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Sorting, Shredding and Smelting Scrap: The Production of Value by Deformation at a High-tech Recycler of Electronic Waste

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Abstract

The global economy of e-waste recycling has received much attention in recent waste studies literature. This article gives an account from the inside of two different sites within a leading high-tech recycling and smelting company in which such e-waste is assessed; and discusses the valuation of electronic waste in the course of its industrial processing. Based on a two-month long ethnography by way of an internship, the article examines how the recycler manages to distinguish and separate out valuable 'scrap', in contrast to valueless 'waste'. The article subdivides the inquiry into two questions. What practices are involved when transforming e-waste into scrap and waste? And how can we appreciate differences in how they are configured? The study of two different facilities in operation next to one another provides additional leverage to the inquiry since the valuation practices involved when assessing the incoming e-waste differ between them. Differences are tied to specificities in how the electronics are sorted out, shredded, and smelted. The article shows how these processes of deformation are linked to the valuation practices and the accounting system of the company. Calculations, it is argued, succeed only because things are literally broken.

Keywords: electronic waste; high-tech recycling; ethnography; accounting; economic value; materials

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Introduction

E-waste, short for electronic waste, is a staple feature of today's global economy. It is the material flip side of the seemingly immaterial IT industries (Gabrys 2011). In 2018, roughly 50 million metric tonnes of computers, smartphones, and printers, as well as plenty of chips were disposed of worldwide (Baldé et al. 2015: 20), and such discarded electronics can be full of hazardous ingredients. At the same time, however, various actors are interested in mining this waste stream, because it includes a high amount of precious materials such as gold, copper, or cobalt as well as lots of sellable aluminium and plastic. During the recent two decades, large-scale high-tech recyclers have emerged that specialized in this type of waste. Vast smelters have been processing e-waste since it was first thrown away about half a century ago. However, before this waste stream grew significantly (because of various fresh digital devices) and new legal frameworks were established (that set up an infrastructure of recycling) (Knapp 2016), it was mostly the so-called 'informal sector' in the Global South that appreciated these materials. This transformation of the global economy of e-waste has already been identified as a significant field of study with various 'hot' controversies (Neyland and Simakova 2012; Pickren 2014; Kama 2015; Kirby and Lora-Wainwright 2015; Bozkurt and Stowell 2016; Laser and Stowell 2020; Lepawsky 2018; Schulz 2019). But the rather new and now powerful high-tech recyclers are still under-studied sites.

In this article I discuss the valuation of e-waste in the course of the industrial processing of this waste. The smelting, often overlooked, is pivotal for the capacity to identify and transform materials and is thus tied both to the valuation and actual processing of the e-waste. Its specific role needs to be examined. Previous research on high tech recycling, moreover, has largely relied on expert interviews and tours of recycling centres offered by companies. Such forms of access can provide and have provided interesting insights, but they cannot provide detailed enough encounters with the valuation and transformation practices in these facilities. Outsiders to a recycling company are not usually allowed to come close to energy-intensive practices (for security reasons and sometimes also for data protection reasons). Recycling centre tours, moreover, can be considered the 'front stage' in Goffman's (1978) sense; they enact a distinct reality (Zapata and Zapata Campos 2018).[1] I went on to study a high-tech recycler from the inside precisely to be able to examine the practices of valuation and transformation up close.

[1] In the field of Industrial Ecology the situation is different (e.g. Manhart 2011), but there the discussion is very 'technical', that is, focused on evaluating machine set-ups or management schemes. Adam Minter's journalistic account *Junkyard Planet* (2013) does a nice job in bridging the debates.

This article presents an analysis of valuation practices based on an ethnographic inquiry of a high-tech recycling company. Employed as an intern for two months, I studied the operations of a global market leader of e-waste recycling in the Ruhr Valley in western Germany. The recycler firm claims to recycle properly and efficiently, and emphasizes that this is the source of its market leadership. The public relations department of this recycler, to give just one example, likes to showcase that almost 500 tonnes of e-waste are processed per day. Recycling is not a trivial task and one has to look beyond those numbers and popular stories though; the company invests heavily in the transformation of materials and has developed various skills to handle their supplies. Their main objective, I learned, is to separate valuable 'scrap' from worthless 'waste'. This distinction between scrap and waste is a key differentiation used by my informants. In this article I will use these terms accordingly, while reserving the notion of 'e-waste' for the unsettled middle ground. E-waste, then, denotes materials with a fate still unknown and where actors grapple with the uncertainties of what the materials are and what they can become.

This article focuses on the following questions: What practices are involved when transforming e-waste into scrap and waste? How can we appreciate differences in how they are configured? I use the notion of *deformation* to signify this transformative process. Deformation has the connotation of a transformation that brings something out of its usual shape, which here is the original shape of e-waste as printers, monitors, computers, and so on. The term emphasizes that forming also necessitates de-forming. The article specifically examines how valuation of scrap occurs around three interlinked material processes of deformation: sorting, shredding, and smelting. In what follows, I bring related discussions organized around waste studies and valuation studies further together by framing the issue of scrap production as a topic of accounting. The sorting, assessing, and processing of e-waste, I argue, is intertwined with the creation of economic value, so that the company tries to gain a surplus with each contract that is concluded (Vatin 2013). This has not been appreciated enough in previous research on high-tech e-waste recycling. The aim with this study is not to assess the quality of the practices, but rather to highlight the practices employed to value e-waste as integral to the industrial processing of such waste. I will follow the material practices, and think with material practices.

The article is divided into three major sections. The first section gives a brief overview of the recent history of the investments the studied recycler has made, while zooming in on their in-house value chain. Against this backdrop, I clarify my methodological tools while adjusting to the particular situations of the field site. A key methodological aspect of this study arose from the fact that the studied company has two distinctly different facilities in operation next to one another, and they each value incoming e-waste in their own distinct ways. This means that similar deliveries of e-waste are assessed and invoiced differently depending within which of the two facilities the work is done. In the subsequent section, I introduce an ethnographic account of these two preparation facilities. Here, I will also deploy the notion of 'deformation'. In the final section, I will discuss the contribution of my ethnographic analysis to previous e-waste studies in particular and waste scholarship in general as well as the field of valuation studies. New insights into the core practices of doing calculations will be provided.

Background to the study and focus of the analysis

Fieldwork at two adjacent sites

I began my fieldwork at the beginning of November 2015 as part of my now concluded PhD research.[2] My ethnography is based on an internship, which translated into two major tasks. I worked with the engineers and workers on the ground to keep the daily workflow going, and I had to produce reports that were checked. My work was paid based on a minimal wage, and I was transparent about my research interest. I had, as part of the internship, to sign a non-disclosure agreement regarding certain sensitive information. Yet, this agreement did not inhibit me from doing fieldwork observations. My fieldwork was making observations, internalizing practices, keeping a diary, creating notes, collecting documents, taking pictures, playing with memos, and drawing connections with my other studies. As a general rule of thumb, I tried not to disturb my interactions with my colleagues when keeping track of things, which meant that I had to draft urgent notes during the lunch break or when I was waiting for somebody (a regular thing to do at this company would be waiting for a call to clean *this* or transport *that* or repair *this* over *there*—being in transition was a normal practice for the other workers as well). I further refrained from tape-recording so as not to disturb interactions. As a result, my notes were written immediately after my shifts.

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[2] In my thesis, I focused on the global enactment of high-tech recycling infrastructures; I followed transformations of waste economies and conflicts over values that ignite during these transformations. I began with a study of e-waste in India, where a new law was passed (and discussed intensively) to support high-tech recycling operations (instead of 'informal sector' work) (Laser 2016). In India, I merely managed to interview these recycling facilities. However, in Germany I gained access to one major recycler. A private reference from an executive was helpful, so that I could directly pitch my interest to the department of human resources without having to explain myself to the critical public relations department (in India, this department was sceptical of my interest).

The weather was sunny during the November mornings when I started my first shifts. After entering through the gates I was greeted by heaps of materials lying around (Fig. 1). What can be seen here are industrial materials, I learned. Copper, above all. The leading engineers also call it ‘classic’ scrap, as in their main source of revenue since this site’s establishment. For more than 100 years, the company has been recycling metals from such materials. When first introduced to this notion, I learned how eager the company is to talk about ‘scrap’ (valuable entities) instead of ‘waste’ (valueless). This is the key notion to be explored. With this the recycler also wants to stress their facilities strive towards ‘zero waste’ where everything is transformed into something to be reused. But I am sceptical since there still is waste: hazardous materials in need of containment, materials that are burned and thus removed, various tiny excess materials that stick to certain surfaces. That is why I will keep using both notions, scrap and waste, plus ‘e-waste’ for materials which are still not transformed and where there is substantial uncertainty.

Figure 1 Classic scrap

Notes: In front, there is classic scrap (lots of copper). A water cannon keeps the materials soaked to tame the dust, hence the mist. The smelting facilities (see below) are in the background. The smelter on the very left, here in front of the pillar and under the small red alarm light, is about 65 metres high.

Source: Photo by the author.

Before I introduce a few conceptual tools for studying the valuation practices at hand, it makes sense to unravel the in-house workflow of the recycling plant. Looking at this helps elucidate why, in the first instance, valuation practices are central to the realm of handling e-waste.

The workflow I present is necessarily simplified to a depiction of a linear flow. The geographers and waste scholars Lepawsky and Mather (2011: 243) correctly suggest that value chain analyses and flow charts often deploy a limited notion of linearity, whereby stuff is considered moving 'up' and 'down' or 'forward' or 'backward', 'implying vertically and/or horizontally arranged beginnings and endings'. Think of products having a life or (as is the case in this situation) discarded electronics being prepared to become raw commodities. In their ethnographic research on e-waste in Canada and Bangladesh, Lepawsky and Mather contend, it made no sense to arbitrarily describe a certain transformation as a beginning or an end of some process that was yet to be realized. They found rather messy value transformations everywhere. Lepawsky and Mather (2011) then propose thinking in terms of (shifting) boundaries and edges—a thought-provoking concept that makes use of notions of science and technology studies (STS) and actor-network theory (ANT). It does, however, make sense here to adhere to a linear structure as a heuristic start: It is through such a linear scheme that interns and visitors are guided through this plant. The staged linearity is a common strategy in the world of recycling technologies for presenting a neat workflow. In other words, the clear step by step sequential process is a way to present the soundness of operations. These depictions therefore help bring the economic facets into being. While there might be boundaries and edges, the actors *stress* that they are grappling with beginnings and endings. It is a performance with consequences.

This is what the recycler's workflow looks like (Fig. 2). The company (1) has *preparation facilities* where materials are prepared for smelting, *smelting operations* where materials are purified, and a *refining factory* where standardized raw commodities are produced. All of these are furthermore accompanied by multiple vast storage and decontamination facilities. To clarify the key processes in the words of the engineers involved: preparation implies shredding materials so that discrete material streams are collected; and smelting and refining are (mostly) pyrometallurgical processes in which unwrought metals are manufactured. Moreover, a lot of activities take place before this recycler gets its supply. Electronic gadgets are produced and used, e-waste is collected, specific materials are stripped off by third parties, and so on. But I will not elaborate what happens before the activities at the preparation facilities. What is relevant for this study is that the company receives its materials from municipal, national, and industrial suppliers. And I'm interested in how the value of these suppliers' deliveries is assessed. As elaborated below with more detail, this will result in a focus only on the first stage of the workflow, the preparation facilities. Before doing that, it makes sense to follow the historical trajectory of this workflow. The entire in-house e-waste recycling process is a rather new operation.

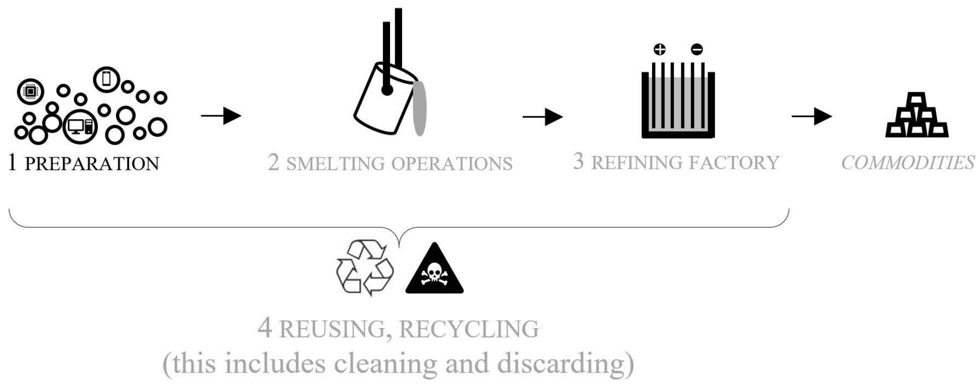

Figure 2 Workflow and in-house value chain of the recycler
Notes: The numbers describe separate facilities on the premises, and the greyscales of the text indicate the focus of the present article: the preparation facilities.
Source: Illustration by the author.

Up until the late 1990s, the recycler only processed 'classic' copper materials. Then, however, management decided to invest in what they call 'complex' or 'modern' scrap: discarded electronics. Engineers proudly told me they were among the first 'global players' to focus on e-waste end-processing in a large and integrated fashion. The statement seems exaggerated, but there is some truth to it. From the 1950s onwards, at least in the global north, electronics began spreading (when households started using kitchen appliances and 'bulk consumers' invested in computers, to name just two iconic developments [Gabrys 2011; Knapp 2016]). These products were thrown away—and recyclers indeed started processing them. Already during the 1980s and 1990s, moreover, e-waste had been identified by pioneers of recycling technologies as an interesting field to experiment with (Sinha-Khetriwal et al. 2005). The scope of these early operations, however, was deemed limited. *Only* when the consumption of electronic devices grew exponentially *and* when e-waste regulations were established during the 1990s, with (for instance) the European legal infrastructure of 'WEEE' and 'RoHS'[3] on the verge to being finalized (Cooper 2000), large mining and refining companies like the recycler discussed here felt confident enough to invest millions of dollars in new technologies. E-waste requires special treatment because of embedded materials such as plastic (which creates additional heat) and because of the new environmental regulations; which is why this was initially a tricky decision, even though an essential one against the backdrop of growing global competition in the sector of mining (Knapp 2016: 1886).

The company studied opened two new facilities in 2005 and 2006 respectively for preparing e-waste deliveries. These two facilities were both integrated into the existing plant. The first facility, which from now on I will denote the *separation site*, processes roughly 400 tonnes of e-waste per day with shredding and automatic separation, and then sends parts of the output to the smelters while other parts (such as plastics) are moved on to be sold to third parties. In the second facility, which I will denote the *sampling site*, e-waste deliveries are assessed by sampling, and it manages about 80 tonnes of materials per day. In my fieldwork, I decided to focus on these e-waste facilities, the *separation site* and the *sampling site*. As a consequence, I worked in the smelting facilities for one day only and just had a quick glimpse of the refineries. Against this backdrop I can now flesh out the concrete focus of my study.

The recycler receives its materials from several sources. The economic value of each delivery is assessed at either of the two preparation facilities. It is here where contracts are successfully completed even though the negotiation precedes these facilities (see below in the next section on the preparation facilities). A key methodological move I now perform is to frame e-waste processing as an issue of accounting. Given that the two sites operate differently, this means that I can examine two different 'moments of valuations', each stabilized by a particular accounting apparatus (Hutter and Stark 2015; Mennicken and Power 2015).

The handling of waste as interlinked with accounting and deformation practices

How do I define accounting, and what will I be focusing on when studying accounting practices as valuation practices? I understand accounting as a two-fold task. The *Oxford English Dictionary* captures this quite nicely. Accounting, it emphasizes, may be understood as 'keeping and verifying financial accounts' on the one hand and 'giving of a satisfactory explanation' on the other. I take

[3] The 'Waste Electrical and Electronic Equipment Directive' (WEEE) and the 'Restriction of Hazardous Substances Directive' (RoHS) are the two instruments with which the EU manages e-waste. Member states must comply with these standards by setting up their own legal recycling infrastructures.

these two kinds of practices as inextricably intertwined. Accounting implies making a judgement, and making calculations are part of this endeavour. From a sociological point of view, such a general understanding of accounting is paramount. The focus should lie on practical issues, as summarized by Hendrik Vollmer (2003: 355) in his seminal review article: 'A sociological exploration of calculative practice [...] should [...] locate notions of accounting, such as those of financial value, calculability or efficiency within the empirical field and treat them as issues, not as resources, for sociological research.'

The issue I am interested in is the separation of valuable scrap from waste. Accounting then means assessing what materials a delivery consists of, and to put a number used in further calculations. Materials are classified (Bowker and Star 2000) and then evaluated with a particular focus on the prices on commodity markets. The supplier of the e-waste is then paid based on the economic value that was established for the delivery. And, importantly, a supplier should not be paid too much, since that would result in an overall loss. It is this calculation that the preparation facilities produce.

Crucially, however, accounting here does not mean that the recycler 'finds' or 'discovers' numbers or fixed relations that are just waiting to be revealed. I draw on Michel Callon's economic sociology to, first, clarify some common misunderstandings about accounting and, second, further sharpen my focus. In the *Laws of the Markets* (Callon 1998: 23), he emphasizes that concrete socio-material practices make a difference: 'The most interesting element is to be found in the relationship between what is to be measured and the tools used to measure it. The latter do not merely record a reality independent of themselves; they contribute powerfully to shaping, simply by measuring it, the reality that they measure.' To put a value on scrap then implies enacting the categories of scrap and waste.

In addition to Callon's performative approach, I moreover frame the accounting endeavour as a pragmatic process in which an apparatus of accounting is stabilized by 'moments of valuation'. This term, introduced by Hutter and Stark (2015), has further been identified by Mennicken and Power (2015) as a fruitful way to approach valuation practices inherent in accounting apparatus. Hutter and Stark (2015: 4) suggest using the notion of 'moments' to emphasize that valuations are spatially and temporally marked. They occur in specific places, and they have a recognizable beginning and end. I use their term as a heuristic to focus on the pragmatic aspects of the valuation process at hand. Hutter and Stark reflect John Dewey's (1939) classic suggestion to focus on value as a verb, to understand values as practical achievements that require hard work. In Mennicken and Power's (2015) research, this is also captured by the notion of 'apparatus'—as the alignment and cooperation of multiple actors with particular skills and passions.

The handling of e-waste is more, however, than accounting practices involving moments of valuation. The e-waste that turns up at the gate of a recycling plant is not only enriched and transformed by numbers. It is equally subject to material transformations. The notion of deformation will be used here to denote how e-waste materials have *become resources*, while something is done to them in a very material way. I take a cue from Nicky Gregson and Mike Crang (2010) who suggest we should focus on processes of becoming and 'unbecoming' in the study of waste. Gregson and Crang argue that waste (inorganic waste in particular) is not something out there which is lying at a certain place, disturbing someone, waiting to be managed; 'waste is a long way from stuff that "just is", but rather that it becomes' (Gregson and Crang 2010: 1028).

The focus proposed by Gregson and Crang helps me situate the handling of e-waste in a broader process of world making. Crucially, they further link waste with processes of *unbecoming*, and this term provides a key background to the notion of deformation. While reflecting on shipwrecking (see also Gregson et al. 2010a), Gregson and Crang highlight that the physical work of demolishing ships is an activity in which things 'are literally unbecoming, reverting to materials as the object materializes' (Gregson and Crang 2010: 1030). The notion of unbecoming clarifies what happens to material arrangements that are broken up and reworked. Most importantly, it is shown that things do not just disappear, whatever is done to them. In yet another study, now on the thorny materials of asbestos, Gregson et al. 2010b: 1067) emphasize this foundational argument: 'It is about material possibilities as well as limits. For, to disappear would be to contradict a fundamental part of the second law of thermodynamics: that material, matter, cannot be got rid of or destroyed, but rather can only transform, mutate, morph.' This calls for a different way of thinking about wasting at the agency level. The authors continue: 'Material might become something else through various treatment technologies; it might morph to conjoin with other materials; or it might stay in the same material state, but what it does not do is disappear.'

Materials, in short, are transformed based on concrete events and practices. As a result, the technologies to treat e-waste should best be understood as transformative technologies, and not as 'disposal technologies' (Gregson and Crang 2010: 1029). The notion of deformation then highlights the particular processes involved when materials are unbecoming. Practices of deformation are of prime importance to the processing of scrap. Based on this I can now return to the empirical details. In these, I need to pay particular attention to how the deformation of e-waste is linked to an accounting apparatus.

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In this section I have given an overview of the empirical field under study as well as provided some conceptual bearings for how to study the processing of e-waste, and in particular the role of valuation practices in these processes. I do agree, as previously mentioned, with Lepawsky and Mather's (2011) general insight that there are no clear beginnings and endings to a value transformation. At the same time, though, it is clear how the facilities, with their configured valuation and deformation practices, enforce the idea of clear beginnings and endings. This then again fits well with Lepawsky and Mather's (2013) more general, performative approach to reality. At the recycling facility, the enforcement of beginnings and endings starts when a contract is set up and ends when a contract is validated. Hence the accounting practices linked to the contracting are further entwined with and demarcate the deformation practices.

So how is valuable scrap produced in moments of valuation and practices of deformation at the two different facilities? What are the tools, skills, and energies used to assess the economic value of a delivery of e-waste? The main problem the two preparation facilities have to grapple with is that the materials need to be broken up and reassembled to be assessed. The uncertainty of 'e-waste' stems from the fact of its diffuse material composition, on which I will now focus. This, furthermore, allows inquiry into how practices of valuation might be differently intertwined with practices of deformation in the two sites examined.

Sorting, shredding, and smelting scrap: The production of value by deformation

Attuning to the first preparation facility and its contracts: the separation site

As explained above, there are two preparation facilities at this recycling plant. I will first discuss the *separation site*. This facility for preparing e-waste consists of roughly two-thirds outdoor space and one-third factory hall. The former is a junkyard-like area where materials are stored whereas the latter is where a shredder and sorting machines are located, all of which is being supervised by a control centre inside the factory hall.

The outdoor area of the separation site is captivating. Journalists, taking waste tours through the separation site, like to focus on the huge piles of e-waste to tell dramatic tales about humans' craving for new electronics. The company, in turn, is keen on talking about the enormous investments they had to make to master the materials. They emphasize, for instance, that a 'one-of-a-kind shredder' had to be built.

But there is more to this than anthropocentric narratives on over-consumption or technological ingenuity respectively. Sticking to the issue of accounting helps me stay focused. As emphasized earlier, crucial parts of accounting apparatus are contracts, which offer a good starting point.

The suppliers of materials to the separation site sign a contract before making deliveries. The agreement is a promise to be fulfilled with a clear temporal marker. In business terms the accounting logic of this first facility is called 'tel-quel' also known as 'bought as seen'. Tel-quel is a rather plainly structured contract that can be split into two major work steps: buying and accepting. First, thus, the purchasing department of the recycling company examines the e-waste the supplier is offering. They need to decide whether the materials are worth buying. This happens before delivery, outside the recycling plant. If the recycler is interested in the materials, a contract is set up in which both parties agree on the scrap to be delivered and its potential value.

Different kinds of scrap indicate different costs. On the one hand, this is a matter of market prices where gold, for instance, is sold at higher prices than copper. On the other hand, different kinds of materials require specific treatments by the company's machinery. The recycler invoices this treatment to cover the abrasion of its machines separately and depending on what machines are to be used. Accordingly, these particular costs are booked under the heading 'treatment charges'. I will return to this notion in a little more detail below (subsection on feeding the accounting apparatus with information); it becomes of relevance at a particular stage of the practical negotiations.

Yet, all these values and costs are tentative at this point. When the materials are delivered to the plant, they are examined for a second time. The e-waste has to be 'accepted'. This is where the contract is actually concluded, while the proper valuation of the materials is of particular interest to the recycler.

On the visual assessment of e-waste deliveries at the separation site

I will now analyse a situation that is key for the conclusion of the tel-quel contract. This will also bring the investigation closer to the practical issue of enacting valuable scrap. In a lucky moment during one of my work shifts, I managed to take a snapshot of this particular situation (Fig. 3). The photo differs from common depictions of the industry, and it will assist me in making my argument. I use a black and white rendering of the snapshot and a grid reference to stress the analytic angle.

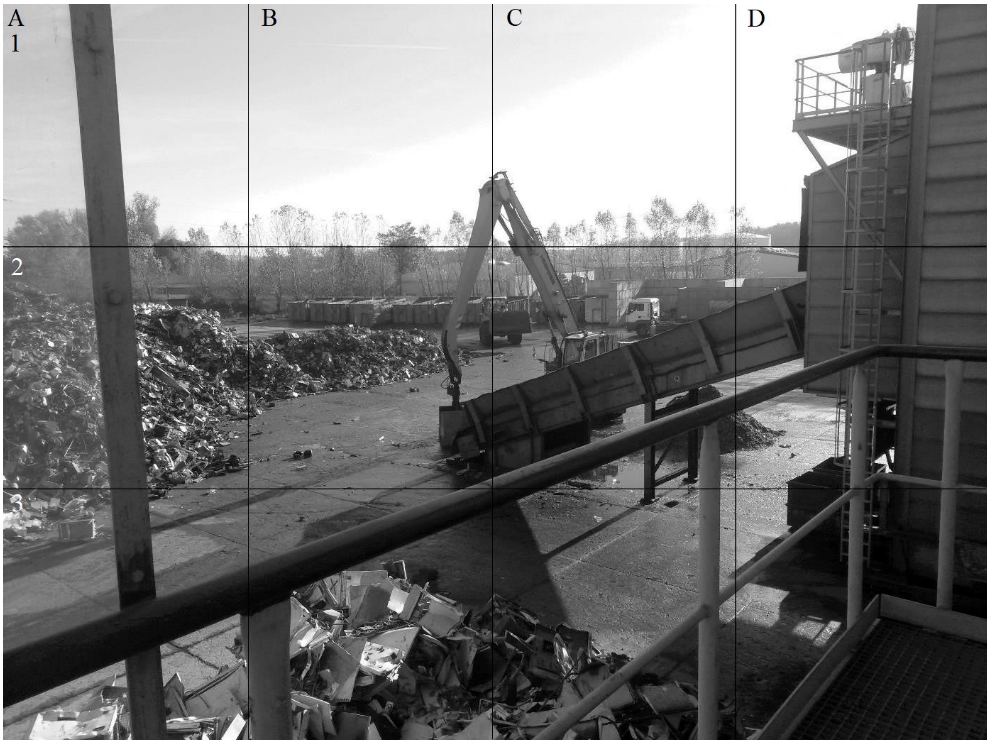

Figure 3 Outdoor space of the 'separation site'
Source: Photo by the author, grid reference added digitally.

Moments of valuation (Hutter and Stark 2015) also denote situations of uncertainty, when something unknown calls for attention precisely because of its being unknown. The idea then is to observe the actors in their very own inquiries. In this particular situation, unravelling the moment of valuation emphasizes practices of deformation. This calls for seeing some things and 'un-seeing' others, however, to appreciate the relevant actions. I will start with the description of a selection of empirical details to then specify the notion of deformation.

Note that right at the centre of this picture there is a heap of materials that is spread out to the right (quadrant B2). The rest of the e-waste, left of it (A2), is about twice as high. This is no random negligence. The entire outside area is divided into segments; it is strictly organized and work is routinized, which is similar to industrial landfills (Reno 2009). What is going on with this heap of e-waste?

When the separation site receives a new delivery of materials, a certain routine is performed. First, trucks and their materials are weighed, where the deliveries also obtain an individual ID-number that is saved in the intranet, both of which happens at the entry gate of the recycling plant. Next, the trucks enter this preparation facility from behind (on the back of the excavator on the right [Fig. 3, quadrant D2]), in order to drop off the materials next to the existing heap of discarded electronics. Above, there is a truck that just delivered its e-waste (C2). In such situations, a truck driver is usually waiting for further instructions from an employee of the facility who oversees new deliveries (this is the only thing that this snapshot does not capture, because the person had already left the area when I took the picture). This employee is in charge of assessing incoming deliveries; he is also the foreman of this facility and oversees security instructions and some other key tasks. He (there are only men working here![4]) plays a crucial part. During my internship, I followed and helped this person (on and off) for about two weeks. It is useful to pay some extra attention to experiences stemming from that period.

The foreman is informed via walkie-talkie when a new truck delivery for this facility arrives and registers at the entry gate. For him (and me, as I am following him doing this), the arrival means quickly grabbing our helmets and going downstairs to the designated drop-off area. Truck drivers and this recycling employee—let's call him Mario—know where to meet. Mario greets the driver and pinpoints the place where the materials should be dropped (Fig. 3, quadrant B2).

When a truck presses out its materials—trucks and containers are equipped with devices that actively push—Mario becomes alert and aware. The pressing-out is a process that takes about two minutes. Printers are squashed, ink is bursting out, computers break, small pieces of metal start falling and rolling—and Mario sees, hears, smells, and senses what is falling out. Here the diffuse mix of e-waste is being de-formed. Because of the way in which the materials move away from each other, or are being squeezed together, it will be possible to *distinguish* different materials. The distinguishing that Mario does here, however, is not *yet* about collecting and transporting actual material streams. This is what the shredder in concert with a complex separation system does, and I will come back to this below. Mario instead is doing essential preparation work that helps to 'find' valuable scrap.

Linking deformations to practices of classification

Mario carries a notebook in which he records information about the incoming e-waste. The notebook helps stabilize the organizational account; the materials dropped can thus be classified and processed in the accounting apparatus. Drawing on Bowker and Star (2000: 10) I take classification to be 'a spatial, temporal, or spatio-temporal segmentation of the world'. This definition of classification is helpful here since it emphasizes the pragmatic and context dependent aspects of any classification.

4 Among the 500–700 workers on the ground (the subcontracted workers are hard to count), just a few are women. In the facilities I've worked at, there were no women at all working on the ground. Other facilities had some diversity because of apprentices. Two general exceptions need to be emphasized. (1) In the middle and higher management (white collar in general), more women are working. (2) As is the case with other waste-related workplaces (Campkin and Cox 2007), there is a clear gender division. Even inside this recycling plant, it appears, the infamous private/public gender divide is reproduced. As a rule of thumb, the safe and rather neat offices are cleaned by women. Every place that is full of dust, debris, and danger—because of the presence of heavy machines—however, is taken care of by men. This might explain, for example, why men clean the shredders.

In his notebook, Mario carries a list that differentiates between, and thus classifies, eleven kinds of scrap, a ranking developed over time and regularly updated within the facility. The routines described here are in constant flux. When the truck driver finishes emptying the container, Mario further investigates the heap of e-waste while keeping his notebook and the ranking with him. He goes around the e-waste and looks for evidence. Sometimes he steps into the heap to pick up and manipulate certain items or to uncover buried stuff; if the pushing out of the materials produced ambiguous signs, Mario has to perform some further material deformation and check again what lies in front of him. It can be as simple as kicking some things around. In his notebook, he then writes down what he takes the delivery to consist of. The notebook is a matter of distancing himself from the heap of e-waste, while the notes demonstrate a proximity to the materials. Totals of '50% e-mix', '30% printers', '20% hard drives,' for instance, is what Mario's notes look like. These are, in fact, the most common classifications he makes use of (although I cannot inform you about the exact composition or make-up of these categories). In short, Mario aims to do two things: identify scrap categories and estimate the volume that each scrap category represents of the whole. The allocation and counting of the materials are used to adapt the separation machines (some sorting technologies may not be needed for less complex e-waste deliveries), but as I will show further below, this is also crucial for the accounting system to be able to allocate value.

The truck driver curiously observes the entire situation within walking distance until Mario finishes his investigation and stops scribbling. The assessment comes to an end when Mario puts a plastic clip with the delivery's ID on the heap of materials (Fig. 4). Mario needs these little helpers to take informative pictures in order to preserve his observations in digital format. I have seen such clips in different places at the plant; they also appear in other pictures below. They play an important role. Later, if there are inquiries by the purchasing department because of revisions or complaints, the ID makes it possible to unambiguously assign a photo to a delivery as it was documented in the intranet. After taking the pictures, Mario goes to the truck driver and gives him permission to leave. This formally concludes the transfer, but not the moment of valuation. Still, when there are no security issues (e.g. hazardous materials) or gross mistakes (very misleading information from the supplier), the materials are ready for shredding and further processing, as indicated above. And this is what happens in the vast majority of cases. Mario thus calls for a wheel loader, which pushes the materials into the rest of the e-waste heap (look closely at Fig. 3, quadrant B2/C2). From now on, it will be quite difficult to reassess the composition, except based on the photos. The newly delivered materials are mixed with other e-waste deliveries.

Figure 4: ID-card
Source: Photo by the author.

Because of the visual assessment, the foreman is able to validate or challenge the numbers originally defined in the tel-quel contract. To achieve his goal, however, Mario has to make use of further devices of the accounting apparatus.

Mario continues working with the notebook when we re-enter the control room. Here, he sits down at his desk and opens an Excel file to calculate the worth of the delivery, which can also be retrieved directly by the purchasing department by way of the intranet. Mario is doing some simple maths to process his notes. Based on the automatically saved accounting data, he can receive information about the weight of the truck at the time of entrance and of exit (via the intranet), which allows him to calculate the weight of the delivery. He finally calculates the value of the delivery by consulting his list of classifications. But there is plenty of work to be done to enable Mario to perform this calculation in the first place.

I use the notion of deformation not only to emphasize particular material transformations that occur during the processing of the incoming e-waste; but also to tie this notion directly to processes of accounting, where calculation practices are key.

Deformations are linked to classification practices. What information, however, is inscribed into these classifications? The accounting apparatus (which Mario is a part of) consists of several additional devices. One must go beyond the immediate situations to understand the links. By following these devices, in fact, one can find more (preceding) deformation practices that were necessary to make classification possible.

Feeding the accounting apparatus with information

One key valuation of the facility I call *the separation site* takes place before high-tech machinery is used to systematically rework the e-waste. This is what the introduction of Mario's routines above emphasized. Nonetheless, the materials are still processed, and the knowledge produced during this processing informs the accounting apparatus, and it also informs Mario. It is a kind of circular process. Previous experiences shape how new deliveries are handled. What machines are used, and what is their relation to the contracts this facility concludes? How is the accounting apparatus fed with information?

In the picture in Fig. 3, there is an excavator with a rather large arm. When I took this picture, the designated worker of this machine had just taken a break, but usually he uses this tool to put e-waste onto a conveyor belt (quadrant C2-D2, hidden behind the protective wall). The belt leads to the powerful shredder that shatters e-waste materials and then feeds a complex system of conveyor belts, sorting machines, and, finally, containers. All of this is located *inside* the facility, protected by a roof and noise-cancelling doors.

In the containers separate fractions of scrap are collected. 'Fraction' is an industry term describing distinct material streams. The term helps the actors to draw boundaries between flows. Each fraction usually consists of similar materials, but the selections are not yet pure enough to be reprocessed. The boundaries between flows are not necessarily very stable. Here the engineers and workers, however, begin to refer to valuable *scrap*, because some of the materials are ready to be sold while others may be sent to the in-house smelting facilities.

Multiple fractions are collected in the separation facility. There are plastics and aluminium; both look like dust and are sold to third parties. Dust in fact appears to be the ideal form in which to offer materials to external partners (and it is a great metaphor for rethinking the electronics industry; see also Gabrys 2011: 138). Imagine finely shredded piles of material, which are difficult to keep apart, yet suitable for further processing without having to shred again. Then the following logic applies: the more separation, with as little contamination as possible, the more value a fraction has (Gregson et al. 2015: 229). But there is also a fraction of 'mixed metals' which is full of leftovers from printed circuit boards—brass, copper, and more—which will be sent to the vast smelting system. This is in-house processing. Finally, a filter system collects the emissions from the shredding process in a separate container. This is a different type of fraction; it can be considered the waste that is sorted out, because it is a hazardous remainder. Note, however, that this waste element may also be reprocessed so that some valuables are recovered. I can only suggest ways in which these waste materials are treated, because I have not worked in the extra filtering facilities of this recycling plant. At the end of this process, this information is centralized, and a selected heap of dust is thrown back into the shredder of the separation site, so that the sorting machinery might pick up some more valuable pieces. Not everything can be recovered though. Instead of following these small (though fascinating) fractions I will keep my focus on the establishment of the contract.

*

Here is a clue illuminating how the contracting system at the separation site is calibrated. The preparation facility constantly keeps track of the materials it is processing. Mario and the entire accounting department use that knowledge to guide their calculations. The tracking is performed in two different ways, although both ways emphasize the internal links of the preparation facilities.

One way has to do with the containers in which the fractions of 'scrap' (or 'waste' respectively) are collected. These containers at the end of the separation machines have to be emptied quite often, when they are filled to capacity. To empty the containers the contents are dropped in designated boxes somewhere on the plant's premises, for instance in a storage hall that collects and sorts materials for the smelting facility.[5] But the separation site is not merely sending its materials away so that they may simply be processed. It wants to track its output. Each time a container is emptied somewhere, a random sample is taken and collected in a separate, rather tiny box. At the end of every month, these particular boxes are sent for assessment to the sampling site next door.

The second way to track the materials only applies to highly specific deliveries, e.g. when a supplier delivers tons of only one type of electronic device, which is so far unknown to the recycler but comes in large quantities at a time. For example, it may happen that a supplier sends a container full of specific devices no longer intended for sale or a load of faulty products. The recycler issues a 'certificate of destruction', which is of particular value in these situations and where suppliers seek data protection (for more on this performance of

[5] This is where the complex internal network of the entire plant comes to light. There are materials going to the smelters, some will be sent to recycling machines and their filters, and others might simply be dropped in boxes on the separation site, as indicated in the text. Look for example at the background in Fig. 3. However, this article is not the place for discussion of all these links and the workers who take over the transitional tasks.

destruction: Herod et al. 2013). In the case of such homogeneous but so far unknown deliveries, the entire shredding and sorting machinery of the separation site is emptied and *only* this delivery is put through the system at the separation site. Similar to the first tracking approach, the resulting output is sent to the sampling facility that inquires as to its exact composition. The difference is that in this case colleagues receive the entire output, not merely a random selection.

Based on the tracking system and the numbers provided by the sampling facility, Mario and the accounting staff can finally perform their calculations. I am not in possession of the accounting algorithms that this company uses or has tried out in the past, but I accompanied Mario while he was doing the basic calculations. And he was in fact eager to explain what is at stake, thus emphasizing the key relationships. Later on, managers validated these basics based on my reports.

The attribution of value, at this stage of the workflow, follows clear guidelines. By way of testing the exact material composition the company now declares what categories were processed with what kinds of precious materials. Then, the value of a delivery is first of all linked to market prices. Each gram processed translates into commodity values, as in: this was a delivery with x% of gold, which was worth \$$y$ at the agreed date in the financial markets, add to this the other precious materials and their values, which in the end mean that the delivery was worth \$$z$. But it does not stop with this simple maths. The calculation that is sought after and agreed upon in the contract is also influenced by the costs of machine abrasion. The heavier are the materials that pass through the system (e.g. metals, instead of plastics), the more the system gets strained, which is measured by standardized costs. Here the company seeks for compensation. This type of cost was introduced above as 'treatment charges', which turns out to be a key yet complex feature of recycling reality.[6] The engineers need to register unusual strain, but neither do they want to charge unrealistic rates, because that could damage the trust of the business relationship. Against this background it becomes clear how important it is to know what kind of material flows through the system. Mario's expert knowledge and the valuation that he performs are crucial for a successful purchase and the adequate adjustment of future contracts.

As indicated with the tracking system, this first separation facility cannot directly assess the materials in detailed fashion. It needs help

[6] More research is required, however, to fully capture the nature and dynamics of treatment charges. The general structure of these charges is shaped by industry-wide negotiations that take place every year, the so-called benchmarks. Focusing on the flexibility of certain companies and their contracts sounds like a promising site for further investigation, while being party to the actual discussions at the negotiation table would for sure provide vital insights.

and therefore cooperates with its neighbouring facility, the e-waste sampling site, which makes a precise calculation possible. But this facility needs help too. I will now shift to this site, which lies directly next door on the same premises. There are links between the operations, yet the two facilities also handle e-waste differently—a different instance of valuation comes into focus.

Turning to the sampling site and its different mode for making contracts

It is now time to turn attention to the other facility studied: *the sampling site*. At the sampling site, there is also an accounting system around e-waste. Besides that, there are suppliers who deliver discarded electronics in need of assessment. Yet, when I moved from the first preparation facility to the second, I was intrigued by the differences. At the sampling site, the e-waste appeared more homogenous than it was at the separation site. I was, for instance, confronted with shipments consisting of only discarded laptops *or* shipments solely made up of printed circuit boards. In fact, there were different kinds of deliveries of different printed circuit board qualities. Heaps of 'dust', in some cases. I remembered that such deliveries were rather rare next door. The machines used and the people working here also differed from those working at the separation site. Different topics of conversation, different break routines, even different smoking habits (like classic cigarette smoking in one facility vs e-cigarette vaping in the other). What is most important, however, is that the sampling site used a different system for agreeing contracts with suppliers. This was somewhat surprising; the uncertainty of electronic waste leads to a strange but (in the end) useful flexibility in the preparation of this type of waste.

The tel-quel contract used at the separation site enables the quick processing of large volumes of materials. (Remember, the separation site handled up to 400 tonnes per day.) The quick and dirty approach of the separation site, however, might be considered problematic for more valuable materials. When faced with precious materials, a minimal difference in the material composition translates into a *significant* adjustment of the economic value of the delivery. The decimal places become of crucial importance. But, interestingly, this is not necessarily the key aspect at this site. The decision where to conclude a contract (in the separation site or the sample site) is also a matter of individual preference. Some business partners just *prefer* to deliver their waste to the sampling site rather than to the separation site, simply because they want to be compensated based on more precise valuations, and they don't mind that the assessment at the sampling site takes more time, which indeed is a key difference.

At the sampling site the processing of e-waste is based on a certain temporalization. The moment of valuation lasts longer. The sampling site wants to determine the precise material composition of a delivery, which justifies much slower processing in more complicated apparatus. For the production of valuable scrap (and partly also to assist the separation site, as shown), a precise assessment is important. So how does this facility process e-waste to produce valuable scrap? Similar to the first facility, a contract is set up before any e-waste is delivered. In this case, however, the delivery is not pre-assessed. The materials need to be brought to this facility for a thorough valuation. This is about zooming in and mobilizing material properties.

Delivering and documenting e-waste deliveries at the sampling site

When a supplier's container arrives at this facility, a worker checks whether the rough attribution made at the entry gate was correct. This process is similar to what is done at the separation facility. Releasing and documenting newly arrived e-waste is also a recurring theme (Fig. 5). Although these particular actions again *appear* similar to what is done at the first facility, this is where things are in fact starting to work differently.

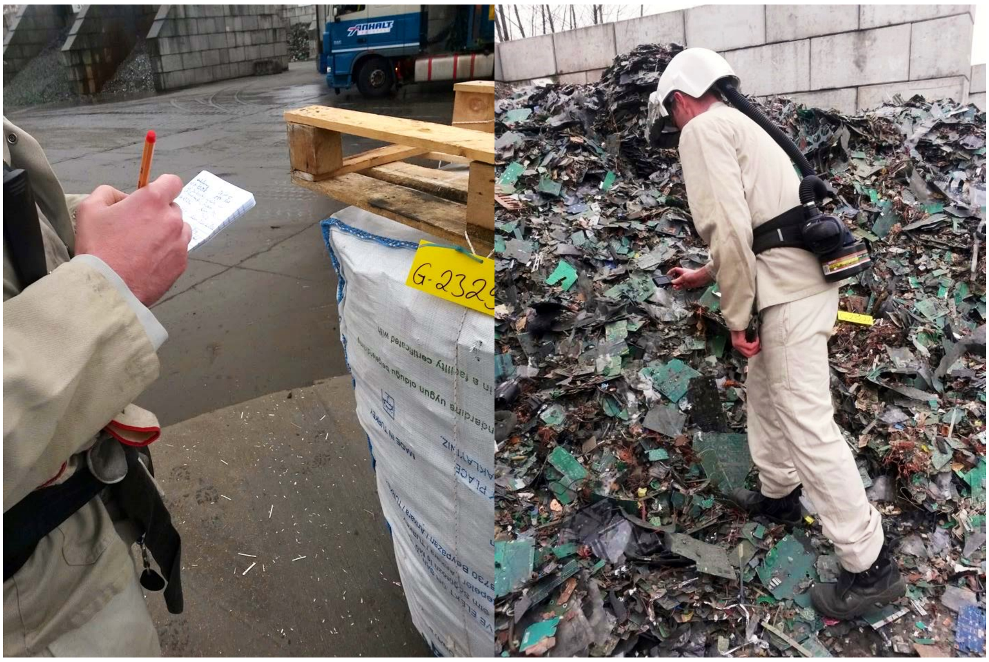

Figure 5 Documenting e-waste
Notes: The foreman on the right uses a digital camera.
Source: Photos by the author.

Expert knowledge plays a different role in this facility, as emphasized by the way in which the peculiarity of materials is handled when deliveries arrive at the outdoor space. Depicted here (on the right-hand side) are printed circuit boards of a medium to low quality. This selection is full of 'organic materials' (some also categorized as 'dust', for instance), as the foreman explained to me. Experienced engineers, he told me, know what lies in front of them, even if they stand in front of vague material composition that looks like dry flower soil (again, this is his analogy, and it is just one way to specify, or approach, 'dust'). This knowledge can be helpful for a quick allocation of materials. Analogies assist in situating the materials.

The order in which materials are then tested is based on an elaborate system, because the smelting facilities of this recycling plant require different materials at different times of the day, and the smelting facilities are communicating their demands to the preparation facilities. What they are not doing in the sampling site, however, is putting a value on a delivery based on a visual assessment in the way Mario did at the separation site. This is also the reason why documenting and classifying things works differently in this second facility. Usually, notes in a notebook and the documentation of things here are used to emphasize that the process went flawlessly or to show that disturbances have been controlled. Against this backdrop, I now turn to the explicit material processing of e-waste at this site.

The deformation practices of the sampling site's shredder system

Even though the e-waste is moved and dropped off at the outdoor space of this facility, the first deformation that is significant for the valuation process occurs in the shredder that comes next, in the factory hall of the sampling site (Fig. 6). From here on, employees are particularly careful as to what is done with the e-waste. Each delivery, and this is critical information, is put into the system separately. In the separation site, in contrast, mixing deliveries is normal (apart from the rare tests of new very specific items). Putting e-waste into the shredder, then, is a slow process controlled by at least two workers. One worker, as seen in this picture, checks the e-waste before it goes into the shredder, while another worker (outside the picture) cautiously puts these materials on the conveyer belt with a wheel loader.

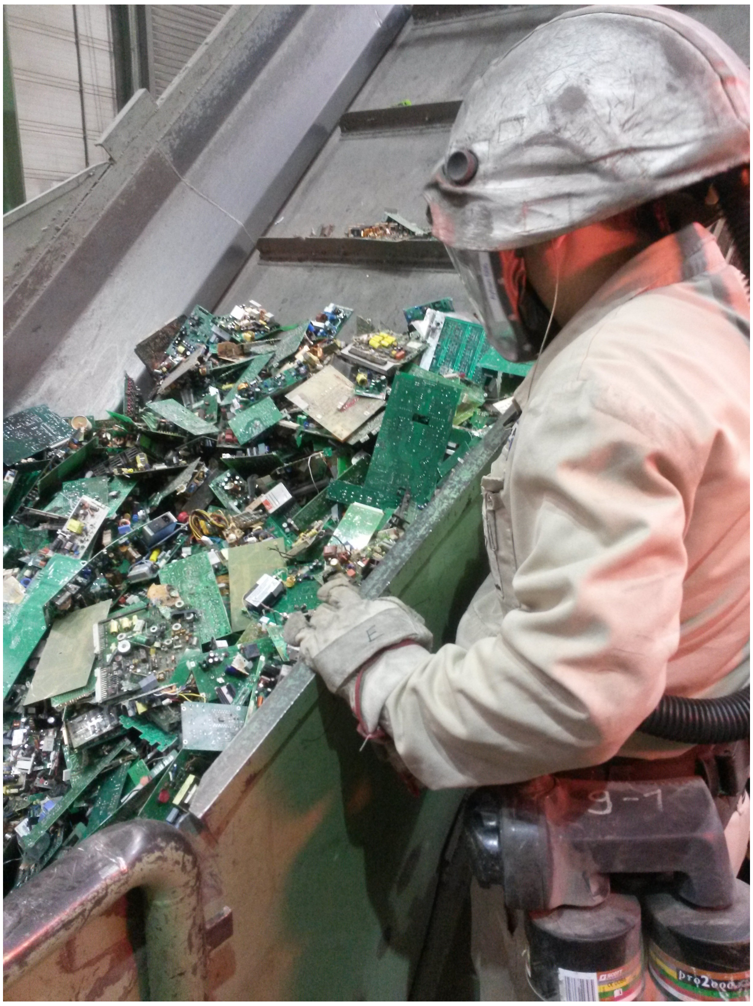

Figure 6 Inside the separation site and on the way up to the shredders
Source: Photo by the author.

What is most important in this particular transformative practice of deformation is its sensitivity. This facility does not use one but three shredders to deform the materials—it is a system of shredders that works in concert with conveyor belts and additional devices. (More on them below in this subsection.) And the system requires careful handling, which first of all is emphasized by the shredder technology itself. As elaborated, materials are dropped slowly onto the conveyor belt that feeds the first shredder. This is to ensure that (a) the worker depicted above can check for large or potentially dangerous items, and (b) the first and most sensitive shredder (situated at the end of this conveyer belt) is not overheating because of too many things coming in. The shredder can only take a limited amount of material at a time. Instead of shattering e-waste (like in the separation site), the materials are rather 'cut'—this is at least how the engineers summarize the differences between the machines here and next door.

What is the benefit of this sensitive and costly deformation? At the end of the shredding process (illustrated in Fig. 7), the materials are collected in two small barrels. Studying the details of the workflow in between helps understand why the e-waste materials require special attention.

Figure 7 Where the output of the shredder system goes
Source: Photo by the author.

The sampling facility cannot test all the materials of a supplier, for instance the 20 tonnes of e-waste coming in with a typical container. The recycler here makes use of statistical methods common in analytical chemistry. In abstract terms, the company strives for a representative sample by way of 'concentration'. The goal is to produce a tiny sample in order to make possible a physical and chemical analysis of what was in the delivery. The shredder described here then is part of a larger process that I will gradually delve into.

Fig. 8 shows the detail of the concentration process from the shredders to the barrels. Three shredders, gradually producing finer-grained pieces of material, work in concert with two devices that select a randomized choice of material. They split the flow of materials twice to increase the degree of concentration, while conveyor belts link all the machines. Only the materials that emerge at the end, however, are of importance for the sampling done at this facility.

In short, two flows of materials can be distinguished. (1) Most of the e-waste that is put through this shredder system is 'discarded'. That is, it is not chosen for the sampling procedure. Therefore, it is thrown into a container. This sorted material is either stored for further processing in the smelting facilities (if free of glass, plastic, etc.) or needs to go through the purification and sorting process provided by the separation site (see the small heap of materials below the conveyor belt in Fig. 3, quadrant C2/D2). Here the two preparation facilities again rely on each other. (2) The materials that are collected in the final barrels by the shredder system are the samples collected. These 10–50 kg are part of the statistical procedure and the valuation process. The 'concentration' process, however, is not yet finished. Much more energy is required to assess the materials at hand.

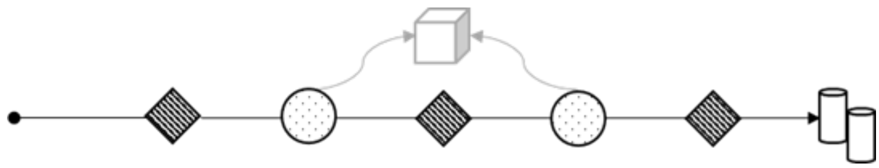

Figure 8 The concentration process of the shredder system inside the sampling facility
Key: Each line is a conveyor belt; a square represents a shredder; a circle stands for a device that splits the e-waste flow by selecting random materials; the box represents a container, in which the discarded materials are put. These are materials waiting to be processed when the sampling is concluded. The barrels at the end of the flow stand for the few materials that are selected for sampling. In reality, thus, the barrels are much smaller than the container.
Source: Illustration by the author.

The shredding of e-waste in this facility can be interpreted as deformation in multiple steps, which explains the vulnerability of the system. Formally, the processing of materials is described as being automatic, even though in reality the workers constantly need to maintain the machines to ensure that the materials are successfully put through. It is not a self-operating system. The first shredder of the system described here for instance needs to be serviced each day, which can involve replacing outworn 'knives' which do the 'cutting', while the conveyor belts and other tools are often clogged so that the colleague shown in Fig. 6 has to repair the system—often by being creative. I also have been part of this process, by helping locate an issue or by cleaning things that were full of dusty materials. My internship involved quite banal cleaning activities that might have been considered degrading at other places, but at this employer these are serious and essential tasks. The control centre of the separation site usually helped; they are equipped with sensors that monitor the system and can tell where to look for what kind of blockages. Their equipment also includes deafening alarm signals to which, paradoxically, one quickly becomes accustomed.

Smelting scrap, turning up the energy use

The shredder system is a first major operation at this facility, but it is not the only one, and perhaps not even the most important one. The concentration effected by the shredder system is just the initial one of this kind. There are multiple concentration processes in this facility—but based on different socio-technical set-ups and alongside new deformations that require new oversight. It becomes increasingly more complex to rework the materials.

One of the 'chosen' barrels pictured above (Fig. 7) has to be moved to an adjoining room to begin the next phase of concentration (the other barrel is stored as a reserve). In other words, most of the materials of the initial delivery of e-waste are not part of the procedure; they have been sorted out in the containers. These are materials on hold.

In the new room, the e-waste chosen for sampling is prepared for transitioning. Recycling is about keeping flows flowing. The materials are tested for any remaining hazardous substances (e.g. mercury), and put into a stove, so that any moistness is removed. After that, the materials are weighed again. The outcome of all the measurements is meticulously documented. At this stage, the materials that were selected by the shredder system already look rather homogeneous—dust, often with a touch of light green. Eyesight, however, is of no use in this case. From a chemical point of view, the materials must be mixed and deformed even further —by way of smelting.

The e-waste preparation facility does not have the machines necessary to do the smelting, which is why they send their barrels full of remaining e-waste over next door to let colleagues do this job. This leads me to a new location. The pictures shown (Fig. 9) are from this other facility, where I spent the last weeks of my fieldwork. This is the so-called 'old' preparation department of the company. It has been sampling material compositions (of 'classic' copper scrap in particular) for half a century but also supports the rather new e-waste facilities. Note that this particular smelting operation I am referring to here is *not* part of what this company actually categorizes as *the* smelting facility (see the idealized value chain in Fig. 2). In what follows I describe a rather tiny machine that is only used to support the sampling procedure; I'm still 'zooming in' to the preparation facilities.

The 'true' smelters are located elsewhere on the plant's premises, and, as indicated at the beginning of the article, they are roughly 65 metres high and used to produce 'new', raw, and standardized commodities. For valuation of the scrap bought, however, the 'tiny' smelting operation done here is sufficient, and of vast importance.

Figure 9 Smelting down the e-waste in a crucible induction furnace (left); and the result of this process (right)
Source: Photos by the author.

Smelting materials is a particularly energy-intensive practice of deformation. The snapshot in Fig. 9 (left) shows the key device of the new process: a crucible induction furnace. This is a high-temperature furnace (it reaches >1200°C), designed for small selections of materials. Altering the aggregate phase of the materials is the ultimate way to blend the selection. Low-value ingredients (such as residual plastics) are removed from the selection, even though, as Gregson and Crang (2010) remind us, nothing is literally destroyed but rather moved.

The entire smelting procedure performed is based on standardized routines, which are also agreed on in the contract. To check that these standards are kept to, a supplier can send a consultant who observes and checks what is done to the materials. This is an intermediate actor that ensures mutual trust. Contamination would result in significant economic losses, which is why it is a good idea to certify the deformation practices. Nonetheless, taking care of the furnace is a challenging task with various non-formalizable skills.

Just like the shredder described before, the smelting system is not running on its own. Putting the materials in and pulling them out is not that problematic, but keeping things going can be quite exhausting and dangerous. Regularly, a worker has to stir the materials with a rod-like device so that the smelting really mixes things through. By way of putting in a rod he (again: only men here!) feels how far the deformation of the materials has proceeded. To do that the worker has to climb up the small stairs (Fig. 9: left) and open up the round protective wall (which also serves as a filtering device for the fumes). I was also allowed to stir the materials once, in full body safety clothing. It is indeed incredibly hot in front of the device; it seems impossible to stand there for long; and it is tricky to feel anything about what is happening inside this machine. Yet workers endure. Some actually enjoy the proximity to the materials. For one person I was talking to, it was a hands-on version of science. Metallurgy in action. Another one, however, did not particularly enjoy what happened to him one day. There was a small explosion in the furnace during stirring which, long story short, hit him so hard that he temporarily had to be put into a coma. He is now used as one prime example of occupational health and safety. Maintenance can be tough; some traces of the work remain permanent.

The outcome of the smelting process, also shown in Fig. 9 (right), is black stone that the workers and engineers actually call 'stone' (*Stein*). In this snapshot, one can see the new metallic entities that have been produced. Well, actually one cannot see any differences anymore, especially no clear colour highlights. This indeed just looks like black stone—even though it is full of precious metals. This is what valuable 'scrap' looks like, in the eye of the sampling site, despite the fact that the stone still needs to be prepared to be assessed. It is important, however, to note that the smelted materials do not represent all the stuff that belonged to the original e-waste delivery. And this goes beyond the plastics.

Metals are also referred to as things that—due to their 'natural' state—can be endlessly recycled. Yet there is a loss of metal during this smelting procedure (which comes on top of the plastics being removed), because 'dross' is produced that requires further treatment. Dross is an impure residue of molten metal that sticks to the furnace and needs to be scraped away, while some things get lost, along the way. For the actual smelting facilities such dross requires a certain creativity to make the most of the procedure. However, for the sampling facility, such loss is less of an issue, because only a small portion of the material is needed for the examination to come. And not all materials are of interest.

Understanding what's going on during the smelting procedure helps in understanding the recycler's priorities. Even though the company emphasizes that it carefully prevents wasting (and sometimes even talks about 'zero waste'), I want to stress that each treatment of e-waste materials (each deformation) is indeed associated with the production of some sort of waste. In the case of the smelting procedure of the sampling site, for example, it is only because of the forceful removal of things (e.g. plastic) that new metallic entities are produced. And some energy reserves that once went into materials are ignored as well. Wasting and dissipation are part of the production of value, just as are hazardous emissions, as others have pointed out (e.g. Tsydenova and Bengtsson 2011; Lepawsky et al. 2015; Stubbings et al. 2019).

My tour through the separation site is almost finished; there is just one more operation to follow. When the smelting is finished, the black stone is moved back to the e-waste preparation facility, where a final sample of the scrap is produced, which is done in a tidy laboratory. The engineer in charge at this laboratory cooperates with yet another specialized chemical laboratory to evaluate the ingredients of the sample, inside or outside of the recycling company depending on the contract. A last key thing I learned while being introduced to these practices is that the key materials the scientists are looking for are just a handful of elements: gold, silver, copper, aluminium, palladium, and platinum. The recycler aims for these metals while, for instance, the much-discussed rare earth metals that can be found in plenty of discarded electronics have to be ignored. The reason here is that they are considered too expensive to extract. It makes more sense for the recycler to let the materials dissipate. Based on this, in any case, the accounting numbers are fixed. I have only briefly referred to the scientific processes that are carried out in the laboratory, because they are of minor importance to the central research question that I am pursuing here.

In the end, the supplier is paid based on a precise overview of what the initial delivery consisted of. The sampling site aims for a representation, while again subtracting standardized treatment charges. In addition, the contract is limited to a few materials, and a margin of error is taken into account which allows for loss or inaccuracy without being penalized. These standardized margins of error can in fact work to the company's advantage, which is why the recycler tries to reduce the actual errors. The more maintenance, the less loss, and the higher the value, without having to compensate.

This is how the preparation activities are concluded. Finally, the materials that have so far been stored are released. Various flows start flowing. What has been collected in the containers during the shredding processes can now be processed by the internal smelting and refining facilities—to produce raw commodities that are also sold at the metal markets—while low-quality and very heterogeneous selections are run through the separation site to produce separate 'fractions' of materials. Having issued a reminder of this general overview, I can now close the empirical section and move to the discussion and conclusion of the article, which will bring it together.

Conclusion

Having visited two adjacent facilities of an e-waste recycler set in the Ruhr Valley of western Germany, it is time to take a step back. What are the practices involved when transforming e-waste into scrap and waste? The comparative element introduced by looking at two e-waste preparation facilities allows inquiry into how the practices of valuation and deformation were differently intertwined at the two sites examined. The comparison illuminates the key valuation practices to keep in mind when discussing high-tech recyclers. But, as I will indicate in this conclusion, my investigation also aids the general understanding of calculation practices and the materiality of valuing.

The first observation is clear-cut. Contracting with suppliers, valuation of the incoming e-waste, and the practices of deformation are intimately intertwined at both sites. Yet, the way these practices are configured differs between the 'separation' and 'sampling' sites. Contracts vary, to adjust to the needs of different suppliers. This is also a matter of establishing a trustworthy relationship. The accounting apparatus of each facility is what ties together the mode of contracting, the moments of valuation, and the processes of deformation. At the separation site, contracting is subject to a rather early valuation where much of the deformation remains to be done. At the sampling site, the contract is concluded only after a more thorough analysis. Different routines and sensitivities are required. Hence, at the sampling site, the moment of valuation tied to the conclusion of the contract goes hand in hand with a very energy-intensive deformation process.

The accounting apparatus is key for the recycler, since it is part of ensuring that it can calibrate what it pays for different supplies in relation to what can be extracted at what cost. The value of the materials is not simply 'detected'. Arriving at a valuation is an achievement depending on both accounting and processes of deformation. The concrete way in which valuation occurs around practices of deformation is crucial—the 'how' of the process is where the different material affordances and skills make a difference. The preparatory work is not a bureaucratic formality in which stiff procedures are to be observed. Without the expertise, flexibility, and attention of the separation and sampling sites, the large smelting and refining plants of this company cannot operate. No 'fractions' of distinct material streams would be produced; economic value would be 'lost'. The actors introduced in this article have adapted to the specificities of e-waste, making possible work on and with these 'complex' materials. This is also about maintenance work worth appreciating, and bodies at risk. In the vast smelting and refining plants, where the prepared e-waste moves to, new services and routines then take place, which may be examined in further research.

From the perspective of valuation studies, my main contribution to the field lies in highlighting that the valuation of scrap is a very material process. I suggest using the notion of deformation to understand the valuation at hand. In order to identify and thus classify things, the foreman I called Mario watches deliveries of e-waste being dropped, squashed, and twisted. And it gets more energy-intensive at other places. The first preparation site puts e-waste through a massive shredder and operates a powerful filter; in order to produce a concentrated block of materials the second preparation site makes use of a high-temperature furnace, while also operating a complex shredder of their own. These are specific deformations. Recycling always means calculation, and especially in following the calculation practice of this industry it becomes clear how much the foundations of a calculation rely on very material breaks. Things must be disassembled with force. The calculation is based on creating deformations, because the accounting apparatus needs separate entities to work with. The machinery in use then not only makes valuations possible, it is part of it and shapes it. Maintenance and tinkering is part of it too. This observation could be useful for completely different empirical sites as well. In other fields of investigation, the induced transformation does not always have to be as irreversible as in recycling, but in many cases it should be possible to identify the consequences of a deformation as an issue that actors have to deal with. Things are altered, which translates into stress, but also introduces new insights and perhaps surprising relations.

From the perspective of waste studies, valuable scrap now can be better understood as a practical achievement. During the internship I learned that contracts are concluded while reflecting on experiences and anticipating future developments. Plus, treatment charges are an important component without which the decisions of a recycler and the establishment of a contract cannot be understood. Much information, however, is missing on that matter. This also hints at the financial markets, and global negotiations among the most important raw material players. The rhythm in which excavators and foremen move around a recycling yard is set by global financial flows, even if recyclers develop creative tools to set their own pace. The commodity markets are showing a complex, sometimes curious reality here. Matching this, my article has also shown that only a limited number of materials is recovered during the recycling process. The peculiarities of this should be taken seriously. High-tech recycling is a special practice that can only handle a limited amount of electronics while consuming a large amount of energy and producing new waste materials.

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