Materializing Energy

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ABSTRACT
Motivated and informed by perspectives on sustainability and design, this paper draws on a diverse body of scholarly works related to energy and materiality to articulate a perspective on *energy-as-materiality* and propose a design approach of *materializing energy*. Three critical themes are presented: *the intangibility of energy*, *the undifferentiatedness of energy*, and *the availability of energy*. Each theme is developed through combination of critical investigation and design exploration, including the development and deployment of several novel design artifacts: *Energy Mementos* and *The Local Energy Lamp*. A framework for interacting with energy-as-materiality is proposed involving *collecting*, *keeping*, *sharing*, and *activating* energy. A number of additional concepts are also introduced, such as *energy attachment*, *energy engagement*, *energy attunement, local energy* and *energy meta-data.* Our work contributes both a broader, more integrative design perspective on energy and materiality as well as a diversity of more specific concepts and artifacts that may be of service to designers and researchers of interactive systems concerned with sustainability and energy.

Author Keywords
Sustainability, energy, materiality, design, design theory

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
Energy is a strange matter. According to physicists energy can neither be created nor destroyed. Even stranger, Einstein's theory of relativity tells us that energy and mass are one and the same. Yet ordinary language speaks to the contrary: energy is "produced" and "consumed"; "used", "saved" and "wasted". Energy—in the most general sense of the term, as well as the more limited and commonplace usage as a commodified and usable resource—is without question a matter of fundamental importance. Whatever it is, energy is deeply implicated in all material and immaterial aspects of our being, including the quality of our everyday lives and experiences; our bodily and psychological "energy" and well-being; global conflict and war; the exercise of political "power"; and the sustainment of planetary resources and our world. Energy is strange in part because it can be difficult to say what kind of matter it is, or if it can properly be considered matter at all.

Approaches to design and sustainability often implicitly or explicitly distinguish between energy and material. Within HCI a number of works have dealt with sustainable interaction design as it relates to, on the one hand, the consumption of material goods (e.g., [3,14,21,31]) and on the other the consumption of energy (e.g., [5,9,22,23,29]). However, notwithstanding the work of Backlund et al. [1] and Mazé and Redström [19], HCI and interaction design have not significantly and explicitly engaged integrally with energy and materiality.[1] The design approach proposed and employed here is one of *materializing energy* in everyday life. Broadly this means rather than approaching energy as *immaterial* (as incorporeal and/or inconsequential) instead approaching energy as *material* in both the more objective but also more significant senses of the term. In order to develop a perspective on *energy-as-materiality* we draw on a diverse selection of scholarly works related to materiality and energy, as well as materially explore energy-as-materiality by engaging in the design and deployment of both novel and commonplace design artifacts.

We build on Redström's notion of "technology as a material in design" [24] and Backlund, Gustafsson, Gyllenswärd, Ilstedt-Hjelm, Mazé, and Redström's notion of "energy as a material in design" [1, p. 6]. However, in addition to approaching energy as a material in design (something that designers shape) our work importantly

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[1] Outside of HCI Elizabeth Shove, for example, has more explicitly taken into account relationships among materiality, energy, and sustainability in her sociological investigations of the "social organization of normality" [27].See also Yolande Strengers' work within HCI on smart-metering [29].

proceeds from an understanding of energy as a material *of design* (something designed into existence) and energy as material *that designs* (something that gives shape to human existence and experience).[2]

Our approach is grounded in a belief that sustainable interaction design can benefit from and indeed likely requires substantially rethinking what energy is, how we use energy, and how we *relate to* and *live with* energy. Our work is in part critical in that we challenge unchallenged assumptions about energy in design. For example, approaches to designing behavioral interventions to promote domestic electricity conservation often implicitly assume if not explicitly take as a matter of immutable fact that electricity is readily and relatively cheaply available, that electricity is accessed through household outlets and delivered to us by large centralized systems of energy production and distribution, and that individuals are physically and emotionally distanced from the consumption and certainly the production of their electricity. While our approach is critical in challenging these types of assumptions it is also exploratory in the search for desirable sustainable alternatives. As such, our critical stances are taken as points of departure for conceptual exploration, material actualization, and theoretical articulation of such alternatives. Far from offering a single prescriptive design strategy or a set of clear and actionable "solutions", what we are offering is perhaps most importantly an alternative of "energy alternatives" for design (as distinct from the technological panacea of "alternative energy"). While critical reflection and provocation are employed as methods as well as intended outcomes of our exploration and inquiry a potentially opposing goal underlies our work: to transform extraordinary scenarios of sustainability into the ordinary, and to allow radically sustainable ways of being to materialize as our normal ways of being.

Electrification: Dominant and emerging energy regimes

In this paper we focus primarily but not exclusively on electricity as a form of energy of central importance in contemporary everyday life and society and of particular relevance to HCI and interaction design. Electrical devices and systems not only demand energy in order to operate but in operating as so are implicated in the enormous and ever-increasing demand for energy. Further, interactive products and systems can be said to mediate our perceptions of and relationships with and within our world—and with energy.[3] It follows that interactive technologies can be designed to mediate action and perception in sustainable or unsustainable ways. Particular attention is further made to emerging technologies with the strong potential to disrupt the current sociotechnical regimes of energy, technologies such as renewable microgeneration, microgrids, demand response systems, smart metering and dynamic pricing schemes to name but a few of the most prominent. While these types of interventions are often positioned as sustainable "solutions" less attention is paid to the potentially unsustainable structures these interventions might knowingly and unknowingly help sustain. We argue that designers and researchers of interactive systems should be mindful of the ways new technologies and the impetus surrounding them could be shaped to more profoundly re-shape social expectations and practices in the direction of sustainability. For example, consider renewable *microgeneration* such as solar photovoltaic, wind, and combined heat and power generation. Environmental psychologist Patrick Devine-Wright articulates one vision of microgeneration and "decentralized" energy systems as sites for the emergence of new behavioral, social, and political paradigms of energy:

> It is likely that decentralized generation from homes and buildings, along with local power plant such as small-scale wind farms or district heating systems with CHP plant, will represent very different contexts for energy behaviour in the future. Deployment of micro-generation and smart-metering technologies will transform buildings into power stations and offer unprecedented opportunities for 'in sight and mind' energy systems. These devices not only challenge accepted ways of imagining or talking about energy generation and supply, such as the utility of the concept of 'power station' in a decentralized energy future…but are also likely to substantially raise the salience of energy issues in everyday life, making people more aware of how heat and power is generated, supplied and consumed, and closing the current awareness gap between personal energy consumption and the consequences of such consumption for environmental problems such as climate change. [6, p. 72]

We offer this scenario of a "decentralized energy regime" [4] employing local and domestic renewable microgeneration as but one of many in which to consider reconsidering assumptions informing sustainable interaction design and HCI research, such as the assumption that there exists an ever-increasing (and unsustainable) demand for energy, or that it does not matter to people where their energy comes from. We believe that such a decentralized energy system is one important yet largely overlooked emerging context on which HCI and interaction design research and practice can focus and in doing so help shape emerging technologies in order to re-shape our material, social and cultural

[2] See Tony Fry for an ontological understanding of design as a "relational ensemble": "Put succinctly, designers design in a designed world, which arrives by design, that designs their actions and objects, or more simply: we design our world, while our world designs us." [11, p. 5-6].

[3] See Don Ihde [10] and Peter-Paul Verbeek [30] on the technological mediation of perception and action.

[4] In fact, Thomas Edison and company's initial system was relatively decentralized, consisting of many "central-station" supply centers located within major cities. See Thomas Hughes's comparative historical account of the evolution of electrical power systems from 1880-1930 [15].

conditions into those capable of being sustained. [5]

The remainder of this paper is structured as follows. First we offer a description of our methodological approach, which relies on a combination of theory and design. The following sections of the paper are then organized according to three critical themes: (i) the intangibility of energy, (ii) the undifferentiatedness of energy, and (iii) the availability of energy. Each of these sections articulates a dominant and too often uncritically accepted position of energy and proposes alternative perspectives by way of combining theory and material design exploration.

METHODOLOGY

The aim of our research is much less about understanding current interactions, experiences, and practices around energy than with developing concepts that may be used in service of designing sustainable *future* interactions, experiences, and practices around energy. Nonetheless we wanted to give our theoretical and design concepts a material basis in order to ground our own thinking as well as the presentation of our ideas. In order to achieve these aims we synthesized a methodological approach drawing on various research and design approaches that, despite their differences, are apparently united in seeking to overcome the traditional dichotomies of thought/action and reflection/production, including research through design [33], reflective design [26], critical design [8], and cultural probes [13].

Broadly our method consisted of the following. We ideated many design concepts and progressively refined several conceptually related sets of new and existing physical design artifacts with the aim of expanding the range of interactions, practices, and experiences commonly associated with energy in everyday life. Theoretical ideas from various literatures—especially literature from philosophy of technology, design theory, material culture studies, sociology and anthropology—guided the development of our design concepts; likewise our design concepts helped us interpret, challenge, and develop theoretical ideas. We then presented the design artifacts to participants and moderated discussions around them. 1-2 hour semi-structured interviews were conducting with 5 participants recruited through student classifieds and personal acquaintances. Each session was conducted in our lab or the participant's home and involved 3 sets of design artifacts: (i) everyday "energy things" (Figure 1), (ii) Energy Mementos (Figure 2), and (iii) the Local Energy Lamp (Figure 3). However, it must be stressed that we did not aim to evaluate our design artifacts per se or to collect or analyze data using qualitative research methods in a rigorous manner, but rather we used them as tools—or

[5] See also, for example, Yolande Strengers' work within HCI on smart-metering demand management systems as a design opportunity to shape sustainable comfort and cleanliness expectations and practices [29].

Figure 1. What *is* energy? Objects used to engage participants in a discussion around energy and materiality.

probes—to prompt reflection and discussion around the material artifacts, abstract concepts they might embody or inspire, and other issues around participants' practices, understandings, and feelings related to energy. We then collectively analyzed the conceptual ideas that informed and emerged through the design of the artifacts, the artifacts themselves, and the data we obtained from participant engagement. Put another way, we engaged theoretical concepts, designs, and observation in a dialogue. What emerged from this dialogue was a rich set of design theoretic concepts and conceptual design ideas that we present in the remainder of this paper.

THE INTANGIBILITY OF ENERGY

A common observation among designers and researchers interested in sustainability and energy is that energy is "invisible". A number of research, design, and art projects have attempted to render "invisible" energy "visible" with a goal of promoting "energy awareness" and motivating energy conservation behavior (see, e.g., [22]). It has been argued that *energy invisibility* and *energy unawareness* are in fact two major consequences of material progress within the last century [28]. However, the energy we use daily to power our devices, homes, and cities is not simply perceptually invisible but also intangible. We are unaware of energy largely because it does not have (and is not designed to have) a strong tangible presence in our lives. The various material technologies that provide us with energy effectively distance us from the material production of energy and even the consumption of energy in many ways. Our relationship to electricity, for example, is limited primarily to plugging a cord into an outlet. Our relationship with energy as well as most infrastructural technologies supporting it may said to be constituted in what philosopher of technology Don Ihde describes as a *background relation* [10]. Through background relations, technologies are present to us only to the extent that they help shape the context of our experience; we do not directly and consciously experience them. In the remainder of this section we develop this notion of energy as intangible by investigating diverse conceptualizations of energy. Emerging through these investigations we propose the notion of *energy-as-materiality* and further outline a simple framework for designing interactions with energy-as-materiality involving *collecting*, *keeping*, *sharing*, and *activating* energy.

Energy as a concept

What *is* energy? The modern word energy derives from the Greek word ἐνέργεια (a term resisting straightforward definition yet often simply translated as "actualization") first used by Aristotle. However, the concept of ἐνέργεια has little apparent relevance to the modern physical concept of energy [17, p. 25]. Possibly first used by Bournoulli in 1717 [17, p. 111], the modern use of the term energy in physics denotes a scalar quantity describing the amount of work that can be performed by a force. According to this definition, energy is an attribute of physical objects and systems and subject to the law of conservation of energy. While physicists have a relatively well-defined meaning of the term energy, popular uses of the term are more diverse and less precise. As social psychologists Stern and Aronson and colleagues point out, "there is no single socially shared concept of energy" in modern society [28, p.15]. Stern and Aronson et al. propose four different yet commonly used conceptualizations of energy: energy as a commodity (e.g., electricity, coal, oil, natural gas), energy as an ecological resource, energy as a social necessity, and energy as strategic material. Rosa, Machlis, and Keating trace historical developments of these types of key themes in the sociology of energy, beginning with energetic theories of society that equated social progress with a higher transformation coefficient of "crude energy" into "useful energy" [25]. However, as discussed by Lutenhiser, Harris, and Olsen, energy has been surprisingly neglected within the social sciences up until the energy supply crises of the 1970's and has since tended to fluctuate with societal concerns about energy [18]. In summary, our limited discussion of the complicated and fascinating history of the concept of energy here points unambiguously to its ambiguous ontological status as indicated by a plurality of conceptualizations of energy—as ἐνέργεια, a scalar quantity, the ability to "do work", a tradable commodity, an ecological resource, a social necessity, a strategic material, a measure of social progress, and a neglected yet fundamental sociological variable.

Energy as a "thing"

Beginning with the word energy we ended with a plurality of concepts rather than a definitive meaning. Perhaps unsatisfied, again we can ask: What *is* energy? As a complementary method of investigating this question we chose to begin with energy itself, or things that were potentially energy. We assembled a diverse range of objects and engaged participants in conversations around them concerning energy and materiality. Objects included consumer products commonly associated with electricity such as batteries, solar equipment, and electrical power adaptors. We also included a range of objects we presumed were commonly not associated with electricity but possibly associated with energy more broadly construed, such as food, simple mechanical devices (e.g., a spring), highly combustible materials (e.g., a match), and various other everyday objects (e.g., a ball). Specific questions we asked participants included: What is energy? What does that word mean to you? Sort these things according to "energy" and "not energy" (Figure 1). Is this energy different from that energy?

Our participants were far from having a single clear and shared conceptualization of energy. Each participant in fact expressed multiple, sometimes conflicting, understandings of energy. For example, one participant described energy as something that "is everywhere" and "all around us" but later claimed that certain objects, such as a bottle of glue, were probably not energy. Another participant explicitly distinguished between two notions of energy: energy as a physical force and energy as a "something we [humans] can put into some activity." For another participant, "you can't hold it in your hand and say '*this* is energy.'" Our participants often made a distinction between energy as a physical scientific concept (e.g., "the ability to do work") and more commonplace uses of the term energy (e.g., a battery as a source of energy), often acknowledging an apparent conflict or contradiction between the two. In addition to expressing diverse understandings of energy, participants tended to appear much more comfortable or secure in discussing material objects than energy based on the questions we asked them. For example, participants did not struggle with the concept of a match, an orange, a solar charger, or a battery. They did however struggle with attempts to reconcile material objects and energy: *Is* this object energy? Or does it only *contain* energy? Or does it only contain the *potential* for energy?

Approaching energy as materiality

Thus far we have discussed diverse, at times conflicting conceptualizations of energy. In challenge to the intangibility of energy as it is currently constructed we propose a perspective of *energy-as-materiality* and a design approach aimed at *materializing energy*. Such an approach takes the design of energy as some*thing tangible* as a starting rather than ending point for designerly inquiry and exploration. Taking seriously the notion of energy-as-materiality allows us to draw on a diverse body of scholarly works that broadly take materiality as a matter of concern in order to re-conceptualize and re-design how we think about and interact with energy and energy-related technologies. Our use of this ill-defined term materiality is intended to carry with it various connotations of the material as more than merely object(ive) but also symbolic, social, political, historical and cultural. At this point and prior to presenting more focused approaches to materializing energy we propose a simple framework for designing interactions with energy-as-materiality:

- **collecting** energy (generating/producing)
- **keeping** energy (storing/maintaining)
- **sharing** energy (transmitting/distributing)
- **activating** energy (using/consuming)

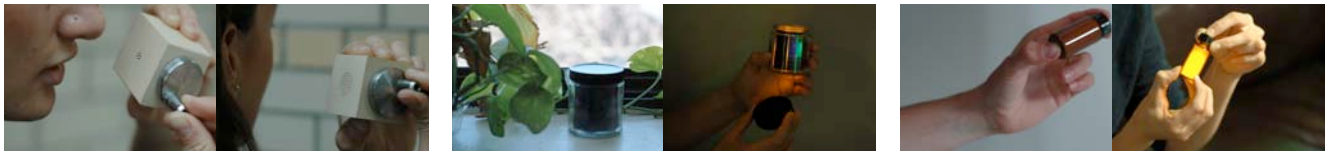

Figure 2. Energy Memento prototypes (left to right). *Crank-Sound Box*. Turning the crank on one face records sound using energy collected from cranking; turning the crank the opposite direction plays the recorded sounds through the speaker on the opposing face. *Light Jar*. The jar collects solar or other light energy; opening the jar activates the energy as a glowing light. *Shake-Light Bottle*. Shaking the bottle collects energy; removing the cap activates the light energy.

Several aspects of this framework are worth highlighting. First, the terms suggest designing for energy as something interacted with and experienced as a tangible *thing*. Second, the terms collecting, keeping and sharing suggest expanding interactions beyond the overwhelming emphasis of interaction design on using/consuming energy. Individuals might instead be more actively involved in collecting ("harvesting") the energy they use on a daily basis, or concerned with how energy is shared within their community. Finally, the terms collecting, keeping, sharing, and activating were chosen with the intention of creating some conceptual distance between their more technically-oriented respective terms generating/producing, storing/maintaining, transmitting/distributing, and using/consuming. We use this framework both implicitly and explicitly throughout the remainder of this paper.

In the next section we articulate a perspective on energy as undifferentiated, draw on material culture studies to describe the design of Energy Mementos, and propose opportunities for shaping the material-symbolic value of energy and energy technologies.

THE UNDIFFERENTIATEDNESS OF ENERGY

Current, centralized energy regimes employing large-scale power plants and distribution networks tend to position all energy as the same, differentiated only by quantity (e.g., kilowatt-hour) and other metrics related to power (e.g., voltage, amperage). While these various abstract scientific properties of energy are manifested materially in the various household outlets and power adapters we interact with on a daily basis as well as the larger-scale material infrastructures of energy such as power lines, our experiences with energy do not significantly presence differentiated instances, types, or qualities of energy. Note for example that the plural form of energy—energies—is rarely used in everyday language. If energy as a *thing* can be said to enter into our everyday experience it is as a single, totalizing entity or phenomena—something vague and amorphous with which our only real concern is "connecting to." Once connected, energy does not matter to us so long as we are able to continue to power our devices, our homes, and our cities. From the perspective of use, all energy is essentially the same—and it is this way by design.

In the remainder of this section we draw on material culture studies and product attachment literature to propose notions of energy attachment, energy possession, and singular energy. We then discuss these concepts in relation to the design and deployment of *Energy Mementos*. We conclude with a discussion of implications stemming from our exploration and discussion of energy as both material and symbolic—as *material culture*.

Energy as material culture

Material culture studies has been described as "a range of scholarly inquiries into the uses and meaning of objects" and which "emphasizes how apparently inanimate things within the environment act on people, and are acted upon by people, for the purposes of carrying out social functions, regulating social relations and giving symbolic meaning to human activity." [32, p. 3]. Material culture studies offers a rich and diverse body of theory and concepts that may be applied and developed in the context of investigating energy-as-materiality, as well as "interaction" more generally. While material culture studies has engaged with "distributed materiality" such as the home, "consumable materiality" such as food, and even "immaterial materiality" such as sound, apparently the field has yet to engage significantly with energy or electricity as material culture. Although we believe many theories and concepts from material culture studies may be useful to investigations of energy-as-materiality, here we consider energy as material culture specifically in order to propose the notions of energy attachment, energy possession, and singular energy—notions of particular relevance to our goal of promoting experientially meaningful and environmentally sustainable interactions and practices with and around energy in everyday life.

The literature related to product attachment (more generally referred to as object attachment or material possession attachment) focuses on people's attachment to particular material objects and, as such, is distinct from general trait materialism, product category involvement, and evaluative affect towards possessions [16]. Rather, product attachment refers to bonds between a person and a particular thing as opposed to a general class of things (e.g., this particular laptop versus laptops in general). Moreover, product attachment literature emphasizes attachment as related to the construction of (social) meanings with and around a material object. Material objects are thus viewed not merely as material or functional objects but as material *culture*. Given the focus of product attachment on particular material objects it is not surprising that a central focus has

been on objects in terms of their singularity or processes through they become singularized, that is, the ways in which a particular object is or becomes unique, personalized, decommodified, irreplaceable (see, e.g., [2,20]). The singularization of objects is related to various *possession rituals* (e.g., using, displaying, storing, discussing, comparing, altering, etc.) [20], through which objects can be said to provide, acquire, or mediate meaning. In light of such perspectives on attachment to material objects we can consider designing for attachment to energy, possession and dispossession rituals around energy, and singular and singularizeable energy. We are now in a position to ask: Can we become attached to particular and plural energies? Can a particular energy be experienced as a singular thing, as meaningful and differentiated from other energies? And, what are the relationships among (energy) attachment, possession, dispossession, and singularity?

Energy Mementos

In order to begin to materially and empirically explore questions raised previously concerning energy attachment, energy possession, and energy singularity, we designed and deployed a set of artifacts called *Energy Mementos*. Energy Mementos are small and unassuming objects intended to allow individuals to collect, keep, share, and activate small amounts or "pieces" of singular(izeable) energy-as-materiality. We designed the Energy Mementos with the goal of prompting reflection on and engagement with particular energies as objects of emotional and perhaps irreplaceable significance. The physical size and form of each object is meant to be suggestive of that of a small physical keepsake or memento and is not intended to communicate any obvious utilitarian function. The interaction with the Energy Mementos was further intended to facilitate discussion of various possession rituals possibly leading to attachment (e.g., using, displaying, storing, discussing, comparing, bequeathing, inheriting, altering, personalizing). A general description in terms of our proposed framework of collecting, keeping, sharing and activating energy is given as follows: **Collecting—**Small amounts of electrical power is generated from bodily motions (turning, spinning, pushing, pressing, etc.) or other sources of micro-power, such as sound or light; the energy is collected by physically manipulating the memento (e.g., placing it in sunlight; shaking it). **Keeping—**The electrical energy collected is stored with small batteries or supercapacitors; the energy is kept "within" the containers (e.g., bottle, jar, box). **Sharing—**The energy cannot be directly transmitted electrically to other mementos or devices, however individuals can share the Energy Memento by physically giving it to someone. **Activating—**The kept energy can be activated as light (e.g., LED, LCD display), sound, or mechanical motion.

For example, the *Shake-Light Bottle* works as follows: Shaking the bottle collects energy; the collected energy can be activated as light energy by twisting and removing the cap, making the bottle glow. One envisioned scenarios for the shake-light bottle would be to carry the bottle in ones pocket, allowing it to collect energy throughout the day as a result of ones routine bodily motions. Later, the bottle could be given to a loved one as an expression of the giver's personal energy. The recipient could then keep the bottle in a special place, such as a shelf or drawer in the home. The recipient could, perhaps in a moment of longing for the giver, open the bottle to activate the giver's energy. The energy would be activated as a unique pattern of light colors and intensities, communicating a unique pattern of daily energy-generating activity of the giver.

We initiated interaction and discussion with participants around several Energy Memento prototypes (Figure 2) during semi-structured interview sessions. Many participants responded positively to the mementos and by virtue of our simple descriptions of their operation alone appeared to identify positively with notions of singular and emotional energy. For example, one participant responded to the description of the mementos as follows:

> **R:** I think of it like magic. Pure, like special little energy. Like my special little recipe for energy, cuz this is like energy that is not a part of that big amorphous grid I was talking about. It's, like, *in my hand*.
> **I:** Is this energy different from other energy?
> **R:** Isn't like all energy the same? Like physics? At the same time: No. I feel very different about this energy. Because it's not very practical…? Like…this infinite world of three pronged outlets…like what am I going to do with this? But at the same time it's better.

Another participant responded particularly strongly to a scenario we proposed in which the Energy Mementos had been in his family for many generations: "I'd want to *add* to it! … I'd never even use it, except maybe for special occasions." However, one participant found the Energy Mementos difficult to comprehend, and instead struggled to find utilitarian value in the mementos. Overall, most participants expressed that the Energy Memento, as energy rather than object, was in some ways very different yet in others very similar to the electrical energy they accessed through the power outlet. The notion that energy could be differentiated and acquire emotional significance was apparently an unfamiliar one yet one that could be assimilated to existing experiences with objects. Still, participants highlighted differences between physical mementos and Energy Mementos, for example, the differences in sensorial richness of a handwritten note versus an LED, and the differing rate and quality of the degradation of energy versus materials like wood over time.

Designing for energy as material and symbolic

Proposing a more explicit treatment of the design of energy as both material and symbolic is certainly not without problems. On a very pragmatic note, the fact that energy is "consumed"—its materiality-at-hand degrading and eventually dissolving entirely—may suggest longevity and

endurance as inappropriate notions to apply to the design of everyday interactions with energy. How and why should the symbolic value of energy endure if its materiality does not? In terms of sustainably re-designing our ßeveryday interactions with energy and energy consuming products, the notion of *care of energy* may be more appropriate than that of *attachment to energy*. We might design for caring for our energy in the same ways that one cares for the materiality of food when gardening or preparing an elaborate meal. As a more concrete example, it may be worthwhile to design microgeneration technologies in ways that promote a form of emotional attachment to or care for energy. Indeed evidence from interviews with residents using domestic microgeneration technologies points toward forms of attachment to energy based on the introduction of these technologies, even among those that did not commission their installation. For example: "The advantage with [solar power technologies installed in his home] is that it makes you think about your energy use more. You value it more…" and "I want to feel that as much electricity as I can use is my own electricity." [7, p. 51-53].

Perhaps more problematic is that designing energy to more explicitly enter into the symbolic realm of consumption may lead to the increased material consumption of energy by way of its being increasingly sought after as an unsustainable object of desire.[6] Criticism of such a "reification of energy" must be taken seriously, yet we must also acknowledge that all material and immaterial technologies are already symbolically consumed, including energy technologies such as solar panels. The material-symbolic value of energy and energy technologies can be considered or ignored by designers as well as manipulated in ways working for or against goals of sustainability. Whatever the case, the symbolic value of energy and energy technologies is always to some extent present. As such, we argue it is imperative that designers aim to sustainably redefine (or "recode" [12]) our understandings of and interactions with energy through careful attention to the material-symbolic value of emerging as well as commonplace energy related technologies and the energy they materialize. The Energy Memento may be viewed as a way of materializing the concept of the material-symbolic value of energy. Bequeathing an heirloom Energy Memento, for example, seems quite unlikely to ever become a common practice but nonetheless serves as useful counterpoint to the current undifferentiatedness of energy and offers an alternative to our currently unsustainable situation in which energy is merely "something to"—something undemanding and undeserving of our sustained care and attention.

THE AVAILABILITY OF ENERGY

As we have proposed thus far, everyday energy is both intangible and undifferentiated. At the same time, electrical and other forms of "usable" energy are readily accessible, at least in most contexts of the "developed world." The occasional event in which energy becomes unavailable—when gasoline prices surge, a power line is down, or we cannot locate a power outlet at a café—are often our only hints at the otherwise unremarkable availability of energy. The availability of energy, as we will discuss, is tied to disengagement with energy and energy technologies. In what follows we draw on theory from philosophy of technology in order to arrive at two different yet related approaches to designing for meaningful and enjoyable *focal engagement* with energy and energy technologies.

Focal engagement, effort and energy

In *Technology and the Character of Contemporary Life*, philosopher Albert Borgmann building on the work of Martin Heidegger argues that modern technology has over course of the last three centuries developed a distinctive pattern which has given rise to a radically new way of life [4]. Borgmann argues that while technology has served well to, for example, combat human hunger and disease it has also exerted a controlling pattern on our lives and detracted from the richness of human experience. For Borgmann, this is tied to technological availability. In Borgmann's terms, something is made *available* by technology if it has been rendered instantaneous, ubiquitous, safe, and easy. Warmth, for example, has been made available by the electric furnace. Borgmann distinguishes between *devices*, which render *commodities* such as warmth available, with *things,* which *focally engage* and are never purely means to some end. Borgmann gives the example of a central heating plant (a device) in contrast to a wood burning stove (a thing). The stove differs from the central heating plant in that it "was used to furnish more than mere warmth. It was a *focus*, a hearth, a place that gathered the work and leisure of a family and gave the house a center. … It provided for the entire family a regular and bodily engagement with rhythm of the seasons that was woven together of the threat of cold and solace of warmth, the smell of wood smoke, the exertion of sawing and of carrying, the teaching of skills, and the fidelity to daily tasks." [4, p. 42]. As another example of what Borgmann terms *focal things* and *focal practices,* the "culture of the table" is contrasted with modern practices around technologically available food: "The Great meal of the day…is a focal event par excellence. It gathers the scattered family around the table…gathers the most delectable things nature has brought forth…recollects and presents a tradition… brings into focus closer relations of national or regional customs, and more intimate traditions still of family recipes or dishes." [4, p. 204].

While Borgmann concludes, in line with Heidegger, that only "pretechnological things" carry the potential for focal engagement, philosopher of technology and design theorist Peter-Paul Verbeek argues that devices, including digital

[6] See Tony Fry for a discussion of symbolic devaluation and the destruction of sign value as a strategy for sustainable design [12].

Figure 3. The Local Energy Lamp. A variety of ways of communicating "qualities" of energy with energy meta-data were explored. For example, white, yellow, blue, and red tinted lighting correspond respectively to the real-time use of energy from "central coal power", "local solar power", "local wind power", and "local human power".

technologies, can also invite experientially enriching and meaningful types of focal engagement [30]. Verbeek—who is critical of Borgmann and Heidegger's perspectives on technology, which he accuses of being nostalgic and romantic—attempts to rescue Borgmann's analysis from the "alienation thesis" of technology. [30, p. 185]. In particular, Verbeek refines Borgmann's concept of *engagement* by distinguishing between *effort* and *focal engagement*. Whereas focal engagement suggests an intrinsically meaningful involvement with a thing, effort suggests a type of engagement that is not intrinsically rewarding and is done only as means to some end. Verbeek gives the example of focal engagement with an electronic keyboard or electronic sewing machine, which is contrasted with the effort involved in refilling the car with gasoline.

A major reason that we are drawing so heavily on Borgmann and Verbeek lies in linking the potential unsustainability of technological availability and consumption with the possible reduction in the richness of human experience associated with disengaged consumption and technological availability. While Borgmann's as well as Verbeek's account of technology and engagement are certainly open to criticism, we nonetheless aim to show how each perspective can be translated into approaches to materializing energy in terms of promoting sustainable focal as opposed to effortful engagement with energy. In particular we outline two different yet related strategies for sustainable energy-interaction design: (i) materializing engagement with energy through engagement with energy devices (e.g., solar panels, mobile phones) and (ii) rematerializing engagement with energy as reengagement with simpler things (e.g., windows, the outdoors, the sun). The former strategy follows Verbeek in assuming that modern technologies can also promote focal engagement. This strategy aims to design for focal engagement with energy by promoting engagement with the material technologies involved in collecting, keeping, sharing, and activating energy. The second strategy follows Borgmann in supposing the difficulty or impossibility of focal engagement with modern technologies. This strategy instead aims to reduce our reliance on electricity and electricity-consuming devices as well as other technologies that require a source of commodified energy. This approach involves what design philosopher Tony Fry writing on sustainability describes as *rematerialization*, the "substitution of human labour for machines in a smart way" [12, p. 79] and the "recoding" of such experiences "as means of…being in touch with circumstances and the quality of material things" [12, p. 219]. Based on this discussion, we propose the following research questions: How might we design for sustainable focal engagement with energy and energy technologies? How might we metaphorically aim to design interactions with energy as gardening, tending to the hearth, or preparing and sharing an elaborate meal? Or how might we literally aim to revive such *focal practices*? And how might we navigate between the two extremes of both strategies of *energy engagement*?

Local energy and the Local Energy Lamp

In order to explore potentials for different types of focal engagement with energy and energy technologies discussed previously, we focused a material investigation around several renewable microgeneration technologies. In particular, we developed a set of design artifacts and questions around the notion of energy that is actually or perceptually limited in its availability. We presented participants with several functional microgeneration systems including a small-scale solar and hand-powered microgeneration and storage systems. We further designed, prototyped and presented to participants a system employing a redesigned household lamp—the *Local Energy Lamp*—capable of communicating the "quality" of the energy it consumed with the quality of light it produced (Figure 3). *Energy meta-data* concerning the source, age, and other unconventional attributes of electrical energy are visualized by varying the color, brightness, and consistency of the light of the lamp, which still functions primarily as household lamp for indoor lighting. The Local Energy Lamp and microgeneration systems were used to propose various scenarios to participants. For example, the color of the lamp's light was implemented to subtly change color to correspond to the availability of different sources of power, or the current source of energy being consumed (Figure 3).

In response to the various microgeneration technologies presented, all participants at times expressed positive reactions, describing the microgenerated energy as being "free", "homemade", "personal", and "clean." Several participants described envisioned scenarios we might describe as being characterized by focal engagement. For example, in reaction to scenarios in which he was able to generate solar, wind, and human energy and engage with this energy via the Local Energy Lamp, one participant responded: "I feel like that'd be kinda cool, especially in today's culture. Cuz you'd get a real sense of satisfaction. … It'd be like gardening but with a laptop, like harvesting power… I wanna compare it to gardening. A lot of people find that pleasurable—in the same way people find cooking pleasurable. Like it's sort of sustaining your life, but a lot of people find it fun…like *tending to your solar garden*." The analogy to gardening, farming, and cooking—all potential

examples of focal practices by way of Borgmann—is a recurring and important theme in our limited empirical study as well as other empirical studies of microgeneration technologies. In the previously cited study of microgeneration technologies in the home such comparisons with gardening and food come up on several occasions. For example, one individual using micro-hydro power remarked: "It gives a certain satisfaction knowing that you're using something you've produced yourself, like growing your own vegetables." [7, p. 3]. These findings point toward design opportunities related to *local energy*, perhaps communicated and verified with systems employing *energy meta-data*, similar to recent "local food" movements. Another promising finding was several participants claiming that they may change their routine consumption practices in relation to the availability of different energy sources, as communicated by the Local Energy Lamp, such as altering the times at which laundry is done to coincide with the availability of solar or wind energy. Again, evidence from the use of actual microgeneration technologies in the home indicates similar practices. For example, an individual using off-grid wind power describes his alteration of heating practices based on wind conditions: "When the wind is blowing right up then I turn the electric heaters on – rather than use the gas from the gas bottles." [7, p.7].

Designing for energy engagement and attunement

Energy engagement could be a powerful way of transforming our relationships with energy in more meaningful and sustainable ways. In terms of materializing energy through engagement with energy devices, designers can aim to design technologies with and through which limiting the availability of energy is not perceived of as increased effort but rather as focal engagement. Consider a decentralized energy scenario in which a micro-wind generator is situated atop the roof of ones house or a local community wind farm is shared by members of a city. In this case, *shifting* [23] the practice of laundering to moments when the wind is blowing may be perceived not as unpleasant effortful engagement but rather as meaningful focal engagement with ones technology and electricity, home and community, wind and world. Similarly, microgenerated solar power could help mediate focal engagement with the sun and solar generated electricity leading to individuals turning off indoor lights when they are not being used. As suggested by one participant it could be like "tending to your solar garden." In terms of rematerializing energy through reengagement with simpler things, designers can design for the replacement or displacement of energy-consuming devices in favor of rematerializing focal things such as hand tools that require only human bodily energy to function. To continue with the above examples, engagement with "local" wind and solar energy could promote displacing the automatic clothes dryer in favor of air drying clothes or displacing indoor lights during the daytime in favor of natural lighting. Services and systems could be cleverly designed to build on the engagement mediated by solar panels between individuals and the sun and the natural rhythms of the seasons, perhaps helping to rematerialize farming and passive solar heating practices.

We propose that one useful way of thinking about *energy engagement* is in relation to *energy awareness*, which is one of the most common strategies taken by interactive systems designers and researchers interested in energy and sustainability. This approach essentially aims to make people more cognitively aware of energy consumption, often through the use of "real-time" feedback and with a primary goal of directly or indirectly motivating conservation behavior. As a bridging concept between energy awareness and energy engagement we offer the notion of *energy attunement*, by which we mean to suggest approaching cognitive energy awareness as an experiential materialized presence of energy that invites focal engagement. As illustrated in the above examples and following the discussion in the introduction an important emerging opportunity area is designing for attunement to the *collection* of energy. Another important emerging area is energy demand response and smart-metering systems, suggesting designing for attunement to the *sharing* of energy. Speaking figuratively, the concept of energy attunement suggests a conceptual shift from shouting at people *about* energy to inviting them to be more in touch *with* energy. However, we also note that strong consideration must be given to the potential for any well-intentioned technological intervention to further separate our selves and our energy and to help sustain unsustainable practices. For example, consider the possibility that equipping homes with advanced energy sensing infrastructures for energy awareness or energy attunement could in fact maintain or increase the demand for energy consuming devices, which would then, of course, demand being sensed.

CONCLUSION

We have drawn from a diverse range of perspectives on materiality and energy in order to propose a more integrative perspective on *energy-as-materiality*. In doing so we have more explicitly drawn attention to the connections between energy and the material conditions of our designed and designing world. We have proposed and employed a design approach of *materializing energy* through the combination of design exploration and critical investigation. Throughout we have suggested energy as an exemplary "immaterial materiality"—as a very real matter that nonetheless often does not significantly and consciously matter to those who variously and inevitably demand and depend upon it. Indeed, the situation is as it is by design. As we have argued, energy is not simply something with which we are unaware, but energy is intangible, undifferentiated, and available; energy has been designed not to matter to us in these ways. What has

changed is that we now realize the conditions that have been designed are unsustainable. Motivated by the aim of working towards the realization of a desirable and sustainable future, while at the same time struggling to determine what such a future could or should be, we have suggested ways of materializing energy that have variously sought to re-design energy as some*thing* more tangible, more differentiated, and less available. It is our hope and intention that both our broader approach of materializing energy and the specific concepts proposed will be of service to designers intent on designing sustainable interactive systems. Just as we recognize that we currently dwell and design in an unsustainable world of immaterial energy, and that this world designs us to treat energy as immaterial, we must also recognize that we can *design* our world to be otherwise.

REFERENCES

1. Backlund, S., Gustafsson, A., Gyllenswärd, M., Ilstedt-Hjelm, 4. S., Mazé, R., & Redström, J. (2006). Static! The aesthetics of energy in everyday things. In *Proc. of DRSIC*.
2. Belk, R. (1991). "Possessions and the Sense of Past." In Russell W. Belk (ed.) Highways and Buyways: Naturalistic Research from the Consumer Behavior Odyssey.
3. Blevis, E. (2007). Sustainable interaction design: invention & disposal, renewal & reuse. In *Proc. of CHI '08*.
4. Borgmann, A. (1984). *Technology and character of contemporary life*. University of Chicago Press.
5. Chetty, M., Tran, D., & Grinter, R. (2008). Getting to green: understanding resource consumption in the home, In *Proc. Ubicomp '08*.
6. Devine-Wright, P. (2006). Energy citizenship: psychological aspects of evolution in sustainable energy technologies. In J. Murphy (ed.) *Governance of Sustainable Technology*.
7. Dobbyn J. & Thomas G. (2005) *Seeing the light: the impact of micro-generation on our use of energy*. Sustainable Consumption Roundtable, London.
8. Dunne, T. & Raby, F. (2001). *Design noir: the secret life of electronic objects*. Birkhauser.
9. Froehlich, J. Findlater, L., & Landay, J. (2010). The design of eco-feedback technology. In *Proc. of CHI '10*.
10. Ihde, D. (1998). *Technology and the lifeworld*. IU Press.
11. Fry, T. (1999). *A new design philosophy: an introduction to defuturing*. UNSW Press.
12. Fry, T. (2009). *Design futuring: Sustainability, ethics and new practice*. Berg.
13. Gaver, B., Dunne, T., & Pacenti, E. (1999). Design: Cultural probes. *Interactions, 6*(1):21-29.
14. Huang, E.M. & Truong, K.N. (2008). Breaking the disposable technology paradigm: opportunities for sustainable interaction design for mobile phones. In *Proc. of CHI '08*.
15. Hughes, T. (1983). *Networks of power*. John Hopkins.
16. Kleine, S. (2004). An Integrative Review of Material Possession Attachment. *Academy of Marketing Sci. Review*.
17. Lindsay, B. (1975). *Energy: Historical development of the concept*. Halsted Press.
18. Lutenhiser, L., Harris, C., & Olsen, M. (2002). Energy, society, and environment. In Dunlap, R. and Michelson, W. (ed.) *Handbook of environmental sociology*.
19. Mazé R., & Redström J. (2008). Switch! Energy Ecologies in Everyday Life. Int. Journal of Design, 22(3): 55-70.
20. McCracken, G. (1988). *Culture and Consumption*. IU Press.
21. Odom, W., Pierce, J. Stolterman, E., & Blevis, E. (2009). Understanding why we preserve some things and discard others in the context of interaction design. In *Proc. CHI '09*.
22. Pierce, J., Odom, W., & Blevis, E. (2008). Energy aware dwelling: a critical survey of interaction design for eco-visualizations. In *Proc. OZCHI '08*.
23. Pierce, J., Schiano, D., & Paulos, E. (2010). Home, habits and energy: investigating domestic interactions and energy consumption. In *Proc. of CHI '10*.
24. Redström, J. (2005). On Technology as Material in Design. In Willis, A-M. (ed.) *Design Philosophy Papers, Collection Two*:31-42.
25. Rosa, E., Machlis, G., & Keating, K. (1988). "Energy and Society", *Annual Review of Sociology 14*:149–72.
26. Sengers, P., Boehner, K., David, S., and Kaye, J. (2005). Reflective design. In *Proc. Critical Computing*.
27. Shove, E. (2003). *Comfort, cleanliness and convenience: the social organisation of normality*. Berg.
28. Stern, P. & Aronson, E. (ed.) (1984). *Energy use: The human dimension*. Freeman and Company.
29. Strengers, Y. (2008). Smart metering demand management programs: challenging the comfort and cleanliness habitus of households. In *Proc. OZCHI '08*.
30. Verbeek, P-P. (2005). *What Things Do – Philosophical Reflections on Technology, Agency, and Design*. Penn State.
31. Wakkary, R. & Tanenbaum, K. (2009). A sustainable identity: the creativity of an everyday designer. In *Proc. CHI '09*.
32. Woodward, I. (2007). *Understanding material culture*. Sage.
33. Zimmerman, J., Forlizzi, J., & Evenson, S. (2007). Research through design as a method for interaction design research in HCI. In *Proc. of CHI '07*.