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Erratic Appliances and Energy Awareness

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Abstract We are exploring how to increase energy awareness through critical interaction design, creating objects that expose issues related to energy consumption in various ways. To draw attention to energy beyond ordinary conceptions as a technical solution in everyday life, we inquire into other ways of relating to energy in design and to uncover the properties of energy as a design material. To learn more about how energy can be made more present in product design, we have been redesigning a series of everyday objects around the theme of 'erratic appliances'. As household energy consumption increases, these appliances start to behave strangely. The aim was to use designerly and experience-based means to make people aware of their energy consumption instead of measuring energy consumption solely with meters and numeric displays.

Keywords Interaction design · Aesthetics · Energy

Introduction

While often at the forefront of trying to expand consumption and material welfare, designers are now increasingly facing the issue of how to achieve the opposite. Perhaps, as industrial design once helped to launch the range of electrical home appliances we can hardly live without today, design can now play a role in increasing consumer awareness of energy use and the consequences of overconsumption.

Thinking about design and its relation to energy use in a product, the importance of energy as a material building the object does not seem to translate into the way we think about its design. Certainly, we notice if the electricity needed is not available – we expect it to present itself to us as we use it, although, in this case, it is hidden to us. Thus, we do acknowledge it as basic material building the thing. Consider, for instance, just the energy needed for maintaining products in standby mode: estimates show that products such as computers, television sets, mobile phone chargers and other electronic appliances on standby consume as much as 300-700 kWh of electricity per year in a common Swedish household (IVA 2002).

While our concern for the styling of everyday electronic objects seems to be ever increasing, electricity is often something that we simply assume will be provided. It is only situations in which we lack outlets, batteries run low, or power failures that we consciously acknowledge its presence – or rather, its absence. Unfortunately, this difference seems to exist also in how we work with the design of such objects. For example, while the furniture fashion market continuously presents new lamps, this is, with respect to the energy technology, often only a matter of creating yet another form or shade. We could even say

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that it is only another way of presenting and packaging (the light of) a light bulb, since we tend to take the standardized electricity distribution for granted. In many ways, the way we relate to electricity in design is an example of what once Borgmann (1995) described as the division of design into separate engineering and aesthetic branches.

Maybe it is not so strange that users of electrical appliances have a hard time relating to their energy consumption, as much seems to have been done to hide such issues away in the ways that we use and experience them. And maybe it is not so strange that designers of electronic objects have a hard time relating to the electrical 'material' they use, as it has not been considered alongside other materials to be used in design, but as a technical problem to be 'solved'. The increasing interest in sustainable design and consumer awareness could, however, represent an interesting opportunity to revisit such questions.

Energy Awareness and Interaction Design

If we consider a lack of energy awareness to be, at least in part, related to the design of our electronic appliances then the obvious question is to what extent we could reposition design to promote reflection and critical questioning. With respect to such objectives, work in the area of critical design provides an interesting perspective. Using strategies borrowed from, e.g., conceptual art such as decontextualization, defamiliarization, fragmentation, and other ways of creating a resistance toward easy acceptance and use, design can be used to make 'users' reflect upon objects, their functions and how we relate to them (Blauvelt 2003; Dunne 1999). Whereas critical design primarily aims at presenting alternatives to mainstream design, it can at times also be seen as a way of passing on questions about use to users, thus engaging in a more rhetoric relation between design and use (cf. also Redström 2006). With respect to an initial attempt at raising energy awareness through interaction design, such approaches therefore represent an interesting perspective.

Another strand of related work can be found under the heading 'captology' and the study of, in particular, computers as persuasive technologies (e.g., Fogg 2002; Redström 2006). Unlike critical design, such work has often been based on a human–computer interaction (HCI) perspective, and so it represents a different strategy compared to the sometimes rather art-oriented work in critical design.

In architecture and urban planning, issues of sustainable development and energy consumption has been explored to a significant degree, including experiments with 'green architecture', self-sustaining systems, alternative ways of harvesting and conserving energy, and new materials. There is also work explicitly working with expressions of technology in relation to energy, such as Toyo Ito's 'Tower of Winds' in Yokohama Japan. In interaction and technology design, however, such issues are less developed, particularly with respect to expressions in use.

In a design research program called 'Static!', we have been exploring critical design strategies as a way of creating objects that resist easy use with respect to energy use. We have approached the issue of how energy seems to be hidden in appliances by considering it to be a design material, thus trying to expose its properties as such (Redström 2005). In practice, this means that we try to find expressions and aesthetics typical of this material, and then redesign existing appliances in ways that expose these properties. These processes, however, work in the opposite direction as well – we try to learn more about how we might think about energy as material through experiments with how the dependency on energy might be more present in the object. Thus, our objective is twofold: on one hand, we aim to make energy-related issues more present to users as they engage with an appliance; on the other hand, we aim to develop knowledge about the properties of energy as material in design.

Erratic Appliances

As part of Static!, we are developing a series of design examples around the theme of 'erratic appliances'. The erratic appliances are meant to embody consequences of energy use as they start to behave strangely as consumption increases. While these appliances can be seen as 'visualizations' of energy use and how it changes over time as we turn our electronic appliances on and off, their erratic behaviors also introduce aspects of risk and indeterminacy with respect to use and usability. As such, they are meant to question the perception of an often very distant relation between one's actions and the large-scale negative effects of increasing energy use. In doing so, however, they are meant to be somewhat humorous as well, raising the questions but not necessarily providing answers.

The appliances we have redesigned have been centered on the home environment, and particularly the kitchen, since it is a place where we use many electronic products in a fairly concentrated space and where we frequently turn things on and off in shifting between different activities. Since the behavior of any given appliance will depend on the overall energy consumption of the local electrical system it is connected to (such as a living), they are also meant to introduce questions of choice – that is, that users need to make decisions about what things to use and when. For instance, turning on the oven could mean that the radio and the blender will not work properly. Considered as a system of appliances, they are meant to embody questions related to the limitations of energy resources and the need to make choices about what to use and when, since in this case it is not possible to rely upon a continuous and unlimited access to electricity.

As a starting point, we created a series of design sketches illustrating how different appliances could be redesigned to become erratic. Doing so, we focused on connections between energy use and possible changes in behavior, as the redesign must be more than random to promote reflection. Thus, we tried to look for examples where the logic behind the functions of a given appliance could be affected and changed as it comes to depend on fluctuations in energy consumption. Ideally, the 'erratic-ness' should expose how the appliance depends on energy as a material building its normal appearance in use. This, in turn, means that we eventually had to dig rather deeply into how the appliance has been made to expose such relations between the materials building the thing and how it appears in use. Below, we present some of our early conceptual sketches for redesigns (see also Fig. 1).

Washing machine A modern washing machine is based on a set of programs, sensors, and actuators that help optimize washing with respect to selected temperature, program, amount of laundry, and so on. Thus, many things can go wrong as it becomes erratic with respect to energy use: spinning rates, water temperature, and program structure might be altered as a result of the connection to variations in the overall energy consumption in the local electrical system. And so, circumstances will determine what combination of programs, temperatures, etc. will actually be used in each case and how our laundry will come out in the end. One could hope that knowledge of when and how the overall energy consumption changes would help one predict when and how to wash what. But then again, you would never know.

TV A fully functional TV is perhaps not considered as functioning this or that way, apart from the fact that it shows moving pictures broadcasted from somewhere else. But, on a more profound level, distinguishing between a properly working TV and a broken one reveals a set of properties normally not considered in everyday use. For instance, if the picture does not stay in place, but rolls or sways from side to side, there is a problem with the synchronization of the image. Or, if the picture is not filling the screen properly, there is something wrong with the deflection. Thus, the technical design of a TV opens up a vast space of possible ways to deteriorate.

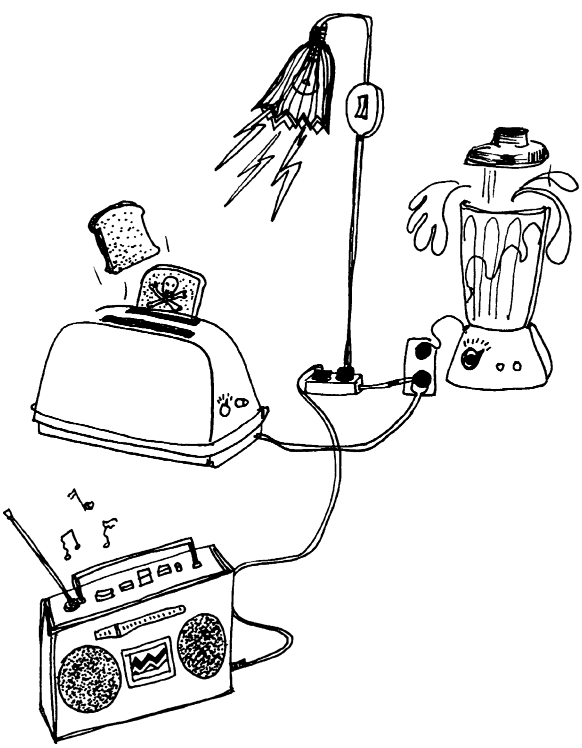

Fig. 1 Erratic appliances. Drawing by Ulrika Löfgren

On a more abstract level, TVs could perhaps be said to create a social place, a place where we watch and comment, laugh, or scream at the same things at the same time, though often in separate locations. The performance of these erratic TVs might be somehow connected to what is going on the building with respect to energy consumption, thus connecting the apartments in yet another fashion. For instance, we could use changes to the deflection as a basis: Whenever another household start using more and more energy, the picture on my TV becomes compressed, leaving black areas at the top and bottom of the screen as if my own space for consumption is reduced when others expand theirs. Correspondingly, we could use synchronization in a way that whenever I start using more energy, the picture on my TV starts rolling and swaying.

Iron An iron is used to iron clothes. As this is done with heat and steam, an iron has user inputs such as setting the temperature and setting the amount of steam. These variables can give a foundation of what an erratic behavior for the iron can be as they both depend on the use of energy. One suggestion could be that the temperature is connected to the overall energy consumption; the iron might behave like one individual in a herd of appliances. And so, if the overall consumption approaches some critical level, making any single individual appliance start to rapidly increase its energy use, the others will follow until the whole herd is bolting. This means the user needs to be careful not to have too many other appliances active at the same time, in order to keep the system in control. More specifically, it means that successful ironing requires an energy system in balance and harmony.

Blender A blender is for blending food, and its primary control is the spinning rate of the blade. Further, the blade spins in a direction so that the food is sucked downwards rather than pushed toward the top. Now, suppose that the rate as well as the direction of the spinning blade somehow depends on the energy consumption in the kitchen. To be able to control the blender, therefore, the user has to anticipate and adapt to fluctuations in the energy usage. The act of using the blender seems to have turned into a precise and delicate matter, as one has to constantly adjust the control as to render the desired result and to avoid food being sprayed out of the device.

Radio Setting out to explore energy as design material, thus working not only with resulting behaviors but also with how different functions were implemented physically, we started redesigning a fairly simple appliance: a radio. Eventually, we might redesign and implement other appliances as well, but as an illustration of the concept, our first prototype had to work also as an individual object, and the radio seemed like a good candidate in this respect.

The Erratic Radio

> As you sit at your office, you switch on the radio and tune in the preferred station. Listening to the music for a while, you realize you need to turn on the light. Starting to turn on a series of desk lamps, the radio gets increasingly noisy as it shifts away from the selected frequency. Only by turning the lights off again, returning to the original state, will the radio work properly again....

Having listened to the radio for some time, you feel the need for some food. As you move into the kitchen, still trying to follow the radio program, it gets increasingly difficult to hear. As you pass the refrigerator and the freezer, the radio loses its channel completely, leaving you with just white noise to listen to. When moving the radio around in the kitchen, its sound reflects how strong the electrical magnetic field is at its current location. In a way, it is like walking around with a Geiger counter in an area contaminated with radioactivity....

The basic functionality of a radio is to be able to tune in on a specific frequency, amplify the received signal, and then play the result in an audible fashion. As such, it depends on energy as a basic material in many different ways. With respect to interaction, what users normally control is the frequency that the radio is tuned to, the volume at which the sound should play, and whether the device should be switched on or off.

One interpretation of the radio, therefore, is that a primary aspect of its use is to select what to listen to. An erratic behavior could imply that it tunes out, perhaps forcing users to listen to something else, somehow exposing issues of energy consumption as it does so. Or it could be that the user loses control over the volume of the sound. Such behaviors would not give the radio new modes of interaction, since the controls as well as the sound output remains, but it would anyway fundamentally change the way it appears in use.

The behavior that seemed most interesting to start exploring was that of tuning in and out to specific frequencies, i.e., radio stations. To be tuned in is a vital quality of a radio, since if it is not able to correctly tune in, it will not be a very valuable appliance to its user. Such a behavior would therefore be likely to be noticed. The way this erratic radio tunes in to stations depends on the energy consumption in its vicinity. The way it does so is by listening not only to the frequencies of potential radio stations, but also to the frequencies around 50 Hz and the electromagnetic fields caused by electrical equipment. The amplitude of these low frequencies then affect how the radio tunes in and out to selected radio channels, resulting in the radio tuning out as energy use increases. In terms of expressions in use, this means that the audio will first start to drift toward noise with slight incremental variations in energy consumption, but as use increases, it might completely tune out (see Fig. 2).

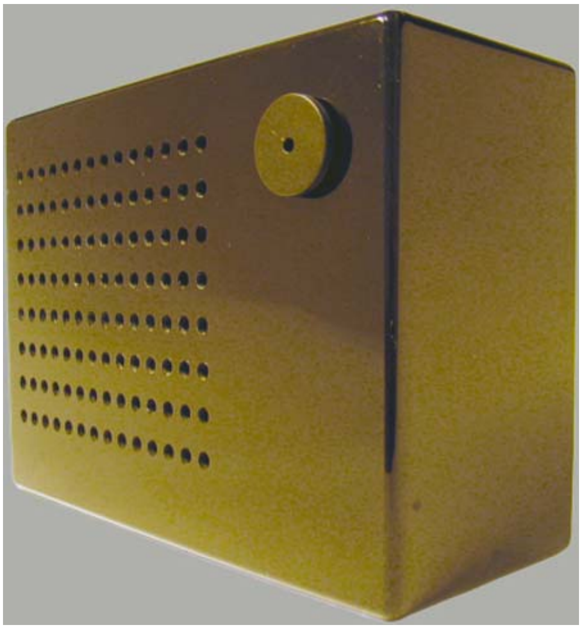

Fig. 2 The Erratic radio

Prototype Design

A radio selects stations using a narrow filter choosing a small part of the frequency spectrum. Tuning determines the center frequency as the knob is turned. This filter consists of a fixed inductor (coil) in parallel with a variable capacitor forming a band pass filter, that is, a filter that only allows for a certain frequency band to pass. When selecting, for example, a station at 103 MHz, the filter is set to pass a narrow band around this frequency to the radio. This band contains the audio signal – which ranges from 10 Hz to 10 kHz – that has been shifted to have the center of 5 kHz at 103 MHz. This gives a frequency band of 102.995 to 103.005. The shift upwards of the audio band is a very small fraction of the center frequency, thus requiring a very narrow pass band of the selective filter. The narrowness of the pass band is the reason why a very slight alteration in the variable capacitance will cause the radio to lose its station or to select a completely different channel. The rest of the radio moves the audio content of the selected channel back down from 103 MHz±5 kHz to 5 kHz, that is, the regular audio band from 10 to 10 kHz. This is then sent to the amplifier as a regular audio source.

In order for the radio to tune out and behave erratically, this center frequency needs to be shifted. The 'erratic-ness' of the radio is thus created through hacking into the radio channel selection filter, allowing a microcontroller to slightly alter the frequency chosen. In order for the radio to react to energy usage, a sensor has been devised, measuring the electrical fields around the radio. This provides a sense, not only for the actual consumption, but also for the electricity that surrounds us in our everyday life depending on where the artifact is placed. This kind of sensing does not provide accurate measurements of consumption, but it gives an additional feature of mobile measurements.

The antenna for the erratic part of the radio has been minimized in relation to its optimum size. That is, it is still of quite substantial length compared to the antenna of a mobile phone. Antenna length is inversely proportional to operating frequency. Thus a mobile phone antenna working at a few GHz is much shorter than an antenna for FM radio of 100 MHz. In the case of electrical field detection, the fundamental frequency of interest is 50 Hz, resulting in an antenna with a corresponding length of several kilometers.

Most of these that have been built are loop antennas with a diameter of more than 4 m. The American Navy has an ELF (Extremely Low Frequency) radio for communicating with submarines submerged at large depths. The antennas for that radio reach across a vast part of Wisconsin and Michigan, respectively. Obviously, this is not an option here. The reduction in antenna size reduces the signal strength to the amplifying stages. To compensate for this, the gain of both stages has been maximized within reasonable limits. Since only signals of low frequency is of interest, the fact that reduced feedback in amplifiers limits high frequency response has no apparent relevance as long as the first few overtones of 100, 150, 200 Hz or so are included.

The actual positioning of the measuring antenna gives slightly different behaviors. If placed near an electrical outlet the measurement is more an actual measurement of changes in consumption, that is, the change in the electrical field around the cable whether there is a field in the cable or not. Only the magnetic – not the electrical – field changes with current consumption. Measuring magnetic fields, however, requires more sophisticated solutions. Inside a cable at the surface of the copper in each conductor, the electrical field is 240 V. This field diminishes with distance to the cable, but is constant whether the current drawn is in mA or A. In this way, the radio can only detect if a switch is pushed, filling the cable with 240 V, causing the field around the cable to rise from 0 V to a fixed value smaller than 240 V. If placed more ambiently in the room, the radio presents an image of the fields your body is being exposed to, due to fields from various outlets and lamps in the room.

Battery operation has been chosen to clearly articulate the idea that the radio is picking up fields in the air. Cables protruding from it might be suspected of faking functionality. The omission of a regular power supply including transformer and rectification also prevents the radio from making it detune itself. Of course, batteries will eventually run out, rendering unpredictable effects before total silence. This, however, should not be considered part of the 'erratic experience'.

The erratic radio is built in black Plexiglas and is $230 \times 170 \times 100$ mm. The decision to make it in Plexiglas was based on an early idea of making the case of the radio transparent. This idea was later discarded because, in future use studies, we wanted focus to be on the 'new' behavior and not the difference in visual appearance. Trying to give it a more neutral visual appearance, the intention behind its minimalist form is that it simply should look like a (stereo-)typical radio – that its design is based on a simple square box with rotating dials for adjusting the tuning and volume, an on/of switch, an antenna mounted on top, and holes for the speaker.

Mis/Using Established Circuits

Both the sensory input and the erratic output of the interactive features of this radio implement the notion of hacked or misused circuits well known to engineers. Here, what are normally regarded as problems are treated as features, enhanced to give another effect than the original intention of the circuit. Considering the field sensor, it is basically two cascaded signal amplifiers with a very high total gain. When designing such amplifiers, electrical engineers strive to achieve as good a S/N (signal to noise ratio) as possible. This allows for a clean signal, which can later be processed with a minimum of noise. In this case, the (low frequency) noise is the only interesting part since it contains the electrical fields often heard as hum in a stereo of poor quality or with its inputs open. Therefore, that is just what has been done. Not only is the input not connected to any source, it has been equipped with an antenna in order to pick up the hum better. The amplitude of the hum is then extracted and sent to the microprocessor. When the amplitude rises above a predefined level, the erratic output is activated causing the radio to behave inconsistently and lose its station.

Fig. 3 Picture from an on-going field study involving the Erratic radio prototype. Picture by Sara Routarinne

The erratic output uses the otherwise unwanted effect of drift in components. In this case, it is a more logical usage of technology, since the goal of the output of the artifact is a negative effect. It is a variable capacitor that sets the center frequency of the narrow filter. If this component shows signs of drift over time, or with temperature, the radio would be really annoying. It would constantly have to be retuned. In a normal radio, this feature would render the product unusable. But, in this case, it is the desired effect. Therefore, a small electrically variable capacitor has been added in parallel to the tuning capacitor, adding to its total capacitance. As long as there is a constant voltage applied to this extra capacitor, it just shifts the total value of the much larger tuning capacitor. Thus, that one will only need to be tuned whenever a new station is selected.

As an ordinary off-the-shelf product, the features of the radio used have originally been carefully engineered, ensuring stable operation (see Fig. 3). When the microcontroller is allowed to change the voltage applied to the extra capacitor, its value changes and so does the total value of the tuning capacitor. The component drifts out of specification causing the radio to lose the station to which it was tuned. For the moment, though, the radio just loses its station whenever the electrical field is larger than its calibrated value. Other more advanced solutions could be imagined such as having the stations gradually tuning out as the electrical field increases. Or, it could jump in and out in a random pattern.

Discussion

When we talk about 'use' and 'users' above, it is clearly a matter of certain ideas about 'use' that guide the design process and not some group of real people (which one might expect should this have been a more typical user-centered design project). What about the potential 'real' use of the erratic radio? Would anyone stand it long enough to experience the effects on their behaviors regarding energy consumption? Where a normal radio is ever present in the background and quite invisible, the erratic radio frequently calls for attention (implicitly) by the invoked need to manage energy consumption or (explicitly) if one wants to override the effect and retune it to its station. Although potentially annoying, it could also be that the radio possesses a certain value because of its engaging qualities. Such ideas about its use and implications remain at this stage, however, speculative. Another step in this project is therefore to present them to people through 'user studies' and exhibitions and see to what extent and in what ways they may, or may not, promote reflection upon energy use. Obviously, these devices are not meant to replace existing designs, and so the question is not so much whether people would like to live them for extended periods of time, but what kinds of questions these devices make their users ask themselves.

It is, however, of some importance that we understand the differences between this kind of use- and user-related researches and the kind of experimental design research presented here. While there is an intention to use the erratic radio in use studies, it is not the case that it has been built only for that purpose, and that what we have described in this paper merely are the preparations necessary for such research. Quite the contrary, we believe that experimental design work like this is quite central to design research, as it as a matter of developing the craft itself, our knowledge of the materials used, etc. – this is why we have been quite detailed in our descriptions of the technical redesign of the radio. The differentiation between these two kinds of research in this project is, however, also because we think that field studies of use should be done with more care and precision than is often the case in quick evaluations of design prototypes – and ideally by another group of researchers. Such a long-term field study involving the erratic radio is currently under way.

To be able to consciously use the properties of energy as a material in design to craft objects that help users become more aware of their consumption habits – and consequences – we need to know the design material at hand. We need to understand how it works, how its properties relate to how we interact with and experience the thing. Obviously, the way we ask questions about a given technology will depend on what kinds of answers we are interested in, and so the questions we ask tell us as much about our understanding as does our answer. Whereas a typical question is "How can we ensure that this device will work for X hours while on the move?", we try to ask questions such as "How can we express the ways in which this device depends on energy?". Thus, working with a different set of questions while redesigning existing electronic appliances helps us uncover hidden assumptions as our perspective has been shifted. In this way, this approach represents a complement to strategies based on developing increasingly energy-efficient technologies.

Further, the approach described here turns our attention away from strictly functional issues, toward questions of expressions in use and aesthetics. For instance, as a design example, the erratic radio illustrates that there are rather rich design opportunities available for designers in rethinking the expressiveness of technology as material. While it is certainly the case in the design presented here, it is not necessary that such expressions related to the use and misuse of technology have to be at the expense of usability and practical functionality. With the erratic radio, the shift away from ease-of-use is intentional as we have tried to complicate typical conceptions of energy and technology as belonging in the background, but as we learn more about how these material properties relate to expressions in use, we can, of course, use it to create things with focus on usability as well.

Conclusions

In terms of research objectives, this work has been focused on ways we might make energy-related issues more present and pressing in our interactions with and use of everyday appliances. To do this, we have tried to 'rediscover' energy as a material building the things. A central outcome of this approach, as we see it, is that it could help uncover design decisions that, over time, have become hidden under increasing technical perfection.

With respect to how interaction design might be employed to bring certain questions forth in the way we use things, we have explored how to embody aspects of choice, distance, and consequence, among other things. The energy systems we live in are often enormous, intangible structures that are hard to grasp. Although we might be aware that our actions have effects even at a global scale, such issues are often remote from our local experiences. To close this distance, or at least remind us of it, we have created things that respond more directly to local conditions. The way they do so have been inspired by some of the potential consequences of overconsumption – that things stop working properly and that overconsumption introduces aspects of indeterminacy and risk. Perhaps, the central issue brought forward, however, is that we users will have to realize that limited resources require us to make choices with respect to what to do and when.

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References

Blauvelt, A. (Ed.) (2003), *Strangely Familiar Design and Everyday Life*. Minneapolis: Walker Art Centre.

Borgmann, A. (1995), The Depth of Design In *Discovering Design*, edited by R. Buchanan & V. Margolin, 13-22. Chicago: The University of Chicago Press.

Dunne, A. (1999), *Hertzian Tales; Electronic Products, Aesthetic Experience and Critical Design*. London: RCA CRD Research Publications.

Fogg, B. J. (2002), *Persuasive Technology: Using Computers to Change What We Think and Do*. San Francisco: Morgan Kaufmann.

IVA, Royal Swedish Academy of Engineering Sciences (2002), Energianvändning i bebyggelsen. Eskilstune: Swedish Energy Authority. (Energy Use in Construction, in Swedish)

Redström, J. (2005), On Technology as Material in Design In *Design Philosophy Papers: Collection Two*, edited by A-M. Willis, 31-42. Ravensbourne: Team D/E/S Publications.

Redström, J. (2006), Persuasive Design; Fringes and Foundations In *Proceedings of First International Conference on Persuasive Technology for Human Well-Being, PERSUASIVE 2006*, edited by W. Ijsselsteijn, Y. de Kort, C. Midden, B. Eggen, and E. van den Hoven, 112-122. Heidelberg: Springer.