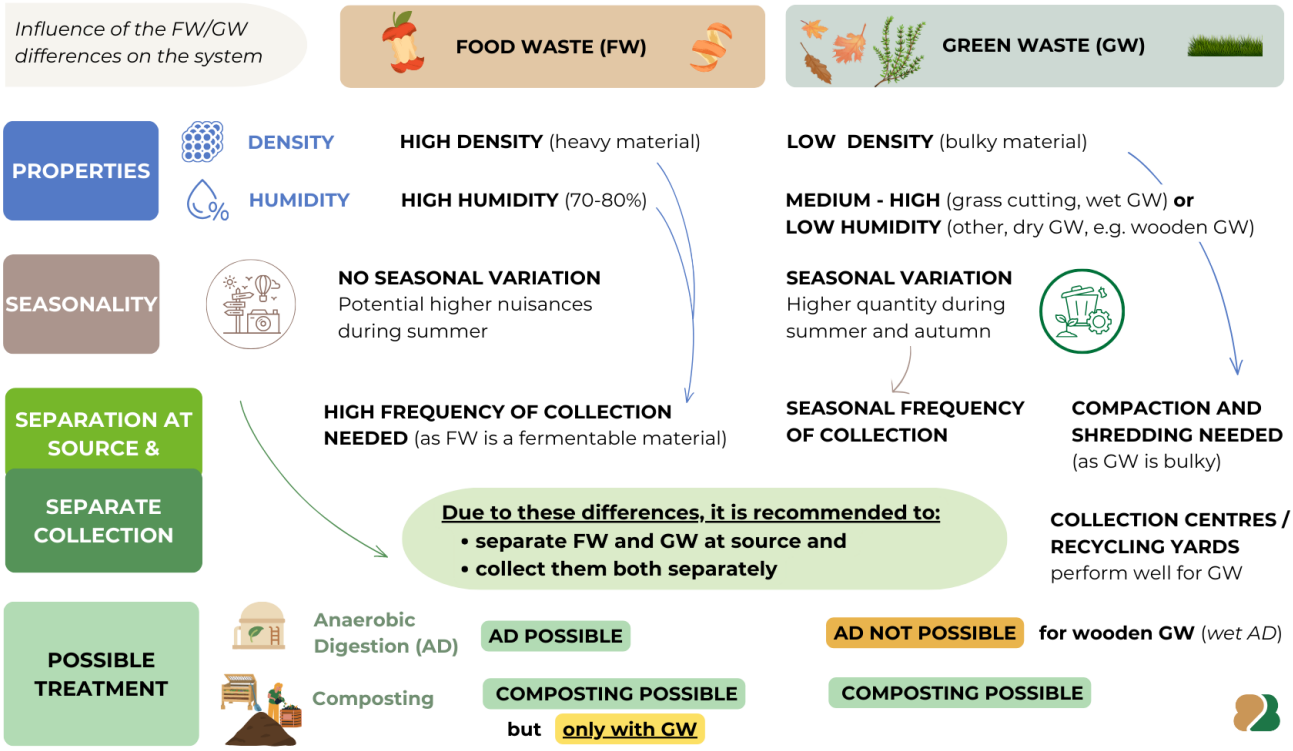
Jointly assess the **technical and economic feasibility** of potential bio-waste management systems beforehand, to maximise the chances of selecting the most effective, economically viable and high-quality system and solutions [14].

Introduce **financial incentives for citizens**, through taxes, fees or Pay-As-You-Throw (PAYT) systems (+). Part of the incomes can cover the collection costs, and in some cases, can also reward a good sorting gesture (i.e. a waste tax cut) or penalise a bad one (by charging more). These mechanisms lead to an increase in the participation rate, a better quality of bio-waste separation and higher transparency on how the system works.

Monitor and minimize the **% of physical impurities** (such as glass or plastic), notably through sampling procedures. Limiting impurities from the collection phase is a cost-saving measure, as it reduces investment in removal systems during the treatment phase (e.g. plastic is hard to remove at a later stage due to its adherence to food waste). Moreover, monitoring quality parameters will reveal the behaviour of bio-waste producers as well as the improvements necessary to maximise the quality of final soil improvers.

Some key parameters **influence the system as a whole**, from separation to treatment, such as:

→ Distribution between food waste (FW) and green waste (GW)



In general, it is recommended to collect separately these two waste streams, considering their different characteristics and their impact on the collection and treatment steps, while aiming for an overall economic viability.

INFLUENCE OF FW/GW ON SEPARATE COLLECTION

Some cities/countries are collecting **both food waste and green waste together**, e.g. in Germany. As a result, more GW is collected (70% vs 30% of FW in Germany), as the population tends to use the bio-bin for GW only [15].

Others are focusing on **food waste collection**, with great results e.g. Milan, the UK. In this case, it is still important to provide an alternative for GW. It can be with another collection system, or a disposal centre such as collection centres / recycling yards [16]. In the latter case, GW is usually collected in good quality, but the quantity is often poor. [20]

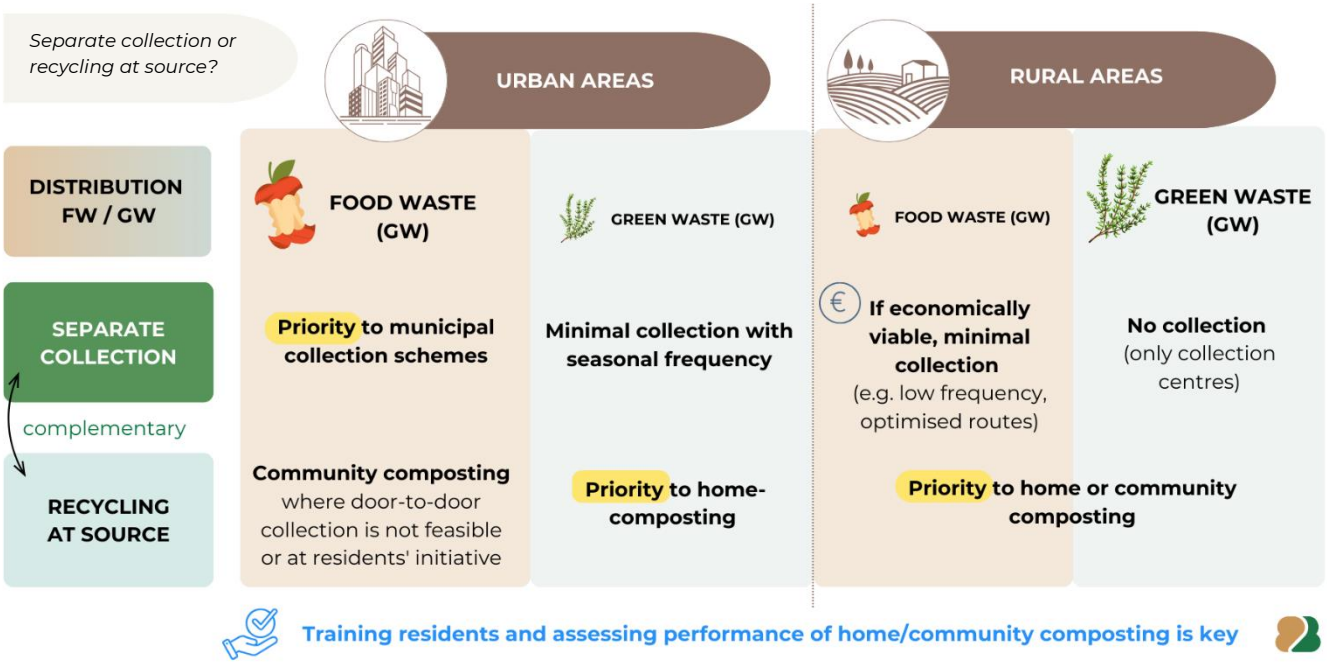
INFLUENCE OF FW/GW ON TREATMENT

The ligneous/woody elements of green waste are not directly degradable by **anaerobic digestion (AD)** [17], as they do not break down without oxygen. Thus, if a territory produces only or mostly GW, composting should be preferred.

Food waste needs shredded green waste as a structuring dry matter for **composting** (notably for areation), with approximately a 2 (GW) to 1 (FW) ratio (but varies in practice).

In Bratislava (Slovakia), food waste and green waste are collected separately, GW is treated in a composting plant, and FW is processed in an AD plant (with a composting step of the digestate at the end – *see section Treatment*).

→ Typology of the territory (urban, rural, or both)



→ **The predominant fraction of bio-waste is FW in urban areas and GW in rural areas.**

In all areas, separate collection and recycling at source should be complementary, while prioritising the most effective approaches.

According to **LIFE BIOBEST** [13]:

In urban areas: priority should be given to:

→ municipal collection schemes for FW, in order to maximise recycling rates

→ home-composting for GW (for households with garden), in order to reduce the amount of GW to be collected. A minimum seasonal GW collection service can be set up, but it must not divert people from home composting (collection centres represent good alternatives).

In rural areas: priority should be given to home and community composting (notably with regards to the higher proportion of households with gardens).

→ Collecting frequently FW can be ecomically and logistically challenging (long distance between collection points, smaller quantity of FW produced compared to urban areas, etc.). However, solely relying on home-composting may increase the risk of non-participation by households, thus leaving recyclable FW in the residual bin. Thus, it is recommended, if it is economically viable, to provide a minimum collection service for FW.

→ With regards to GW, it is recommended to avoid offering a collection service, to promote home-composting or delivery in collection centres.

SET SMART OBJECTIVES FOR YOUR MUNICIPALITY, BEYOND THE LAW ITW

"Our main goal is to respect the law and propose a bio-waste collection or recycling at source solution for every citizen."

"Our main goal is, by the year 20XX, to:
- reduce the amount of bio-waste in residual waste by X kgs/person.year (+)
- serve X% of the population with a bio-waste collection system
- ensure that the level of impurities in the bio-waste collected is below 3%[1]
- return most of inevitable bio-waste (>X%) into the soil."

Indeed, the only requirement to meet Article 22 of the Waste Framework Directive (WFD) is to introduce at least one bio-waste management approach. **In the absence of legally binding targets, some municipalities tend to select and rely only on the least expensive measures in the short term rather than on the most performing ones, which are also more cost-effective in the long term.**

There is **another key parameter** that is also **overlooked** (e.g. only 1 sentence in the WFD[2]): citizen behaviour. Sorting behaviours of bio-waste producers should be mapped, public opinion must be sought, and their voices should be considered as a first step, when selecting or optimising a bio-waste collection system.

It is thus essential to go beyond the law, and to set **Specific, Measurable, Acceptable, Realistic and Time bound (SMART) objectives** towards long-term and long-lasting impact. These objectives must not relate only to quantity or economic viability but also, and most importantly, to user-friendliness, behaviour change and quality.

→ Increase user-friendliness, foster behavioural change
→ Optimise the quality and minimise impurities
→ Optimise the costs of your overall waste management system

Don't choose the easy way out, think long-term!

For more tips and methods *on context mapping, objectives setting and stakeholder consultation, take a look at the following steps in the Bin2Bean Living Lab Toolbox:*
→ *"Where are we now" (context and system analysis, understanding users needs)*
→ *"Where are we going" (visioning, setting SMART objectives)*

[1] Impurities should be < 5% to allow an elimination of impurities to an high extent. < 3% is better with regard to the new EU treshold values for plastics in soil improvers. [20]

[2] "Consumers should be incentivised to change their behaviour including through education and awareness raising." Directive (EU) 2018/851, 30 May 2018. Page 6.

1/ Separation at source: the sine qua non condition

Separating bio-waste at source is the prerequisite for any bio-waste management system. It enables to keep the level of impurities low and ensure a high-quality end-product.

** This section may be longer than the others, but if you skip it, the rest might not work very well...*

→ How does it work?

BIO-BUCKETS AND BINS [12, 13, 18]

There are several types of equipment that can be used for bio-waste sorting and collection (a complete overview is available **here**). The **size of the bin** should be adapted to:

→ The type of collection scheme.

→ The type of bio-waste producers and the quantity of bio-waste produced:

- for citizens, the bio-waste bin – or **bio-bucket** – should be rather small (between 5-10L), as it:
  - saves space in the kitchen,
  - encourages regular emptying, which improves quality and reduces nuisance, flies and smells (+).

For small households, a tall, wide, transparent tupperware (closed) can work, but it must be emptied more regularly (e.g. every 2-3 days).

The secondary bin (to be taken out for collection) can go from 22L (single-family households) to 120L (multi-family buildings).

- for professional producers (e.g. restaurants, schools), the bin can go from 20 to 1100 L.

In both cases, the size must be optimised to avoid hindering manual transport by users or collection operators, given that bio-waste is a heavy material.

As a municipality or bio-waste management actor, providing sorting equipment for free or at a reduced price is a good incentive to encourage public participation and raise awareness on how to sort bio-waste.
It can be done for instance through home delivery or distribution event days.

Milan and Bratislava: provide households with

- a 10-litre vented kitchen bin (*ventilated system that allows to dry out food waste and slows down the putrefaction process*)
- certified compostable bags (*1 year's worth for Bratislava*)
- secondary bins for family households/buildings.

Out of the 20 European cities surveyed,

→ ***10** provide or provided bio-buckets to citizens and*

→ ***8** give / gave them for free* (*Dusseldorf (DE), Sevilla, Cardedeu (ES), Mikkeli (FI), Porto (PT), Ljubjana (SL), Bratislava (SK), Bordeaux (FR)*).

COMPOSTABLE PLASTIC BAGS: GOOD OR BAD IDEA?

The use of compostable plastic bags for bio-waste separation is not **unanymous** [19]. While some actors recommend them to increase user-friendliness, others discourage their use to limit the risk of contamination in the following processes. Indeed, some "compostable" plastic bags do not biodegrade completely or rapidly enough, and can cause microplastic pollution.


IN FAVOUR
of compostable plastic bags

Zero Waste Europe [12]:

→ Improve the user-friendliness of the system: limit odour, facilitate the sorting and transport of food waste.
→ Allow visual inspection by bio-waste collectors
→ Limit contamination, notably by conventional plastics

Bicy (solution provider) [ITW]

→ Accept compostable materials that pass their plant technical specifications (**OK Compost** Industrial)
→ Do not have contamination problems

Major issue: risk of microplastic contamination
Need to assess their level

Beware of resource efficiency: single use plastics should be minimised, food production should be prioritised.

ZOOM on the OK Compost labels *(TUV)*

The two OK Compost labels guarantee complete biodegradability of certified bioplastics under **home** and **industrial** composting conditions. These labels are distinct to address the different conditions of the two processes, notably with regards to temperature. *A material labellised "OK Compost Industrial" is only compostable under industrial conditions and will not biodegrade in a home composting setting.*

→ the label OK Compost Industrial is based on the European Reference Standard EN13432
→ the label OK Compost Home works if home-composting is **well-managed**.

'Biodegradable and compostable plastics - challenges and opportunities'

AGAINST
compostable plastic bags

In favour of paper bags

Hamburg:
"So-called biodegradable plastic bags are not fully biodegradable in our composting plant."

Most citizens do not differ between compostable and non-compostable (or partially biodegradable) plastic bags. [20]

Most municipalities allow compostable **paper bags** as a substitute for compostable plastic bags. However, the suitability of this alternative depends on several parameters, which are not fully assessed, such as:

→ the paper bag composition,
→ whether it has coating or not,
→ the treatment facility, the composting time, etc.

The biggest controversy about compostable paper bags is that they do not rely on a certification so far [ITW].

There is no single answer! [ITW]

→ **Adjust to your treatment facility** (composting, AD, or both) and technical specifications, for example:
  - if your composting time is too short (less than 3 months) to fully biodegrade compostable plastic bags, then prioritise paper bags,
  - if your composting time is long enough, try OK Compost certified compostable plastic bags.
→ **First test the bags** into your facility and see what works. Assess contamination.
→ **Adjust to the habits of your bio-waste producers** (citizens, professionals) to optimise user-friendliness, for instance:
  - if people are used to garbage bags for residual waste, plastic compostable bags might ease the transition to biowaste sorting for beginners?
→ **Clearly inform and train** people on what they can use or not. Explain clearly the link to the needs and possibilities of the treatment facility.
→ **For small composting units**, avoid bags of any kind. [20]

WHAT CAN BE PUT IN THE BIO-WASTE BIN?

Good question! Take a look at these *infographics (examples - future link)*. It depends on:

→ the management system in place,
→ the type of collection,
→ the solution provider (collection and/or treatment actor),
→ whether food waste and green waste are collected together or separately, etc.

Each municipality or solution provider should clearly inform and train citizens, professionals and other bio-waste producers on what can exactly be added, or not, in the bio-waste bin.

We need to be clear about the instructions for sorting bio-waste, because there are a lot of preconceived ideas." *Marianne THIBAULT - French Citizen Compost Network*

→ *How to make it work?*

CONSIDER THE BEHAVIOURAL DIMENSION

Behaviour is defined as the interplay between **habits** (automatic responses) and **intentions** (conscious choices).

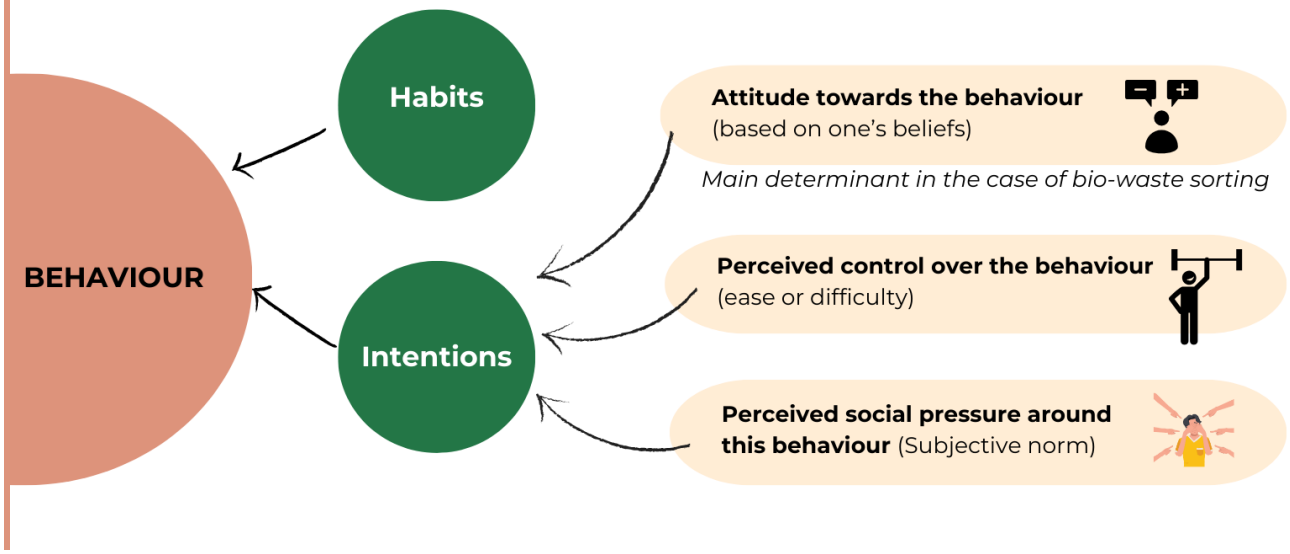
Bio-waste sorting can be seen as a behaviour in which citizens or bio-waste producers **plan** to engage and/or, in some cases, are already **used to** adopt.

To ensure that everyone embrace a good bio-waste sorting behaviour **in the long run**, the current waste (or bio-waste) sorting habits and practices must be mapped, understood and considered, along with the factors influencing these behaviours (*e.g. survey targeting citizens (future link)*).

WHAT INFLUENCES OUR INTENTIONS?

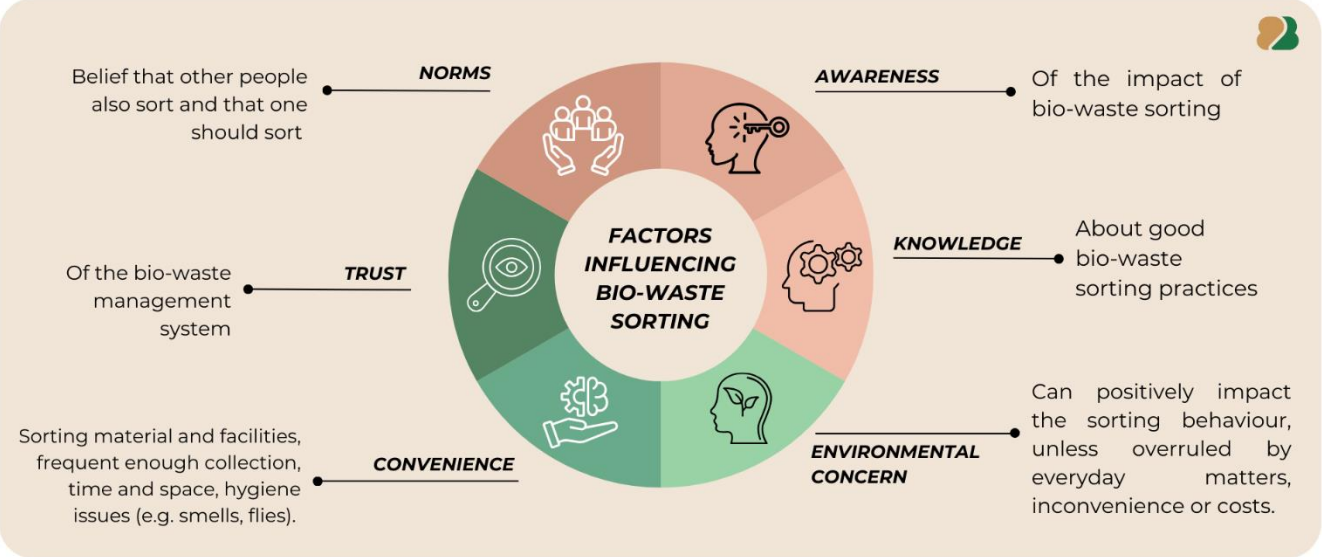
The intention to adopt a behaviour is influenced by:

→ the attitude towards the behaviour, determined by one's beliefs about the behaviour (strongest influence in the case of bio-waste sorting [21, 22]),
→ the perceived control over the behaviour, or the perceived ease or difficulty of performing the behaviour, and
→ the perceived social pressure (subjective norm) around this behaviour. [23]



FACTORS INFLUENCING THE BIO-WASTE SORTING BEHAVIOUR

Several factors can influence the **intention** to adopt a bio-waste sorting behaviour, and thus the sorting behaviour in itself:



AWARENESS AND KNOWLEDGE

The lack of **awareness** of the positive impact of bio-waste sorting, and of the reasons why it should be sorted, represents a barrier to perform the behaviour. It is due to a general lack of knowledge on the topic, resulting from insufficient communication and education. [21]

Sharing specific **knowledge** on good sorting practices, *e.g. what and how to sort, what can be put in the bio-waste bin*, positively influences citizens' bio-waste sorting behaviour, whereas not having this knowledge is a cause of non-sorting. [24, 25]

→ *These two types of information are complementary, given that even people with high awareness of the positive impact of bio-waste sorting can report not to sort, out of confusion on the approach to follow.*

Regarding **knowledge of personal waste generation**, its influence is ambivalent: while it has been found that such knowledge does not influence one's sorting behaviour significantly nor positively [26], providing feedback, for instance through a mobile app or stickers, about one's sorting behaviour and comparing it to the local averages has been found to encourage biowaste sorting [27].

Out of the 455 Europeans surveyed,

→ **95%** of sorters (*332 respondents*) and **85%** of non-sorters (*123 respondents*) agreed or agreed very much to the statement "It is important that citizens sort their bio-waste".

→ To the question "What information would you like to know about bio-waste sorting?" the first most selected answer (by **63%** of sorters and **56%** of non-sorters) is "Positive impacts of bio-waste sorting on the environment".

→ While **70%** of non-sorters did not correctly estimate the share of bio-waste in their bin (which is 1/3), notably by overestimating it, this number drops to about **47%** among sorters.

→ To the question "Does your municipality/region/country give you enough information about bio-waste sorting?", the most selected answer was "enough" among sorters (**41%**), and "not enough" among non-sorters (**37%**).

ENVIRONMENTAL CONCERN

While people with higher **environmental concerns** sort more their bio-waste [28], environmental concern is an overall weak predictor of bio-waste sorting behaviour. Indeed, even environmentally aware people can find themselves overwhelmed, for example when their personal situation does not allow them to sort their bio-waste due to lack of time or budget (in cases where collection is subject to a charge), or when there are too many different sorting bins, or due to inconvenience and lack of motivation. This is in accordance with environmental concerns being generally overruled by everyday matters. [29]

Out of the 455 Europeans surveyed,
→ environmental reasons are the most selected when asked "Why do you sort bio-waste?" (**86% of sorters**).

CONVENIENCE

Convenience factors encompass many different factors that can be barriers to biowaste sorting: improper or lack of sorting material and facilities, not frequent enough collection, lack of time and space, hygiene issues (smells, flies,...) [30]. However these issues were mostly quoted by non-sorters [31], for whom convenience factors are the most decisive. Overcoming convenience factors is necessary to increase sorting behaviours, as solely providing information is not enough. [32]

Out of the 455 Europeans surveyed,
→ Among the **non-sorters** (*123 respondents*), to the question "What are the reasons why you are not sorting or stopped sorting your bio-waste", **74%** of all selected answers related to convenience, led by the lack of adequate sorting equipment (biobucket, dedicated bin, bags) and the lack of biowaste management systems.
→ Among **sorters** (*332 respondents*), to the question "What obstacles or limitations do you face when sorting your biowaste?", **43%** of all selected answers related to convenience, led by hygiene issues.
→ **90%** of sorters and **30%** of non-sorters have a know access to a biowaste management system.

TRUST IN THE BIO-WASTE MANAGEMENT SYSTEM

Trusting the waste management system, and most importantly that the sorted waste will be recycled, has a positive impact on bio-waste sorting behaviours [26]. Whereas a general lack of transparency of the waste sorting and management processes has a detrimental impact on these trust levels [27]. For instance, in a study implemented with 465 Europeans [33], about 70% of sorters with access to a biowaste management system trusted the latter, while only 30% of non-sorters trusted it. The same results were observed in the Bin2Bean survey:

Out of the 455 Europeans surveyed,
→ Among people who have access to a bio-waste management system, **70%** of sorters trust or rather trust it, while this number drops to **31%** among non-sorters.

> Trust is a very important factor; it is important for citizens to know what will happen to their bio-waste so that they feel that sorting is useful."
> *Dr. Francesca Grossi, Interim Head of Sustainable Lifestyles, Collaborating Centre on Sustainable Consumption and Production (CSCP), partner of bioSOILUTIONS*

NORMS

The beliefs that other people also sort (**descriptive norm**) and/or that one oneself should sort (**moral norm**) encourage individuals to sort. Observing that other individuals or food actors do not sort their bio-waste is discouraging, as individual efforts are deemed pointless. [21, 22, 23]

Out of the 455 Europeans surveyed,
- → The share of people agreeing or agreeing a lot to the statement "Other people (family, friends, neighbours) expect me to sort" was of **61%** for sorters and **28%** for non-sorters.
- → Besides, **40%** of sorters consider that they have been influenced by other people (family, friends, colleagues, neighbours) to sort bio-waste, and **52%** consider that they have influenced other people to sort, in turn.

There are many other individual barriers to sorting bio-waste that must be mapped and considered, such as [ITW]:

- → **mental blocks** (e.g. "sorting bio-waste will mess up my kitchen" (more flies, smells, etc.)) -> *need to understand where they come from and how they can be unlocked*,
- → **complicated circumstances/context** (e.g. economic crisis),
- → **personal constraints** (e.g. related to time, budget or health),
- → **personal priorities** (that do not necessarily include adopting an appropriate bio-waste sorting behaviour), etc.

It is important to consider that there is an imbalance between barriers and benefits:
- → barriers are at the level of the individual,
- → benefits are at the level of the environment, the society
- → there is little self-interest nor direct rewarding."

Laura Temmerman, Researcher at imec-SMIT, Vrije Universiteit Brussel

BOOST MOTIVATION / FOSTER BEHAVIOURAL CHANGE

There are a number of tried and tested ways of stimulating motivation to sort bio-waste[3], but there are also many more to discover and ideate.

One must seek to answer the question: **"How to make this information not boring?"**[4]

The answers will inevitably vary depending on the context, on the type of person / population you are addressing, and on the various behavioural factors mentioned above.

Let's imagine some examples of different types of people (these are just examples, many more are possible[5]), as well as their main determinant factors and strategies to reach them:

[3] Examples: media & awareness campaigns (e.g. Love Food Hate Waste – WRAP), education programmes in schools, citizen surveys, public visits to waste facilities, information points in the neighbourhoods, cooking workshops (city of Murcia, Spain), or basing on three pillars: education, motivation and reminding, with a focus on engaging school children at a young age (city of Münster, Germany) (+) // **Examples/ideas of messages (+)**

[4] Question raised by the City of Düsseldorf when answering our city survey.

[5] Those are just internal and fictional ideas to base on / inspire from, they are not tested nor proved. To define personas adapted to your local context and population, check out the guidelines in the *Bin2Bean Living Lab Toolbox* and brainstorm/map with your team, or by surveying your population, all the main population types which should be considered. Another key parameter to consider is whether people have a garden/exterior or not.

Examples of different types of people (assumptions/examples)		Main determinant factors	Which awareness raising / motivation booster action(s)? (examples)
People without environmental awareness or concern	People who do not really care about bio-waste management, who just want to manage their waste as quickly and easily as possible.	Convenience Norms Trust	• Find out their interests (+), adjust your communication strategy to them • Reach them where they do not expect it • Adopt financial incentives (PAYT) • Facilitate their behavioural transition by making it most convenient to them (e.g. with compostable plastic bags)
	People who do not know anything about bio-waste sorting, but who are open to know more, learn and try some time, if they are enough guided.	Awareness Knowledge Convenience Norms	• Inform them in the clearest, most concise and visual way (by focusing on their main determinant factors, see here on the left), not necessarily mentioning the link to the environment -> try to explain why they should sort bio-waste and how it can be convenient). • Adopt different approaches to motivate and encourage them to try (e.g. app, games) give them a boost!
People with environmental awareness or concern	People who would like to sort their bio-waste but lack the time or motivation to do it at all, or to do it regularly and/or correctly, or procrastinate this action.	Convenience Awareness Knowledge Environmental concern Norms	• Inform them in the clearest, most concise and visual way (by focusing on their main determinant factors, mentioning in priority the link to the environment -> remind them why they should sort bio-waste, how important it is for the environment, provide them with samples of compost & guidelines of use, etc.). • Adopt different approaches to motivate and encourage them to engage in bio-waste sorting, in the long run (e.g. app, games, rewards, incentives), give them a boost! Help them avoid procrastination!
	People who would like to sort their bio-waste but are mentally blocked by convenience factors or lack of trust in the system.	Convenience Trust Environmental concern Norms	• Share good practices of other bio-waste sorters to avoid or reduce inconvenience (e.g. there are people who do not have flies or smells by having a biobucket in their kitchen, if it is closed and emptied regularly). • Deconstruct biases, show how it can be convenient to sort bio-waste (e.g. “why do you think your residual/mixed bin stink? Because you did not remove bio-waste from there. Sorting bio-waste in a small biobucket and empty it more regularly will actually reduce smells in your kitchen”). • Make sure that your bio-waste management system is optimal and trustful • Build trust around your system (e.g. show pictures, videos, organise visits, create a short, visual concise leaflet presenting your system with performance numbers, etc.) • Remind them how important it is for the environment to sort bio-waste
	People who are regularly sorting or composting their bio-waste without too many barriers, as they know how it works, are motivated and have turned it into a habit.	Environmental concern Norms	• Keep them motivated: adopt different approaches to maintain or increase motivation (e.g. rewards) • See whether they could engage or help in increasing the motivation of others -> multipliers

As you may have understood, the first good practice is thus to start by mapping your local context and citizens (again, tools are available in the *Bin2Bean Living Lab Toolbox*).

Once you have identified a few 'types' of people within your local population, design a mix of tailored awareness raising, communication and motivation booster strategies. One approach or one campaign, targeting the population as a whole, will not be enough nor effective.
Diversify formats as much as possible (face-to-face, social media, games, app) and be as clear and simple as possible in your messages.

> People really need to understand why they are doing this, it is not enough to say "important for the climate" as for a lot of people this is not clear, they do not connect the dots, there is a need of changing their behaviour in a way that they are motivated, beyond the money incentive.
> If you do not understand something, you do not want to put efforts into it, especially if it makes your life more complicated"
> *Dr. Francesca Grossi, Interim Head of Sustainable Lifestyles, Collaborating Centre on Sustainable Consumption and Production (CSCP)*

A substantial budget should be allocated to fund these strategies, over several rounds, to ensure that the rest of the system (collection / transformation / use in soils) rolls optimally.

Transversal recommendations and good practices are listed below:

→ *IMPLEMENT FAIR AND ADJUSTED FINANCIAL INCENTIVES (PAYT)*

Wherever possible from a regulatory point of view, PAYT systems are recommended to increase citizens participation, notably to reach the 1st 'type' of people (example) listed in the previous page (i.e. people who do not care about bio-waste sorting nor the environment).

The regulatory and policy context must be adjusted to support and deploy these money-based incentives, as a key complement to other actions.

Out of the 455 Europeans surveyed,
→ To the question "What do you think would encourage you to start or keep sorting your biowaste?", **40%** of sorters and **32%** of non-sorters selected financial incentives, which ranked respectively 1st and 3rd (with regards to all possible answers).

PAYT schemes for citizens should be carefully designed to avoid illegal burning / dumping and to avoid increasing inequality. The amount of fees could be graduated according to the revenues of the household, in a fair and feasible way (+). PAYT could be incorporated in local charges (e.g. a citizen reducing its amount of residual waste would see its charges linked to residual waste collection reduced).

There are many possible ways to implement financial incentives, for example:

> In the UK, food waste collection is part of the local tax, if citizens ask for green waste collection, they have to pay separately for that.

> In Milan (Italy), there is a fining system: if you put your bin out and it is not well sorted, you get a note. After 3 notes you get a fine.

→ *INCREASE CONVENIENCE*

1) Make your bio-waste management system accessible, convenient and easy to use
   → Make it easy to sort bio-waste, and more difficult to leave it in residual/mixed waste.
2) Provide sorting materials, with clear and visual guidelines
   → Adjust the materials distributed to the main 'types' of people identified, e.g.
      - distribute a biobucket + compostable plastic bags or suitable paper bags (if your plant does not accept compostable plastic bags) to the 1st 'type' of people previously listed (i.e. people who do not care about bio-waste sorting nor the environment or "beginners"), to ensure a smooth and easy transition to bio-waste sorting.
      - the most experience people might not even use bags or might already have a biobucket, but might need a reminder of sorting guidelines.

→ *PROVIDE CLEAR, VISUAL SORTING GUIDELINES, WHILE RAISING AWARENESS ON THE POSITIVE IMPACTS OF SORTING BIO-WASTE*

People should receive the necessary knowledge to understand why and how to sort bio-waste. Show them how it works, support them in their behavioural transition, inspire them with examples, videos, testimonies of other citizens already sorting, work with local influencers or local communication channels, share existing videos/content, develop an app (e.g. Junker app in Italy), adjust existing materials to your context, etc. Make it look feasible and accessible, make it look like it is the norm, show how to optimise the time that it takes, how to reduce inconvenience (e.g. smells, flies).

→ Out of the 455 Europeans surveyed,
To the question "What information would you like to know about biowaste sorting?", the main selected answers were:

- Positive impacts of bio-waste sorting on the environment and on my community
- What happens to my biowaste after it is collected
- Precise guidelines on what I can put in my biowaste bin/biobucket, and on how to optimise the quality of my biowaste sorting and minimize hygiene issues.

**Sorters and non-sorters had the same top answers, but in a different order.*

→ *MAKE PEOPLE FEEL LIKE THEY ARE NOT LEFT ALONE IN THIS CHANGE OF HABITS & BUILD TRUST*

Inform people about what will be implemented beforehand, and continuously as the bio-waste management systems are developed, giving them space to express their uncertainties.

"In the city of Lund, citizens were made aware 6 months before that the waste management system was going to change (e.g. with leaflets, website). Once the system was implemented in a small area, the city launched a **call center**, open 7/7, to cover all the possible questions, doubts, problems, lack of knowledge and complaints of citizens. Staff from the call center were trained to answer to all questions and try to understand what did not work in case of complaint.

This requires upfront investment, but was proved as **one of the best ways to improve awareness**, combined with other methods (digital, public events, posters, etc.). If you do not give the opportunity for direct communication with citizens, it becomes quite difficult to make it work.

Thanks to all this feedback, the city was then able to improve their system.
Lund are front runners, but their approach cannot always be replicated on the same basis due to national regulations."

Dr. Francesca Grossi, Collaborating Centre on Sustainable Consumption and Production (CSCP)

→ FOLLOW A HUMAN-CENTERED APPROACH

Activate social norms, highlight examples of people regularly sorting their bio-waste (in pictures, videos, interviews), use social media, show that it's feasible and can be easy when done right. Sometimes, we just need to see other people do an action to try it out ourselves.
Activate the spirit of play and/or competition, deploy activities around the topic, create or use existing games to sensitise on the topic (e.g. La Boucle du Compost collective game created in France, in the process of being adapted in Romania), develop an app with gamification (e.g. HOOP Trainers app where players are invited to complete 3 missions in order to transform 'Dubiop' to 'Cirklop' (+)), or where people can see for instance a score linked to the quantity and/or quality of their bio-waste, or see the performance of their neighbourhood, etc.

> "Games have been shown to have a direct impact on sorting behaviour, increasing the % of valid sorting." *Laura Temmerman, Researcher at imec-SMIT, Vrije Universiteit Brussel*

> "The fun format is the most relevant, as it is the easiest way to reach the public."
> *David Arlabosse – Creator of "La Boucle du Compost, Composting Master*

→ MONITOR PERFORMANCE

Put colored stickers on the bin, depending on whether it was well sorted or not.

"For example, in Münster (Germany), incorrectly filled bins are warned with a yellow card for the first time, and if repeated will not be emptied and marked with a red card." (+)

> "The key is to implement efficient and individualised models (that identify the user and allow controls of the collected material) and monitor performance." (LIFE BIOBEST)

→ HOW TO REACH PEOPLE THAT ARE NOT INTERESTED IN BIOWASTE SORTING?

Activate multipliers and social norms, e.g. through children, friends, colleagues, find/appoint ambassadors.
Go talk directly to people, in local events, markets, by going door-to-door to distribute sorting materials etc.

For example, in Murcia (Spain), as part of a high variety of engagement activities, they implemented **'biopatrols'**, where trained teams were positioned in different parts of the city to discuss directly with citizens. Once face to face, people dared to ask all their questions and express their doubts. They were proven particularly successful and were helpful notably in the first weeks of introducing the bio-waste management system. They also led to a snow-ball effect through multipliers (e.g. from students to parents). (+)

> **It is important to go to events that are not related to the bio-waste topic, go where people are not necessarily sensitised, think outside the current framework, open the dialogue, ask people if you can ask them a few questions, make sure that they do not feel targeted negatively**. Resources need to be planned for all of this."
> *Laura Temmerman, Researcher at imec-SMIT, Vrije Universiteit Brussel*

→ *IN SHORT*

1) **Map your local context & citizens**: their interests, habits, barriers, etc.
2) **Make sure that your system is trustful and easy-to-use**, ensure that the transition to bio-waste sorting will be easy for citizens and bio-waste producers.
3) **Increase awareness of the issues at stake**, the good behaviours to adopt and good sorting practices, at least several months before implementing your system. Diversify formats (door-to-door, social media, games, app, posters, face-to-face interactions etc.). Ensure that questions are answered and doubts are cleared.
4) **Provide clear and simple sorting guidelines**, along with sorting materials.
5) **Keep looking at the barriers and levers** of citizens & bio-waste producers, after each awareness raising, even when the system is launched. One campaign will not be enough.

2/ Separate collection

There are two main systems for the collection of bio-waste, or waste in general: door-to-door and drop-off / bring scheme.

Door-to-door scheme

Bring scheme

→ *Door-to-door vs bring* [12, 13, 34, ITW]

DOOR-TO-DOOR: THE BEST-PERFORMING SOLUTION

According to several studies and experts (ISWA, Zero Waste Europe, ECN, Life Biobest) **door-to-door collection** delivers better results in terms of participation rate, bio-waste quantity and quality (fewer impurities).

The region of Catalonia (Spain) compared door-to-door and bring schemes across several municipalities and observed that, with door-to-door:

→ the quantity of bio-waste collected was **doubled** and
→ the % of impurities was **cut by 3** (4,7% door-to-door vs 14% bring)

Out of the 20 cities surveyed,

→ **3** implement only door-to-door *(Dusseldorf (DE), Cardedeu (ES), Bratislava (SK))*
→ **9** implement both door-to-door and bring schemes *(Zagreb (HR), Hamburg (DE), Porto (PT), Albano Laziale (IT), Mikkeli (FI), Münster (DE), Ljubjana (SL), Egaleo (EL), Amsterdam (NL))*.
→ **5** implement bring only *(Sevilla (ES), Istanbul (TR), Bordeaux, Nantes (FR), Elblag (PL))*

COMPARISON ACROSS PARAMETERS

POPULATION DENSITY

While bring schemes can represent a more viable option in very low density areas (e.g. rural areas) or a more feasible one in high density areas (with a density >15,000-20,000 inhabitants / km2), **door-to-door is perfectly applicable in intermediate-density or dense areas and should be the preferred solution there**.

Milan (Italy) is an example of **dense city** (>7,000 people/km2) which is a pioneer in door-to-door collection since 2013:

- → it covers 100% of the population with a food waste collection scheme
- → that reaches a collection rate of **87.5%,** an impressive score!
- → with a low level of impurities (around 5%)

This notably results from a strong political will and stakeholder engagement.

> "What's generally needed is having the will from the local people (e.g. housing associations), and the local municipality leader, **the mayor in Milan was very willing to promote door-to-door collections**." *Jane Gilbert, Chair of the ISWA Working Group Biological Treatment of Waste*

COSTS

While door-to-door can appear as the most expensive solution at launch, **costs can largely be balanced**, notably by adapting and optimising the waste management system as a whole. Indeed:

→ With door-to-door collection of bio-waste, the residual waste collection rounds can be reduced (both in terms of frequency and quantity), as, without bio-waste, the residual bin does not need to be collected as often.

→ Adopting solely a bring scheme for bio-waste collection, when most of the other waste streams are collected in door-to-door, just adds a new collection round on top of the others, without changing the current system and thus represents in the end an additional cost.

→ Bio-waste treatment is cheaper than residual waste treatment, which can offset the costs of collection.

→ The fewer impurities there are throughout the process, the fewer residues there are at the end of the process, the more savings can be made on the process, thus offsetting the higher initial costs of collection. As previously mentioned, door-to-door presents better results in terms of overall performance and minimising impurities.

→ **There are several ways to fine-tune and optimise the system to make door-to-door collection of bio-waste economically viable**, wherever it can be implemented. A thorough analysis of economic efficiency should cover all parts of the system, i.e. logistics, controls, treatment of the organic and residual waste fraction and sales revenue.

The region of Emilia-Romagna (Italy) compared door-to-door and bring schemes, each with or without PAYT (Pay As You Throw), across several municipalities and observed, **with door-to-door**:

- → higher captures and better quality of the food waste collected, even more with PAYT *(4,5% of impurities vs 6,9% for mixed systems and 10,3% for bring)*
- → **lower operational costs**

PEOPLE'S HABITS AND PERSPECTIVES

When people are used to having their waste collected at their door, it can be harder to motivate them to bring their bio-waste to containers (even if it's 100 meters away), especially if they have to do it regularly (more regularly than glass, for example) and cannot go on their way to work for instance (if the bio-bucket needs to be cleaned).

→ Out of the 455 Europeans surveyed,
To the question "Which biowaste management system is the most convenient according to you?", **door-to-door collection** was the most selected, followed by home / community composting.

ENVIRONMENTAL PERFORMANCE

Door-to-door can be described as "noisy, more polluting" due to its longer collection routes compared to the bring system.
However, given that door-to-door is already used in a lot of territories for most waste streams, the aim is once again to **rebalance and optimise the waste prevention and management system as a whole**, in order to reduce the associated environmental impacts and nuisances.
For instance, it is possible to use compartmentalised trucks, which can collect several waste streams, thus optimising the collection rounds and saving costs. In Lund (SE), the municipality provides compartmentalised bins (including a fraction for food waste), with the same compartmentalisation for trucks [12]. However, this approach needs to be carefully thought through, as it must be optimised according to the density of each waste stream. For example, packaging waste is bulkier than food waste, which has a high-density, thus it requires intermediate emptying or an adaptation of collection routes [15].

Moreover, while both door-to-door and bring schemes use trucks, there are more and more solution providers across Europe collecting bio-waste in door-to-door with electric cargo bikes, such as Bicy in Bordeaux (FR) (who collects from professionals).
It is also possible to use electric trucks, which is the case for instance in Denmark since citizens complained about the noise and space of thermal trucks.

Environmental performance should not be underestimated.
Yet, it should not be considered solely when talking about **bio-waste** door-to-door collection, but for the waste prevention and management system as a whole!

→Good practices and recommendations [12, 13, 34, 35, ITW]

RETHINK YOUR WASTE MANAGEMENT SYSTEM AS A WHOLE

WE NEED TO FACILITATE THE PROCESS FOR WHAT WE WANT TO COLLECT."

"If packaging is properly separated and bio-waste properly sorted, there will not be much left in the residual waste bin: **why come to the door to collect waste that we do not really want?**

Why not reverse the collection systems: bio-waste in door-to-door and residual waste at bring / drop-off points?" *Muriel Bruschet - National bio-waste referent at ADEME, The French Agency for Ecological Transition*

FREQUENCY

Bio-waste should be collected **at least once a week**, depending on the regional climate and season (several municipalities increase this frequency during warm months), in order to limit the risk of nuisances (smells, moisture) and encourage participation. Introducing bio-waste collection at this minimum frequency enables to reduce the frequency of residual waste collection.

Bratislava (Slovakia) implements a high collection frequency for food waste (2 times a week) and low collection frequency for residual waste (one time every 1, 2, or 4 weeks). Food waste collection is seasonally adapted (i.e. higher during summer).

Another example: "Some municipalities in the UK, have a weekly food a weekly food waste collection and alternate weekly for other waste: 1 week dry recyclables + food waste, 1 week residual waste + food waste. The residual bins are smaller than the food waste bins, which encourages people to segregate their waste better." *Jane Gilbert, Chair of the ISWA Working Group Biological Treatment of Waste*

CHOOSE BRING ONLY WHEN ALL OTHER WASTE STREAMS ARE ALREADY COLLECTED IN BRING AND WHEN DOOR-TO-DOOR IS NOT FEASIBLE

→ In very low density areas (e.g. rural areas) or high density areas (e.g. residential complexes, large/high building units), where all other waste streams (paper, plastic, glass, and most importantly, residual) are already collected in bring/drop-off schemes, and thus **where people are used to this system**, it makes sense to implement a **bring system** for bio-waste as well, by adding a new container in existing collection points (with strong awareness raising campaigns).
When high density areas are part of an urban area that is not as dense everywhere, bring (implemented in high-density areas) should then be **complementary** to door-to-door (implemented in the rest of the city).

Hamburg (Germany - 2,455 people/km2) has implemented separate household bio-waste collection since 1994, with a mixed system:

- → Door-to-door for "regular density" housing areas
- → Bring schemes for residential complexes / large housing areas, through locked ***underground containers***.

Underground containers reduce the visual impact of containers on the street, are easier to implement in a highly dense area and reduce hygienic impacts, e.g. linked to smells [35, 36]*. But there are some places (e.g. Spain) where they do not work well (high cost of investment and maintenance, low results of quality and quantity)* [52]*. See again* *How to make it work?*

- → For urban areas which are collecting most or all of their waste streams in door-to-door, then, according to the point above: **bio-waste should be a door-to-door stream** and the whole waste management system should be redesigned accordingly (while considering the habits of citizens and bio-waste producers). Relying only on a bring system will not be enough and could delay the achievement of your bio-waste recycling targets and hinder the positive impacts that effective bio-waste management could have on your territory. [ITW]

DISCUSS WITH OTHER CITIES AND EXPERTS

Discuss with other cities/territories similar to yours, exchange good practices and experience, visit the ones with good performance, participate to tailored events / webinars, consult experts (e.g. local/national experts, apply for technical support with LIFE Biobest experts, follow on LinkedIn: European Compost Network, Zero Waste Europe, Bin2Bean, join Bin2Bean Stakeholder Forum, check the LIFE Biobest events, join the BioWaste Hub, etc.).

"The best is mayors talking to mayors "we had the same concerns as you have right now, we implemented this and it worked…" " *Enzo Favoino – Zero Waste Europe*

EXPERIMENT IN PILOT DISTRICTS BEFORE IMPLEMENTATION

WHY

- → Enables to test and validate a system pre-selected as "optimal"
- → "Enables to test new ideas, evaluate them, adjust if need be, and to dismiss them if not successful"
- → Can help determine specific collection parameters
- → Can maximise the participation rate

HOW

"**Criteria for choosing a suitable pilot area**: choose a neighbourhood, quarter, etc. where the problem is relevant, but the framework conditions are not too difficult. It will be easier for you to implement your pilot if you already have established partnerships to local actors in the area.

The size of the pilot area should be selected in such a way that it is manageable (not too big to not stretch your resources and capacities too much) and big enough to provide information and data on several aspects, depending on the theory/ hypothesis/ tools you want to test." *Britta Petters – HiiCE – Hamburg Living Lab (Partner in Bin2Bean)*

FIND CONSENSUS AT LOCAL LEVEL, PROMOTE SYNERGIES ACROSS ACTORS

"A consensus is needed across municipal and regional governments, politicians, local service providers, and civil servants. To have a well-designed system, synergies are necessary across different stakeholders and sectors." *LIFE BIOBEST*

"Using a *Living Lab approach* further provides the opportunity to get in touch with stakeholders, involve them more deeply and better understand their needs, pains and gains." *Britta Petters – HiiCE – Hamburg Living Lab (Partner in Bin2Bean)*

→ *To know more*

LIFE BIOBEST	• Guideline on the separate collection of bio-waste • Guideline on governance and economic incentives for bio-waste separate collection and treatment • Country Factsheets on the analysis of communication and engagement practices for bio-waste separate collection and treatment • Policy brief – Regulatory barriers
Zero Waste Cities	How to best collect bio-waste
SCALIBUR	Best practices for biowaste management: Factsheet with 34 examples of solutions and best practices on collection, transport, social awareness and characterisation of bio-waste, implemented throughout Europe.
European Compost Network (ECN)	Guidance on Separate Collection
European Committee for Standardization (CEN)	Key factors for the successful implementation of urban bio-waste selective collection schemes
WRAP	• Household food waste collections guide • The impact of food waste collections on household food waste arisings • Commercial food waste collection
City Loops	OMSW (Organic Municipal Solid Waste) flow optimisation tool
ADEME	Comparative study of separate biowaste collection practices in urban areas
International Solid Waste Association (ISWA)	A Practitioner's Guide to Preventing and Managing Contaminants in Organic Waste Recycling
BIN2BEAN	*Future recommendations for the collection and transformation of bio-waste **with focus on quality**, based on the experiences of our Living Labs* -> follow us on LinkedIn to not miss them! Bin2Bean

3/ Transformation into soil improvers

Feel free to check these *infographics (future links)* for a gentle reminder of:

- What is Anaerobic Digestion (AD)? wet or dry AD? liquid or solid digestate?
- What is composting (industrial, home-composting, community-composting)?
- What are their common points and differences?

In the case of AD, please note that, in addition to the importance of separate collection, it is essential to use specific AD plants (with bio-waste as the sole input), in order to obtain a quality output for the soil. In this section, 'AD' refers to specific AD using only bio-waste as input, and not to 'general' AD using any organic waste. *Reminder: difference bio-waste / organic waste*

→ *Anaerobic digestion (AD) or composting?* [2, 17, ITW]

Anaerobic Digestion (AD) offers the additional benefit of producing energy (biogas), in addition to a fertiliser (digestate, *under certain conditions*), which enables to reduce our dependence on fossil fuels and increase the cost-effectiveness of the system. [2]

Composting produces soil improvers, which cannot be produced by AD alone and which are very much needed, *as previously presented*.

→ In most cases, wherever possible, **the recommendation is to combine both approaches**, either at territorial level (across several plants) or within the same industrial plant (*see zoom box below*), in order to obtain high-quality soil improvers from bio-waste, in a cost-effective way. This varies according to the different local parameters *previously presented*, as further *explained here after*.

The better the integration, the stronger the system." *Jane Gilbert, Chair ISWA WGBTW*

"Both approaches should be encouraged: the soil needs to be supplied with organic matter, as long as it is of good quality." *Antoine Pierart, ADEME, soil thematic coordinator*

Zoom on combining both processes in one plant (*composting the solid digestate*)

Composting the solid output from AD (*solid digestate*) enables to stabilise and sanitise it (which in turn, increases the organic content of the soil), reduce its level of nutrients (which can be too high for the soil), and increase its quality. The compost obtained by direct composting and the one obtained by composting solid digestate are similar in composition and quantity.

According to experts (e.g. ISWA, EEA, JRC), it is one of the best approaches to adopt - at least for territories that can implement it - both in terms of material and energy recovery (LCA results) [2]. New bio-waste facilities are mostly combined plants.

→ Adopted in in Hamburg, Bratislava, Amsterdam city-regions

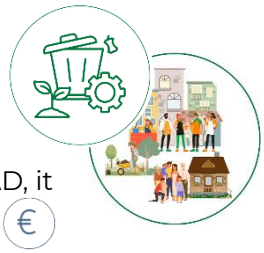
Out of the 20 cities surveyed,

→ **4** have all treatment options available on their territory (AD, industrial-, home-, community -composting) *either managed by the city or a solution provider (Hamburg (DE), Bordeaux (FR), Mikkeli (FI), Amsterdam (NL))*

→ **2** rely only on home composting *(Cardedeu (ES), Sarajevo (BA))* (+)

→ Comparison across parameters [2, 37, ITW]

TYPE OF BIO-WASTE PRODUCER / AMOUNT OF FEEDSTOCK



The capacity of both methods depends on the individual technical solution. When there are large bio-waste streams to transform (e.g. from large food industries), AD would be the most suitable option.
However, in cases where the amount of bio-waste generated is too small to feed AD, it is better to focus on composting, otherwise AD would not be economically viable. (€)

SYSTEMS AND FACILITIES IN PLACE

→ Are there already (a) composting plant(s)? AD plant(s)? both? home, community composting units?
If no industrial plant, start with a composting plant, until you know more precisely the amount of bio-waste produced in your territory.

→ Are there owned by the city/region or are they private?
For example, the city of Helsinki owns the bio-waste treatment facility, they thus only need to tender the logistics, which allows to reduce the costs. (€)

→ What are their performance in producing high-quality soil improvers? If the latter is low, what do they need to do better?

LOGISTICS AND TYPOLOGY OF THE TERRITORY, SPACE AVAILABLE

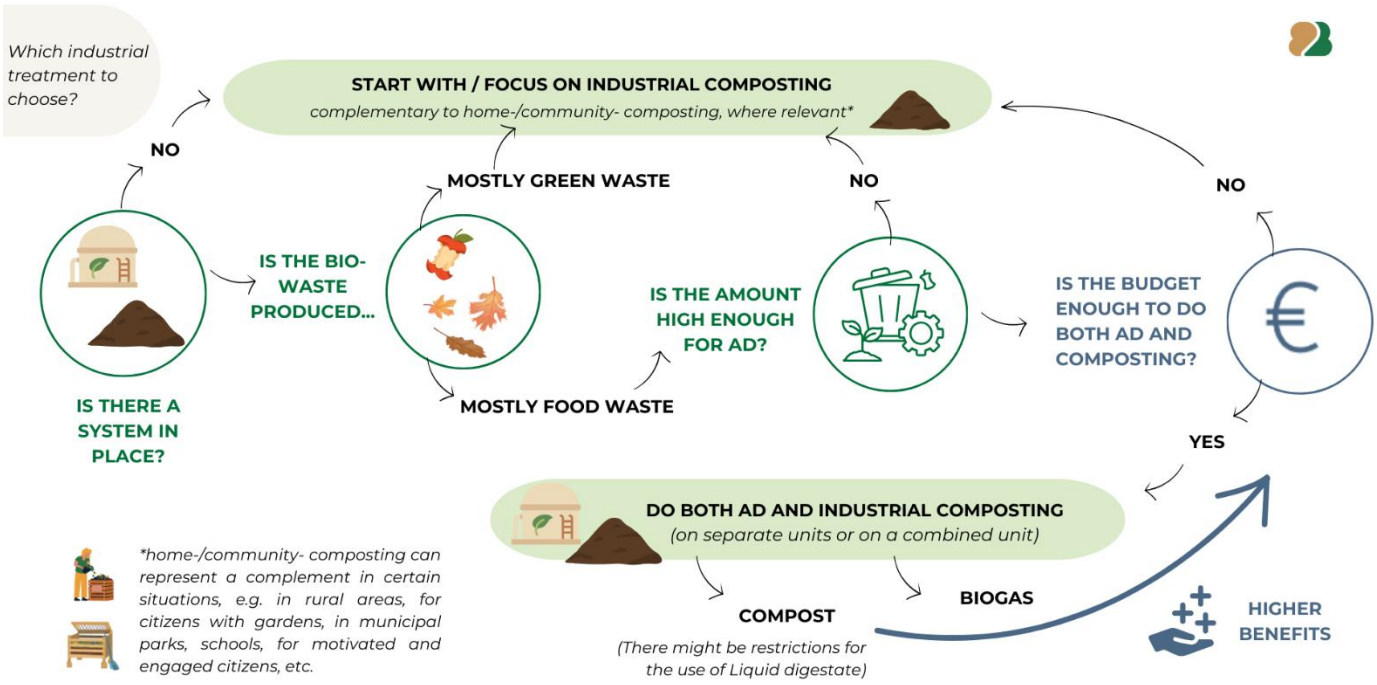
→ While composting can be implemented at several scales (individual, community, large/industrial scale)[37], AD is – at the moment – mostly implemented at large industrial scale.

When comparing industrial composting and AD, an AD plant alone takes up less space than a composting plant.
In the case of a combined AD/composting plant, where the solid digestate is composted (*see zoom box above*), it takes up as much space as a regular composting plant.

COSTS

While **AD** requires **a higher investment than composting** (millions of euros [38], can be calculated here or here), it can result in a **higher cost-effectiveness** thanks to the income of energy recovery. *Energy production makes AD more profitable depending on the possibilities on site, e.g. customers for heat, gas for cars, electric power.* (+)

> In Finland, for the moment, the principal bio-waste treatment method used is composting (70% of bio-waste collected). But AD is increasing, and is predicted to further increase in the upcoming years. There are several reasons for this change, but the main is economic: AD is more cost- effective, cheaper for the municipality thanks to the incomes of energy recovery.
> Some cities also use green public procurement, which you can benefit from if you reduce your carbon and environmental footprint. *Anna Virolainen-Hynna, Executive Director Biokerto (Finnish Biocycle and Biogas Association)*



SOIL TYPES AND NEEDS, WEATHER CONDITIONS, ENVIRONMENTAL PERFORMANCE

Liquid digestate and compost have different effects on the soil.

"A nutrient-rich liquid has potential to leach more easily, whereas a solid product is generally more stable when applied to soil. Compost is more likely than digestate to confer long-term benefits to soil." *Jane Gilbert, Chair ISWA WGBTW*

There are several cases where it is **not** recommended to apply liquid digestate on soils, and where composting should be preferred to AD:

- when it is **raining**, or on flooded soils, because there is a risk of river and groundwater contamination [39].
- on polluted soils (e.g. nitrogen pollution/over-fertilisation, e.g. in the Netherlands)
- in regions with low levels of organic matter in agricultural soils (+), where composting would be the most environmentally preferable option.

"The UK, over the last 15 years, has gone down the route of promoting wet AD for food waste focussing on generating low carbon energy. Liquid digestate can only go to the fields in certain times of the year. AD plants often pay farmers to take the liquid digestate, it has a negative value at the moment." *Jane Gilbert, ISWA*

With regards to home and community composting, the compost obtained cannot necessarily be used in agricultural fields (e.g. in France), and when directly used by citizens, can cause a risk of over-fertilisation (which can also occur with purchased fertilisers).

In addition to rain, temperature must also be considered, as for instance composting can be difficult to implement in winter times, given its need for temperature rise (+), notably in countries with low/very low winter temperatures (such as Nordic countries).

If mismanaged, composting and AD can have important negative environmental effects, notably by emitting *methane* [3].

PEOPLE'S HABITS, PERSPECTIVES AND ENGAGEMENT

Citizens' habits, perspectives and engagement are directly correlated to the effectiveness of **recycling at source (home-composting, community-composting)**. Here are some examples of perspectives:

→ **Community composting** can be viewed as a **social activity**: it creates social links, provides meeting points, participates to a dynamic neighbourhood life, enables a social mix [ITW]. Both community and home composting represent actions that citizens can take for climate and environmental protection [40]. People who want to engage themselves (e.g. as a volunteer) in a sustainable practice, at local level (for their city or territory), can do it through community composting.
A potential reward is feeling proud, feeling responsible, being well regarded by society and, for the ones who can, use the obtained soil improvers.

→ The **barriers** are similar to the ones of the bring system: citizens may struggle to find motivation to home-compost or bring their bio-waste to community-composting units, while respecting the "opening hours" and composting steps.
→ If home and community composting are mismanaged (e.g. flyes, rodents, smells), it can decrease the involvement of citizens.

→ *To know more*

LIFE BIOBEST	Guideline to promote quality compost and digestate
European Compost Network (ECN)	• Compost and digestate for a circular bioeconomy - Overview of Bio-waste Collection, Treatment & Markets Across Europe • Good practice Guide: How to comply with the EU Animal By-Products Regulations at Composting and Anaerobic Digestion Plants
Zero Waste Europe	Community Composting – A Practical Guide for Local Management of Bio-waste
WRAP	Promoting home composting (Information sheet)
Réseau Compost Citoyen	Technical Factsheets on community and home composting [in French]
ADEME	Bio-waste: from separation at source to methanisation [in French]
European Environment Agency (EEA)	The State of Soils in Europe
HOOP	Innovative Circular Biowaste Valorisation—State of the Art and Guidance for Cities and Regions

4/ Use of soil improvers from bio-waste

→ *Soils need organic matter*

As previously explained, action must be taken to protect soil health.

ORGANIC MATTER: THE CORNERSTONE OF SOIL HEALTH (+).

"Organic matter is intimately linked to many key physical, chemical and biological soil properties. In fact, it is so important to soil functions that it is almost impossible to find a soil property that is not influenced by organic matter in some way." [55]

Organic matter is essential not only for plant production, but also for soil life and the proper functioning of the soil. It:

- Provides key nutrients for plants (e.g. nitrogen (N), phosphorus (P), potassium (K))
- Ensures biological activity in the soil
- Regulates the presence of pathogens
- Conditions the soil's physical properties, such as:
  - → root anchorage,
  - → water infiltration and holding capacity,
  - → porosity,
  - → aeration,
  - → and the stability of soil structure, which helps resist soil erosion. [56]

In addition to the agronomic role, organic matter also plays an environmental role:

- → Carbon storage
- → Substitution of mineral fertilizers
- → Maintaining biodiversity
- → Pollutant retention

Every year, the soil looses a part of its organic matter through mineralisation. To compensate this loss, organic matter must be added, for instance with crop or forest residues or exogenous organic matter.

COMPOST = ORGANIC MATTER

The increase in soil organic matter following compost addition is influenced by:

- the amount of added compost, as compost is mostly made of organic matter
- the compost maturity and stability (+), the more mature the compost, the more stable it is and the longer it will remain in the soil. [45]

→ *Compost or digestate?*

Main effects and risks of applying compost and digestate on soils.

Impacts	Compost	Digestate (whole or liquid part)[6]
Soil organic matter	*Significant effect*, depending on the compost maturity, the quantity of compost added and the initial organic matter levels of the soil	Not a significant impact
Carbon sequestration in soils	Humus, a component of compost (thanks to the lignin material), brings resistant organic carbon: on average, 24% of compost organic carbon remains in the soil after 8 years [42].	Not a significant impact, - as the carbon contained in the waste is transformed into biogas (so it is taken out of the balance), - and there is low concentration of humus.
Nutrients benefit	Lower levels of nutrients than anaerobic digestate. Small part in a readily available form, but increase nutrients level in the long-term: nitrogen, phosphate, potassium, sulphur and magnesium.	*Major effect:* large quantity of nitrogen readily available for crops (80% of its total nitrogen content [43]) - phosphate, potassium, sulphur and magnesium
Soil biodiversity and microbial activity	Significant increase noticed in soil microbial biomass and earthworms population.	Not a significant impact
For which soils?	Agricultural soils, as it improves the general quality of the soil and thus crop production Dry soils or soils with low organic matter (i.e. 45% of European soils): improve the water holding capacity and workability, prevent desertification. Contaminated soils: can reduce the leaching of hazardous contaminants to groundwater, due to its chemical characteristics.	Agricultural soils mainly, notably when plant-available nitrogen is needed (need to measure the quantity, avoid overfertilisation)
Risks and good practices	- low risk of ammonia and methane emissions - if applied when immature, risk of smells and toxic compound development - can be spread at any time of the year	- liquid: as other liquid manure and agricultural residues, it should not be applied when it's raining, or on flooded soils, because risk of river and groundwater contamination [39] - ammonia emissions: use injectors and precise application to limit them

[6] As the solid part of digestate is composted, this column only refers to liquid digestate.

→ *Recommendations and good practices* [ITW]

- Start from the soil needs and texture: there's no point in trying to change the texture of a soil, which changes over thousands of years. One has to make the most of its advantages and limit its disadvantages. [X]
- Properly characterise the soil and the composts that are going to be used, not just from the regulatory point of view, but also in terms of level of stability, maturity and biology of the composts. [ITW-FIBL]
- Take into account current logistics and methods for spreading (soil improvers or fertilisers). [ITW-ADEME]
- Deep burial (ploughing) is not the best way of incorporating organic matter into the soil. Surface incorporation (harrow, cover crop, etc.) is preferable to pre-mix the organic product not far from the surface. [X]
- For field tests, multiply the number of replicates, e.g. 5 replicates at parcel level, per modality tested. [ITW-FIBL]
- Train both the city and the end-users (farmers, soil managers) with technical knowledge on the use of soil improvers from bio-waste.

→ *To know more*

International Solid Waste Association (ISWA)	Benefits of compost and anaerobic digestate when applied to soil.
European Compost Network (ECN)	Factsheet - Sustainable use of compost and digestate to improve soil organic matter
WRAP	• Field experiments for quality digestate and compost in agriculture. • Compost and Digestate in agriculture: Good practice guidance.

ARE THERE OTHER SOIL IMPROVERS?

One soil improver that is frequently mentioned is **biochar,** a carbon-rich material produced by thermal decomposition of biomass, through a pyrolysis process. While it enables a long-term carbon sequestration in soils, its agronomic added value is not clearly established, notably compared to compost or digestate. In addition, the conflicts of use and tensions over biomass and resource flows must be taken into account. A thorough analysis must be carried out to prioritise biomass recovery processes. In the case of urban bio-waste, which is currently a very limited resource, other models, than biochar, would be more viable and efficient. In the case of polluted soils, e.g. urban or industrial wasteland, it can have an interest as its matrix can bind pollutants. Still, **biochar requires additional research** to become a mature and economically viable option. [ITW-ADEME]

Furthermore, EU projects, such as SCALIBUR and ValueWaste, developed innovative solutions ranging from enzymatic hydrolysis of bio-waste and Solid State Fermentation – in order to obtain a compost fitted with biopesticidal properties (CENER, AERIS – SCALIBUR), to pelleted and digestate-based recycled fertiliser (Ekobalans – ValueWaste). When officially validated and on the market (TRL9), these solutions will be complementary to compost, as they are not focusing on

improving soil (e.g. biopesticide – reducing pests, fertiliser – supporting plant growth) nor obtained from bio-waste (e.g. biochar obtained from sewage sludge – WaysTUP!).

→ *Market of soil improvers*

In Europe, compost is mainly used in **agriculture and horticulture** (around 50% of the compost produced in 2022)[44]. An important part is also used as a soil improver by landscapers, citizens, and municipalities, in parks and private gardens (22%). Moreover, compost is often used in growing media, as it is a good alternative for the use of peat, whose harvesting is particularly harmful for the environment[2]. On the other hand, liquid digestate is almost entirely used in agriculture, representing 93% of its use.

On average, both compost and digestate are sold at a price far below their theoretical potential in terms of nutritional value, with digestate often provided for free, and compost sold around 10€ the tonne [44]. In the case of digestate, this can be due to the surplus of nutrients brought to the soil e.g. from animal manure surplus. In both cases, this points to a potential lack of acceptance of bio-waste based soil improvers by end users.

WHO SHOULD PAY? DIFFERENT PERSPECTIVES

'Farmers will pay for the compost because it's a great product!'
→ if we look at it as this perspective, we may be disappointed.

'Farmers using compost helps cities get rid of waste that would otherwise be incinerated or landfilled.'
→ the cities need to pay for this service offered by farmers, or at least be available to reduce some barriers to use it.

It's also very important to bear in mind the legal advantages of using compost: in The Netherlands, you can apply it in winter, and you get a discount on the amout of P (phosphorus) you apply in the form of compost, compared with manure or mineral fertilizer. [45]

One way to **maximise their acceptation** is to involve end-users in the definition or optimisation of the bio-waste management system, and to consider as early as possible their expectations regarding the composition and effects of soil improvers and regarding their soil needs (*reminder*). This would enable to better close the loop and recycle as much as possible the outputs of bio-waste management into the soil [14]. But the most important lever to maximise acceptability of organic soil improvers is to optimise their quality and fulfil reliable and recognised certifications. Indeed, producers may be reluctant to use compost because of the potential presence of plastic or other residues.

→ *A matter of Quality*

"Benefits to the soil may only be realised if the compost/digestate is of high quality." [8]

THROUGHOUT THE PROCESS

Quality management schemes – QA/QC (*definition*)

The **European Compost Network (ECN)** has developed a European Quality Assurance Scheme (ECN-QAS) for compost and digestate, in order to harmonise quality standards at EU level. Indeed, across the 11 EU countries[2] that have already developed and implemented compost quality management schemes so far,

different quality criteria and different national rules applied. Based on these existing experiences, a common EU standard for composting was defined, and then transferred to digestate. It represents a benchmark and a basis to build one's own scheme. It is a voluntary/free process: do not hesitate to get in touch with ECN!

Animal by-product regulation (+)

When bio-waste may include parts of animal origin:

- it has to be transported in sealed and covered vehicles[14].
- industrial composting and AD units need to have a health approval by a competent authority to prove hygienisation[46], i.e. a thermal treatment (70°C, 60 min.) is required to destroy pathogenic organisms, in order to be able to use the final product as fertilising agent.

Good practice Guide: How to comply with the EU Animal By-Products Regulations at Composting and Anaerobic Digestion Plants

HACCP (Hazard Analysis Critical Control Point)

A Practitioner's Guide to Preventing and Managing Contaminants in Organic Waste Recycling

FOR THE FINAL PRODUCT

EU Fertilising Products Regulation (FPR) (+)

The FPR regulation covers both fertilisers and soil improvers (+), and sets minimum conditions for treatment (based on the ECN-QAS) and threshold values for nutrients and contaminants such as:

- physical impurities (maximum 5% content for glass, metals and plastics, and 3% for plastics only),
- heavy metals,
- biological contaminants and bacterial pathogens, such as Salmonella (which needs to be absent).

If a soil improver meets these requirements, it can be freely traded in the EU market [20, 48, 49].

Plastics are the main and most frequent contaminant found in bio-waste, as even if most of it can be removed before treatment through visual inspection and removal, or mechanical sorting, it still remain in the form of microplastics [2].

In general, the level of heavy metals remains under limit values in the case of compost and digestate [43].

The FPR will boost the role of the European Single Market, help reduce the environmental impact of soil improvers and fertilisers, limit their risk on human health as well as reduce Europe's dependency on imported fertilisers. New EU rules will soon make it possible to market more bio-waste-based soil improvers and fertilisers in the EU. [54]

National quality standards and norms

Several European countries also have adopted national fertilising products regulations and quality standards, with limit values that are sometimes stricter than the EU ones. Following a survey conducted by the EEA, 24 European countries (including UK, Switzerland, Turkey and other countries outside the EU) had a national standard for compost quality, more or less detailed and advanced [2].

Testing methods

To assess the safety and quality of a soil improver, here are examples of laboratories tests on product samples:

- Biotests measuring the phytotoxicity (i.e. germination and plant growth)
- Tests to assess stability and maturity (i.e. oxygen uptake, self-heating, residual biogas potential)
- Chemical analyses to measure essential nutrient content
- Chemical analysis to assess harmful contaminants and pollutants, i.e. physical impurities, heavy metals, organic pollutants, pesticide residues
- Microbiological analyses to assess biological contaminants (i.e. salmonella and *E.coli*)

Harmonized testing methods are needed. European Standards (EN) and Technical Specifications (TS) provide analytical methods for safety and environmental criteria, such as pathogen detection and contaminants determination, to be used by producers and National Authorities to verify the compliance of fertiliser products with the new Fertiliser Product Regulation (FPR). The ENs are currently under development and are expected to be published in 2024 and 2025.
The deliverables will ensure full harmonisation of the European Single Market, granting producers access to CE marking, and will play a pivotal role in fostering the use of bio-waste-based soil improvers and fertilisers. [54]

CERTIFICATION, LABELS AND STANDARDS

When the characterisation of a soil improver from bio-waste meets the national and/or European threshold values, it is usually **certified**, e.g. through a label. For instance, in Germany, there is a German Quality Assurance Organisation (BGK) which is responsible for awarding 'RAL' (German Standard setting institution) quality labels for compost or digestate [50].

Sometimes it is just indicated that the product is respecting the national standard. For example, in France, compost can be standardised with the norm NFU44-051 (French compost quality standard) by a testing laboratory, which also includes a certification for use in organic farming. Indeed, according to EU regulation [51], compost and digestate obtained from source-separated bio-waste are eligible to be used in organic farming, if they respect stricter limits for some heavy metals [49].

The insurance of a quality product through standards and certifications is a key lever for maximising the good marketability of soil improvers from bio-waste, as it helps to build trust for the end-users. However, considering the current lack of acceptance by end-users, setting and establishing a European requirement for all Member states to implement quality assurance systems and standards would enhance and boost the market of safe and high-quality soil improvers from bio-waste [2].

Conclusion

HOW ABOUT A SNAPSHOT OF THE FUTURE?

Let's imagine a world where:

- → We stop wasting edible food,
- → We sort our bio-waste correctly and regularly,
- → Our bio-waste, of high quality and suitable quantity, is collected effectively and efficiently,
- → It is then transformed into high quality, certified soil improvers,
- → That restore the soil's essence and health,
- → And save our foundation of life on earth!

Bio-waste, Healthy soil, it is everybody's responsibility. ITW
So, what are we waiting for?

THANK YOU FOR USING OUR HANDBOOK!

Thank you for reading and going through our **Bin2Bean Handbook "From bio-waste to soil"**!

If you liked it (or even if you did not), it would be great to have your opinion **here** (5 secs).

"When one doesn't master a subject, it's good not to be alone." ITW

Don't forget to follow Bin2Bean on LinkedIn and to join our Bin2Bean Stakeholder Forum!

Let's keep in touch and work all together, from a common ground, towards more sustainable foundations!

Notes

WHAT IS MECHANICAL BIOLOGICAL TREATMENT (MBT)?

→ **MBT represents a cheaper alternative to incineration, which outputs end up in landfill.**

MBT is a mechanical separation of biodegradable waste from residual waste followed by a regular bio-waste treatment (e.g. composting or AD). The output is a stabilized organic fraction but with all the impurities from residual waste, except the valuable ones (metals, some large plastic parts, some cardboards). **The quality of the "compost" obtained from MBT is thus only acceptable for landfill.**
The main goal of MBT is to reduce the percentage of biologically degradable waste (stabilisation), and to represent a cheaper alternative to incineration. In case of considerable landfill taxes (e.g. Greece) or strict limit values for organic carbon (e.g. Germany, where organic residues of MBT must be further processed to meet strict targets (low biological activity as required by law)), MBT is no longer a cheaper alternative.

Author: *Dr Henning Friege, N3, partner in Bin2Bean.*

DEFINITIONS: LAND DEGRADATION, DESERTIFICATION, FOOD SECURITY[9]

Land degradation = 'a negative trend in land condition, caused by direct or indirect human induced processes, including anthropogenic climate change, expressed as long-term reduction and as loss of at least one of the following: biological productivity; ecological integrity; or value to humans'.

Desertification = 'land degradation in arid, semi-arid, and dry sub-humid areas resulting from many factors, including climatic variations and human activities'.

Food security = 'a situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life'.

WHAT IS PAY-AS-YOU-THROW (PAYT)?

The Waste Framework Directive (WFD) [5] follows the **polluter-pays** principle and **extended producer responsibility** schemes.

- **Polluter-pays principle**: "The polluter pays principle is a simple idea at the core of EU environmental policy: those responsible for environmental damage should pay to cover the costs."
  - → In the WFD (Art. 14): *"The costs of waste management, including for the necessary infrastructure and its operation, shall be borne by the* ***original waste producer or by the current or previous waste holders****."* This also applies to bio-waste, but the level of charges or the relation to mixed waste is not specified.
  - → "**Pay-as-you-throw (PAYT)** (+, toolkit) is a scheme in which waste fees paid by users are modulated according to the amount of mixed waste delivered to the waste management system. **The aim of PAYT is to enact the polluter pays principle in a fair way** and its adoption can lead to outstanding results in waste management performance, increasing the amount of waste that is separately collected and sent for recycling while reducing mixed waste." The PAYT principle shall / can be applied to any waste fraction, it is mostly used for mixed / residual waste (+).

    To introduce PAYT, user identification is needed. It is quite easy in door-to-door schemes (caddies or bins with tags), for bring schemes there is the need to include electronical ID locking systems and volumetric limitation. [52]

"The engagement of residents to ensure a correct understanding of the features of the PAYT scheme is also key for its success, in order to avoid illegal dumping or the transfer of waste to other territories not served by a PAYT scheme."

- → PAYT schemes for citizens should be carefully designed to avoid illegal burning / dumping and to avoid increasing inequality. The amount of fees could be graduated according to the revenues of the household, in a fair and feasible way. For instance, in Germany, people who benefit from social welfare do not have to pay for waste management charges.
- → For example, in France, **PAYT does not automatically apply to households**, as the local authorities are responsible for citizens' waste management. (+)

- **Extended Producer Responsibility**: "policy approach that makes producers responsible for their products along the entire lifecycle, including at the post-consumer stage". (+)
  - → In the WFD (Art. 8): *"In order to strengthen the re-use and the prevention, recycling and other recovery of waste, Member States may take legislative or nonlegislative measures to ensure that any natural or legal person who professionally develops, manufactures, processes, treats, sells or imports products (producer of the product) has extended producer responsibility."*

BIN2BEAN will dive deeper into the PAYT and charging policies topics throughout 2025, join our Stakeholder Forum or follow us to know more.

IS COMBINING BOTH INDUSTRIAL COMPOSTING AND ANAEROBIC DIGESTION (AD) MORE EXPENSIVE?

***Q/A** with Dr Henning Friege (N3, partner in Bin2Bean)*

A: That depends: If there is a lot of green waste (GW), a separate composting parallel with an AD is cheaper than processing bio-waste + GW in an AD.
Q: But if there is a lot of GW, why not doing composting only? Because one would «miss» the biogas added value?
A: Yes, we all started with composting. AD is more expensive, but the revenues from Biogas can compensate for the cost difference depending on the national regulation.

HOW DOES AD RISE ITS TEMPERATURE?

With fossil fuels or with the heat produced in the composting process (in integrated plants) or with biogas

RESULTS OF THE CITY SURVEY ON THE TYPE OF TREATMENT FACILITIES

Out of the 20 cities surveyed,

- → **4** have all treatment options available on their territory (AD, industrial-, home-, community -composting) *either managed by the city or a solution provider (Hamburg (DE), Bordeaux (FR), Mikkeli (FI), Amsterdam (NL))*
- → **4** have both an AD plant and a composting plant on or near their territory (*not necessarily combined in one industrial plant, Hamburg and Bratislava have combined/integrated AD/composting plants*) *(Münster (DE), Ljubjana (SL), Bratislava (SK), Istanbul (TR))*
- → **4** have only a composting plant on their territory *(Düsseldorf (DE), Elblag (PL), Sevilla (ES), Egaleo (EL))*
- → **7** enable both community and home composting *(Albano Laziale (IT), Mikkeli (FI), Porto (PT), Nantes, Bordeaux (FR), Hamburg (DE), Istanbul (TR), Kyiv (UA))*
- → **4** enable only home composting *(Düsseldorf (DE), Cardedeu (ES), Sarajevo (BA), Egaleo (EL))*

EXAMPLE OF INTERESTS THAT PEOPLE COULD HAVE, AND THAT COULD BE LINKED SOMEHOW TO BIO-WASTE MANAGEMENT

Cooking, Sports/Nutrition/Health, Farmers welfare, Biodiversity, etc.

WHAT IS QA/QC?

"Quality management includes Quality Assurance (QA) and Quality Control (QC).

- Quality Assurance (QA) focuses on providing confidence that *quality requirements* will be fulfilled. An alternate definition is "all the planned and systematic activities implemented within the quality system that can be demonstrated to provide confidence that a product or service will fulfill requirements for quality."
- Quality Control (QC) focuses on fulfilling *quality requirements*. While quality assurance relates to how a process is performed or how a product is made, quality control is more the inspection aspect of quality management. An alternate definition is "the operational techniques and activities used to fulfill requirements for quality." " [47]

DO FLIES AND WORMS IMPACT THE QUALITY OF BIO-WASTE?

***Q/A** with Markus Montag (SRH, partner in Bin2Bean)*

Q: How do flies impact the bio-waste and its quality? I understand how they can be annoying/repelling to users/citizens, but do they actually contaminate the bio-waste?
A: "The flies are only unpleasant from the user's point of view. However, as this also reduces the frequency of use (of the biobucket and/or of the bio-waste collection system), it has a direct impact on the amount of bio-waste collected."
Q: What about worms?
A: Worms usually come from meat or fish scraps. Apart from the disgust factor, it is not a problem for bio-waste or compost quality. The user can get rid of them when cleaning the bio-bin, or can order another one and exchange so that they have a clean one again.

IF BIO-WASTE GOES MOULDY, DOES IT MEAN THAT IT'S NOT RECYCLABLE ANYMORE AND SHOULD GO IN THE RESIDUAL WASTE?

***Q/A** with Markus Montag (SRH, partner in Bin2Bean)*

Q: if bio-waste goes mouldy at some point between separation and treatment (for instance, when it is still in the biobucket at households, or in the containers / truck, or when it waits for treatment, etc.), is it a bad thing? Does it impact the process? Or on the contrary, is it good, as during the process (let's say composting), there is mould growing, so it's just part of the process?
A: This does not affect the composting process. Bio-waste usually "molds" when there is a high C/N ratio and higher humidity. Fungi are important organisms that drive/initiate the decomposition processes (i.e. always present in the composting process). Overall, therefore, neither questionable nor bad for fermentation or composting.

WHICH QUANTITATIVE TARGET TO SELECT TO MONITOR PERFORMANCE OF SEPARATE COLLECTION?

***Feedback from Enzo Favoino** (Chair of Scientific Committee of Zero Waste Europe)*

"The most important target - i.e. the quantitative one - should not be fixed in terms of "separate collection target" (i.e. X or Y % of total biowaste to be separately collected, or X or Y kgs/person to be separately collected) for this would go against other concurring and positive measures that trim the amount of biowaste to be separately collected (as home composting and food

recovery programmes). The best way to define the target is to call for a phased reduction/minimisation of organics left in residual waste (in kgs/person.year) so that all positive practices belonging to circular economy, including food recovery programmes, home composting, and community composting, may merge with separate collection in order to meet the target."

WHAT DOES THE FERTILISING PRODUCTS REGULATION (FPR) COVER?

The regulation covers:

- Fertilisers
- Soil improvers
- Liming materials,
- Growing agents,
- Plant bio-stimulants and
- Blends.

DEFINITIONS OF SOIL HEALTH AND SOIL FERTILITY

What is a healthy soil?
"Soils are healthy when they are in good chemical, biological and physical condition, and thus able to continuously provide as many of the following ecosystem services as possible:

- provide food and biomass production, including in agriculture and forestry;
- absorb, store and filter water and transform nutrients and substances, thus protecting groundwater bodies;
- provide the basis for life and biodiversity, including habitats, species and genes;
- act as a carbon reservoir;
- provide a physical platform and cultural services for humans and their activities;
- act as a source of raw materials;
- constitute an archive of geological, geomorphological and archaeological heritage." (+)

What is soil fertility?
"Soil fertility is the ability to sustain plant growth by providing essential plant nutrients and favorable chemical, physical and biological characteristics." (FAO)

WHAT IS COMPOST MATURITY AND STABILITY?

Content extracted from:

- Current Approaches and Future Trends in Compost Quality Criteria for Agronomic, Environmental, and Human Health Benefits
- Assessment of compost maturity-stability indices and recent development of composting bin

Compost maturity = degree of completeness of the composting process.

Compost stability = refers to a specific stage or decomposition or state of the OM during composting.

Compost quality = the stabilised and sanitised product of composting, which has undergone an initial, rapid stage of decomposition, is beneficial to plant growth and has certain humic characteristics.

To go further:
Maturity is the degree or level of the completeness of composting and implies improved qualities resulting from the "aging" or "curing" of a product. Compost characteristics such as color and odor give a general idea of the decomposition stage reached, but they give little

information with regard to the degree of maturation. A mature compost does not have a negative effect on seed germination or plant growth, implying a stable organic matter content and the absence of phytotoxic compounds and plant or animal pathogens. Compost maturity is associated with plant growth potential or phytotoxicity.
Stability is defined as the rate of O2 uptake by a compost sample and is related to the compost's microbial activity.
Since phytotoxic compounds are produced by microorganisms in unstable composts, stability is considered a criterion of maturity.

Compost maturity and stability are often used interchangeably, although each refers to specific properties of these materials. Stability indicates the degree of biological decomposition that the composting feedstocks have achieved, and hence the potential for unpleasant odor generation. Then, stability is a key property that a mature compost should possess.

EXAMPLES/IDEAS OF COMMUNICATION MESSAGES

- "With each meal, cook something back to the earth."
  "When you prepare your lunch box, prepare one for the earth."

- Show that it's simple, show that anyone can do it, that "cool" people do it too, make people want to sort their bio-waste.
  Indeed, when we procrastinate on something, it's either because it is complicated, or because we don't want to do it or because others don't do it.

- Work on the notion of disgust: ensure that people are no longer disgusted by bio-waste, that they see it as something that they can take in their hands, that is not dirty, something to treat well, to not waste, make sure that people understand the worth of bio-waste, that it is like gold for the earth.

Interviews

Country	Name of the Institution	Name of the person(s) interviewed	Expertise/Description	Date of discussion
FR	Les Détritivores (Bordeaux)	Romain Lamouille, Operating manager	Solution provider collecting bio-waste from food professionals and citizens, and transforming it in their industrial composting facility	19/12/2024
	SUEZ	Pablo Kroff, R&I program manager	Waste management solution provider	
	Crozon (Brittany)	City officer working on bio-waste management		20/12/2024
	Bordeaux Métropole	Hubert Griffiths, Head of the Strategic Waste Plan mission	Metropole which covers 28 municipalities	12/01/2024
FI	Biokerto (Finnish Biocycle and Biogas Association)	Anna Virolainen-Hynna, Executive Director	National association promoting nutrient recycling and the development of biogas	30/01/2024
UK	International Solid Waste Association (ISWA) – Carbon Clarity	Jane Gilbert Chair, ISWA Working Group on the Biological Treatment of Waste Director, Carbon Clarity		16/02/2024
EU	European Compost Network (ECN) – ENT (LIFE BIOBEST)	Stefanie Siebert, managing director of ECN Steffen Walk: scientific officer from ECN Mike Stinavage and Gemma Nohales: ENT, coordinators of LIFE Biobest		19/02/2024
FR	ADEME (The French Agency for Ecological Transition)	Muriel Bruschet, national bio-waste coordinator, Circular Economy Department Antoine Pierart, soil thematic coordinator Miriam Buitrago, soil engineer		21/02/2024
	FIBL (Research Institute of Organic Agriculture)	Tanguy Balanant, engineer and researcher in horticulture and agroecology		06/03/2024

FR	Bicy (Bordeaux)	Lily Ponthieux, Marketing Manager & Government Procurement	Solution provider collecting bio-waste from food professionals in door-to-door and from bring schemes, and transferring it to either an industrial composting facility or an AD plant.	06/03/2024
EU (based in IT)	Zero Waste Europe	Enzo Favoino, Chair of Scientific Committee of Zero Waste Europe, Pioneer of Separate Collection and transversal expert in bio-waste management, optimisation, policy, citizen science and climate change.		08/03/2024
FR	Réseau Compost Citoyen – La Boucle du Compost	Marianne THIBAULT, national coordinator of the French Citizen Compost Network David Arlabosse, member of the French Citizen Compost Network and creator of the game La boucle du Compost.		20/03/2024
EU (based in IT)	Collaborating Centre on Sustainable Consumption and Production (CSCP)	Dr. Francesca Grossi, Interim Head of Sustainable Lifestyles, partner of SCALIBUR and bioSOILUTIONS	Social sciences: Behavioural change, awareness raising on bio-waste sorting, psychology, citizen science, participative approaches, perceptions and narratives	17/04/2024
BE	VUB (Vrije Universiteit Brussel)	Laura Temmerman, Researcher at imec-SMIT		18/04/2024
LV	Riga-Stradin University (Latvia)	Kristine Blufelde-Rutka		16/05/2024

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This report has been designed using:

- *images and icons from Canva.com,*
- *one photo from Stadtreinigung Hamburg (SRH) (partner),*
- *two photos from Bicy.*

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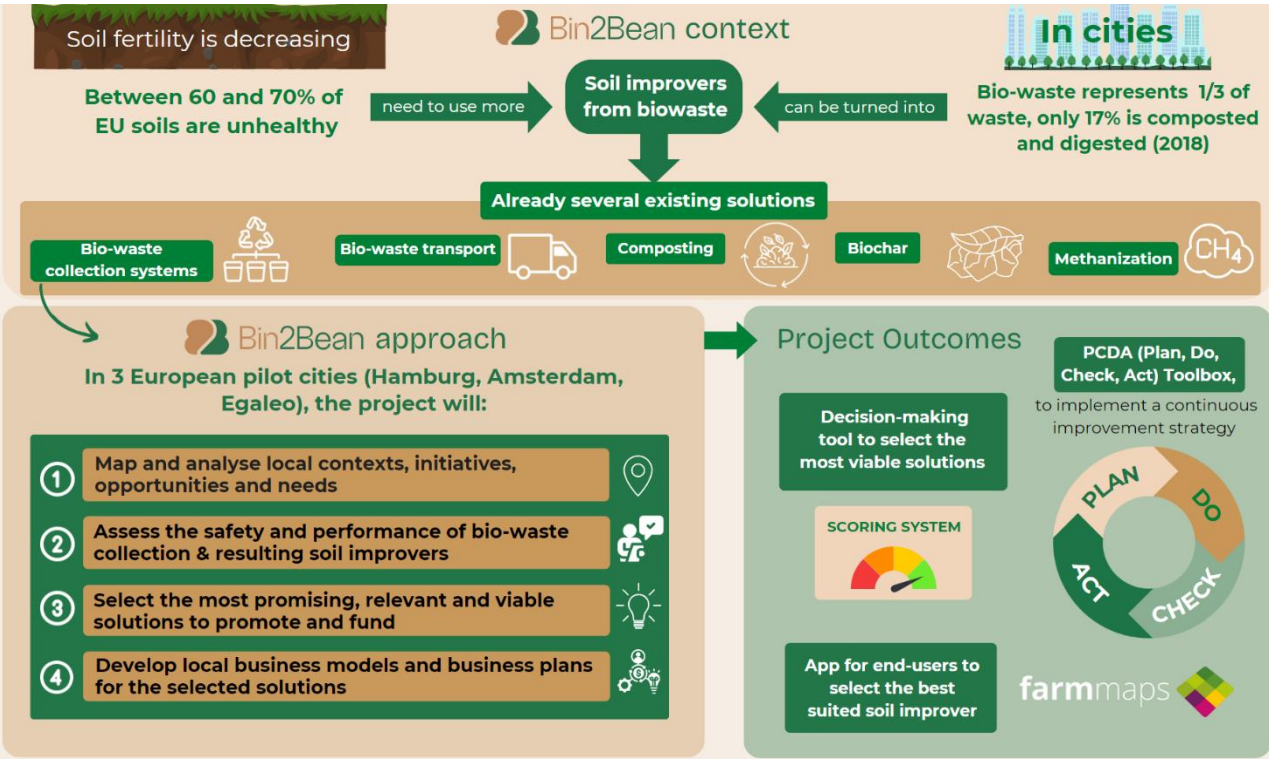
What is Bin2Bean?

Bin2Bean is a research-action project, co-funded by the European Commission under the Mission Soil, which aims to optimise the performance of bio-waste collection and transformation into soil improvers. It started in September 2023 and will last 3 years.



Bin2Bean collaborates with 3 City-Region Living Labs (*Amsterdam*, *Egaleo*, *Hamburg*), which have different states of progress and levels of experience on the topic, to implement a series of activities:

1. **Map local contexts**, in terms of state-of-progress, existing initiatives, needs, material and monetary flows.

2. **Design a tailored evaluation framework** to demonstrate the safety, environmental and socio-economic performance of bio-waste collection systems and soil improvers.

3. **Develop a scoring system**, fed by data from the evaluation framework, to help cities select the most effective and market-ready solutions adapted to their context.

4. **Develop tailored and viable business and/or community models** for the highest scored solutions, according to stakeholders' willingness-to-adopt.

5. **Draft local, national and EU policy roadmaps**, including waste charging policies and citizen awareness campaigns.

All this will feed into a **PDCA (Plan, Do, Check, Act) toolbox**, enabling any city-region to create a continuous improvement loop towards effective bio-waste recycling and regenerative soil systems.

Bin2Bean

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