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Biowaste as fluid matter: valuing biogas and biofertilisers as assets in the Finnish biogas sector

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ABSTRACT

In this article, we examine the effort of turning biowaste into an asset in the everyday practices of Finnish biogas plants. Drawing from social scientific waste studies as well as new materialist and posthumanist approaches, we approach biowaste as unruly, *fluid matter* inclined to leak and spill over and capable of affecting the possibilities of valuing it. Our analysis shows how biowaste resists the efforts to turn it into completely homogenous mass; how this mass has to be taken care of over the production process; and how it is not always clear whether the practices produce valuable assets or problematic excess. We argue that to better understand the possibilities for a transition towards a circular economy, it is important to acknowledge that the processing and valuing of waste does not offer complete control over it, but also requires careful alignment with waste material that does not always act as wished.

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Introduction

> The floor of the building used for preparing biowaste for further treatment is covered by dark brown, smelly goo – the decomposing biowaste that has spread on the floor. The biowaste has been shovelled from the storage room to the pretreatment machine called the Cow. At the moment, there is also a lot of foam on the floor overspilling from the 'kettle' used for treating sewage sludge. Amongst the goo and the foam one can spot few objects that are still recognisable as carrots, cutlery, red onion, and torn beverage packages, for example. (Field diary entry, 24 May 2021, Southern Biogas LTD)

The above entry is written on the first day of field work in a Finnish biogas plant, situated just outside a smallish, quiet town located in Southern Finland. The plant treats both biowaste (collected for example from municipalities and food industry businesses) and sewage sludge. The described scene illustrates the transformation that food once defined as worthless waste undergoes when it is transported to the biogas plant. There are items that are still identifiable as vegetables, for example, just like there are objects, such as shreds of food packaging and scratched cutlery, that should not be there in the brown lime in the first place, but most of the stuff has already started to decay and turn into smelly slurry. For the most part, the material has transformed into an anonymous, general mass that bears hardly any traces of the objects that have gone into it or reveals the connection to the practices that have produced the discards, such as disposing of leftovers in homes or spoiled products in supermarkets (Figure 1).

Simply put, biogas plants like this one treat organic waste to produce renewable energy, namely, biogas and biofertilisers, from it. For the plants, biowaste[1] amounts to a valuable resource and not simply a matter of concern. That biowaste and especially the end products of the biogas production

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Figure 1. Cutlery and fruit peels on the floor of the biowaste pretreatment hall.

process can be regarded as assets in the first place, that is, as 'something that can be owned or controlled, traded, and capitalized as a revenue stream, often involving the valuation of discounted future earnings in the present […]' (Birch and Muniesa 2020, 2), is conditioned by the adoption of the circular economy (hereafter CE) as an economic rationale and business model. As a response to the unsustainable linear economic model of take-make-use-dispose that is met with the constraints on the availability of resources, the CE aims, for example, to reduce, reuse, repair and recycle materials 'to close the loops,' recover energy from waste, and decouple economic growth from the use of virgin natural resources (see e.g. Geissdoerfer et al. 2017; Ellen MacArthur Foundation n.d.).

The somewhat technocratic CE discourse of turning waste into an asset has, however, been problematised from many angles (see e.g. Corvellec, Stowell, and Johansson 2022). For example, waste scholars have pointed out that the CE is far from being an uncomplicated technical system; it is, rather, constantly produced in concrete and mundane hands-on practices that entail leakages and disruptions (Holmberg and Ideland 2021; Lehtokunnas and Pyyhtinen 2022). In this article, we examine such practices of making circularity through turning biowaste into assets like biogas and fertilisers at Finnish biogas plants. In the endeavour, we draw from the pragmatist approach to value as valuation, according to which no object is valuable as such, but its value is enacted in practice (Dewey 1939; Greeson, Laser, and Pyyhtinen 2020; Muniesa 2012). However, instead of understanding biowaste only as a passive intermediary for creating value at the plants, in line with new materialist and posthumanist perspectives (e.g. Barad 2007; Bennett 2010) we attend to how also biowaste itself actively affects the possibilities of valuing it. To explore these issues, we ask: *through what kind of concrete, hands-on valuation practices may biowaste turn into an asset* *in everyday operations of biogas plants, and how does waste participate in or complicate these practices?*

The article contributes empirically to the field of social scientific waste studies (e.g. Douglas 1966; Thompson 1979; Hawkins 2006; Greeson, Laser and Pyyhtinen 2020; Gregson and Crang 2010; Gille 2013; Holmberg and Ideland 2021) by focusing on the making of circularity, and theoretically to the field of material studies (e.g. Stocking 1985; Appadurai 1986; Miller 1987; Graves-Brown 2000; Hetherington 2003; Miller 2005; Hicks 2010) by shifting the focus away from waste as a clear-cut object or entity to approaching it as *fluid matter*. We employ the metaphor of fluidity which we take from Marianne de Laet and Annemarie Mol (2000) to underline the relationality and processuality of waste (for other contributions addressing waste as fluid and mutable, see e.g. Alexander and Sanchez 2018; Crang et al. 2013; Lepawsky and Billah 2011; Liboiron 2016). The boundaries between valuable asset and worthless waste are not fixed, but rather transient and situational; the *whatness* of the material is dependent on its *whereness* (see also Pyyhtinen and Lehtonen 2021). Secondly, in contrast to the common object-centred or oriented tendency in material studies, by focusing on biowaste as *fluid matter* instead of *fluid object*, like de Laet and Mol (2000) do, we wish to highlight how not all that is material is imprisoned within objects.

Our research materials were generated by way of fieldwork conducted at two Finnish biogas plants: the Southern Biogas LTD and the Western Biogas LTD (both company names are pseudonyms). In addition to ethnographic observation at the two plants, 11 semi-structured interviews were conducted with experts in the biogas sector and staff members of altogether seven different Finnish biogas plants. The article is organised as follows: First, we will provide a brief description of the current state of biogas production in Finland as part of the national CE transition goals and provide justification for the selection of our sites. Then we will present the theoretical background and materials and method of our research. After this, we move on to our analysis, in which we analyse how biowaste is first turned into more or less homogenous mass; how this mass is taken care of; how the mass itself affects how it can be valued; and how the valuation of biowaste that is transformed into biogas and biofertiliser is entangled with and limited by societal and economic relations. Finally, we will present our conclusions.

Background: Finnish biogas production and the sites

The CE is high on the political agenda both in the EU and globally. Championed by such important agents as the European Commission, multinational companies, management consultancies, NGOs, and academics alike, the CE is identified as a pathway toward a more sustainable society and is expected to promote economic growth by creating new businesses and job opportunities, increasing resource productivity, and bringing net savings (EU Commission n.d.).

Finland has laid great emphasis on the transition towards a CE during the last decade (Åkerman, Humalisto, and Pitzen 2020), and one goal related to this is to develop the operational environment of Finnish biogas plants. Currently, the potential income from biogas and fertilisers is rather low in the country, and this creates insecurity and commercial viability for the business operations of Finnish biogas firms (Valve, Lazarevic, and Humalisto 2021). The potential income from these products has been low due to the low electricity prices in Finland, the costliness of infrastructure investments that would enable plants to distribute gas efficiently, and the underdeveloped markets for biofertilisers, among other things (see e.g. Winquist 2019). Currently, the business models of Finnish biogas plants are dominantly, but not exclusively, based on the so-called gate fee, which means that the businesses are dependent on the processing fee they charge their customers for the waste management services that the companies provide them (see also Åkerman, Humalisto, and Pitzen 2020; Valve, Lazarevic, and Humalisto 2021).

In Finland, all recycled biowaste is either composted or treated at biogas plants. At biogas plants, the biomasses are handled through a treatment process called anaerobic digestion in which microbes break down organic material, releasing biogas from it as a result. The digestate that comes out from the biogas reactor when microbes have broken down the biowaste can be used as a fertiliser as such or reprocessed for a certain use. Currently, there are approximately 80 biogas plants that treat different biomasses (such as biowaste, manure and sewage sludge) operating in Finland (Suomen biokierto ja biokaasu ry n.d.). Some of these plants are owned for example by animal farms that produce biogas from manure, and others by municipalities or private or state owned companies.

The two biogas plants where the fieldwork was conducted were selected as sites of this research, because both of them treated biowaste collected from various sources: households, retail stores, and food industry businesses. By this we wanted to get at how the waste valuation practices at the plants are connected to waste generation at multiple sites along the food chain. It was also useful to conduct the research at plants that differed in their size, location, modes of distributing the end products, and to some extent also values. Southern Biogas LTD was larger both in terms of their production volume and the number of employees. The most crucial difference as to their modes of distributing the biogas was that Southern Biogas LTD produced biogas for traffic use, while Western Biogas LTD did not sell biogas for traffic use at all at the time when the fieldwork took place. Otherwise, the modes of distributing gas were rather similar: the gas that was generated was used to produce heat and electricity.

Theoretical framework

The making of circular economy and fluid matter

The idea of the CE, as Gregson et al. (2015) note, is 'more often celebrated than critically interrogated'; the use of the concept 'in both practitioner and academic literatures tends to be approbatory, uncritical, descriptive and deeply normative.' It is, however, important to subject the CE to critique, given its prominence in academic, practitioner, and policy spheres and discourses. Scholars have stressed that while there is a strong political will to make waste circular, accomplishing it in practice is often far from being simple (Gregson et al. 2015; Corvellec 2016; Corvellec, Stowell, and Johansson 2022). Researchers have also undermined the idea of a perfect circle (Žižek 2010; Skene 2017; Valenzuela and Böhm 2017) and pointed out that CE policies focus mainly on technical solutions and industrial systems; the socio-cultural change that the CE requires in the everyday practices has received less attention (Hobson 2016). Recently there has been a rise in studies problematising the possibilities of creating circular practices at the level of everyday life (Hobson 2016; Holmberg and Ideland 2021). The research done on mundane practices of making circularity has, however, mostly (but not exclusively) focused on consumer practices; other parts of the consumption-production system have not received equal attention.

In this article, we approach the CE in pragmatic terms, by paying attention to how it is enacted and made to be in everyday practices at the biogas plants. The practical enactment of the CE is also nicely addressed by the concept of 'make-up work' coined by Holmberg and Ideland (2021), with which they illustrate how CE policy is performed in practice, and how the practices of turning waste into resource through, for example sorting and cleaning, also generate new waste. For Holmberg and Ideland, the concept of make-up work exemplifies how the interruptions and leaks were handled along the waste treatment process in the Swedish biogas plants that they studied (Holmberg and Ideland 2021). Somewhat similarly, in our analysis, we are interested in how the circularity of biowaste is made in concrete, hands-on practices performed by experts. However, we also go beyond this view by highlighting how accomplishing circularity is not up to people and their practices alone. Waste itself plays a part in how it can be manipulated and what it can be turned into. In doing this, we explore the desired and undesired changes that the materials fed into the process go through, and how these changes complicate the possibilities of working with them and valuing them.

To inquire into the vague boundaries between value and waste, we highlight the *fluidity* of biowaste. In their well-known analysis of a Zimbabwe Bush Pump, Marianne de Laet and Annemarie Mol (2000) examine the pump as a 'fluid object,' by which they mean that it is not 'well-bounded but entangled,' it 'doesn't impose itself but tries to serve,' and it is 'adaptable, flexible and responsive' (227, 226). Like de Laet and Mol, with the metaphor of fluidity we wish to emphasise the vagueness of boundaries and the relationality and processuality of waste. In the processing of biowaste, the boundaries between valuable asset and worthless waste are not fixed, but vague, transient, and context-dependent (see also Greeson, Laser, and Pyyhtinen 2000; Lehtonen and Pyyhtinen 2020).

However, to us, biowaste also exemplifies other characteristics of fluidity not embodied by the Bush Pump. First of all, as our analysis will show, while to some extent also being flexible, mutable, modifiable, and responsive, biowaste also presents a form of *unruly* matter that undermines and easily escapes human control (see also Reno 2015; Doeland 2019). It is not merely a manageable object, but it spills over, leaks, expands, spreads, smells, decomposes, decays, and tarnishes, and thereby also invites us to venture beyond the good and wanted agency of matter. Secondly, we examine biowaste as fluid *matter* (instead of as a fluid object) to suggest a reorientation in the approach to materiality. Not all that is material resides in objects (see also Pyyhtinen 2015). Even in the cases when matter assumes an object form, it goes through constant movement, variation, and renewal. The seemingly im/passive and fixed solid object closed in upon itself only momentarily imprisons the material flows within its organised form, only to disintegrate later and join new assemblages; objects are already crystallised out from the flows of materials and their transformations (Ingold 2011, 2013). In the process of its rendering into an asset, biowaste is at once *more-than-object* and *less-than-object* (cf. Pyyhtinen 2015). It is 'more' in the sense that it is not a clear-cut, well-bounded, and isolated object but entangled both in its nature and performance: it is connected, for example, to contracts between the biogas plants and their customers, to the prevailing waste management infrastructure, to political decisions, and to the economic, technical, and social context of society at large. This latter aspect is also highlighted by de Laet and Mol's analysis of the Bush Pump. However, while the Bush Pump is also a solid object, biowaste is not; it is 'less' than an object insofar as it is rendered anonymous mass at the plants. This means that its characteristics as a clear-cut object are stripped away and it is turned into a general, unidentifiable mass.

Valuing waste as an asset

Currently, the valuation of biowaste in biogas plants significantly involves the 'valuation of discounted future earnings in the present' (Birch and Muniesa 2020, 2). As we mentioned above, biogas and fertilisers that the plants produce do not generate enough revenue in the present, and thus Finnish plants are dependent on the gate fees that they collect. It is however hoped that selling these products may create a revenue in the future. Here, value and the valuing of biowaste result from the process of *assetization* (Birch 2017), that is, from turning things into assets. An asset is not simply a commodity that can be sold, but it is rather an object that creates an income stream. Kean Birch (2017, 468) illustrates this by taking music copyright as an example: while a particular saleable item, such as a CD or an LP, is a commodity, music copyright is not a commodity but an asset that creates a continuous revenue stream to its owner. Closer to the subject at hand, carbon credits and the related certifications can be seen as assets, since they are not simply commodities produced for sale (Birch, Ward, and Tretter 2022).

In the same way, making power purchase agreements or other kinds of contracts with customers creates a revenue stream for energy producers, such as biogas plants. What is more, activities such as financial support granted by the state (for innovating new technology to create novel uses for biogas and fertilisers, as well as different certificates that verify that the energy is produced from renewable resources) are essentially entangled with the assetisation process of biowaste – only agents fulfilling certain criteria are given access to these benefits that contribute to the valuation of the end products. Thus, products created from biowaste entail specific modes of ownership and control as well as technoscientific expectations that are related to their qualities as renewable material and energy (Birch and Muniesa 2020).

In examining the assetisation of biowaste, we follow the movements of value orchestrated in the everyday practices of the biogas plants. We do not treat value as something that would lie inherently in biowaste and the products produced from it. The materials are made valuable in practice, for example in the hands-on processing of biowaste at the plants, and when biogas producers try to tinker the production process to create new markets and uses for biogas and fertilisers. Theoretically, we draw here from the pragmatist approach to value as valuation (e.g. Dewey 1939; Muniesa 2012; Birch 2017; Greeson, Laser, and Pyyhtinen 2020; Lehtokunnas and Pyyhtinen 2022; Lehtonen and Pyyhtinen 2020). However, in the everyday operations of the biogas plants, it is not always perfectly clear whether the practices produce waste or value. Thus, we also aim to show that the perfect management of biowaste or its value is not possible: practices that create value always also produce waste (Greeson, Laser, and Pyyhtinen 2020; Lehtonen and Pyyhtinen 2020). What is more, managing and valuing waste is not only a result of human mastery over matter, but it involves working with and joining forces with materials and non-human entities which actively participate in the treatment processes at the plant, which may sometimes have unexpected consequences.

Therefore, we hold that when analysing the valuation of biowaste as an asset, it is important to pay attention to the activity and dynamism of waste matter. While waste scholars have taken an interest in materiality (Moore 2012), more often than not they have tended to portray discarded objects as more or less passive and inert, just waiting to be endowed with meaning and handled by humans. In contrast to this socio-constructionist approach (most famously Douglas 1966; Thompson 1979), and inspired by new materialist and posthumanist perspectives (e.g. Barad 2007; Bennett 2010; Coole and Frost 2010; Braidotti 2019), some of the more recent inquiries within the field of waste studies have turned the focus on the effects of waste matter itself (e.g. Hawkins 2006, 2009; Gabrys 2009; Gregson and Crang 2010; Hird 2012; Gille 2013; Van Bemmel and Parizeau 2020). Gay Hawkins (2006, 4–5), for example, has stressed the affective capabilities of waste matter, suggesting that

> to reduce waste to an effect of human action and classification is to ignore the materiality of waste, its role in making us act; the ways in which waste is both a provocation to action and itself a result of that action.

Along similar lines, we examine biowaste materials as in themselves active and effective, able to '*have a say* in what they become' (Hawkins 2013, 56), and how biowaste becomes effective in its relations to humans and non-human others. For example, the microbes in the biogas reactors as well as the functioning of the technology and the infrastructure affect in a very concrete way how everyday operations can be organised at the plants and how and what kind of waste it is possible to circulate and value.

Materials and method

The materials of the article consist of three weeks (75 h) of participant observation and 11 semi-structured interviews conducted by the first author. The materials were collected during Spring and Autumn 2021. The ethnography was conducted at two biogas plants, Southern Biogas LTD and Western Biogas LTD located in Finland. During the observation periods, the ethnographer spent 5 h per day at the plant and observed daily tasks, such as cleaning, sample taking, and maintenance work. Occasionally she herself also took part in some simple work tasks. Short jottings were written during the days at the plants, and more detailed field diary entries (79 pages in total) were written at the temporary accommodation after each day in the field. All the employees that participated in the research signed a research agreement.

In the ethnographic observation, we were not so much interested, for example, in the biogas plant as an organisation or in the social relations between the staff members as in the routinised, everyday practices that contribute to the operation of the plant and to the valuing of biowaste. During the observation period, the ethnographer became familiar with the biogas production process on a mundane level and got to know the everyday routines. Ethnographic interviews were conducted alongside observing the operations.

To top up the ethnographic observations and the interviews conducted *in situ*, a number of additional interviews (11 in total) were conducted with staff members of seven Finnish biogas plants that process biowaste, and with two experts working in the field. Most of the participants worked as managers or experts, but some of them also participated in practical work tasks at the plants, such as maintenance. Each interview lasted approximately for one hour. With the interviews, we were especially interested in finding out more about the conditions that make the operation of biogas plants possible in the Finnish context, and about potential disruptions in their operations: for example, how the steady flow of feedstock is secured, what are the possibilities of building new infrastructures, and how the end products are moved forward.

The analysis of the data (both the interviews and the field diary) was conducted through thematic coding. The analysis is mainly built on the observations in the field; the interviews were used to connect these observations to a bigger picture of the Finnish biogas sector. First, the key themes that recurred in the data were identified through a systematic reading of the data and then highlighted. The themes of assetisation and valuation guided the reading of the data. The next step consisted of encoding the key themes by using the Atlas.ti software. After this, based on the ethnographic fieldwork, the researchers divided the different phases of the production process of the plants in three simplified clusters: firstly, getting waste in and pretreating it; secondly, monitoring and taking care of the process; and, thirdly, selling the end products. In the analysis, the production process is described on a fairly general level. A fine-grain description would compromise our attempt at theorising fluid matter and contributing to discussions on materiality; the unavoidable price of generating theoretical abstraction is the loss of nuance (see Healy 2017).

Analysis

Sorting and anonymising incoming biowaste

In the first section of the analysis, we focus on the efforts of biogas plants when they process the incoming waste. The biogas plants (as well as many other CE businesses) are able to operate and receive waste thanks to certain waste governance practices that oblige households and businesses to recycle their waste. When biowaste is entangled with certain waste governance practices and contracts that are crucial for the CE, it is enacted as more-than-object.

While the circular practices of households and businesses condition the operations of biogas plants by feeding them with incoming waste, the connectedness of the waste to consumption and production practices is effaced during the production of biogas and biofertilisers. This was discernible in most concrete terms at the plants: before waste was fed to the reactors where microbes start breaking it down, it was crushed, sorted, and rendered into an anonymous, indistinct mass.

The ethnographer got to observe how the production process started with moving biowaste from the storage space into the pretreatment machinery that crushes the waste and tears off the plastic and metal packaging from it. At Southern Biogas LTD, there was a large hall for storing incoming biowaste, and the waste was piled on the floor of this hall. At Western Biogas LTD, by contrast, the waste transport companies dumped the incoming waste into a ‘pool’ that was cast into the floor of the waste reception hall. Usually during the shifts, there was one employee responsible for running the pretreatment process. At Southern Biogas LTD, the employee responsible for the process fed the feedstock to the pretreatment machinery by using a tractor. At Western Biogas LTD, the feeding was carried out by using a remote-controlled hoisting machine. While doing this, the worker responsible for the task also monitored the process by checking the surveillance cameras and listening and observing the machinery to ensure that things ran smoothly.

The pretreatment and sorting of biowaste imposes several requirements on the machinery of a plant, since a large quantity of the biowaste arriving at the plants is originally packed in plastic packages or metal cans. The plant has to remove unwanted contaminants from the incoming biowaste, and sorting practices are key to accomplishing this. Households often pack their biowaste into biodegradable plastic bags, and even though these bags are specifically designed for recycling biowaste, they are not perfectly suitable for the processing of the incoming waste at biogas plants. Moreover, the biowaste collected from retail stores and food industry businesses often arrives at the plants still packed in its original wrapping, and also other contaminants, such as sand, may end up among the waste. All these objects have to be mechanically removed from the waste and the mass needs to be crushed before the waste materials can move further along the process. The machinery contained for example a 'screw' which was used in this make-up work of mechanically extracting plastic and metal from the biowaste mass to which they did not belong (Figure 2). Here, the solid biowaste packed in plastic or metal is not yet valuable for the plant as such, but it has to be made valuable through concrete practices of sorting, separating, and crushing. The biowaste is rendered less-than-object in a very concrete process of transformation: once contaminants like cutlery, plastic packaging, and sand have been removed, biodegradable items like carrots, onions, meat, bread, and fruit are turned into browish, smelly mass by the pretreatment machinery. The indistinct, homogeneous mass that results from the process no longer bears any resemblance to the objects that have gone into it.

Figure 2. A worn 'screw' used in biowaste pretreatment machinery to separate plastic and metal from biowaste.

While being essential to the assetisation of biowaste, the aforementioned practices of sorting, separating, and crushing nevertheless seldom succeed in completely mastering the composition of biowaste (see also Gregson and Crang 2019), and thus the biowaste also resists its valuation practices. Even if the plants constantly aim to optimise the operation of their plastic, sand, and metal separation machinery, such contaminants as small pieces of plastic may nonetheless remain in the slurry, creating potential blockages in the pipes and occasionally even causing the mechanical parts of the plant machinery to break down. Over time, contaminants such as plastic or sand also inevitably gather inside the reactors:

> A plant worker shows me the inside of a sludge tank that is under construction and says that once one of the reactors was almost full of sand. It had taken them weeks to restart the process even after the reactor had been emptied. Emptying a reactor is expensive, because the production process is brought to a halt and they need to order specific machines capable of completing the task. (Western Biogas LTD, 3 June 2021)

Objects and materials, such as sand and plastic, that do not belong to biowaste thus disturb the production process and generate extra costs. What is more, the plastic wrappings and packages that are separated from biowaste during the pretreatment process usually cannot be recycled, mainly because some of the packages may also contain other materials in addition to plastic, and the mechanical separation process also severely damages them. Because of the poor quality of the items, the recycling plants do not accept them for recycling purposes, and for that reason the plastic waste separated from the biowaste needs to be incinerated. At Western biogas LTD, transporting plastic waste elsewhere to be incinerated caused considerable expense since the plant was located far from the nearest incineration plant. Thus, at the biogas plants the handy packaging that on the shelf of a retail store once protected food from spoiling or made it convenient for consumers to take their waste to the recycling bin turns into inconvenient excess. The fluidity and heterogeneity of biowaste becomes apparent in situations where valuable biowaste contains a lot of material that is, in the end, not valuable for the biogas plants but rather disturbing and a cause of economic loss, and thus biowaste resists its turning into homogenous material that would be easily processable and become a source of value.

Caring for the reactors and slurry

Once biowaste has gone through the pretreatment process, it has been turned into more or less homogeneous slurry. At both of the plants studied, this slurry was then fed first into large containers located outside the main building where biowaste reception and pretreatment are housed and, from there, to the reactors. Optimising the gas production in the reactors as well as the composition of the fertilisers produced from the digestate required taking care of both the reactors and the indistinct, less-than-object mass that biowaste had become during the pretreatment process. This care implied 'collaborative and continuing attempts to attune knowledge and technologies' (Mol 2008, i) to keeping the process alive, smooth, and as efficient as possible. To optimise the conditions for the biogas production in the reactors and thus render biowaste into an asset, it was important to, for example, take special care of the temperature of the slurry that was fed into the reactors. The slurry needed to be warm enough, approximately 35–40 degrees, to create optimal conditions for the microbes. Thus, the process required constant monitoring, and materials that should not be mixed must be kept separate. Here, the practices focused, again, on keeping the mass fluid yet under control.

While biowaste is fluid matter, and the production of biogas at the plants blurs and even undoes rigid boundaries between value and problematic excess, it is not completely devoid of boundaries. On the contrary, the practices of dealing with the stuff also establish and try to maintain clear boundaries as to which materials should or should not be mixed together. The two plants where the ethnographic fieldwork took place treated both biowaste and sewage sludge. It was important for the plants to keep these raw materials separate, since farmers as customers are often unwilling to accept fertilisers which include human-based material. (Some foodstuff companies may refuse to buy cereals from farmers if they have used such fertilisers in the cultivation.) The sewage sludge and biowaste-based feedstock were kept apart throughout the whole production process: there were, for example, two entirely separate reception areas for the streams of these two materials, and the plants also had separate biogas reactors for them. Especially at Southern Biogas LTD, the workers expressed their frustration over the limitations preventing these two streams of raw materials from mixing with each other:

> After lunch, I discussed my research and the utilisation of biowaste in biogas production with the plant manager and a plant worker. The plant worker said that biowaste is a good material, but it doesn't produce enough methane. He said that it would be best for the biogas production if they could add some shit from the sewage sludge to the biowaste that they use. However, the problem with this is that it is difficult to get rid of fertiliser that contains human-based material. (Field diary entry, Southern Biogas LTD, 26 May 2021)

The plant has to ensure their ability to get rid of the digestate to secure the continuation of the production process, even if this may lead to producing less methane and thus compromising value creation. The more methane the biogas contains, the more energy there is in it. However, because of the limitations related to sewage sludge based fertilisers, the potential gain that could result from mixing these two materials cannot be actualised. Here, separating biowaste-based slurry from sewage sludge acts as a technique of making difference (Law and Mol 2008) and thereby also enables the plant to keep biowaste as homogenous as possible. Through creating boundaries, the practice aims to make sure that the fluid biowaste would not slip from valuable matter to problematic excess.

In addition to the fact that the plants need to pay special attention to avoid mixing biowaste with sewage sludge, the process itself requires close monitoring. To ensure the steady operation of the reactors, the temperature of the slurry, the formation of foam in the reactors and the pH value of the slurry need to be carefully monitored. This monitoring is carried out, among other things, through taking samples and following different factors in reactors by using sensors. The workers emphasised that it is important to monitor the process for several reasons: for example, if some specific substance disrupts the chemical balance of the feed, this may cause foaming in the reactors. The foam may go to the pipe through which the gas is transported along the process, in the worst case breaking machinery. At both plants, there were several computer screens in the control room that displayed in real time how different parts of the process were running. The screens displayed templates about the process as a whole (e.g. reactors, tanks), and for example the level of foam in the reactors as well as the temperatures were expressed in numbers. However, at the Western Biogas LTD the level of the foam was also checked every day by looking inside the reactors through small windows placed on the upper part of the reactors. The employees carefully followed the functioning of the machinery and the smoothness of the process on their shifts, and the intensity of the feeding was adjusted based on this information. However, not even the closest monitoring can ever give the plants complete mastery over the process, because the slurry, the reactors, and the machinery can act in unexpected ways:

> The plant worker told me a story about how one time just before the end of his night shift one of the reactors had started to uncontrollably effervesce. He and his colleague ran downstairs to shut down the feeding, but some foam still ended up on the floor from one of the pipes. They washed the floor and thought that the situation was over, but then his colleague started to hear a buzzing sound from the pipe. The worker told me that the buzz tends to signal that there is once again some foam from the reactors in the pipe and, when this happens, the reactor vomits, as it were: just like people throw up if they eat something unsuitable, the reactor will start to uncontrollably foam if something causes imbalance in the process (Southern Biogas LTD, 25 May 2021)

In the situation described in the fieldnote, waste acted as unruly matter that foamed and spilled over in uncontrollable ways, ultimately making the reactor 'vomit' its contents. Feeding biowaste too intensively or feeding the wrong kind of biowaste to the reactor can result in foaming or have other kinds of unwanted consequences. For example, during the fieldwork at Southern Biogas LTD, the gas production in one of the reactors was almost completely down (the reactor was 'dead,' as the maintenance workers expressed it), partly resulting from testing a new batch of waste in the process. Thus, the production process cannot be intensified arbitrarily, nor is all available biowaste suitable for processing. Finding out whether a particular batch of waste is suitable for the plant is a precarious process, since there is not always enough information available on how some substances may affect the production process. Thus, separating the valuable batches of waste from the valueless ones has to be carried out through joining forces with the machinery and the waste materials. Taking care of the process does not entail perfect control but involves sustained and careful tinkering with the machinery and the flows of materials (see also Heuts and Mol 2013, 125) and, again, creating boundaries between 'good' and 'bad' waste streams.

Selling the end-products and dealing with the overflows

After the microbes had broken down the slurry, and gas production in the reactors had reached its end, the digestate was run through pipes from the reactors to sanitation containers. In these containers, the temperature of the digestate was raised to 70 degrees Celsius to kill hazardous bacteria, enabling the safe use of the digestate as a fertiliser. After the sanitation process, fertilisers were then moved to storage pools (liquid fertiliser) or halls (dried fertiliser). The gas was stored, depending on the facilities of the plant, in separate gas storage or at the upper parts of the reactors. From this storage, the gas was moved forward to customers or to the different processes of the plant in which the gas is utilised to produce heat and electricity.

During the production process, biowaste undergoes a transformation from waste matter to assets: biogas and fertilisers. Turning these end-products into monetarily valuable assets proves, however, rather difficult. The difficulties are not only related to the fluidity of the matter itself and the machinery of the plant, but has also to do with underdeveloped markets, low electricity prices, and the costliness of investments. Based on our data, the difficulties of selling and distributing biogas do not result from the lack of demand for biogas. Rather, one of the main issues currently is that selling the energy does not create enough cashflow to justify costly infrastructure investments that more efficient gas distribution would often require. The CEO of Southern Biogas LTD highlighted that the investments to machinery and infrastructure are often really expensive relative to the turnover of the plants, and many other research participants pointed out the same issue. In addition to the problems caused by the costliness of investments to new infrastructures, the following example from Southern Biogas LTD further illustrates the mundane practical obstacles that biogas plants face when they try to distribute the gas:

> When we were about to start the bigger motor that converts gas to electricity, I asked the maintenance worker whether the plant also has another, similar motor, since I had seen a motor like this one earlier today in another part of the plant. He answered that the motor I saw is smaller than this one, and it is currently broken. He also said that it would cost something like 20,000 euros to fix it, and this is why it is currently under consideration whether it will be reasonable to fix it or not. The maintenance worker told that the smaller motor would be better than the bigger one that is still working, since it consumes less gas and thus it could be kept running almost all the time, even if the gas storage would not be completely full. The bigger motor can be started and kept running only if there is enough gas in the storage, and the prevailing demand for electricity also has to be taken into consideration when starting it. (Southern Biogas LTD, 27 May 2021)

The employees, plant managers, and CEOs have to take several factors into account when they consider whether it is reasonable and cost-effective to, for example, fix or start a motor or not, and thereby they also come to value biogas differently depending on the situation. Sometimes it was more reasonable to even get rid of some of the gas than start the motor. Torching was also used in cases when the gas storage was too full. As having an overfull storage could lead to environmentally hazardous methane leaking out, occasionally the plants burn excess gas in a torch. In situations like these, biogas becomes nothing but an excess that needs to be got rid of, and the valuation practices themselves end up producing new kinds of waste (see also Holmberg and Ideland 2021; Greeson, Laser, and Pyyhtinen 2020) that has to be dealt with.

When discussing the use of biogas, the research participants often referred to a specific policy issue: the current aim for the electrification of passenger car traffic in the EU and Finland disrupts the assetisation of traffic biogas, and car manufacturers have cut the production of biogas cars. However, they also often mentioned that legislative action in Finland obliging transport fuel distributors to annually distribute a certain amount of fuels produced from renewable raw materials, is a good thing for traffic biogas producers. This illustrates the nature of biowaste-based biogas as an asset that is more-than-object: its assetisation is thoroughly entangled with national and EU energy policies.

If it is not easy and straightforward to make a profit from biogas, it is no less difficult to generate value out of the biofertiliser produced from the digestate. According to our participants, currently there is demand for the fertilisers in agriculture and gardening, but the problem is that farmers, as one the largest group of potential users and purchasers, are often unwilling to pay for the fertiliser. According to our informants, one reason for this is that the farmers may already have manure in their disposal that they can spread to the fields without any additional costs. They may also for example consider the use of fertilisers made from non-renewable resources more convenient and easy. Thus, in the current situation, the fertilisers were sometimes considered as a troublesome material that the plants just need to somehow move forward:

> I went to talk to the CEO of the plant and asked him whether he considers the production of fertilisers or gas as more important for their business. He said that the fertiliser is a 'necessary evil' for them and they just try to somehow dispose of it. He said that at times it is hard to get rid of the fertilisers, and it is also difficult to obtain money from them. He said that they get some money from the organic fertiliser, but the other fertilisers they have to give away for free (Western Biogas LTD 4 June 2021)

While possible excess biogas can be burned in a torch and thus ridded quite effortlessly if needed, fertilisers need to be stored, and the storage spaces, of course, are not infinite. To prevent the fertilisers from piling up and filling up storage space, the plants have to find ways to set the matter in motion: in some cases, they give it away for free, and occasionally they even pay for the freighting. Even though biogas producers often stress the ecological value of the fertiliser that they produce (it could substitute currently used fertilisers made from non-renewable raw materials), here the valuation of the fertiliser nevertheless means that the plant tries to get rid of it in the least costly way (see also Valve, Lazarevic, and Humalisto 2021). Thus, on the one hand, in turning biowaste into biogas and especially into biofertiliser, the production of biogas does not currently succeed in transforming that matter into a valuable asset, but its unruliness and excessness remain a constant matter of concern in the process. The wasteness of the material does not wear off just like that.

Yet, on the other hand, the excess still 'contains rich potential for reinterpretation and reuse' (Edensor 2005, 311), and several problems that Finnish biogas producers currently face are probably not permanent. In fact, many informants had faith in the prospect that selling the energy would generate profit in the future, one way or another. However, while the term 'reinterpretation' easily renders the materials themselves as passive and inert, biofertiliser or biogas do not just passively wait out there to be utilised. As we have shown in our analysis, they are made to be and manipulated in concrete practices, and they also themselves delimit and shape these practices. What is more, as more-than-objects, they have a capacity to provoke action (see also Hawkins 2006), such as the current aim in the biogas sector to promote policy programmes to support the assetisation of fertilisers and biogas shows.

Conclusion

In this article we have analysed, through an ethnography of the everyday operations of Finnish biogas plants, the practices of turning biowaste into an asset, and how waste itself affects the possibilities of valuing it. Following the leaky practices in which value and waste are produced at the biogas plants comprises the main empirical contribution of the article. Based on our research, the question as to whether biowaste can be successfully translated into an asset in the context of the CE cannot be answered by a simple yes or no. Instead, our analysis has shown that there are several grades and shades of successful (and less successful) action and management of waste (see also de Laet and Mol 2000).

Our analysis suggests that, in contrast to the system-level CE discourse that cherishes the idea of all-out elimination of waste through turning it into a resource, it is important to acknowledge how the valorisation of waste cannot be carried out simply by means of more efficient mastery of waste matter. Making waste circulate requires concrete hands-on work that does not guarantee perfect control over waste matter but entails careful alignment with materials that do not always act as wished. The research examining such hands-on work has so far mainly (but not exclusively, see e.g. Holmberg and Ideland 2021) focused on how consumers, for example, save food from ending up as waste (Lehtokunnas et al. 2022; Mattila et al. 2019). By contrast, one of the aims of this article has been to examine how the CE is enacted on the production side in concrete and messy everyday practices. Integrating these two into one holistic view remains a task for future research.

Our emphasis on the fluidity of biowaste and the products produced from it – biogas and biofertilisers – does not merely insist on leakages, spills, and interruptions as integral to the normal operations of the biogas plants that we studied. The point that waste management is not perfectly circular, and accomplishing circularity requires concrete 'make-up' work, has already been made by previous research (Holmberg and Ideland 2021). By approaching biowaste as *fluid matter*, we wish to contribute to the reorientation in waste studies (and material studies alike) from clear-cut objects to approaching waste as fluid, mutable, and flowing (see also Alexander and Sanchez 2018; Crang et al. 2013; Lepawsky and Billah 2011; Liboiron 2016). As long as the focus is on crystallised objects, it is difficult if not altogether impossible to grasp the constitution of material things and follow the changes that materials go through.

At the biogas plants that we studied, the processuality and fluidity of biowaste was manifest throughout the entire process. Before the biowaste was fed into the reactors, it first had to be pretreated and turned into an anonymous, less-than-object mass. Interestingly, though, the plants seldom succeeded in completely mastering the composition of the mass, because contaminants such as small pieces of plastic and sand easily remained in the slurry. In order to optimise gas production inside the reactors as well as the composition of fertilisers, the waste matter and the technology had to be taken care of through monitoring and balancing the volatile process. During the production process of biogas, biowaste itself as well as the microbes in the reactors strongly affected the ways in which waste could be valued, since a wrong kind of attunement with them could have caused foaming or even completely killed the process.

What is more, while biowaste itself lacked clear boundaries due to its fluidity, it was nonetheless essential for the plants to establish several boundaries in order to be able to value it successfully. For example, sewage sludge had to be kept apart from biowaste-based slurry, and the plants needed to separate problematic batches of waste from the valuable ones. Finally, when the microbes in the reactors had chewed up the waste, biowaste was turned into new assets: biogas and fertiliser. However, as our analysis showed, the boundaries between valuable assets and problematic excess are not fixed, but themselves rather fluid. Ultimately, in the operations of the biogas plants, fluidity thus not only had to do with the qualities of biowaste itself as it is transformed into a slurry in and through the treatment process, but it also extended to the ambiguous, precarious, and shifting line between waste and value/price (as the products of digestion may not always create a revenue stream or reach the market to be sold). For example, on some occasions the fertilisers turned out to be problematic excess that the plants just had to get rid of, and the problems with the distribution of gas sometimes forced the plants to burn excess gas in a torch. However, this is not to say that the plants could not succeed in creating monetary value out of their end products in the future. The current energy crisis in Europe resulting from the Russian invasion of Ukraine has already changed the situation of the Finnish biogas sector. For example, according to the Finnish Biocycle and Biogas Association (Virolainen-Hynnä 25 Aug 2022), interest in both biogas and biofertilisers has grown after the prices of natural gas and mineral fertilisers have gone up. In this sense, the value of biowaste, biogas, and fertilisers is not only fluid but also 'virtual' (Deleuze 1966, 1968; Lehtonen and Pyyhtinen 2020) – it may actualise in some other situation, through different processes in social and economic organisation.

For us, the fact that the workers at the biogas plants tinkered with an array of precarious, vague materials instead of solid objects also meant that their practices enacted biowaste at once both as less-than-object and more-than-object. It was enacted as 'less' in the sense that its nature as a clear-cut object was stripped off, and it was transformed into an anonymous, homogenous mass to enable its valuation. At the same time, valuing biowaste as an asset also called for producing and manipulating it as more-than-object by creating new relational entanglements for it. Generating value at the plants entailed practices of assembling, that is, classifying, grouping, sorting, and creating new relations. In result, biowaste became part of another regime of value and novel configurations, which involved contracts and also simultaneous coordination between several different sectors, such as the energy industry, waste management infrastructure, and agriculture. At the same time, the integration of biowaste into this value regime also required that it was *disassembled* from its previous connections to the processes of consumption and production that had produced it (Greeson, Laser, and Pyyhtinen 2020). As a whole, by breaking things open and by showing the complex societal, technological, and economic relations that different materials are entangled with, we believe that this kind of approach, which emphasises the fluidity and volatility of matter and the relational settings of which it is part, can also help scholars tap into the vulnerabilities, complexities, and sustainability challenges of not only waste management and food systems but all attempts at establishing order.

Notes

1. With biowaste we mean biodegradable food and kitchen waste. This may include food waste, inedible parts of food (e.g. peels and bones), and side streams from the food industry.

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