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RESEARCH

# Recycling Food Waste

## An Investigation into the Delicate Process of Bio-waste Valuation

François-Joseph Daniel*,† and Marion Martin*

For more than 20 years, Europe has been encouraging household bio-waste recycling. This trend is spurred by the promise of a circular economy built around the diversion from landfills, the regeneration of farmland and the production of alternatives to fossil fuel energy. It involves valuation processes, through which a value—both economic and environmental—is assigned to the material in circulation. This article investigates the nature of these processes, particularly the ways in which value is created within the chains of actors that make up these industries. Through the analysis of a case of source-separated household bio-waste collection, we show that bio-waste valuation processes are difficult to master. Due to the living, putrescible, unstable and relatively unlucrative nature of this material, valuation processes are fragile assemblages. They largely depend on the policies, infrastructures, practices and material conditions involved in the handling, care, transport and processing of food waste.

**Keywords:** source-separated collection; recycling; waste recovery; valuation; economization policies; municipal waste

### Introduction

Food waste regularly makes the headlines. Worldwide, over 40 tonnes of food are estimated to be thrown away every second,[1] even as the world's resources are strained and hunger and malnutrition remain real problems (FAO et al. 2020). While preventive measures have been initiated in many European countries to limit waste quantities, there has also been a significant drive to recycle this waste. For more than 20 years, Europe has been encouraging household bio-waste[2] recycling to divert it from public landfills and incinerators. Numerous initiatives have been developed to recycle bio-waste, supply the compost production sector and in some cases produce biogas.[3] Such recycling is emblematic of a recent trend in capitalist societies (O'Brien 2012) towards the political and institutional organization of the supply of residual material and the structuring of economic channels around recycling. This trend is spurred by the promise of a circular economy built around the diversion from landfills, the regeneration of farmland and the production of alternatives to fossil fuel energy.

This recycling project has recently been endorsed within EU regulation. The 2018 waste directive[4] stipulates that by 31 December 2023, Member States must ensure that 'bio-waste is either separated and recycled at source, or is collected separately and is not mixed with other types of waste'. By directly calling on residents to carefully sort organic residual material, public authorities are relying on citizens' civic-mindedness to implement this recycling and to enable the production of high-quality urban compost without risk to the environment. While some local authorities have committed to supporting domestic compost or civil-society collective composting initiatives in order to comply with the regulations, many are planning to introduce bio-waste collection to centralize the processing of this material on dedicated platforms. For these local authorities, this recycling policy marks the start of a second chapter in source-separated collection after the 1990s and 2000s saw the generalization, in most European countries, of the collection of many waste categories: packaging, used batteries, WEEE, textiles, and so forth.

The emergence of a new collection stream (and the prospect of again mobilizing residents to sort bio-waste) not only follows on from this long history of efforts by waste management organizations to mobilize users, but also raises anew some of the questions surrounding waste recycling. Many sociological analyses have endeavoured to grasp the figure of the eco-conscious consumer and user and the associated policies to rally and empower residents (Barbier 2002; Evans, Welch & Swaffield 2017; Rumpala 1999). They have shed light not only on the drivers of waste sorting, the material and social conditions that cause this practice to be observed and the profiles of sorters, but also on the social engineering policies, their effects on individuals and their implications for waste governance, putting citizens to work, and leveraging guilt (Caillaud 2018; Evans 2011). Few studies, however, have

* ENGEES, GESTE UMR MA 8101, Strasbourg, FR
† Université´ de Strasbourg, Strasbourg, FR
Corresponding author: François-Joseph Daniel (francois-joseph.daniel@engees.unistra.fr)

seriously considered the circular economy projects underlying these policies, from plate to gate, one might say. Discard studies, which have largely studied recycling economies (Alexander & Reno 2012), seem to have overlooked the thorny issue of bio-waste and its specific economies of return to the soil.[5] The fixation on the efficiency, meaning and interpretation of policies around small acts has disregarded the more opaque realities of the structuring of the techno-economic industries that govern the recycling of this material. Once sorted, residual material mobilizes different actors in the recovery sector; they are subject to economic transactions and material transformations, to ultimately be reclassified as marketable products and eco-friendly fertilizers. This material is involved in socio-economic processes, at several levels, through which a value—both environmental and economic—is assigned to the material in circulation. Following economic sociology scholars such as Çalışkan and Callon, (2009, 2010), this value assignation corresponds to a socio-economic process of valuation. In this perspective, value is not understood in essentialist terms. It is not purely inscribed in the material properties of objects, nor is it the mere result of abstract and subjective institution's appraisals. The process of valuation originates from both human and non-human assemblages that eventually create value; it not only builds on social dimensions (networks, social relations, rules, conventions, etc.), but also symmetrically considers the materiality of markets and their objects (techniques, sciences, standards, calculation instruments, etc.) in the construction of economic relations. These valuation processes do not necessarily involve economic practices or devices; the said value of things is not always and systematically quantified, monetarized and understood as economic.

This article intends to analyse the processes of valuation in the context of bio-waste recycling. By investigating the ways in which value is created within the chains of actors, it asks the following questions: what are the valuation processes in bio-waste recycling chains? What are the specificities of the human/non-human assemblages that take part in these processes? What are the difficulties and challenges of valuing bio-waste? The paper intends to answer these questions using an economic sociology perspective that builds on discard and valuation studies (Callon, Millo & Muniesa 2007; Çalışkan & Callon 2009; Gregson, Watkins & Calestani 2013). It begins with a brief presentation of the issues surrounding the recycling and valuation of recovered material in the field of bio-waste, followed by a case study of bio-waste collection, by tricycle, launched in the historical city centre of Strasbourg in 2018. After presenting the contours of the case-study and the qualitative survey that served to analyse it, we show how valuation processes unfold at different points in the value chain. We conclude this reflection with a discussion on bio-waste policies and the role of public authorities in the design of the associated value chains.

## Valuing Waste: A Bibliographic Review

Like many recycling companies, bio-waste recovery projects are part of organized industries striving to change the economic status of material. When qualified as waste, the objects have no value; they even endorse a negative value in the situation where their holder is willing to pay to get rid of them, what the economist Jevons calls 'discommodities' (Jevons 1888 [1871]; Lupton 2011; Lupton 2017: 87). For each of the industries involved in the recycling of these discommodities, the goal is to make material usable, to invert the value regime governing it by disassembling wastes (Greeson, Laser & Pyyhtinen 2020) and converting it into a genuine valuable product. At the end of these supply chains, the residual material is transformed into usable and marketable material on markets for economic goods. The restauration of economic value is closely associated with environmental benefits; the burden of dealing with waste and pollution slightly diminishes and a new non-extractive resource emerges. While the techno-economic processes underlying bio-waste recycling have received little attention until now, the broader sociology and anthropology literature on recycling provides considerable insight into these value chains' conditions of operation and into the associated valuation processes.

Firstly, valuation processes are embedded in local or global recycling networks, more or less formal chains of actors within which material is exchanged, transported and processed (Alexander & Reno 2012; Gregson & Crang 2015). In these recovery industries, value extraction hinges on a range of factors, including the geographical distance travelled, the efficiency of the practices, mechanisms and technologies used for the sorting, dismantling and packaging of recovered material, and the labour costs involved in these operations. The work to separate the material is where value is truly created, and, as some scholars show, this work often relies on 'practices of care' where the material is repetitively and meticulously dealt with (Ureta 2016). Secondly, the value chains obviously take on different forms, depending on the types of material recovered and its intrinsic properties. However, they all share the difficulty associated with the more or less unstable nature of the waste, its handling and its level of hazardousness. Waste often has uncertain and complex properties, and the technological, human, logistic and commercial arrangements adopted to recycle it depend heavily on the quality of the material and the promises associated with its recycling. The value of the material once it reaches the end of the supply chain is therefore not just the result of technical and human artefacts; it is deeply rooted in the materiality of the residues, the operability of processing tasks and the geography of the streams and circuits followed by this material. These conclusions are congruent with broader findings in economic sociology; in most economic sectors, the things exchanged are 'animate' (Çalışkan & Callon 2009) in the sense that their materiality does influence the nature of economic relations and transactions between actors.

Finally, the organization of economic transactions between the different actors is punctuated by mechanisms and devices, at different points of the chain, to assess the quality of the material exchanged (Callon, Millo & Muniesa 2007; Gregson, Watkins & Calestani 2013). Before entering recycling circuits, the material is assessed, whether its physical state is solid, liquid or gaseous, to give the actors

concerned guarantees regarding its composition and innocuousness. Gregson, Watkins and Calestani (2013) argue that the value of residual material is not decided solely during the market transaction; it really materializes through the implementation of the technical evaluation mechanisms that structure the activities surrounding the dismantling, sorting and recycling of material. These mechanisms bring into being both a safety assessment of the material (to make sure that it is sanitarily and environmentally harmless) and a quantified monetary value. Their purpose is not limited to estimation and calculation. By appraising the quality of material, they give value to objects, stimulate exchange and thus serve as real market mechanisms conducive to a valuation of residual material. These mechanisms, sometimes involving more sensory and experiential assessments, not only inform the different actors on the quality of the goods exchanged, but also give value to the objects and perform the relationship of economic exchange (Crang et al. 2013).

Bio-waste recycling, from plate to gate, is no exception. It is embedded in technical-economic assemblages, calculation devices and sorting and evaluation practices that ultimately guarantee the quality of the material, organize its transfer and produce value. Not only is the value created by this process economic, but the resulting compost also holds an environmental value: it becomes an ecological product, a soil enrichment resource used to replace chemical fertilizers. However, this valuation process is delicate for several reasons. First, this residual material is rarely pure. It is irremediably and unevenly soiled with plastic residues, metal or glass that can render the compost unfit for consumption or obstruct processing operations. This difficulty raises tensions surrounding the qualification of the material, which wavers between product and waste (Gregson et al. 2015). Moreover, this material is tricky to handle, for organic residues are unstable and easily putrefy. Bio-waste is not merely inert matter devoid of effect; it consists less of objects per se, with clearly defined properties based on their shape and texture, than highly and rapidly evolving matter. In fact, humans cope with non-human entities, such as microbes and bacteria that are enrolled at some point to process the waste but that can also create nuisances and other undesirable effects. The resulting instability does influence the quality of economic exchanges within the value chains. Finally, prospective economic gains from bio-waste remain limited compared to more lucrative recovery industries, such as rare metals. Household bio-waste and its by-products have a relatively low value.[6] Due to the specific qualities of bio-waste (impurity, instability and low market value), the associated valuation processes are closely linked to the command of biological and logistical processes, the quality of the infrastructure mobilized to guarantee the hygiene, sanitary condition and processability of bio-waste, and the existence of mechanisms (including sensory mechanisms) to assess residual material throughout the value chain. The example of Bioclou, which we now present, will be used as a case-study to illustrate some of the particularities of these recovery chains.

## Methodology: A Case-Study of Separated Food Waste Recycling

In order to analyse the valuation processes at stake throughout the bio-waste recycling chain, an in-depth case-study was conducted. The use of this research method is not simply about generating anecdotes but rather about providing a 'nuanced view of reality' that reveals the main properties of the phenomenon (Flyvbjerg 2006). In this section, we present the case-study, describe the recycling chain and introduce the qualitative survey that permitted us to gather empirical data and achieve the analysis.

### *Presentation of the case*

The Bioclou is an experiment of bio-waste collection that was initiated by the Eurometropolis of Strasbourg (Eurométropole de Strasbourg – EMS), the local authority in charge of municipal waste management. In 2018 the EMS services, in collaboration with a local social and solidarity-based organization (Régie des écrivains) and a waste management professional (Recybio), designed and implemented a system to collect bio-waste by tricycle within a limited area in the heart of the city's historic centre (**Figure 1**).


**Figure 1:** Left: 'bio-buckets'; right: 'Bioclou' collecting system.

We chose this experiment as a case study as it was likely to illustrate the stakes and difficulties of collecting bio-waste in big cities. Although some large urban European areas like Milan have already put this measure into practice, many others are hesitant to launch similar projects. That is especially true in France, where bio-waste collections have been developed mainly in rural or suburban areas. With the 2015 regulatory evolutions that imposed the sorting of bio-waste at source,[7] some cities like Grenoble, Paris or Strasbourg initiated the collection of bio-waste in their city centres despite what some perceive as the delicate nature of the issue. Bioclou, located in the city centre of Strasbourg, presents many of the attributes of a 'difficult case': small dwellings, densely populated area, vertical housing and distance from the countryside.

### *Description of the value chain*

The Bioclou value chain is comprised of a series of actors among whom material and money circulate. The first component of the chain is a mobile voluntary collection point: a cycle vehicle fitted with bins for household food waste. The vehicle, called 'Bioclou',[8] can be found on a town-centre square twice a week. It was designed to meet the urban planning constraints peculiar to old city centres (narrow streets, heritage area) and was contracted to a collection agent hired by the Régie des écrivains to carry out the bi-weekly runs. The households that agreed to take part in the experiment (nearly a hundred) were instructed on how to proceed with their bio-waste. They were provided with bio-buckets[9] lined with kraft paper bags, thereby facilitating the storage and transport of the bio-waste to the collection point and its disposal in the Bioclou bins (**Figure 1**). At the end of each run, the collection agent takes the material to a storage space belonging to the local council. It is then given to Recybio, who transfers it to a nearby composting platform. The bio-waste is then composted by a farmer who uses the compost in his fields or sells it to other users (farmers, landscapers).

Throughout this recycling chain, the actors involved engage in particular economic relations (see **Figure 2**). The resident gives their food waste for free to the collection organisation Régie des écrivains who transfer it to the transport company Recybio. Both organizations are paid for their services by the local authority EMS whose waste management budget originates from the general household waste collection tax. Recybio, finding itself in possession of a discommodity (commodity with a negative value), pays the farmer-composter to take the incoming quantities of bio-waste.[10] This farmer then uses the compost on his farm and sells (or gives away) a share.[11] The value of the recovered material (compost) only becomes positive in this last stage, when the compost is sold to other users.

### *A qualitative survey*

To understand the bio-waste valuation processes at play in this value chain, we carried out qualitative field research in 2019 on the social-material trajectory of waste, with a special focus on how value materializes through interactions. We conducted comprehensive interviews (Kvale & Brinkmann 2009) with the main actors who make up this chain, namely, the agents working from the organizing authorities EMS (an engineer, an elected official and an intern), two employees from the solidarity-based organization Régie des écrivains (the collection agent and the manager), the manager from the waste management company Recybio and a farmer-composter. We also held 7 interviews with the residents participating in the experiment (3 men and 4 women aging from 27 to 70 years). Three of them lived with roommates, two in households with children, one in a couple and one alone. We met with a total of 14 people during (approximately) one and half hour sessions. All the interviews were recorded, integrally transcribed and analysed using a thematic transversal approach. Finally, we made several field observations (Musante & DeWalt 2010), particularly during the collection sessions and during a visit to the storage and composting sites. One of us even took part in the experiment, as a resident of the Bioclou area during the study. A total of 40 hours of observation were conducted. Notes were systematically taken during these different phases. This additional participant approach allowed us to make some embedded observations that wouldn't have been otherwise possible. Particularly, it allowed us to take into consideration the sensory dimension of bio-waste and the material conditions of assessing, handling and working with waste from the households to the farm.

In what follows, we describe the different socio-technical assemblages that structure and govern exchanges and,

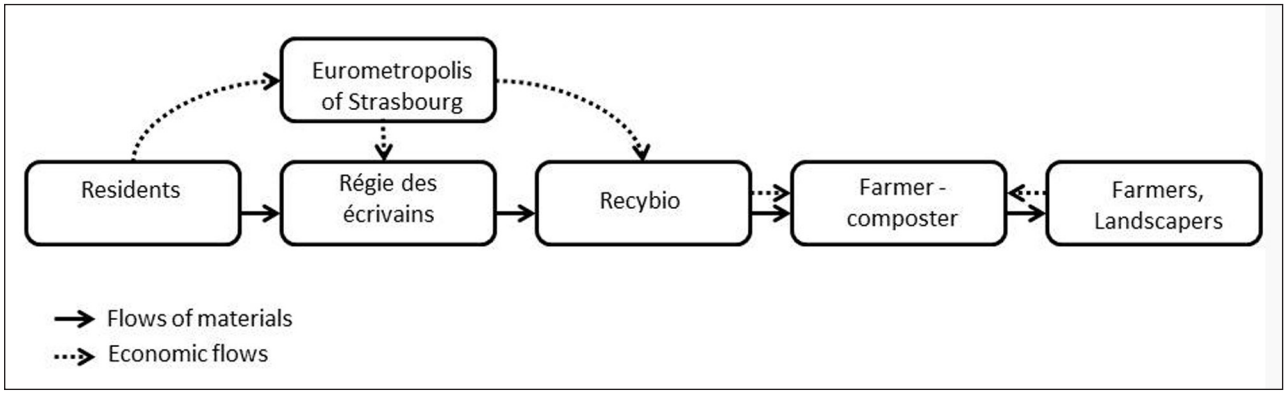


**Figure 2:** Bio-waste recycling chain of the Bioclou.

at different points in the value chain, enable the circulation and valuation of the material.

## Results

### *The act of sorting as a labour of care*

The first link in this value chain is the voluntary work of the residents involved in the experiment. As in other types of recycling, careful sorting and separation is what gives value to the material recovered (Crang et al. 2013; Gregson et al. 2015; Gregson, Watkins & Calestani 2013). The voluntary nature of this experiment partly explains the participants' positive attitude towards the scheme and their commitment to this new practice. Many of them attribute a latent value to bio-waste, embodied in the imminent promise of return to the soil. Some even directly use the term compost to refer to their bio-waste, as though the fact of having sorted it immediately gives it a different status from that of waste—that of useful, fertilizing matter. This representation of waste as a resource gives meaning to the practice of sorting, even if the sorters have a rather abstract understanding of what happens to their bio-waste once it is taken away by the collection service. In a more or less conscious or abstract way, the residents live their involvement as a form of civic participation in the recycling of waste, the return of organic matter to the soil and the maintenance of farmland, as the following short excerpts show.

> 'In any case I'm happy that we lose absolutely nothing, therefore that everything is recovered, […] that we can reuse it' (male resident aged 49 years); 'Because what's the end goal? It's that it can be recycled and put back into circulation in the soil' (resident aged 55 years).

In practice, this civic engagement translates into sustained attention paid to bio-waste, combined with a set of concrete measures to make the act of sorting operational. The participants all found a place for their bio-bucket in their homes; they had to sort the material more or less scrupulously to separate the organic from the inorganic and had to regularly empty the bio-bucket during the collection time slots. This was really a labour of care, which gradually became normalized and routinized within the participating households. It implied ordinary practices, which, as for any labour of care, are defined by repetition, regularity, invisibility and little recognition in return (Tronto 1993).[12] The care involved in the handling and sorting of material is integrated into domestic habits and norms—more or less renegotiated to make room for these tasks—surrounding practicality, comfort and above all cleanliness and hygiene (Shove 2003). By regularly emptying the bio-buckets, or making sure they were airtight, residents prevented bacteria from pre-digesting the waste and thereby odours from developing. These practices, adopted to pacify the coexistence with bacteria, microbes and odour development, are met at all the different stages of the value chain.

The precision, regularity and assiduity of sorting practices can easily be disrupted when the standards of domestic life are challenged head-on. For example, some users, dissatisfied with the collection times, have ended up not taking their bio-bucket to the collection point because they were unable to synchronize their usual habits with the time slots offered. Likewise, other participants reported that they did not take their bio-waste to the collection point when it over-accumulated (the bio-buckets were too small) or when it generated unpleasant odours in hot weather. These examples show that sorting and care practices are informed not only by an implicit objective of agronomic recycling and soil maintenance, but also by ordinary nuisance-prevention considerations. The fear of potential odours caused by decomposing waste leads to small adjustments within the household to ensure a good balance between the very abstract objectives of a return to quality soil and individuals' olfactory comfort. Through these arrangements, the (economic) value assigned to waste becomes a little less negative.

### *Social control and support work*

The delivery of bio-waste bags to the collection point in the allocated time slots is a key point in the trajectory of bio-waste. When the bags are deposited in the bins, the collection agent can control the quality of the users' sorting practices. He could open the bags and check the composition of their content. However, in reality effective control of practices is difficult to achieve, as one of us observed during a collection run. When the topic of the quality of the inputs and compliance with the instructions came up in conversation, the collection agent suggested that we open one of the bins to show us the deposit. A pestilential, almost unbearable odour came out, and the collection agent immediately exclaimed, 'I can't look!' This anecdote, which culminated in a knowing laugh about this abyss of repugnance, does not reflect any failure on the part of the collection agent. Rather, it illustrates the difficulty of dealing with decomposing residual material, to which waste professionals are accustomed (Jeanjean 2006). Controlling the quality of sorting practices can be neglected owing to the irreducible disgust produced by the aftermath of bacterial development. In practice, the collection agent only rarely checks the contents deposited, and the organizers are well aware of this:

> There you have someone who checks the [bag]… well, who checks… who at least checks that someone brings the bag back. […] He won't open it and check if everything is as it should be inside, but at least he checks that he [the inhabitant] has brought back the right bag. And then, if he sees that there is something else, then at least he can communicate with the people and say to them 'this is good, this is not good, …' (Régie des écrivains – manager).

Although the collection agents' presence does not ensure proper and systematic control of the bags' contents, it does nevertheless fulfil the essential function of social supervision as the sorted bio-waste is deposited. First, it provides a physical and social presence that personifies the figure of control and authority. This presence discourages the incivilities to which the voluntary deposit sta-

tions sometimes fall prey. Moreover, it gives a human and public form to an organic matter recovery activity that is usually rendered invisible. At any time, the collection agent can remind people of the sorting instructions and provide information about the purpose of this process. These direct interactions thus enhance the quality of the deposit by providing users with a point of contact, a form of support and minimum symbolic authority that encourages them to adhere to and comply with the instructions.

### *Transporting the bio-waste collected: 'Massification' work*

Once the collection agent (of Régie des écrivains) has dropped off the bio-waste at the collection point, Recybio takes over and transfers it to the composting sites.[13] The economic challenge, for this new player, is to optimize the logistics so as to generate sufficient profit. This logistical optimization is a delicate operation, for the service provider does not always have a choice of outlets: few composting or digesting centres in the surrounding area are willing to take in bio-waste. The choice of outlet generally comes down to the proximity of the collection site, negotiations on the amount invoiced for the service and the quality of the batches. Some facilities are less concerned about the purity of bio-waste, as they have depackaging machinery upstream of their process that allows them to separate packaging from biodegradable organic material. In all cases, the service provider must carefully calculate his journeys and costs in order to batch trips, for he also has batches of waste from other areas to collect. He tries to make as few trips as possible by transporting a maximum amount of material, reducing the number of trips to make by grouping together several streams with the same destination. This practice, known as massification, helps to optimize logistics costs and, according to our informant, to 'achieve economies of scale' (EMS – intern).

Massification involves bio-waste sometimes having to be stored because the quantities collected, which may be quite small, are not sufficient to be transported to the composting centre immediately. In the case of the Bioclou, the bio-waste bins are stored in a room just a short distance from the collection point. They are placed in a cold room, then picked up a few days later by the service provider, who will use this trip to transport bio-waste from other collection areas and thus pool transport costs. Massification can therefore involve storage practices that can be relatively costly from an economic, energy and environmental point of view, as cold storage entails additional costs. The logistics also require taking specific precautions to prevent odours, as these types of material degrade easily and are quickly subject to putrefaction. The challenge, for the collection professionals, is to maintain good relations with the people living or working near their routes and storage sites. It is important for them to limit odours and to couple speed and airtightness when moving material so as to remain sufficiently discrete. In so doing, bio-waste reverts to being a clandestine and invisible object in the public space.

At this stage, the process of valuation involves a significant investment from the different actors at the beginning of the chain (residents engaged in the sorting activities, local authorities and Régie des Ecrivains responsible for organizing bio-waste collection and the transport company Recybio involved in the massification work). However, the value of the material is still not quantified and the collected bio-waste is not assigned a proper economic value. Rather, its value remains latent but will be revealed in the following steps: while entering into market transactions, biowaste is subject to economic practices meant to describe and perform its value. That is what Çalışkan and Callon (2009, 2010) call a process of 'economization' through which the actors are involved in activities of qualification that describe the economic qualities of their product. As we will see now, this process of economization marshals a whole set of practices, devices and analyses that allow the actors to produce and define the values of this material.

### *The 'characterization' of the batches as an assay device*

Once massified, the quantities of bio-waste become real resources, but their qualification as such is still uncertain. Despite the sorting operations carried out by the inhabitants, no one really knows what actually makes up these mounds of rotting food waste. Uncertainty remains regarding their composition. Yet knowledge of the quality of these deposits is essential for structuring the transactions between the actors in this bio-waste recycling chain. For Recybio, this knowledge is particularly necessary upon receiving the bio-waste bins to negotiate the price of the service and, upon delivery to the composting site, to agree on the price charged by the composting farmer. For this reason, Recybio, after receiving the bins, performs a characterization.

The aim of this exercise, which is not mandatory, is to assess the exact composition of the batches in order to determine the percentage of undesirable matter and to distinguish between bio-waste and non-bio-waste. It allows for identifying the types of waste present in the bins and the possible share of non-organic waste (inert matter, plastics, etc.). The more or less pure or clean nature of the samples—in other words the absence of undesirable matter—is what guarantees the value of the batches. Characterization helps to reassure the composting site manager who receives the bio-waste. It provides proof of content and acts as a passport that authorizes access to the recycling sites, as attested to in the following account:[14]

> So with the characterizations, we're looking to show just how clean the product is; [...] but it's true that it reassures the processing centre to say 'well listen, here we have this inside, we've characterized it, it's this'. Maybe sometimes there will be a little more, sometimes a little less, but that's the average. And there are some who will say 'Well no, I can't take it, because there are 2% [undesirables]. I want zero.' (Recybio – manager)

The service provider carries out the characterization himself; he empties the bins on the ground and goes through

its composition following standardized protocols. This stage involves direct contact with the decomposing material: 'I take the bin, empty it on the ground and sort it with tongs [smile]' (Recybio – manager). The humoristic tone adopted by the agent to reveal his method shows how this practice is counter-intuitive; how the idea of digging into this smelly magma of bacteria instinctively provokes repugnance and disgust; how humour can serve to deflect his assimilation with the waste. However, this step of characterization is crucial for him to prove the quality of the product and thereby secure the transaction with the composting site manager. Characterization can be done in front of the farmer as a guarantee of the reliability of the assessment. It is carried out prior to the transaction, but not systematically. Above all, it provides Recybio with a commercial argument to justify the quality of the material when the contracts are signed. Characterization thus serves as an assay device (Callon, Millo & Muniesa 2007; Gregson, Watkins & Calestani 2013) that governs the commercialization of the material recovered and allows the economic transaction to take place. However, while it is useful for qualifying the batches of material and structuring economic exchanges, this is not always enough. In practice, the managers of the outlets also carry out a sensory assessment of the quality and cleanliness of the batches. This is the case of the farmer-composter we met, who pays attention to the characterizations but also visually assesses the bio-waste mounds at the time of delivery and later when he handles the material.

> I'm not interested in having a characterization and knowing that there are such and such percentages of plastic. I just don't want any... [...] what I do find is [a lot of] plastics... Well in the end 'a lot' is relative, there are brackets but... (farmer-composter).

As this quote shows, characterization standards do not in and of themselves guarantee the value of residual material; they coexist with sensory evaluation practices, which also shape the relationships of exchange between the protagonists.

### *Evaluating the quality of the compost*

This dual form of evaluation is also practiced in the last link of the recycling chain, when the compost producer carries out transactions with buyers. The issue for these actors is to come to an arrangement where the compost is no longer the achievement of a successful recovery, but where it appears to be a safe and valuable product that enriches the soil and improves their fertility. Here again, the economic exchange is informed by quality frameworks. Formally, the farmer-composter is subject to the French standard on organic soil fertilizer (NF U44-051), which defines the regulatory criteria for good quality compost. This standard sets out impurity threshold values not to be exceeded,[15] and laboratory tests are carried out on each compost batch sold. Although these thresholds provide benchmarks for assessing the quality of the compost, once again, they are not always enough for the farmer-composter to be able to sell the compost to fellow farmers and to his few landscaping clients. If compost is to be deemed of good quality, visible forms of pollution must also be removed (see **Figure 3**). For example, small bits of plastic or glass need to be meticulously removed:

**Figure 3:** Left: compost being processed; right: finished product. The picture on the left shows the quality of the product before it has gone through all the sorting and screening stages.

while the standard tolerates these, potential compost buyers do not accept them. According to our informant, the sight of even the smallest particle of undesirable material is likely to damage the reputation of the compost, the composting farmer's business and, ultimately, the quality of the soil.

Evaluating compost is therefore not only a matter of conforming to a standard,[16] it also involves 'subjectification' processes (Çalışkan & Callon 2009; Miller & Rose 2008; Roitman 2005) whereby the value of objects is constructed through basic sensory operations, following which the compost is qualified. The feel and smell of compost play a crucial role in these processes. The compost should be neither too fine nor too coarse, and the smell of putrefaction should have given way to a more neutral earthy smell. These evaluations are essential: not only do they perform the economic transaction, but they also support the prior assemblage and sorting work carried out by the farmer-composter to remove undesirable material; fairly basic mechanical screening is carried out, as well as manual sorting at all stages of the composting. Here again, meticulous care requiring dedication and patience is given to the material.

## Discussion: Bio-waste Recycling Chains as a Fragile Assemblage

The qualitative analysis provided in this article moved the sociological focus away from the service users and their individual engagement to consider a broader valuation process involving a wider range of social, economic and material assemblages. It shed light on the complex valuation processes in which these recycling streams are embedded, and through which both economic and environmental values are created. These processes are structured around the following: networks of actors through which residual material circulates; care practices, social control and support work that facilitate the sorting of bio-waste; infrastructures and managerial practices (including massification work) that optimise its transport and processing; and evaluation devices and practices to guarantee the state of this material and allow for its quality to be improved at different points in the value chain. These chains are not just the sum of logistics links through which material and economic flows circulate, or even an entanglement of economic agents sharing a profit. Rather, they also correspond to human and non-human assemblages involved, at different stages, in the valuing of the material. These assemblages comprise a set of actors who, with varying degrees of attention and discernment, sort, separate and process the material in order to return vital matter to the earth. They also involve bacterial colonies that play a major role in the processing and metamorphosing of the material into compost, and assay devices that allow the economic value to take shape. Through these practices, devices and non-human actors, a valuation process unfolds to restore the value of residual material and put it back into circulation. Although the material formally changes economic status (from negative to positive), it doesn't materialize directly into an economic value. It involves an economization phase that happens when the material is transferred into the market: that is, only when the bio-waste reaches the hands of private economic actors can its properties be formally evaluated and quantified and its value qualified as economic.

This qualitative study has obvious limitations for it doesn't shed light on the whole diversity of food waste recycling chains, nor does it provide a quantitative measure of the economic flows. However, the case-study clearly shows that bio-waste recycling valuation processes are fragile for at least three reasons. First, bio-waste's highly unstable nature and its propensity to degrade easily raise hygiene, storage, handling and nuisance issues. The working of the chain is a tricky equation between, on the one hand, the organizations of human actors and, on the other hand, the temporalities of bacterial colonies whose activity can easily become uncontrollable. These issues raise questions about the domestication of bacteria as well as the working conditions of the professionals involved and the risks of odour nuisance all along the route taken by this material. They affect and create vulnerability in the valuation processes. Second, valuation processes are challenged by strong constraints of locality. Because the prices of the material remain relatively low, in order to be profitable, the material cannot travel far. The economic rationales at play are invariably informed by logistical dilemmas that force the actors involved to optimize their trips and to prioritize short supply chains. This local attachment contrasts with global recycling networks, where the geography of streams is defined by the offshoring of sorting processes (Gregson & Crang 2015). Third, the end value of compost fundamentally relies on the quality of the sorting done by residents at the very beginning of the chain. The main implication of that fact is that the upstream actors play a significant role in the valuation process. The bio-waste recycling chains are profoundly structured by public economic support, largely financing the social organization of waste collection. The (environmental) project of return to the soil is contingent on the service fee paid by the local authority. It hinges on the willingness of this authority (and indirectly of the residents who pay the household waste collection tax) to pay for this service. The promotion of such initiatives by public authorities therefore amounts to full-fledged political choices. It corresponds to real valuation policies, that is, policies that shape the social, technical and economic structuring of these chains and strengthen the processes of value creation from the outset. These policies determine not only the degree of public investments but also the choices made around infrastructure, technologies and institutions. They largely condition the nature of the valuation process and the quality of the return of organic material to the soil.

## Conclusion

By way of conclusion, it is worth reflecting on the design of these valuing chains and drawing some further research questions. Public authorities' involvement in bio-waste recycling projects has led to the emergence of different initiatives, technologies and actors. These value chains differ in their collection methods, the technologies used, their degree of centralization and industrialization, their forms of citizen involvement, their circuits of return to the soil and so on. Without taking a normative stance on any one of these initiatives, at least three key aspects of their

design warrant further reflection. First, despite the limited effect of food waste policies on the valuation process of food waste (Arnold 2021), these policies do have some effects: they define an implicit relationship to the environment and work in these industries. The case of the Bioclou illustrates a specific configuration where the organizing authorities devised a solution that was relatively costly compared to other bio-waste collection methods, but with environmental benefits (the tricycle-trailer) as well as social benefits. These policies do convey singular ways of articulating social, economic and environmental considerations. Yet while economic costs in these value chains are generally fairly well known, the social and environmental benefits are not necessarily calculated, monetized and taken into account in policy design choices, which may constitute a first limitation. Following this perspective, some academic works addressing the ontologies of the different economic, social and environmental values of compost could be further undertaken. Second, the design of these policies lends a certain coherence to the overall recycling project and gives meaning to the different successive operations in the chain. The Bioclou case has shown that such a meaningful organization is not a given to everyone. While the citizen-sorters had a more or less vague understanding of the ultimate composting project, they were unaware of its social and material inner workings. Once bio-waste is collected by the public service, it becomes invisible in the eyes of the sorters. This invisibility deprives citizens of an essential resource, that which enables them to embody the product of the labour of care they carried out and to maintain it in time and space. It is quite conceivable that the industrial rise of recycling solutions is likely to exacerbate this issue. Therefore, the issue of how composts and soils become an environmental value or fall into a public blind spot is another research question for social scientists. Finally, these policies largely define the conditions of success of the project to separate, sort and care for organic material. Through support, communication, social engineering and control measures, public authorities can encourage, promote and control the quality of operations surrounding the return of matter to the soil. The stakes here are crucial for soils: it is not only a matter of taking care of these living entities essential to human life (Puig de la Bellacasa 2014) by enriching it, but also of avoiding contaminating soils by adding compromised matter, of which the long-term effects on living organisms remain uncertain. The great challenge of bio-waste economization policies is therefore to articulate a project of economic valuation of material without distorting the ideal of a return to the earth. Accordingly, research regarding practices and social engineering needs to be pursued to better grasp the mechanisms, resistance and challenges of sorting and caring for bio-waste.

## Notes

[1] https://www.lemonde.fr/les-decodeurs/article/2017/10/16/gaspillage-41-2-tonnes-de-nourriture-jetees-chaque-seconde-dans-le-monde_5201728_4355770.html.

[2] According to the European Directive 2008/98/EC on waste, 'bio-waste' means 'biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants'. In France, fermentable waste accounts for nearly one third of residual waste (Seroussi et al., 2018).

[3] More recently, energy production systems (biogas) have emerged. In this article, we focus on the composting sector.

[4] EU Directive 2018/851.

[5] One exception is the work of Gregson et al. (2015) on organic waste recycling streams in the United Kingdom.

[6] The urban compost from these value chains is sold locally at prices well below market value (around €3/tonne).

[7] See the 2015 Energy Transition Law for Green Growth (https://www.legifrance.gouv.fr/download/pdf?id=FMF1TotItrXlqeQwdI7cZ_aib6Ml9xQU-us85f-gyoEk=).

[8] The word 'Bioclou' comes from the colloquial term 'biclou', which means 'bicycle' in French.

[9] The bio-buckets are containers of a few litres in which food waste is stored before being transported to the collection point.

[10] Recybio is paid about €60 per tonne to remove the bio-waste and pays about €40 per tonne to the farmer-composter to take the waste on his farm (these amounts are approximate but represent accurate orders of magnitude).

[11] The compost from bio-waste is sold at about €3 to €4 per tonne.

[12] This regular and assiduous work to sort and deliver bio-waste to the collection agent at the scheduled times involves a tacit (and more or less negotiated) division of tasks within households, which would warrant more in-depth research, particularly from a gender studies perspective.

[13] The gain that Recybio derives from his activity is the difference between the service invoiced to the EMS (which here amounts to approximately €60) and his costs (service paid to the composting platform managers + overheads).

[14] Characterization can also provide an indication of the quality of the sorting carried out by the inhabitants and the support and communication work needed to improve this practice.

[15] According to the 'NF U44-051' norm, compost batches should not exceed the following percentages: 0.3% of Dry Matter (DM) for the 'Films& EPS > 5 mm', 0.8 % of DM for the 'other plastics > 5 mm', 2% of DM for the 'glass & metal > 2mm' (see AFNOR, 2006).

[16] This supports the point made by Timmerman and Epstein (2010), who argue that the multiplication of standards has not given rise to a uniform social world exclusively governed by expertise.

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## Competing Interests

The authors have no competing interests to declare.

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