Uncovering Practices of Making Energy Consumption Accountable: A Phenomenological Inquiry

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Reacting to the discussion on global warming, the HCI community has started to explore the design of tools to support responsible energy consumption. An important part of this research focuses on motivating energy savings by providing feedback tools which present consumption metrics interactively. In this line of work, the configuration of feedback has been mainly discussed using cognitive or behavioral factors. This narrow focus, however, misses a highly relevant perspective for the design of technology that supports sustainable lifestyles: to investigate the multiplicity of forms in which individuals or collectives actually consume energy. In this article, we broaden this focus, by taking a phenomenological lens to study how people use off-the-shelf eco-feedback systems in private households to make energy consumption accountable and explainable. By reconstructing accounting practices, we delineate several constitutive elements of the phenomenon of energy usage in daily life. We complement these elements with a description of the sophisticated methods used by people to organize their energy practices and to give a meaning to their energy consumption. We describe these elements and methods, providing examples coming from the fieldwork and uncovering observed strategies to account for consumption. Based on our results, we provide a critical perspective on existing eco-feedback mechanisms and describe several elements for a design rationale for designing support for responsible energy consumption. We argue that interactive feedback systems should not simply be an end, but rather a resource for the construction of the artful practice of making energy consumption accountable.

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12

1. INTRODUCTION

Motivated by rising global energy demands and a growing awareness of the scarcity of natural resources [EIA 2011b], the design of environment-friendly technology has become an important issue at the intersection of different disciplines. Design-oriented

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research ranges from promoting an overall sustainable product life cycle [Blevis 2007] to technologies supporting "green" lifestyles or environmentally friendly behavior [DiSalvo et al. 2010; Dourish 2010; Woodruff et al. 2008]. When looking at the big picture in energy consumption, domestic resource consumption makes up more than one-fifth of the overall usage of energy, and with a growing trend in terms of the absolute consumption rates [EIA 2011a]. This trend can be explained by rising incomes, higher living standards, a shift towards smaller households and larger dwellings, and a growing demand for electrical appliances [EEA 2011]. Hence, an increasing emphasis has been put on the research of technologies that enable people to take on an active role in reducing power consumption at home [Chetty et al. 2008; Fischer 2008; Pierce et al. 2010].

Studies have repeatedly pointed out the positive effects of feedback mechanisms in enabling consumers to gain a better understanding of their use of resources and to identify and depict energy savings potentials [Darby 2001; DiSalvo et al. 2010; Fitzpatrick and Smith 2009; Mankoff et al. 2007]. Over the past 20 years, feedback mechanisms have been widely studied in environmental psychology, mostly taking positivistic stances, such as rational choice models or norm-activation models [Froehlich et al. 2010; Stern 1992]. Using these approaches, Darby showed, for example, that feedback mechanisms can influence energy consumption in a positive way and can increase the potential of energy savings by 10%–15% [Darby 2001, 2006]. The positivistic stance of these approaches has been criticized, however, for overemphasizing the importance of deliberate and individual choices and disregarding the fact that individual consumption takes place in a larger socio-technical context [Gram-Hanssen 2009; Shove 2003; Wilhite et al. 2000]. Existing positivistic models take the research subject for granted, without actually looking into the phenomenon of energy as it is constructed by the people themselves [Kempton and Montgomery 1982].

By contrast, Pierce and Paulos [2010, 2011] take a phenomenological stance to describe the relationship between humans and energy. The authors argue that energy is an imperceptible entity that has disappeared from our consciousness. Hence, design should render it perceptible again, in order to make it a visible part of our everyday lives, so that we can develop an emotional connection to it. A crucial foundation for the design of technology lies, therefore, in gaining an understanding of energy as an entity within our world, and in understanding how we use it, how we relate to it, and how we live with it. Pierce et al.'s phenomenological turn provides an interesting change in the research on energy feedback mechanisms because it reveals how the positivistic studies on this subject take for granted precisely what has to be actually uncovered by empirical research, namely *what* we are talking about when we talk about energy.

Methodologically, our work is grounded in Garfinkel's [1967] phenomenologically oriented Ethnomethodology and his concept of "accountability", which refers to members as situated practices of looking and telling by which phenomena become observable and reportable. In particular, accounting practices are not external to phenomena but constitutive by expressing its ordering structures. To study these structures empirically, we adopt Crabtree's technomethodological operationalization of Garfinkel's [1967] concept of breaching experiment as short-term practice intervention through technical artifacts [Crabtree 2003, 2004a, 2004b].

In our case, we studied the world of energy consumption as perceived by people. To do so, we provided 16 households (46 participants) with electricity usage monitors and took the collected data as a starting point. We then discussed with the participants how they interpreted their energy consumption and made it accountable.[1] Based on these

[1]We refer here to "energy consumption" instead of "electricity consumption", as our participants did not strictly distinguish between energy and electricity. Our participants typically talked about their energy

accounts, we elaborated on the household members' categories and methods, which turned energy consumption into a meaningful object for them.

We provide here a description of the revealed structure of the phenomenon of private energy consumption, as reconstructed from the accounts given by participants of the study, and list several implications that this structure has for the design of interactive technology to support sustainable lifestyles.

2. ON A PHENOMENOLOGY OF ENERGY CONSUMPTION

Instead of resorting to armchair theorizing and speculation, we must consult 'the things themselves', or that which 'manifests itself' or 'gives itself' [Overgaard and Zahavi 2009]

In simple terms, phenomenology refers to the study of "phenomena" as they appear in our *lifeworld* [Sokolowski 2000]. The concept of lifeworld (from the German word "Lebenswelt"), refers to the world that we experience in our ordinary life, the world that we perceive as opposed to what we think are the causes of our perceptions [Fällman 2003]. Phenomenological investigation aims to study the nature of the phenomena in question by analyzing, from a first-person perspective, the constitutive structures of the conscious experience. As researchers, however, we have no direct access to someone else's first-person perspective. A fundamental claim of phenomenology (like pragmatism) is that something like *direct experienc*e does not exist. Every sensation is always linguistically mediated, embedded in the horizon of a mundane world of disclosure. The aim of empirical phenomenology studies is to recover the phenomenon from the various traces and expressions of social interaction left by people, so the foreign perspective is made accountable [Garfinkel 1994; Oevermann 1993; Titscher et al. 2000].

A defining element of phenomenology is the transformation of the false subject-object dualism into a correlation between what is experienced and the mode of experiencing it [Ihde 1986]. This transformation creates what Ihde [1978] calls the instrumental character of the constitution of objects: what is given depends on how it is given, including the involved technical instruments by which it is given. By changing the mode of experiences through the design of technical instruments, we as designers contribute to the constitution of the lifeworld of people. A central implication of this *non-neutrality of technology* [Fallman 2011; Ihde 1978] is that the matter of design should not be the artifact in isolation, but the co-evolution of the artifacts and the social practices in which they are embedded. It is not enough for design inquiry to just uncover the configuration phenomena of someone else's lifeworld. It also needed to explore the ordering principles, methods, and technologies that are part of the configuration process.

The insights of phenomenology hint to an incompleteness of the rationalistic environmental research paradigm [Strengers 2011] regarding the design of interactive technologies to support responsible energy usage based on feedback mechanisms. In particular, energy consumption does not exist in itself, but is always energy consumption for someone. The energy of flashes, volcanoes, or windstorms is usually not perceived as energy consumption, but as natural phenomena. This highlights that energy and energy consumption are different concepts. This is not to say that energy consumption is a purely imagined category, but to stress that the inquiry into energy loses its subject matter if reduced only to the language of natural science (e.g., by reducing normative categories like wasting through the use of definitions based on physical categories like kW). In other words, energy as a part of our lifeworld has

consumption when referring to the consumption of their electrical appliances. This does not deny the fact that other types of energy exist, so it might be more accurate, from physical perspective, to use the term "electricity". However, such a terminology would not pay justice to people's ordinary practice, so from a phenomenological stance the notion of energy consumption seems to be more appropriate.

an essential normative character that could not be reduced to any physical concept of energy which is by definition descriptive [Statistisches Bundesamt 2011; Winch 1958]. Therefore, the focus of study for the design of sustainable interactive technology should not just be materialized energy as an entity of the natural world (e.g., measured in physical terms like "kW"), but rather energy as part of an intentional world, where it carries a meaning (e.g., given and judged in normative terms like "wasting" or "sparing").

In their work, Pierce and Paulos have been following a phenomenological approach towards sustainable interaction design, emphasizing the intentional constitution of energy consumption [Pierce and Paulos 2011]. To approach the phenomenon of energy, the authors use a postphenomenological framework, proposed by Ihde [1978] to differentiate and understand current design approaches. Using several categories of human-machine relations described in the work of Ihde, such as background, embodiment, hermeneutics, or alterity, Pierce and Paulos outline the diverse human-electricity relations. Based on this characterization, they draw a useful theoretical foundation to explain the diversity of approaches in HCI and to open new paths for the design of sustainable technology.

The arguments and categorization of Pierce and Paulos provide an interesting twist to the theoretical discussion around feedback systems. The phenomenological approach raises not only the question of what a relationship between humans and energy looks like, but also the question of energy as a socio-technical phenomenon and the accountability of the human-energy relationship. The work of Pierce and Paulos centers on human-technology and human-electricity relations [Pierce and Paulos 2011; Pierce et al. 2010], uncovering an important element for the design of supporting technology, namely the question of what the mundane human-energy relationship looks like in practice.

An important element to consider when addressing this question is that intentional qualities are not directly accessible. Empirically, we can only study the way people report a phenomenon. Approaching energy consumption calls, therefore, for empirically uncovering the mundane configuration of the phenomenon as it manifests itself to particular people in particular settings. Garfinkel [1994] used the term ethno-methods to characterize the ordinary methods with which members of a certain practice constitute and make an orderly world accountable. He argued that these ordering principles are not a prerequisite, but an outcome of making the actual setting "detectable, countable, recordable, reportable, tell-a-story-about-able, analyzable-in short, accountable" [Garfinkel 1994].

Garfinkel's ethno-methodological ideas were introduced to HCI by Lucy Suchman's [2006] work on situated action. The ethno-methodological stance in HCI was further elaborated by Button and Dourish [1996], who introduced the concept of techno-methodology, explicitly building on the ethno-methodological tradition. This concept was later further developed by Crabtree [2003, 2004a, 2004b] as a way of approaching the design of interactive systems. In particular, Crabtree recognized the nonneutrality of technology, by treating it not as an external element that is used in ethno-methods, but as an integral element in the constitution of ethno-methods.

In this tradition of techno-methodology, we here argue for the need of an inquiry centered not only around the phenomenon of energy, but also on the mundane methods and technical instruments involved in energy consumption. Complementary to the theoretical phenomenology focused on the human-electricity relation [Pierce and Paulos 2011], we need an empirical phenomenology focused on revealing what is taken for granted, such as the ordering principles used by people to constitute and make energy consumption accountable. In other words, together with *what* people make accountable, we propose to examine *how* this is made accountable. To address this need, we have been following a research agenda defined by three elements:

—reconstruction of the elements used by people to make energy consumption describable;
—analyzing of the reconstructed methods in relation to accountability;
—envisioning technology to support or improve existing methods or to explore alternatives.

In the following sections, we present the results of the outlined research agenda. First, we uncover the phenomenological structure of energy consumption and the ways people make them accountable. By interpreting these results, we have derived relevant implications for the design of technologies that support sustainable practices of energy consumption.

3. ACCOUNTING FOR ENERGY CONSUMPTION PRACTICES

To uncover the phenomenological structure of energy consumption practices, we conducted an empirical study with a total of 46 participants from 16 households between June and October 2009. We used an experimental and explorative approach based on a reinterpretation of the ethno-methodological concept of breaching experiment [Crabtree 2003; Garfinkel 1967]. The basic element of this approach was the introduction of experimental technological elements and prototypes meant to purposely disturb the system of already embodied practices [Crabtree 2004a]. This type of intervention is not aimed at providing prototypical solutions for a particular problem. Instead, we hoped gain insight into how these practices emerge, how people adapt to technologies, and how unforeseen breakdowns can emerge from the use of technology.

To explore practices of energy consumption, we introduced a simple, off-the-shelf metering device with Kilowatt/hour feedback in each household. In all cases the technical intervention constituted a disturbing element in the sense of Crabtree's concept of breaching experiments, as the introduced technology had not been used before in any of the households. We did not install more advanced devices, such as ambient eco-feedback or game-oriented solutions, as promoted in HCI, because these systems are solely studied for their motivational effects, but not in regard to the way in which people use them to reflect on their consumption. Hence we could not directly make use of other studies, but had to conduct our own inquiry using simple feedback mechanisms.

We used a snowball recruiting method [Flick 2007] to get in contact with the participating households. Participation was voluntary and no financial compensation was offered. To create a qualitative sample [Flick 2007], we selected households that varied widely in demographics (age, gender), living arrangements (home owners, apartments), and social as well as professional background. There were a total of 46 participants; some were students, others were unemployed or professionals and academics. The age of the participants ranged from 9 to 61 years. All households were located near the city of Bonn, Germany and had a similar cultural background, representing a typical sample for a German urban region [Federal Statistical Office Germany 2011].

This means our sample was quite diverse in regard to aspects such as demographics and gender, for example. When considering issues like electricity prices (about 24 EUR cent/kWh), billing practices (monthly or quarterly billing based on estimated consumption with a yearly adjustment to the real consumption), weather conditions (moderate summers and winters), and general cultural background (urban, western lifestyle), then our sample was quite homogeneous.

An overview of some of the characteristics of the households and of the participating people is provided in Table I.

Table I. List of Households (AP = rented apartment, SP = separate home)

No.	Type of flat	m^2	Type of household-	Permales
H1	AP	45	single	P1, male, 29, designer
H2	AP	56	single	P2, female, 21, pharmacist
H3	AP	45	single	P3, male, 29, electrician
H4	AP	50	single	P4, female, 28, trainee
H5	AP	78	couple	P5, male, 28 unemployed P6, female, 26, student
H6	SP	130	family	P7, male, 56, physician P8, female, 52, secretary P9, male, 21, student P10, male, 19, student
H7	AP	28	single	P11, female, 17, student
H8	SP	168	family	P12, male, 61, Teacher P13, female, 60, teacher P14, male, 28, carpenter
H9	SP	123	family	P15, male, 36, CEO in a large company P16, female, 35, housewife P17, female, 12, student P18, female, 9, student
H10	SP	130	family	P19, male, 49, soldier P20, female, 44, housewife P21, male, 19, student P22, female, 17, student
H11	SP	112	family	P23, male, 42, self-employed engineer P24, female, 42, part-time marketing expert P25, male, 11, student P26, female, 9, student
H12	SP	250	family	P27, male, 57, civil servant P28, female, 53, housewife P29, female, 18, student P30, male, 15, student
H13	AP	72	couple	P31, male, 25, shopkeeper, P32, female, 22, student
H14	SP	190	family	P33, male, 48, manager P34, female, 44, nurse P35, female, 19, student P36, female, 17, student P37, male, 14, student
H15	SP	129	family	P38, male, 44, Technical designer P39, female, 44, housewife P40, male, 16, student P42, male, 15, student
H16	SP	135	family	P43, male, 42, mechanic in a large industry P44, female, housewife P45, male, 21, student P46, male, 19, student

The breaching experiments happened in three phases.

(1) *Getting familiar with the context.* As a first step, we conducted one semistructured interview in each household, with one or two participants, to get to know the people and to uncover attitudes and motivations that affect their energy consumption.

Fig. 1. A PowerMeterClock and power meter installed in one of the households (left). Some of the appliances measured by the power meter (right).

The questions in the initial interviews mainly focused on attitudes towards resource consumption and on how participants managed electrical consumption.

(2) *Implementing smart metering.* On the same visit as the interview was conducted, we installed basic smart metering infrastructure that measured energy consumption on an appliance level in the entire household over a period of 7 to 10 days. The duration of exploration slightly differs because of availability of participants. The installed infrastructure consisted of 7 wall socket sensors that measured energy consumption and a *PowerMeterClock* (refer to Figure 1). The PowerMeterClock acted as a buffer that stored consumption information and simultaneously provided rudimentary real-time information, such as the current electrical power usage und accumulated consumption of each appliance. Additionally, the consumption data of the entire household was recorded by recording the meter reading manually at beginning and the end of the study. To take each particular housing situation and the different preferences into account, the sensors were installed with the help of the participants. During the trial, the participants continued with their daily life, while the smart metering infrastructure measured the selected appliances.

(3) *Posttrial interviews to uncover individual household practices.* After the first week, we started collecting data from the households. The collected measurement data provided the basis for the preparation of post-trial workshops. The data was taken from the sensors on each appliance and from the measurements of the entire household. The overall consumption data was derived from power meters provided by the local energy provider that were generally installed in the basement (refer to Figure 1).

We again visited each household shortly after the data collection visit, and this visit was used for post-trial workshops. The aim of these workshops was to obtain an

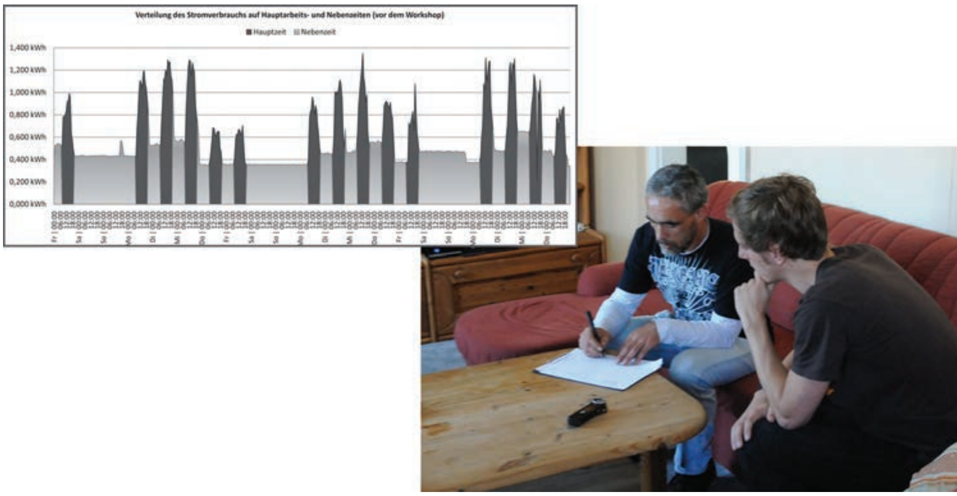

Fig. 2. A researcher conducting a post-trial interview. The graphic on top was one of the visualizations used to indicate electricity consumption.

insight into *how* the phenomenon of energy consumption manifested itself in the different private households. We used paper-based and computer-based dynamical graphic representations that provided visualizations of the consumed electricity in units of power (Watt) and energy (kWh). These representations were then discussed with the participants in regard to their consumption behavior.

All interviews were recorded and several parts were also captured on video. This resulted in more than 20 hours of audio data being analyzed, combining open coding methods [Strauss and Corbin 1990] to structure the observed phenomena, and sequence analysis methods [Pilz 2007; Titscher et al. 2000] to produce a verbatim analysis of the expressions of the phenomena in their natural orderliness. This analysis provided the foundation to uncover and support the categories and methods presented in the next sections.

4. THE CONFIGURATION OF ENERGY CONSUMPTION

The analysis of the data collected in the interviews and workshops provided insight into the different ways in which people perceive energy consumption as a meaningful part of their life. This section will present the most relevant of our observations, illustrated with extracts from the collected body of data.

4.1. The Nature of Wasting Energy

As mentioned before, energy consumption is always energy consumption for someone. This constitutive feature of energy has a specific meaning, which emerges from the fact that people have to pay and are made responsible for their energy consumption. Therefore one might expect that people reflect on their consumption in economic terms. As we will show in Section 5.5, the category *money* does play an important role as an accounting unit to compare consumption. A more precise inquiry revealed, however, that participants primarily thought about energy in terms of wasting and not in terms of absolute costs. The first element that we would like to present in our account is, consequently, the phenomenological structure of *wasting*, and in particular how and when energy is considered wasted and how wasting is attributed to someone.

4.1.1. Wasting Energy: An Expression of a Careless Lifestyle. In an early work on sustainable interaction design, Woodruff et al. [2008] conducted a study on supporting what they call "green" lifestyles. They showed that living green represents a value system focused on the reasonable administration of the resources available. In green ethics, it is considered wrong to drive a luxious car just for fun; it is deemed a bad lifestyle choice because of the resources wasted. Taken to an extreme, these green-value systems provide fixed definitions of what wasting is. In our fieldwork, however, we observed that the value systems of our subjects were more subtle, as the following interview sequence shows.

Interviewer: What do you think are the top five most used appliances?
John (P7, 56, physician and father of two adult sons, living with his wife in a separate home): Well, first the TV and my desktop computer, then my wife's laptop [laughing], then the washing machine and then my office downstairs in the basement. Which is not used regularly. . .but in regards to energy consumption, it's in the top five. . .also the lights and [. . .] I actually changed our lights to low current and energy-saving bulbs [. . .] I would add them to the top five or top ten.
Interviewer: Did you determine this through consumption [. . .] the top five? Because I thought [. . .] as a first step, more like, what is used, no matter how much it consumes. . . just that. . .
John: No, actually [. . .] I would prefer to categorize it, like, by saying [. . .] this is media energy, which is like leisure energy and the other, that is for example [. . .] yes, well, working energy. For example the fridge [. . .] it is easy to ignore, because [. . .] the fridge is always on [. . .] when you think of it, but you never really realize how much it consumes.
Interviewer: And how would you picture media energy and working energy [. . .] eh leisure energy and working energy?
John: So [. . .] Usage that happen in my free time, like media energy [. . .] so to say, the computer (desktop PC on a desk) is running, if I am currently not working, for fun, then the TV is on as well, and there's also another computer connected [. . .] and [. . .] my wife for example goes online as well (with her laptop)
Interviewer: Yes.
John: Basically there are three workspaces that are occupied only for media [. . .] where I'm only doing media stuff and [. . .] perhaps the washing machine downstairs, that is work energy on the other hand [. . .]I mean, I need that somehow [. . .] yes [. . .] that is the way I categorize it. I have to do the laundry but I do not have to watch TV. So I have the opportunity to say [. . .] OK [. . .] I leave the TV off and go on the Internet [. . .] but then again I would like to see a movie [. . .] and my PC [on the desk] is still running even if there is another PC [used to watched movies] with the same functions.

While explaining the consumption of the diverse appliances, John refers to his energy consumption using two categories he calls "leisure energy" and "working energy". He further elaborates this by describing the characteristics of these categories. In his example of "leisure energy". he discusses the energy consumption by questioning its validity, in this particular case by "leaving the computer on without using it". For him, "not working" with the computer, but having it turned on, is not necessarily a reasonable way to use energy. The characteristics of what John means by "working energy" emerge when he talks about the "need" of having a washing machine. John separates them "simply" by comparing the need "of doing laundry" with the nonexisting requisites "of watching TV".

"Wasting" emerged as a common category, appearing in almost all cases of our analysis. However, the following discussion about reasonable use, between the interviewer and between Hans, a father from one of the households, shows how the interpretation of "wasting" is quite random and depends on the personal way of life.

Hans (P43, 42, mechanic and father of two grown up sons): [. . .] and things like leaving the computer on for three days because you're downloading huge files from the Internet, you know [. . .] and you benefit from this, and if you benefit from it, you should pay for electricity. [Interviewer: Yes] The minute that you download a large file, you are using the computer. That's simply your usage time.

Interviewer: Yes, but that is not necessarily reasonable use. Doing your homework on the computer, it makes more sense than watching a movie you've downloaded from the Internet.

Hans: Well, but then [name of feedback system] needs to be able to distinguish between useful and nonuseful energy consumption. [. . .] If I were a movie fan, and if I wanted to see a movie, then what?[. . .] Well, as soon as these things [the computers]are needed, no matter for what, then you should pay for electricity. The crucial point is how to deal with these things [computers] when they are not needed.

While giving an account of his consumption, the father refers to what he calls "beneficial use". He legitimizes the consumed energy by valuing the intention of downloading files. The interviewer introduces the idea of reasonable use. While considering the opinions of the interviewer might appear as a methodological flaw for an ethnographic study, at this point the interviewer is speaking of his own experience with computers, so we decided to use the dialog. For the interviewer, downloading files is not necessarily "reasonable use". In doing this, he shows that, for him, purposes are not neutral, but they are matter of subjective values. The father acknowledges the argument of the interviewer, but concludes that a distinction between right and wrong should be made by the system. For the father, the judgment of a purpose is crucial to legitimize the usage of energy and "useful" and "nonuseful" energy are the relevant criteria to describe energy consumption as "wasting". Again, in this argument, the father expresses that the perception of such purposes is subjective: "If I were a movie fan [. . .]." This reveals a seminal difference with dogmatic green-value positions which assume the existence of an objective vantage point to judge purposes. In the presented episode, the father identified a *consumption purpose* as a basic category to make consumption accountable. For him it is important to distinguish between right and wrong purposes. However, how these distinctions are made is a matter of subjective consideration, and consequently, they cannot be delegated to any externally defined algorithm.

4.1.2. Wasting Energy: Inefficient Use of Resources. The link between energy consumption and purpose represents a first basic element in defining wasting. This attribution allows the judging of energy consumption as wasteful by connecting it to a careless lifestyle. A second element in the definition of wasting arises from the form that consumption takes on in relation to the use of resources. The following discussion about data presentation illustrates this point.

Interviewer: OK, so if you have information like the one displayed, is this one interesting for you?

Martha (P4, 28, trainee and single, living in a rented apartment): Yes. I think it is interesting, but only if I have a reference to compare it to. For example, if I knew that my washing machine uses this much and a washing machine should normally consumes that much. I can't really apply that information right now [. . .] I mean, I am aware that a washing machine consumes more energy than a fridge. I just thought that [with the system] I would be able to see if you can somehow save electricity or if you can identify a black sheep in the apartment.

Interviewer: Well, you have a display here [. . .] the information that you are missing is a comparative value [. . .] is there something else?

Martha: Well, for example, I would find that interesting with regards to the fridge. The energy consumption is rather stable [...] but it would be interesting to see what the comparative value of a newer standard model would be. And a new washing machine that runs on a 40 degree program, how much energy that would use.

In this sequence, Martha states that for her the "reference to compare how much" energy her washing machine uses in relation to a "very modern washing machine" is the relevant question whether she "can somehow save some electricity" in her apartment. The same concern later came up again when Martha mentions her wish of being able to compare the "usage" of her refrigerator with a comparable one. In Martha's account, the significant elements are the used resources and a comparison with the consumption of alternative appliances. In her case, the purpose of energy consumption is already settled and accepted as necessary. So wasting becomes defined by the amount of used resources. Avoiding waste and saving energy can be achieved by replacing devices that are less energy efficient. The purpose itself (cooling, washing) remains out of the question and, hence nonnegotiable [Strengers 2011].

4.1.3. Wasting Energy: Connecting Purpose and Used Resources. The aforementioned elements defining the waste of energy, used resources and purpose, are not independent and their interaction constitutes a third element in defining waste. The following vignette illustrates this connection. Here, one interviewee imagines how a feedback system should present continuous energy consumption.

Interviewer: Do you think, with such visualizations, if you had the option of following and checking your energy consumption continuously, do you think you would be able to control your consumption better?

Simone (P20, 44, housewife, living with her husband and two children in a separate house): Yes, I think that if I had those data in mind, I would pay more attention to what I turn on, I mean, of course not to how long [they remain on]. I would try now and then to not have all appliances running. If I knew my usage, or [if I knew] how many kilowatts I'm using [...] I would turn off the TV and then I would go on the Internet or maybe I wouldn't turn music on while I'm surfing the Internet to save some electricity. Maybe it would be interesting or more intriguing for me, at least. Actually it would stop me if I knew how expensive it was.

The initial reflection of Simone articulates the link between *purpose* and *use of energy resources*. Her strategy of turning the TV off when it is not being used does not question the benefit of watching television in general. Just as in Martha's case, here, wasting represents an expression of a suboptimal use of resources. Simone's strategy to avoid waste, however, is not to replace the device with a more efficient one, but to cut back in electricity consumption by changing the activity and reformulating the activity's purpose from watching television to entertainment, and hence, moving to something less expensive in terms of energy consumption. This linkage is clarified in the last statement of Simone: "actually it would stop me if I knew how expensive it is." A similar account was often expressed in the post-trial interviews. In most of the cases, energy waste is not completely subordinated under the purpose or the used resources. Waste in these cases can only be judged by the proportionality making the connection of purpose and used resources to the subject of reflection.

4.2. Energy Consumption and the Present Self

A further observed element in consumption accounts is the construction of a relationship between the subjects and their energy consumption. This construction is where feedback plays an important role because it can create a connection between agency and consumption. Previous work in environmental psychology has shown that monthly energy bills are too detached from the consumption context to be useful in fostering environmentally friendly practices [Kempton and Layne 1994]. To solve this problem, immediate feedback has become one of the most important design options [Darby 2006; DiSalvo et al. 2010; Froehlich et al. 2010]. In our daily life, we do not perceive energy itself as being consumed but *services* that consume energy [Wilhite et al. 2000]. Consequently, we should not only consider the detachment of feedback information from the context of consumption, but also the detachment humans perceive when using the energy-consuming aspect of technology.

In the following sections, we will reconstruct the relationship between people, services, and consumption starting empirically with the perspective of people and their accounting practices, as defined in our phenomenological agenda. We have observed people talking about consumption and have found categories that fit into the phenomenological notions of background and embodied services [Ihde 1978]. An *embodied service* is a service that stems from an activity actually performed by an individual, while a *background service* is part of our domestic environment, makes our lives possible, and has become an integral part of our daily practices.

4.2.1. Background Services as Baseload. In our interviews, background services manifested themselves in what Bob, one of our participants, called *baseload*. In his perception, a specific amount of energy must be used to cover basic needs. In the following sequence, Bob explains this.

Bob (P23, 42, engineer, living with his wife, son, and daughter in a separate house): So I'd find it good, if there were a certain baseload that is necessary for the house. That would include all devices that you cannot switch off such as the router, a fridge, a freezer, and so on.
Interviewer: Telephone and so on.
Bob: If you knew this baseload and could compare it with the energy consumption of all the devices that you could but should not turn off, standby units, so to speak.
Interviewer: Yes.
Bob: And then, of course, the devices that are turned on whenever needed. If you had this separation, then you could probably manage your energy usage better. The heating, the fridge, or the freezer, you cannot change anyway. You can replace them, and you just know that there is a certain baseload used in a household.

What Bob describes is an aspect of how always-on devices become permanent habitants of the electrified household. The interesting point, however, is that always-on devices are seen as background services which are attributed to the house ("that is necessary for the house"). For example, Bob mentions his router, refrigerator, or freezer as appliances that need to be continuously running, compared to other devices that should consume energy only when actually needed.

When becoming a background service, detached from an ongoing activity, the human relationship with the device changes, and consequently the ways of how consumption is made accountable changes. The central aspect observed for background services is that they create a baseload that, in the eyes of the consumers, cannot possibly be changed because it is essential. Hence, this consumption is not considered wasteful. In contrast, consumption created by embodied services running without any concrete, present need are deemed as a waste of energy, as, for example, Simone states in Section 4.1.3.

"I would then turn off the TV and I would go on the Internet or maybe I wouldn't put music on at the same time that I'm surfing the Internet, to save some electricity [...] it would stop me if I knew how expensive it is."

4.2.2. Feedback, Action and Interpretation. A further element in the construction of one's own energy consumption is the relevance of context. The following sequence taken from an interview with George explains this aspect. The interviewer asks George if a physical display of his consumption would be interesting, and while agreeing, he mentions a fundamental problem with such a display.

George (P1, 29, designer, living alone in a rented apartment): I want to have the facts, because... that's why I said that there are devices which I cannot turn off and if the fridge is on, it's on. And if a flower wilts or whatever turns red... I don't care, because I cannot change it anyway.

For George, the relevant element is not absolute energy consumption but rather energy waste. Immediate feedback makes sense for George only if energy consumption is caused by the immediate acts of an individual, that is, when there is space for a corrective action. This does not necessarily imply that feedback on consumption is irrelevant. Rather it shows a need for additional mechanisms that indicate paths of action. In George's case, for example, alternative options could be changing the position of the refrigerator to a cooler space or to provide options for buying an environmentally friendlier one.

The argument underlying the comment of George additionally shows a more subtle problem with traditional feedback mechanisms. George points out how they fail to create a link to a certain activity or to a certain class of consumptions. In the case of embodied services, the activity creating the consumption is present, and can be used to construct meaning for feedback information. In contrast, the background service provided by the refrigerator is not present to George. The perceivable hook for this consumption is not available, and consequently George cannot semantically interpret the provided feedback.

5. METHODS OF MAKING ENERGY ACCOUNTABLE

In the previous section we discussed what energy consumption means for the participants. In this section, we will move our focus towards how the participants made energy consumption accountable. This change of focus is very important, because the ways in which people account for their consumption can have a significant impact on energy consumption and waste. As discussed previously, we refer to these mundane practices as *methods* in the tradition of ethno-methodology. We will here present four methods we observed. The first refers to the direct comparison of energy consumers. The second refers to money as a universal instrument to make consumption comparable. The third refers to the mapping of consumption to the accounts of others. The fourth and last method presented refers to the mapping of consumption to reconstructing routines.

5.1. Consuming Appliances of the Same Type

One of the methods used by people to give a meaning to consumption, which was observed often, was the use of comparisons to other appliances regarded as being of the same type. The following excerpt illustrates this method.

Interviewer: Would it also interest you, in that respect, how others look? Meaning, that if you now measure your own use, that we'll look at in minute, we can look at it now [...] does that correspond to your expectations of how a refrigerator behaves?

Mike (P12, 61, teacher, living with his wife and son in a separate house): Yeah, that is what I expect from a refrigerator. When it comes to the household, checking how much electricity I consume and how much a four-person-household consumes? That actually wouldn't really motivate me. I probably would have a look at where and how I use what amount of energy. How much electricity it is, what that amounts to in terms of money and where I could change something. And if I say that's ok, I'll allow myself that comfort, then I have to pay for it too. So, in regards to that, what others households consume, isn't that interesting to me.

Interviewer: That means [that you would] a comparison between various types of equipment, within the same device type. You know that a refrigerator of a certain brand uses a certain amount of energy. So then you know how much your model should consume, but you can see that it actually consumes much more. Would that be useful?

Mike: Right. That would be interesting. Actually, only for the same type of devices. If I'm going to buy a refrigerator, I am doing it because I need one and it is also clear to me that it consumes electricity. And then, when making a purchase, I would look for one that does not consume too much energy. I can compare old devices with newer models and can then calculate if it would be profitable to exchange my old one for a newer one. Then, maybe I would think about buying a new one [...] and not wait until the one I have is broken.

The interviewer brings up the possibility of comparing the consumption with the values measured by other consuming groups of people. Instead of following the suggestion of the interviewer, Mike rejects the idea of comparing himself to a statistical conception of expected consumption of a similar type of consumer (a four-person household), stating that for him it would be more helpful to think on the device level, comparing the energy consumption of devices of the same type. Instead of identifying wasteful activities, it seems that the primary concern for Mike was in making the wasting of resources detectable ("I can then calculate if it would be profitable to exchange my old one for a newer model"). This form of comparison can often be found in our results, and it is mostly used to make inefficient consumption visible and accountable. We observed this comparison being made to detect wasting for both embodied services (like watching TV) as well as background services (as provided, e.g., by a refrigerator). They were more common, however, when describing wasting by background services. A possible explanation for the preference expressed by Mark is the structural limitation, created by the need of categories to allow comparisons. When talking about the background service of cooling, it is easy to compare two sorts of refrigerators. Often, however, the reasons for energy consumption (watching football or driving to work) have their own qualities which are not directly comparable. In the following section we will present an observed method that people used to deal pragmatically with the problem of comparing disparate categories of consumption.

5.2. Money as a Universal Accounting Instrument

A phenomenon observed many times during our data collection was the use of money as a reference system to make energy consumption accountable. The following sequence illustrates this. It is taken from a discussion where in a couple and their son analyze their consumption during a reflection workshop. The couple is completely astounded by the high consumption resulting from the computer activities of their son. Their request for an explanation from him leads to the following discussion.

Daniel (P27, 57, civil servant, living with his wife and two sons in a separate house): You won't be getting any allowance for some time. Do you know how much electricity your computer uses?

Jacob (P30, 15, student): Nope!

Daniel: It's absolutely outrageous!

Jacob: What?

Daniel: It used 77 kilowatts this week.

Interviewer: Since last Saturday.

Daniel: In the kitchen, the dishwasher uses eight kilowatts and it runs every day, sometimes twice a day.

Jacob: How much is that?

Daniel: Yes—that's fourteen cents a kilowatt hour times 77, do the math, fifty-two weeks. Imagine what your computer costs!

Jacob: Should I do that now or what?

Emma (P28, 53, female, housewife): No, you don't need to calculate that now. I just wanted to say that the cost of your computer is about the same amount of your weekly allowance.

[Jacob leaves the discussion rather annoyed and confused]

This sequence shows very nicely how energy consumption accounts can jump between several different reference systems. In a first attempt to articulate his frustration about the energy consumption of computer his son's, the father uses a physical unit (kWh) as a reference system. He further extends his explanation by contextualizing the consumption of the computer with a comparison to an appliance with a well-defined role: the dishwasher and its comparatively low consumption in a week (8kWh compared to the 77kWh). As implied in his conversion, the father attempts to provide some measure of the efforts that one-tenth of the energy consumed by the son can cover: the cleaning of the dishes for a whole week. None of these reference systems seems to impress Jacob. To make himself clear, the father moves to a monetary reference, proposing an approach to go from the consumption of the computer to monetary value. The father does not make things much clearer to Jacob and his use of big numbers points to an attempt to bring his son to empathize with the feelings of both parents. Jacob begins to understand, as his rather confused answer shows. The mother makes a final conversion to a reference system that belongs almost completely to the world of Jacob. She shows her son that the energy consumed by his computer accounts for almost as much as his weekly allowance.

The sequence shows how the physical units like kWh can fall short in supporting the accountability of consumption in social settings. The majority of people, like the son and the mother, are not very familiar with the meaning and use of kWh. The ability to understand and convert kWh into other units, as shown by the father, represents an exceptional skill. In this context, the use of money as a common ground for making sense of consumption proves useful to bridge the different worlds involved in this interaction [Kempton and Montgomery 1982]. At first glance, the appeal of money as an accounting instrument might lie in the mentioned lack of skills to correctly interpret kWh. A more in-depth look at the many changes of reference systems in the sequence reveals, however, that it is not just a matter of knowledge that can be overcome, for example, by learning how to use kWh readings. As an accounting instrument, the physical reference system provided by kWh has a fundamental structural limitation: although it allows abstracting from specific appliances like computers or dishwaters into consumed electricity, the abstraction ends there, and it only allows comparing consumption in absolute amounts. In contrast, money represents a universal accounting instrument that can be used to compare and exchange any disparate couple of qualities [Karjalainen 2011]. In particular, it allows comparing between any type of consumption, such as playing computer games, buying new trousers, or washing the dishes. The mother uses this quality of money to convey the extent of consumption represented by the computer usage as a quality that can be understood by her son.

It is important to note that our observation refers to money as an instrument to make a comparison. In our study the focus was not on the motivational effects of money, as a price signal to urge energy savings, as often discussed in rational choice-oriented approaches in environmental research. For us, money was a universal instrument that could be used to abstract a specific quality in every situation to appraise the value of something. This major advantage is alsoat the same its major drawback, namely in that it detaches compared qualities from their concrete value within the actual context [Fraser 1998]. This connection, however, plays a very important role for consumption accounts, as observed before in our outline of the strong connection between the definition of waste of energy and the personal perceptions of purposes and goals. So the property of universality that accounting instruments, like money (as a universal economic unit) or kWh (as a universal physical unit), provide, at some point needs to be contextualized and embedded into the lifeworld of people using this category. In this sense, the pattern observed in the sequence, of reaching for universal reference systems and then moving to a contextualized reference system is not just another strategy, but it represents a necessity when accounting for consumption.

Contextualizing references requires the actors to have a shared definition of the situation. This definition is at the same time established and negotiated during the actual social interaction [Shove 2003]. This negotiation is visible in the presented sequence. In his attempt in contextualization, the father establishes a relation between running the dishwasher and using the computer. His sentence implies a rhetorical question: "Do you realize that playing with your computer consumes ten times more than the dishwasher?" The mother goes one step further in the negotiation of a reference system that would allow her to convey her frustration. She moves from the universal frame of money into the lifeworld of her son, comparing the consumption of the computer to the weekly allowance. In essence, she asks rhetorically "Do you realize that playing with your computer costs just as much as all the things you buy with your weekly allowance?"

The central point that we want make here is that accounting methods are biased instruments. They shape the space in which agency is negotiated. In this context, smart metering technology alters the domestic ecology by changing the ways in which consumption becomes detectable. In their presence, the son needs reasons to explain his own consumption not as an absolute, but compared to other subjective reference systems.

5.3. Using Others' Consumption as a Reference

Comparison of consumption has a long and persistent presence in environmental psychology as well as in sustainable interaction design, under the concepts of *comparative feedback* and *social comparison*, respectively. One important motivation for eco-feedback technologies can be traced back to the theory of social comparison [Brynjarsdóttir et al. 2012; Jacucci et al. 2009]. Following this theory, social comparison can motivate the adjusting of behavior in two ways: first, comparison can signal failure to comply with accepted social norms. Second, comparison can increase the motivation to contribute by being informed that others are also contributing.

An interesting use of applying social comparison based on feedback technology appears at a later point in the discussion between Daniel and Emma, presented before. The situation takes place at the end of the field trial and refers to the energy usage of their sons Jacob and Paddy. The participants were asked if they would like to continue with the trial and what would they like to do with the equipment in the future.

Interviewer: So what else?

Daniel (P27, 57, civil servant): Now, if we had the equipment for another week, we would give Paddy (P29,18, student) another one [. . .] placed there somewhere, and see what is better. This would be interesting. Perhaps it really is because of the old monitor. And then we could in comparison, measure at Jacob's (P30, 15, student)

Emma (P28, 53, female, housewife): Yes, that would be an option. Although he does not sit there [at the computer] so often [. . .].

Daniel: Yes, but we would have a reference value, to see if something is wrong with Paddy's or Jacob's and then we'd know where the problem is [...].

Emma: Yes, but then it would be easier if you would measure each device separately, then you would see immediately which device would is consuming way too much.

Daniel: [interrupting] Yes, I agree, yes, if we measure at Paddy's and his consumes half as much energy, then something must be fishy with Jacob's stuff.

Emma: Yes, but then he would have to leave it on as often as Paddy and that's not the case. That's why it is easier[..].

Interviewer: One could, one could indeed extrapolate. One could say yes ok now Paddy is using it, he has used it for two hours now [...].

In the sequence we again see a comparison used to account for energy consumption. Contrasting to the previous portion of the discussion, this part refers to the comparison between individuals consuming energy. In this case, knowing consumption behavior does represent an end, but it serves rather as a means to make problems with energy services accountable. The primary concern of the comparison is not to figure out if Jacob's lifestyle is wasteful, but to find out if *something is wrong* with the consumption of Jacob, which was initially blamed on a faulty monitor. The strategy points towards using comparative social feedback as an inquiry instrument to discover opportunities to save energy. For the father, comparing the information coming from both of his sons represents a good additional strategy to discover problems. The mother, however, relativizes the usefulness of this strategy, pointing out that the use of this strategy has to consider the differences in the habits of both of their sons. The transcript presents two issues that are central in comparisons: the need for dimensions to make consumption comparable and the relevance of the social context to be able to draw a usable conclusion from comparative social feedback.

5.4. Habits and Situated Actions as Resources for Accounting

Reflecting on routines and habits is a very important component of accounting for energy consumption. The following sequence provides a good example of this type of reflection. It comes from an interview where Hendrik uses the provided computer visualization to evaluate the data collected in the week prior to the interview together with the interviewer.

Interviewer: That's 10-minutes intervals.

Hendrik (P31, 25, shopkeeper): The day in 10 minutes [...] make it half an hour [I:ok] so now one can see that from the computer.

Interviewer: I'll also add the total [...] so [...] here you have the consumption.

Hendrik: The computer is still on[...].

Interviewer: Yes... around one o'clock you play around....somewhere around 1:30 or so... you turn it off [...] Then it is in standby or probably there is something running.

Hendrik: But that's not possible because the multisocket has a switch. [I: was it off?] It was off. I turn it off when I turn the computer off. That's why I wonder why it keeps using energy. You cannot attribute it to the computer... there are a couple of devices there...but they are actually all off...except for the phone... it could be the phone.

In the sequence, both participants are trying to make sense of the data. The interviewer guesses that Hendrik left the computer on standby. Hendrik, however, adds information from his own habits to correct the assumptions of the interviewer. He knows that, because of his habit of switching off the entire muiltsocket, the computer can't be using energy, so he looks for alternatives. Based on the readings and his knowledge of the configuration of the outlets and devices, he identifies the phone as a possible candidate. This example reveals an interesting relationship between energy consumption records and habits. In a previous section, we showed how energy data can serve as a tool to asses habits in terms of energy consumption. In this case, however, this is reversed, and the habits are used as a foundation to make sense of the energy consumption data.

Our second example also comes from the evaluation interview with Hendrik. This time, he reflects on an exception to his routines as a basis to build an account.

Interviewer [looking at the screen]: What catches my attention in the configuration is... that you for example [...] that in the sensor 5... you have peeks in there... quite a few. Also quite regularly in the evenings. Around 9pm... could we... other mode... could we take a closer look at that?

Hendrik (P31, 25, shopkeeper): That is [...] that's actually because on those days I had no satellite reception... and I listened to Internet radio the whole night, so I didn't turn the computer off... it only went into standby mode. Correspondingly, those peeks are probably from evening to morning.

Again, it is the interviewer who tries to make sense of an interesting pattern appearing in the data. Hendrik tries to correlate the pattern with his past activities. He quickly finds an explanation and provides an account of the exceptional pattern of consumption ("on those days I had no satellite reception"). Here, a particular exception to Hendrik's normal routine provides the foundation to give a meaning to the observed peaks in the measurements.

The two presented examples show the use of one's knowledge of routine actions and situated exceptions as an accounting instrument. The third sequence describes an example where the exception is taken as a rule. The sequence again is taken from the interview with Emma and her husband, presented before.

Interviewer: And now you had this watch...did you think during the week that maybe you could have seen things better, in a different way?...That I can show when what happened when....

Daniel (P27, 57, civil servant): Only the daily accumulation [...] one can't see much.

Emma (P28, 53, female, housewife): Well, on which days was it the highest? [Daniel: only accumulation?] but that's not interesting. What's interesting is the final result. I thought, if I look at the accumulation for seven days, then you add it up and then you'd also have previous values. For each day [...] It depends on who is at the house, who is there and what they plan to do. And it changes afterwards... it fluctuates. Then no one uses the television, obviously no one uses the computer. The dishwasher is regularly in use. What else do we have? Of course...the other devices. Oh yeah, you worked this week, for example, so we didn't have any coffee in the morning, those things add up, so for me it was only the final results that were important not the daily routine.

Emma states that the energy consumed by the family depends on their presence in the house. She recalls specific events (not having coffee with her husband) which, from her perspective, provide a valid explanation for the oscillations in energy consumption shown in the graphics. However, because of contingencies of the daily situations, Emma was not interested in the energy consumption of the particular events, but what the effect of all these events in the end was ("what's interesting is the final result").

Overall, the presented examples give an insight into how reflection on past activities provides a foundation to account consumption readings. These recollections primarily serve as a basis to contextualize the data provided by the energy monitors. The measured values, by means of these recollections, are no longer an abstract number of KWh, but rather the meaningful results of specific activities.

6. DISCUSSION

In the literature, providing direct feedback is one of the most discussed instruments to influence energy consumption behavior. The design of energy feedback systems is dominated by a rationalistic paradigm where principles of efficiency and rationality are applied on a household level [Froehlich et al. 2010]. Most of the intervention studies building on this paradigm [Abrahamse et al. 2005] show positive effects of saving energy. Paradoxically, at a macro level, examples like the large-scale deployment of smart meters in Germany show that the expected effects of feedback mechanisms are not necessarily visible [Mazé and Redström 2008] and that the average energy consumption is still growing [van Dam et al. 2010].

This misalignment between both levels is related to a shortcoming on a micro level. Qualitative in-depth studies of feedback systems in the wild show that energy practices are far more complicated than the simple cause-effect or linear models used by rationalist paradigms: "There is little information available on what kind of feedback households prefer and what kind of feedback works most effectively in reducing household energy consumption" [Karjalainen 2011]. Addressing the blind spot of rationalistic paradigms, research has focused on consumption practices in daily life and has made important progress in the last years to understand what kind of feedback users prefer [Bonino et al. 2012; Karjalainen 2011; Roberts et al. 2004] and how eco-feedback works in the situated context [Hargreaves et al. 2010; Pierce 2010; Strengers 2011]. Strengers [2011], for example, shows how people have difficulties making sense of the information provided by eco-feedback systems. The topic of the situated use of energy feedback remains by large, however, an open issue.

Contributing to this research, our results show that a phenomenological stance provides an appropriate analytic lens to understand how eco-feedback works, by revealing how people use it to make energy consumption accountable and explainable. Following the phenomenological agenda described in Section 2, we obtained in-depth insights about the configuration of energy consumption as a meaningful element in the lifeworld of people (refer to Section 4) and how this configuration is created by people's use of diverse accounting methods (refer to Section 5). In this section, we want to summarize these findings, delineate a critical perspective on existing eco-feedback mechanisms, and discuss design implications and guidelines for sustainable HCI resulting from our fieldwork.

6.1. Energy Consumption as Phenomenon

The first step in the proposed phenomenological agenda called for a description of the elements defining the configuration of energy consumption. Our observation shows that people primarily reflect on their energy consumption in terms of wasting. By deconstructing it as an objective quantity and analyzing its configuration, we observed three basic elements characterizing Waste.

—To define consumption as waste, people connect energy consumption to a purpose. This purpose can be linked with a judgment about being "useful" or "nonuseful", a judgment that is strongly related to a personal view and that is not necessary ascribed to a universal value system. We observed that valuing the intentions behind consumption defines whether energy is considered wasted or not.

—A further structuring element of the perception of waste is the efficiency of use of invested resources. Sometimes, wasting becomes defined by the amount of used resources and the purpose itself remains irrelevant.

—In most of the cases, energy wasting cannot be subordinated completely to the purpose or to the used resources. We showed that in many cases, waste can only be judged by proportionality mediating between these two elements, as presented in Section 4.1.3.

Our study shows that energy consumption does not exist by itself, but is always an attribute of other meaningful categories. A similar observation was made by Wilhite et al. [2000], who pointed out that people do not consume energy, but use services that consume energy (e.g., by using the Internet in an assembly of devices and appliances like PC, monitor, router, data centers, etc., that consume energy). We further observed that in attributing energy consumption, people differentiate between background and embodied services. This observation connects the results of Wilhite et al. [2000] with the thoughts of Pierce and Paulos [2011] on the human-electricity relationship. Synthesizing these ideas with our own observations, we can define two modes of energy consumption.

—*Embodied services* are those forms of energy consumption originating from the actual, present agency of the subject.
—*Background services* are those forms of energy consumption that make the lifeworld of the subject possible, but without an explicit involvement of the subject.

Our relationship with energy depends on the kind of service causing consumption. Consumption as an embodied service creates a feeling of direct responsibility in case of waste. In contrast, background services are often perceived as constituting a necessary foundation, belonging to a world external to the individual's agency, and hence these services are perceived as not being subject of one's responsibility. The kind of service attributed to energy consumption also affects the definition of waste (e.g., the standby consumption of the TV used as an embodied service is wasteful, yet the always-on consumption of the router used as background service is necessary, and hence not wasteful). Consequently, the use of feedback mechanisms must take into account the kind of service being monitored. Direct feedback is more suitable for embodied services, whereas total cost of ownership can be more suitable for background services.

The qualities of a phenomenon cannot exist in a vacuum. They emerge when we make the phenomenon accountable, so a further step in our phenomenological agenda called for a reconstruction of the methods used by people to make energy consumption accountable. In our study we could identify four common methods.

Comparing appliances of the same kind. This first method was based on comparing consumption among appliances of the same kind. This was typically used as way to detect wasteful resources. This strategy was used both for embodied and for background services, but it was more common for background services, which can be explained by the fact that they are often based on appliances that are easily comparable (such as comparing two refrigerators), whereas embodied services are constituted by several appliances, some of which might even be unknown (e.g., watching football).

Using money as a universal reference system. A second method observed was the use of money as an universal reference system to make consumption accountable. This confirms previous findings of Kempton and Montgomery [1982] about money as a popular method for expressing energy consumption. In contrast to physical energy units, the skill of using money as an accounting method is already part of the cultural knowledge that we acquire during our lives. We can easily understand "10 dollars" but, unless we are trained specifically for this, it is not easy to understand the meaning of "10 Kwh". The use of money as an accounting method emerges from its quality of expressing an exchange value capable of making the unequal equal [Fraser 1998]. By virtue of this quality, energy consumption can be brought into relation to any other kind of consumption. This advantage is at the same time, however, a major drawback.

It detaches the compared elements from their concrete value within an actual context [Fraser 1998], which is central to establishing a richer relationship between the compared categories. As an observable expression of this drawback, we observed that accounting with money was typically embedded in a web of other accounting methods which were used to recontextualize the abstract meaning of money with regard to the particular context.

Referring to someone else's consumption. A further observed method was the use of someone else's consumption as a reference for measuring one's own consumption. People used this method as an inquiry instrument to detect anomalies in consumption, and to trace wasteful appliances or behavior. To be able to use and interpret this sort of reference, people required sufficient understanding of the context of the used data. People didn't express any problems when using data from their own household, but were not interested in using other statistically similar households, as they had problems assigning their households to a certain category.

Providing social comparison on a household level is quite popular [Mankoff et al. 2007; Stapel and Suls 2004]. However, our study confirms previous findings showing reservations against this kind feedback [Følstad 2008]. As expressed by one participant in a study conducted by Roberts et al. [2004], "each individual house is a different one." Our findings indicate that comparative feedback would be perceived as useful if the social context of the comparative data is provided as a complement to allow people to draw usable conclusions from.

Habits and past actions as a resource for accounting. The last observed method consisted of the use of knowledge on local habits and past actions to provide a meaning to energy consumption. In literature, routines and habits have become a key element of the latest research in theories of practice (refer to Davis [1989] and Hassenzahl [2006]). Practices are understood as routinized, embodied action, not only encompassed by mental and physical forms of activity, but also imprinted by artifacts and closely linked with perceptions of the world, common language, and shared identities. In our study we observed that routines and habits provided practical knowledge about life history, which was effectively used to give visualized data a meaning. Habits were used to establish a relationship between energy consumption and specific situations and activities in the past. The reference systems provided by habits are highly personal and bound to a specific context. In this sense, the use of personal habits is complementary to the use of money. Accounting with money helps to decontextualize categories from a specific situation. Accounting by means of routines and habits helps recontextualize consumption in a specific situation, giving energy consumption a meaning in the personal lifeworld, which, as we observed, can change the perception of consumption.

Figure 3 provides a visualization of the results of our exploration of the phenomenon of consumption. Energy consumption represents a phenomenon that is configured by elements such as the ones presented in this article: wasting energy and modes of consumption. These constitutive elements appear in concrete forms. For wasting energy, the observed forms were comsumption purposes and efficiency, as well as the relationship between these two forms (see Section 4.1). It also appears in different modes of consumption: as embodied or as background services (see Section 4.2). The inquiry into how these forms came into existence leads us to identify four accounting methods: accounting with appliances (see Section 5.1), accounting with money (see Section 5.2), accounting with other (see Section 5.3), and accounting with *habits* (see Section 5.4). These accounting methods are not used alone. Instead, they constitute a toolbox where the diverse items are composed fluidly by our participants to deal with the complexity and dynamics of their everyday energy consumption, as the lines connecting the

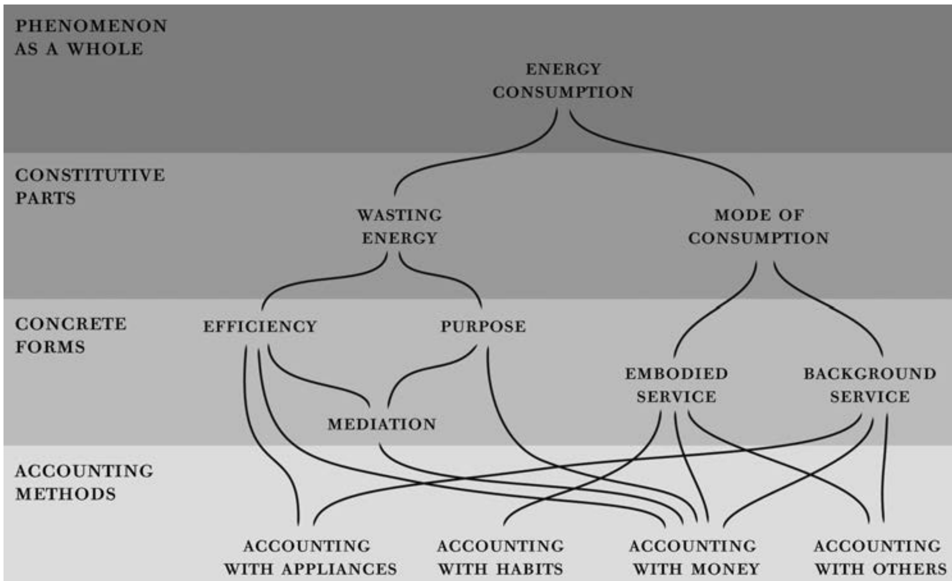

Fig. 3. Structure of the phenomenon of private energy consumption as reconstructed from the accounts given by participants of the study.

different elements show. The connections in the diagram are not exhaustive, however, and only represent connections that were observable in our empirical work.

6.2. Implications for Design

Button and Dourish [1996] pointed out three forms of learning from fieldwork investigation.

—*Learning from critique*. Fieldwork helps to uncover a false assumption in framing the problem.
—*Learning from fieldwork accounts*. Fieldwork helps to inform design around where specific features is used.
—*Learning from techno-methodological design*. Is where fieldwork helps to adopt foundational ethnomethodological principles to the general design concept.

Although there is no clearly defined demarcation between these forms, we still find them useful as guiding principles to structure the lessons learned from our study. As pointed out by Dourish and by Gaver, there isn't necessarily a causal link between observation and design implications [Dourish 2006; Gaver et al. 2003], and in that sense, we cannot show a direct link between fieldwork observations and our guidelines. Consequently, what we want to provide in this section is rather a series of design interpretations that show forms in which designers can use our results as a form of scaffolding to explain design decisions. This form of interpretation leaves space for inspiration as a whole and not resulting just from empirical work.

In the rest of this section, we use our results to delineate a critique to the existing paradigm in sustainable interaction design. We then provide aspects of a design rationale for sustainable interaction, and we close the section with foundational principles to further work in sustainability in HCI.

6.2.1. Critique on the Dominated Eco-Feedback Design Paradigm. There is a growing amount of research in HCI stressing the need for adequate technologies when approaching sustainability. A specific application from this research is the aforementioned progressive introduction of smart metering in Germany. While studies in controlled setups show benefits in using smart metering systems, the German experience shows a lack of user confidence and market acceptance which might point to a failure of the existing design concepts [Bundesververband Verbraucherzentrale 2010; Paetz et al. 2011]. Using our study as a foundation, we can identify two false assumptions in the framing of the problem which could explain this contradiction:

Physicalism in eco-feedback design. Because energy is a physical entity, there is the false assumption that this also applies to the consumption of energy and hence, the design has to center around the physical entity. Our study demonstrates, however, that although energy consumption has a physical substrate, it is primarily an entity residing in the lifeworld of people. In environmental research, this physicalism has been already criticized by Stern [Hassenzahl 2007], who argued that "blind spots" within this paradigm lead to ignoring aspects of "social organization of energy consumption." A consequence of this false physicalism is that feedback systems often fail to provide energy consumption information with a meaning emerging from people's daily life. Strengers [2011] identifies this problem, pointing out a "need to rethink the role and design of eco-feedback, rather than simply improving feedback within existing paradigms."

Rationalism in eco-feedback design. An important consequence of the results of environmental psychology is the dominance of a rationalistic paradigm that stresses [Strengers 2011] the importance of principles of efficient and rational decision-making [Strengers 2011]. Within this paradigm, energy saving is mainly a matter of making correct, deliberate, and rational decisions. The purpose of technology is to persuade the user to make the right decision and to provide the needed information to support that decision. This kind of rationalism is visible, for example, in the false assumption that wasting can be an objective, measurable quantity. Our study shows that wasting is socially constructed. To be accountable, waste depends on socio-technically shaped practices. Further examples of this false rationalism are the presumption that social comparison works only by means of motivation or that money is just an economic factor. Our study shows that both serve as a foundation for people to give a meaning to energy feedback data.

We want to argue here that the design of supporting systems should drop these false assumptions and focus design on the reconstruction of consumption as it appears in the lifeworld of people. This should not suggest dropping the idea of eco-feedback just because it is no silver bullet or because the relationship between energy, technology, and practice is too complex and multifaceted to be addressed by design. Both arguments are true, but eco-feedback, nevertheless, plays an important role in providing measured data as a resource for people to construct their own consumption practices in an environmentally conscious fashion. For systems to be able to play this role, eco-feedback needs to be weaved into our complex daily lives, and consider the particularities of individuals in accounting for consumption.

6.2.2. Designing Basic Features. The observation of the phenomenon of energy consumption provides insights into defining relevant features for technology that support sustainable lifestyles. Here we use the observed elements and methods to derive aspects for constructing a rationale for the design of sustainable interaction.

Wasting energy. The first element presented in our results is the fact that people primarily think about energy consumption in terms of wasting. Even though wasting (in the form of money) is also a key category in rationalistic paradigms, the majority of existing eco-feedback systems are mainly based on visualizing absolute values like kWh, CO_2, EUR, or USD [Froehlich et al. 2010; Hassenzahl et al. 2003]. Our study showed, however, that feedback should also inform us about the relationship of waste with the purpose of consumption and with the source of consumption, and furthermore, with the interplay of these two aspects. Approaches that move in this direction are, for example,the work of Bonino et al. [2012] on visualizing energy in the form of traffic lights with specific categories of consumption in terms of waste.

Consumption and the present self. A further argument in our work, which is rarely addressed in literature, is the form of relationship that people develop with the consumed energy. One of the few works that goes in this direction is the research of Pierce and Paulos [2011]. However, the primary research interest therein lies on supporting the creation of an emotional bond with energy. Our study shows that there are differences in how people develop their relationship with services consuming energy, and the perceived mode of consuming service defines the constructed relationship depending on the mode of the services. In the case of embodied services, people can take direct influence on energy consumption and therefore it makes sense to use direct feedback mechanisms that respond to specific actions of the user. In the case of background services, on the contrary, consumption is not perceived as part of any actual agency, so in these cases the system should rather support users in thinking about the total cost created by the consumption of the background service, including economical as well as environmental aspects.

Comparing consuming appliances of the same type. Eco-feedback systems should provide basic means to support the practice of comparing the consumption of appliances. In particular, the system should allow the comparing of appliances both locally as well as with others of the same type available on the market.

Accounting with money. Our findings show that money is an essential element in existing accounting practices. It worked due to being a learned universal system, used by people to understand and explain consumption and by using their ability to judge it in terms of a familiar unit. In this sense, the use of money as a unit in current eco-feedback systems represents a useful feature. However, the existing design approaches reduce money to just an external, economical motivation for saving energy. In doing this, they miss the potential of money being used as a method for connecting, contextualizing, and creating meaning for consumption in the lifeworld.

Accounting with others' consumption. Eco-feedback systems should provide appropriate means for comparative feedback. As noted before, existing systems address this issue only on a household level and use values based on statistic information externally imposed. The lack of transparency regarding the social context of data and the reasons motivating its aggregation, however, undermine the confidence of people and make the extraction of useful conclusions difficult. Design should consequently explore new strategies to include social context of consumption and to improve the explainability of the parameters defining comparisons.

Accounting with habits and situated actions. As we observed, energy becomes explainable by means of actions causing consumption. Existing eco-feedback systems, however, provide only limited support for connecting the provided data to individual actions. Several systems provide a timeline or other historical perspectives of consumption, but they often lack elements to correlate temporally structured activities with the temporally structured energy consumption. The design of sustainable interaction should take into account the need for establishing this connection, providing features to support the discovery of patterns and exceptions based on uses and habits.

6.2.3. Designing for Accountability. Addressing the third form of learning discussed by Button and Dourish [1996], in this section we want to extract foundational design principles that underlie the critique and the concrete features presented in the previous sections. All the elements and accounting methods that we observed are not isolated, but are part of a complex network of situated practices of decontextualization, translation, and recontextualization, which provide the basis for making sense out of energy consumption. This work manifested itself in the fluid movement of reference systems to express consumption, for instance, in forms like “weekly allowance”, “two lunches”, or “five wash cycles.” In these movements, an important factor was the ability to make consumption data transparent and explainable. These observed characteristics in accounting for consumption hint to a need for supporting systems which take into consideration the situatedness and subjective character of consumption and allow users to move easily between reference systems to explain consumption. We here adopt the techno-methodological concept of *designing for accountability*, in the form of two different but closely connected design principles that should help in getting systems that expose the described qualities.

Providing contextualization for interpretation. As discussed, contextualization plays a significant role in making sense of the energy consumption data. Our findings show that the interplay between energy consumption and a rich context for interpretation helps in understanding consumption and in building competence to account for it. In our studies, people used speculative assumptions and personal memories to give a meaning to the presented data, which in many cases proved insufficient to reconstruct the context for a particular dataset. Existing solutions fell short of providing additional elements to help in this contextualization. An explanation for this shortcoming is the need for mediating between two disparate categories: physical energy measurements and intentional context as part of the lifeworld. The first one is easy to digitally measure, model, and mediate, whereas the second is a construction that cannot be captured [Dourish 2004]. An approach to bridge this gap lies on shifting the focus from data visualization to the idea of contextualization support. To enrich energy consumption measurements, eco-feedback systems should adapt technologies for capturing and tracking personal activities [Chalmers 2004; Flick 2006] and integrate this information into the energy consumption data, to foster learning and reflection on personal consumption patterns. In this context, privacy issues emerge which are out of the scope of this article, but which need to be weighed against the benefits of context tracking.

An option for capturing personal activities is to use collecting mechanisms to feed retrospective analysis. An example of this approach is the research on the SenseCam [Sellen et al. 2007], which provided a mechanism to capture time-lapse recordings for future analysis. This sort of systems could be used to create a corpus of contextual information to support users in case of the need for putting a particular situation in context and draw connections with energy consumption data.

A further method is the enrichment of the environment with cues that help users build a richer context for the interpretation of consumption measurements. This could, for example, be implemented by using sensors on an appliance level and tagging mechanisms to create individually tailored categorization based on dimensions such as device, individual, or group activities, situations, names of persons, rooms, etc. These categories can be particularly useful in the context of embodied energy services, because they provide different perspectives to better understand the particular conditions of current consumption.

Making computational support adaptable. We showed that consumption is highly individual and that feedback needs to consider this in order to be understandable. People have their own value systems which define, among other things, when consumption is viewed as wasteful. These value systems can be highly dynamic and change from situation to situation. A good example of this dynamic can be observed in Section 5.2, which shows in a short sequence several shifts between different reference systems to account for the same consumption.

A way to address these issues is to make systems open to adaptations by the users. An important foundation for moving in this direction can be found in the results of the End-User Development (EUD) community [Egan and Policy 1995], which has been working in the creation of tools and techniques to allow users to redefine the behavior of the system and to tailor it to their needs. In the context of sustainable HCI, these methods could be used on several different levels. In the case of comparisons, for example, adaptability could make it possible to include individually defined metrics or to redefine comparable groups and classes. A further form of adaptability can be seen in the tagging idea presented in the previous section. With the help of user-defined tags, users could progressively create a feedback system that displays consumption in a language that is more meaningful, and that better captures the different reference systems in use for a certain situation. This would allow users to analyze consumption based on personal patterns and filters, to detect individually defined forms of wasting.

7. CONCLUSION

In our work, we have introduced a phenomenological approach to understand energy consumption practices. Existing research on sustainable interaction design has mainly focused on unmediated feedback of consumed energy units [Froehlich et al. 2010]. Although these efforts provide a useful foundation, they miss the relevance of the embodied quality of energy consumption. Building on the work of Pierce and Paulos [2010, 2011], we constructed a theoretical background that focuses on the importance of energy consumption as a practice embedded in people's daily lives. To inform our framework, we conducted fieldwork to observe existing accounting practices and to explore the potential of technology to create new practices. Our empirical investigation revealed diverse elements of energy consumption understood as an intentional, embodied entity.

To explore accounting practices, we introduced basic metering devices in 16 households, to observe and discuss the practices emerging around them. A central issue observed in our results is the importance of mechanisms used by people in making their own consumption processes accountable and explainable. This issue showed the need for technology to provide a foundation for these mechanisms. For future designs, this implies a change for the intended use of eco-feedback artifacts. Following our results, these artifacts should provide feedback mechanisms to support people in creating mundane methods to configure their energy consumption. In this sense, feedback is no longer a goal, but rather a resource that becomes part of a more complex system of energy consumption practices.

Technology should help people contextualize information and support the construction of connections between consumed energy units and events in life. We believe that these connections will help people to reconcile their energy practices with their intended lifestyle, creating an important opportunity for HCI to contribute to an environmentally friendly life.

Our study indicates that supportive technologies should include, but are not limited to, persuasive feedback devices. In particular, our study reveals that people need more than sheer motivation. They need rich feedback technologies that help them create meaning in regard to the measured energy data. We do not claim that our study describes the phenomena in its entirety, nor do we expect that the provided list of elements and methods is complete. In particular, our study is limited in several dimensions. First, while our short-term intervention presents a suitable breaching experiment to illuminate how people use existing methods to structure the new situation introduced by technology, a more long-term study is needed in order to study the transformational character of new technology in everyday practice. Second, our study is also limited in the sense that we only have first indicators that, for example, smart meters do not just give feedback on the objective reality, but intervene in the complex network of relationships within domestic life. Making the individual consumption accountable through more fine-grained monitors, for example, also increases the pressure to justify "wasteful" lifestyles (as indicated in Section 5.2). As a third point, our study was conducted in a specific urban region with a dominant western culture, so to generalize the findings and to convey them to other cultures and socio-technical conditions might not be straight-forward. Finally, the design of appliances is a complex process involving several stakeholders: providers, utilities, product manufactures, all of which have their own characteristic sense-making processes and play a part in designing the resulting concepts. A multistakeholder perspective was out of the scope of this article, but it remains an important question for future work.

Our study provides a conceptual framework which is empirically grounded in the mundane accounting methods of people. Future studies could further investigate the relationship between practices, performance, and reflection, a topic often disregarded in approaches informed by practice theory. We did not, for instance, investigate the very interesting question of the relationship between our results and the findings of the motivationally-oriented HCI research on energy behavior [DiSalvo et al. 2010]. In particular our study prompts the question as to which extent does the perception of something as a background service affect energy-saving motivations, without regard to proenvironmental attitudes [He et al. 2010]. In addition, our study also prompts the question of the correlation between accounting practices and proenvironmental attitudes. These are intriguing questions that we would like to help uncover, but at this moment still remain to be answered.

Thus, our observed elements and structures should be read as an empirically motivated hypothesis that is open for further exploration. Our inquiry represents a next step towards providing a practice-centered understanding of energy consumption. We empirically show that an environmentally friendly lifestyle is not only a motivational, but also a practical question of how to make energy consumption accountable.

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