# User-centred Design for sustainable Behaviour

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## Abstract

*Traditional eco-design has a strong focus on the supply side. Even when focusing on the use phase of products, still impacts directly under the control of the manufacturer dominate. However, the way users interact with a product may strongly influence the environmental impact of a product. Designers can try to influence this behaviour through the products they design. Several strategies have been proposed in the literature, such as eco-feedback and scripting. Existing literature in this field has its limitations. Publications either focus on a single strategy, or do not take a design perspective, or lack empirical data. This paper will present a typology of the different strategies available to designers. This typology will be illustrated with examples and experiments related to two sustainability problems, namely littering behaviour and energy using products. Furthermore a methodology will be presented for applying these strategies. This will be demonstrated in a case study on an energy meter.*

**Keywords:** product design, user-centered design, sustainable behavior, sustainability, eco-feedback, scripting.

## 1. Introduction

Many modern cars prevent us from making mistakes that will cost us a lot of time and effort. For example, they make it impossible to lock the driver-seat door from the outside without using the key. This prevents you from leaving your keys inside the vehicle and locking yourself out. If you leave the lights on while opening the door, a noise will sound, guarding you from draining the battery. These are solutions that require little cost to implement, other than making a proper design. And—essential to their success—the user is not hindered by them. Interventions like these take into account the behaviour of people, require a relatively small investment, and prevent undesirable, costly side effects of product use.

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To design the right product (feature), studying user behaviour, characteristics, needs and skills, and implementing solutions that fit those, are all essential. In short, the solution lies in user-centred design for sustainability. Until now most sustainability approaches have focused on fulfilling functions in a more sustainable way, within a given use-profile. User-centred sustainable solutions provide an alternative strategy: they aim to change the use-profile into a more sustainable direction.

Within the field of sustainable product design the focus has been strongly on the supply side; how can impacts be lowered through design-for-disassembly, recyclability, use of environmentally conscious materials and dematerialization.

For many durable consumer goods, it is widely acknowledged that the major part of the environmental impacts is caused during the use phase, in particular through energy consumption (*e.g.* Brezet and Van Hemel 1997, p. 152; Stevels and Griese 2004; Abele *et al.* 2005, p. 92). Looking for instance at the consumer electronics industry, one sees a strong focus of the scientific community on recycling although from a lifecycle perspective energy consumption is much more important (Pascual *et al.* 2003). Of all efforts made to lower the energy consumption of products, again the supply side dominates, with the focus being on environmentally conscious energy sources and increasing energy efficiency through technological solutions. However, the actual demand for energy during the use phase depends also on the way people use a product in daily practice. For instance, energy-saving features only are sustainable if they are actually used by consumers. Therefore, design strategies focusing on energy-efficient usage of products are likely to complement technological solutions. With sustainable product design having a solid tradition in technical disciplines (in particular mechanical engineering), research that has addressed the demand side or human side of products, and how this can contribute to energy-efficient product use, is very limited. One likely reason is the traditional lack of cross-fertilization between sustainable product design research and human-focused design disciplines like user-centred design and interaction design.

## 2. Goal

The goal of this paper is to examine the potential for inducing more sustainable use of products through design and to explore the role that user-centred design can play in developing such products. To this end, section 3 reviews the available literature that acknowledges the role of user behaviour in sustainable product design. From this review, the proposition is derived that there is ample room for further cross-fertilization between the domains of sustainable product design and user-centred design methodologies. Section 4 introduces the concepts of user-centred design, human-product interaction and usability. In section 5, within a context of usability theory, a typology is proposed on triggering sustainable behaviour through product design. As will be demonstrated several distinctive approaches are possible for pursuing a more sustainable use of products. Throughout this paper the implications of the typology are illustrated by two examples, namely littering behaviour (section 6) and energy consumption in consumer products (section 7). These two cases are both strongly linked to consumer behaviour, but at the same time they differ distinctly. Section 8 will discuss how to approach the design of a product to induce sustainable use. Subsequently section 9 will present a case study where an eco-feedback product (an energy meter to determine energy consumption of appliances) is designed using a user-centred approach. The paper concludes with a discussion in section 10 on marketing of user-centred eco-design products.

## 3. Related literature

Several studies have been carried out showing that sustainable technology does not automatically lead to sustainable user behaviour. Derijcke and Uitzinger (2006) describe a case study in which they studied the behaviour of residents regarding some sustainability related issues in housing. They found that a *'reasonable* *share of the residents did not know that their toilet had a flush stop, and therefore did not use it'*. They also found people misunderstanding a mechanical ventilator with settings 0, 1, and 2. As people believed that 0 meant 'off' (which is not true) they operated the ventilator unnecessarily at higher levels, thereby wasting energy. On the other hand Völlink and Meertens (2006) found that installing prepayment gas meters, creates a form of repetitive feedback that caused a 4% reduction in gas consumption; an example where a technological intervention did lead to more sustainable consumption.

Several authors have discussed how product design can influence users. For instance, Jelsma and Knot (2002) applied (as one of the first) the idea of 'scripting' to sustainable product design. They defined scripting as the design of a product-layout guiding the behaviour of the user, in a more or less forceful way, to comply with values and intentions inscribed into the product by the designer. If it would be the designer's intention to inscribe increased likelihood of sustainable usage into the product, this would mean designing products in such a way that unsustainable behaviour is made difficult or impossible, while sustainable behaviour is made easy or easier, or even automatic. Jelsma and Knot (2002) applied their concept of scripting to sustainable service systems, in particular to clothing care systems.

While Jelsma and Knot tried to change behaviour through the design of the product, another approach is to change the design of the product to match the actual way people use it, in order to reach a more sustainable result. For instance, Rodríguez and Boks (2005) studied people's interaction with the collection of consumer electronics in their homes. They found that people often have multiple appliances switched on at the same time, like a computer and a television set. Furthermore appliances are often switched on, while only part of their functionality is used, e.g. a TV switched on only to hear the news.

Rodríguez and Boks suggest several product features, e.g. a blind mode in order to adapt the array of product energy modes (on, off, stand by) to the actual use of the consumer. In blind mode the image would be switched off or dimmed strongly and sound would continue.

Besides the adaptation of products to give users more settings to choose from, Rodríguez and Boks explore the possibilities of automatic responses by products. This could be achieved through communication between appliances, allowing intelligent control, e.g. automatically dimming sound and image of the TV when the phone rings. This type of features would have to be designed very carefully from a usability perspective. If features would annoy people, because they act when it is not wanted, the feature will be switched off.

Smit (*et al.* 2002) present preliminary work on what they call 'user-centred eco-design', which is presented as a possible solution for reduction of environmental impact of products. Here, eco-design theory and practice is taken from its comfortable roots in materials science and technology, towards a more marketing, user and consumer-related arena. It is stated that traditional eco-design methods and models are less appropriate and new methods, approaches and models are necessary as issues of behaviour, acceptance and desirability are rarely found in eco-design literature. In their paper they describe a user-centred design process of a human powered remote control for television sets, in which they not only tried to solve the engineering challenge of making a remote control work on human power, but also made sure this was done in a way acceptable to consumers.

As may be apparent from the above examples, there are several distinct ways in which designers can try to induce sustainable behaviour. Jelsma and Knot follow a scripting approach, Völlink and Meertens looked at feedback and Rodríguez and Boks looked at automation of certain functions and at extending the number of different settings a product has. Up till now little material has been published that tries to capture all these approaches in one framework.

A first attempt at such a framework is presented by Lilley (*et al.* 2005). Lilley refers to this approach as product–led interventions. She places these product-led interventions within a larger context of other types of interventions, namely educational interventions and technological interventions. Educational interventions can be split into three strategies; linear dissemination of information, incentives and penalties, and finally guilt. Lilley goes on to debate the effectiveness of these educational interventions. Technological interventions are the improvements in energy efficiency achieved by CE companies, for instance energy consumption in stand-by mode.

Lilley (*et al.* 2005) defines three types of product-led interventions:

- Scripts and behavioural steering—following the definitions by Jelsma and Knot (2002);
- Eco-feedback—products informing users of the impact of their behaviour, hoping to induce attempts by users to minimize that impact;
- "Intelligent" products and systems—products circumventing the user's decision making process by ceding the decision making to the product.

From the literature it is clear that there are several approaches possible to induce more sustainable behaviour through the product design. An overview of the available design strategies is missing, as is a clear approach for choosing the right strategy for a given product. It is obvious that a thorough understanding of human-product interaction is preferred, and that the usability of a design solution is key. Hence the next section will discuss the user-centred design approach, which aims at obtaining insight in human product interaction, and using this insight in creating designs with a high usability.

## 4. Human product interaction, usability and user-centred design

User-centred design is a design approach that puts the user centre stage during the entire design process. Instead of focusing on technological possibilities and quality measurements in terms of components, it takes solutions that fit the user as a starting point and measures product quality from a user point of view (Vredenburg *et al.* 2002), taking into account needs, wishes, characteristics and abilities of the projected user group. The aim of adopting a user-centred design approach is to improve the quality of the interaction between the user and the product.

### *Human product interaction*

Four basic factors play a role in human-product interaction (Shackel 1984): the product, the user, his/her goal, and the context in which the interaction takes place. For the current generation of products the elements of Shackel's framework can be extended, to take into account that today's products are often product-service combinations, function in networks with other products, and that other people are also involved in or affected by a person's product use (Figure 1).

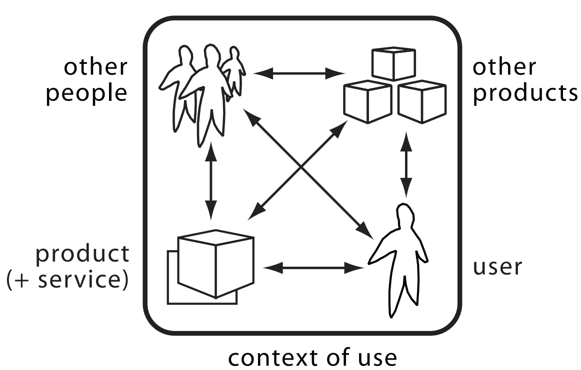


*Figure 1: Figure 1. An extension of Shackel's framework for human-computer interaction, featuring the product as a product-service combination, and including 'other products' and 'other people'.*

Rooden and Kanis (2000) have also proposed a more elaborate interaction framework (Figure 2) that includes more details of user characteristics, and relations between the product, the user and the context. This framework includes the output of the product in terms of feedback to the user (*e.g.* dialogue screens), product performance (*e.g.* a typed letter) and – very relevant in the context of design for sustainability – the side effects, which can be noise, heat, or waste production or energy consumption. This interaction framework is one of the few that explicitly includes side effects—the effects we aim to minimize.

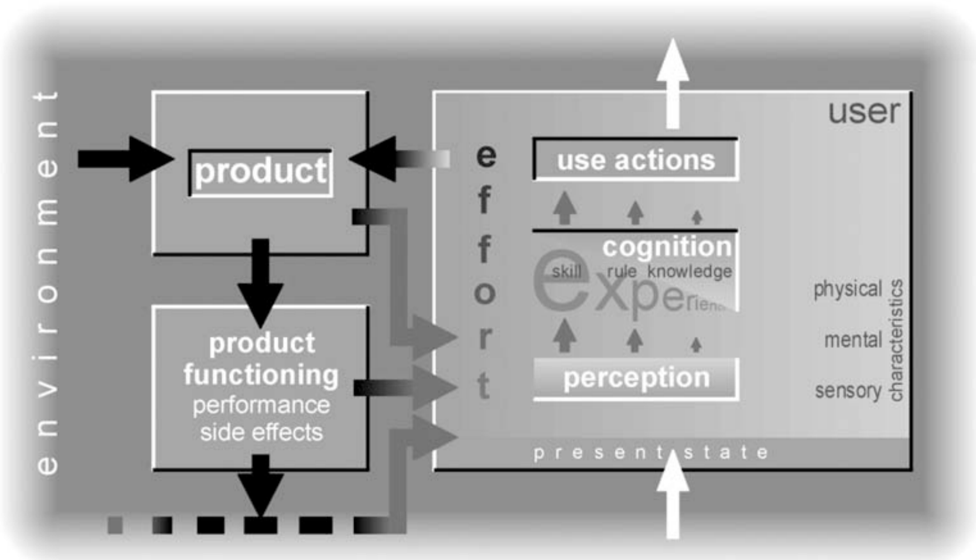


*Figure 2: User-product interaction (Kanis and Rooden, 2000).*

***Usability***

Brian Shackel was one of the first to coin the term usability, which he defined as the "*user's ability to utilise the functionality of a product in practice*" (Shackel 1984). How usable a product is, depends on the user, his/her goal with the product, the product properties and the context in which the product is used. Because the usability of a product depends on so many issues, we can't really speak of *the* usability of a product. To stress this, the ISO definition of usability states that the usability of a product is the extent to which a product can be used by *specified* users, to achieve *specified* goals, with effectiveness, efficiency, and satisfaction in a *specified* context of use (ISO 1998). If we apply the notion of usability to sustainable behaviour, we could say that the user-centeredness of a solution for sustainability can be evaluated by assessing how effectively the side-effects of a product's use are reduced, what the costs are (money, time, effort), and how satisfied the users group is about the effect of the solution on

1. the use of the product and
2. reducing the side effects of the product.

***User-centred design***

The quality of human-product interaction can be improved by following a user-centred design process (Preece *et al.* 2002, Vredenburg *et al.* 2002). Most design processes involve the basic design cycle as presented by Roozenburg and Eekels (1995, see Figure 3). It consists of an analysis phase in which the designer tries to understand the problem at hand and the aspects that play a role, a synthesis phase in which solutions are generated, a simulation phase where solutions are simulated, which are subsequently evaluated in the next phase. At the end of the cycle the design is decided on, or the cycle iterates back to earlier phases to evaluate whether the analysis and synthesis were done properly.

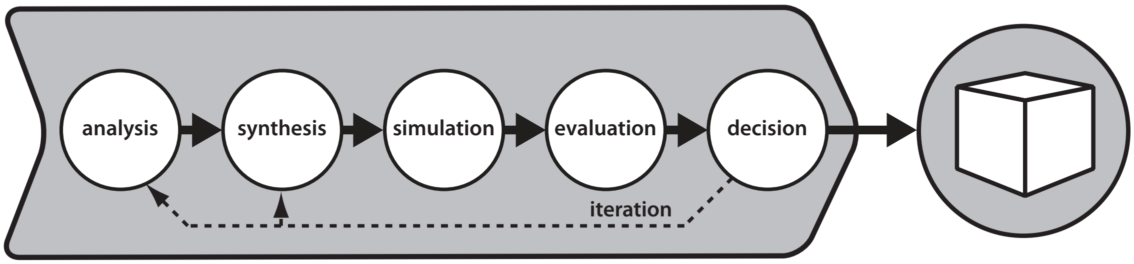


*Figure 3. The basic design cycle (after Roozenburg and Eekels, 1995)*

Not all design problems require the involvement of users in the design cycle. For example, when designing a new diesel engine, one could perform an analysis of the problem, design a new engine and evaluate its performance without including users in the process. However, as soon as you want to know how users feel about the characteristics or sound of the new engine, you would have to follow a user-centred design process, in which users can be involved in each of the steps. This is visualized in Figure 4, by adding the interaction framework from Figure 1 to the basic design cycle from Figure 3.

During the analysis phase the designer does not only explore the technological possibilities and business aspects of a product, but also looks at primary user needs, user behaviour and preferences through techniques for collecting user information, such as *context mapping* (Sleeswijk Visser *et al.* 2005) or *contextual inquiry* (Holtzblatt and Jones 1993).

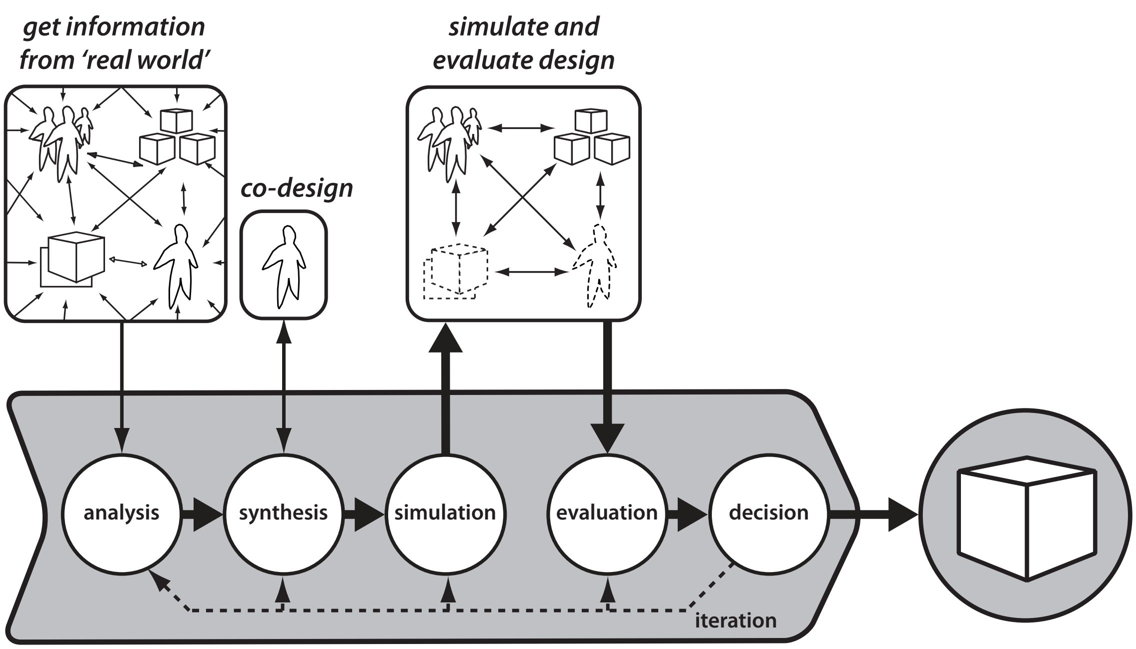


*Figure 4. The user-centred design cycle.*

During the design phase users can be actively involved in generating concepts (Gyi *et al.* 2006). Different types of simulations of the created concepts can be made, each with its own level of sophistication. Paper prototypes are suitable for early testing, but in other cases a completely functional product will be built. After the simulation of the solution has been made, it can be evaluated with users in a usability test or field study. Each phase has its own appropriate toolbox of user-centred design or evaluation methods, as for example shown in the tools matrix by the *UsabilityNet* project (Bevan 2003). Some user-centred design methods are shown in the case study at the end of this paper.

The concepts of human-product interaction and usability are important enablers for understanding the interaction process for a particular product, and assessing unwanted side effects of product use. The concepts give an overview of the factors that play a role in product use, understand the causes of unwanted side effects of product use and provide measurements to evaluate product use. The user-centred design process shows the options open to the designer to include the user in the design process, and to thus generate solutions that fit the user and evaluate the real world effectiveness of these solutions.

## 5. A typology of design strategies

Design for sustainability has emerged from technical disciplines, such as mechanical engineering, and has therefore focused strongly on the supply side of a product. Typical tools for eco-design, such as the Life Cycle Design Strategies, or LiDS wheel (Brezet and Van Hemel 1997) point out the different aspects that designers can focus on trying to reduce the impact of the products they design. The fifth strategy of the LiDS wheel is "reduce the impact during the use phase". As demonstrated above, this strategy should consist of both a technical component and a psychological aspect. The typology proposed in this section covers the psychological part.

Section 3 has described previous work on inducing sustainable behaviour. So far, literature in this field seems rather scattered. A typology, combined with a design approach based on user-centred design (section 4), can be a useful tool for designers in implementing the psychological part of the fifth LiDS-wheel strategy.

Looking at how different approaches to reduce environmental impacts during the use phase are interrelated, two options can be distinguished.

First, there is the option to adapt a product better to the actual use by consumers and thereby try to minimize negative side effects (as described by Rodríguez and Boks 2005), i.e. work towards eliminating mismatches between delivered functionalities and desired functionalities. Here this approach is called *functionality matching*. A mismatch between delivered functionalities and desired functionalities is unsustainable twice. Redundant functionalities have an unnecessary impact, while missing functionalities can trigger unwanted behaviour, with subsequent unsustainable effects.

Second, there is the option to influence behaviour through product design (as described by Jelsma and Knot 2002 and Lilley *et al*. 2005). A distinction similar to Lilley's can be made here (Lilley *et al.* 2005). The first approach is *eco-feedback*. Here the user is presented with specific information on the impact of his or her current behaviour, and it is left to the user to relate this information to his or her own behaviour, and adapt this behaviour, or not. One step further is *scripting* where the product is designed in such a way that the design triggers the sustainable use by either creating obstacles for unsustainable use, or by making sustainable behaviour so easy, it is performed almost without thinking about it by the user. *Forced-functionality* refers to either intelligent products (as defined by Lilley 2005) that adapt automatically to changing circumstances, or to designing-in strong obstacles to prevent unsustainable behaviour.

The distinction between design options made above is reflected in the model proposed in Figure 5. This distinction is an elaboration on what previous authors have proposed; an adaptation was made in order to make different approaches more meaningful to designers. Jelsma and Knot (2002) state that scripts can be "more or less forceful", whereas in this classification the forced changes in behaviour are incorporated in "forced functionality". This makes the forced-functionality group larger than the "intelligent products" group as defined by Lilley. This change is made because to designers this classification may be more meaningful as it puts the split between inducing and forcing. Referring back to the user-centred design, as described in section 4, functionality matching can be seen as focusing on making the right product, while adapting-use-through-product can be seen as making the product right.

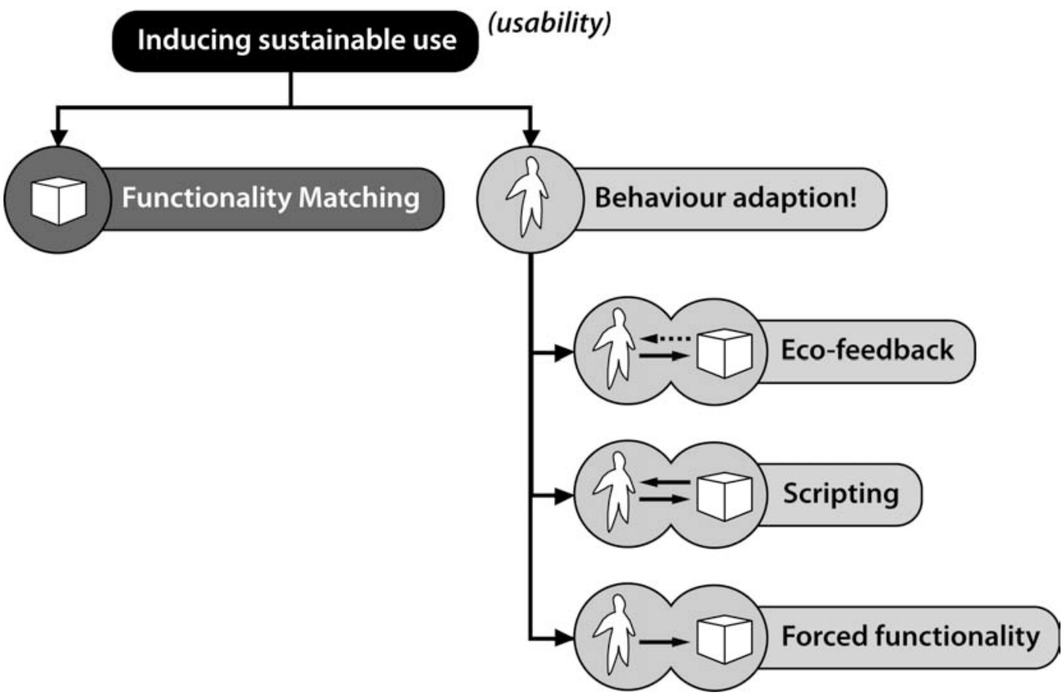


*Figure 5. A typology of sustainable behavior-inducing design strategies.*

To illustrate how these different approaches may lead to different solutions, each approach is discussed within two application cases; section 6 will discuss littering behaviour, section 7 addresses energy-using products. Examples used are based on either existing products, examples from literature, or on research at Delft University of Technology.

## *6. Example 1: Littering behaviour.*

A first example of how the typology presented in section 5 can be applied is in the case of littering. Here, a good example of *functionality matching* is the placement of litter bins in a park. This example is based on a project performed in collaboration with the Rotterdam municipal maintenance services. The project aimed at reducing the litter problem in parks, especially in relation to summer barbecues. Although in favour of such park activity, for reasons of furthering social integration, the city would like to see the resulting pollution reduced. Within the project the behaviour of people using the park was observed unobtrusively for several weekends (Kwok 2006). It was found that essentially all people made an effort to clean up after their picnic or barbecue, often using their own litter bags. Typically people took their garbage to the closest litter bin. If this bin was full, garbage bags were placed beside the bin instead of locating a different bin that was not full, which in some cases had been available within 5 meters. Increasing capacity of frequently used bins, or clustering them, would thus be more helpful than to simply increase the number of bins, matching the behaviour already present with the users of the park.

The three *behaviour adaptation* approaches can also be applied in this littering context. An example of *eco-feedback* is the application of anti-litter labels to packaging, for instance informing the user how long a product will take to decompose when left in nature. A first experiment on labelling disposable coffee cups (Wever 2006), showed a significant reduction of cups littered. In the test before the application of the labels the litter percentage was 11,2%. With the labels applied this dropped to 6,71%, a signification reduction according to a performed $\chi^2$-test. In the after test some weeks later the percentage had increased again to 14,1%, indicating a lack of memory effect, which may partly be caused by the short period in which the labels were applied.

Another experiment reported on by Wever (2006), compares the littering behaviour related to two packages for the same soft drink. One package was a PET bottle, with reclosable cap; the other was a Cartocan (a solid cardboard container with a cylindrical shape) with a tear-off lid. Both the Cartocan itself and its lid were littered significantly more than the bottle and its cap. Of the PET bottles 2,6% was littered, while 5,8% of the Cartocans was littered. Additionally, 4,1% of the tear-off closures of the Cartocan were littered, while none of the PET bottle caps were, increasing test significance when counting total number of littered objects. The cap contains a *script* that motivates user to re-screw it to the bottle. The reduced littering of the bottle itself appeared to be due to the fact that re-closing it allowed users to not finish the drink in one go, and to retain the bottle for refilling with tap water. Both are examples of *functionality matching*.

An example of *forced functionality* is the change of tabs of soft drink cans, which happened in the 1980s. Before this the tabs came loose from the can entirely. These loose tabs were notorious for ending up littered and causing harm to people and wildlife. Then a redesign was implemented with a stay-on tab (an invention credited to Cudzik 1976). As the tab stays on the can, this automatically prevents the sharp closure from being littered.

## 7. Example 2: Energy-using products

The typology from Figure 5 can also be applied to energy using products, such as cars and appliances. In this field an example of *functionality matching* is the blind mode on televisions as suggested by Rodríguez and Boks (2005). Their suggestion was the result of observational research on how people use appliances in the home. They found that people often have multiple appliances switched on, using only part of their functionality. An example is switching on the TV to hear the news, while occupied in other activity such as surfing on the Internet or ironing clothes. By adding a sound-only mode to televisions (through a blind-button instead of digging into set-up menus) it can deliver a desired functionality in an eco-efficient way. This option is becoming more relevant with cable or satellite decoders, which also supply radio channels.

Another example of *functionality matching* lies in getting people to switch-off their television fully, instead of leaving them on stand-by, which still consumes energy. It would be helpful if the TV set could be switched off entirely through the remote control – which is the typical (and only) way users operate their TV. Currently hardly any TV set will allow this, although some remote controls have a function to switch off the TV set entirely when the power button is pressed a second time (*e.g.* a high-end Grundig wide-screen CRT television set).

This option on remote controls has to be known by users in order to utilize it. Here an example of *eco-feedback* could be to show a message on the TV screen directly after it is switched to stand-by, explaining that pressing the button again will fully switch off the set, thus saving energy. Another example of *eco-feedback* is the screen in many cars, giving drivers feedback on their fuel economy. Many drivers see this information as an incentive to drive as economically as possible.

An example of *scripting* in energy using products can be found with products powered by photo-voltaic cells. In order to capture enough solar energy to power portable products, it is essential that such products are exposed to sunlight as much as reasonably possible. Scripting can help ensure that that people are induced by the product to place it in such a way that it exposes the PV-cells to the light. An example of this is the application of PV cells in mobile phones, as discussed by Kan (*et al.* 2004).

An example of *forced functionality* would be hybrid cars, like the Toyota Prius, that automatically recoup kinetic energy when the driver brakes to reduce speed. Another example is the automatic adaptation of the settings (contrast and brightness) of television sets to ambient light conditions.

## 8. Choosing an approach

The classification presented in Figure 5 gives an overview of different approaches available to product designers wishing to minimize environmental impact during the use phase. However, Figure 5 does not, in its current form, present a way of choosing a specific approach. This is because the best approach depends on the specific product and its context. *Functionality matching* is the least intrusive approach, but probably also yields the least improvement from a sustainability point of view. From this approach through *eco-feedback*, *scripting* and *forced-functionality* respectively, the intrusiveness increases, as does the certainty and extent of the sustainability improvement. How far a designer feels he can go in his design depends on the specific context.

Clearly in a project trying to implement one or more of the strategies presented here, more skills are needed than creative design alone. As Jelsma (2006) already proposed for the scripting strategy, it seems wise to assemble a team including engineers and psychologists, to allow them to assess the potential environmental improvement and the acceptability respectively. Not all approaches may be feasible for all products. Providing eco-feedback for instance is much easier for products with a display than products without one.

## 9. Case study: design of a user-friendly energy meter

The idea of eco-feedback is to present users with information on the (in)efficiency of their behaviour. The user is assumed to relate this information to his or her own behaviour, and adapt it to be more sustainable. A familiar example is the information on fuel consumption in cars.

Recently a project was conducted in the Netherlands to apply eco-feedback to electronic and electrical devices in people's homes (Menheere 2006). This example emphasizes the importance of the usability of products that intend to support sustainable behaviour. Milieu Centraal is a Dutch non-profit organization that aims to stimulate consumers in more environmental-friendly behaviour through, among others, publicity campaigns. One of their campaigns concerned an 'Energy Meter Relay'. Participants in this campaign could use an energy meter free of charge for three weeks, on the condition that they would give the meter to a new family after three weeks. An evaluation of the project by Milieu Centraal showed that people that had used the energy meter could, on average, save 7% in energy consumption (Koens and Groeneveld 2006). On a national level this would reduce $CO_2$ emissions by almost 1 megaton. The intended reduction of $CO_2$ in The Netherlands, within the context of the Kyoto protocol on climate change, is about 13 megatons.

The campaign was generally successful but a participant survey revealed problems. Some participants found the meter to be too complex and some returned their meters to Milieu Centraal for this reason even though they were motivated to use it. Consequently, Milieu Centraal decided to cooperate with Delft University of Technology to redesign the product with an emphasis on usability.

### *Usage problems*

In this study, some of the problems identified in the product itself were poor and non-native terminology. Users could not understand the English and non-conventional abbreviations on buttons. Multiple combinations of buttons or button pushing sequences were required to get access to some of the functions. In addition, it was sometimes physically impossible for users to plug the device into the wall-socket that was supposed to be monitored, because the device had an integrated plug and its embodiment extended beyond the surface of the wall-sockets (as can be seen in Figure 6). If any furniture was close to the wall socket, the device simply wouldn't fit.


*Figure 6. Example of a usage problems with the original product, encountered during the home visits: the physical design of the product forced users to use the product upside down.*

In addition, the measuring device could only be operated when inserted into a wall socket, requiring people to lie down on the floor to see the readings if the wall socket was built in at low height. Essentially, people were not able to perform the basic tasks that the product should enable them to do. To make matters worse, the manual was not considered helpful.

### *Approach*

In the redesign project, first an inventory was made of the problems that arose, using a phone and Internet-survey of participants. Home visits were made to see how participants actually used the product and to gather in-depth qualitative information on the user interface problems that people experienced.

Based on the user interviews and additional Milieu Centraal data, personas were generated. Personas (Pruitt and Grudin 2003) are fictional in-depth descriptions of users, describing in this case among others age, occupation, hobbies, style preferences, attitudes towards electronics, family life and beliefs. This rich description serves as a constant reminder for designers while working on the product. They are not designing with numbers from a marketing report in the back of their head, but they can say to themselves: “What would Harry or Margret think of this?”

Based on these personas detailed scenarios (Fulton Suri and Marsh 2000) were written of all steps required to use the energy meter. From these, the most frequently performed steps necessary to use the product were determined as input for the user interface design.


*Figure 7. On-screen (left) and physical simulations (middle) of the product during user evaluations (middle and right).*

Next, concepts for user-interfaces were conceived and simulated in interactive MS PowerPoint™ presentations. After a usability test one of the concepts was chosen, which was developed in more detail and evaluated through a heuristic analysis (Nielsen and Molich 1990) and an evaluation by a group of designers based on the method of cognitive walkthrough (Rieman *et al.* 1995). These methods allow designers to take the user into account without having to recruit actual participants, which can be useful in case of time restraints. Finally a physical mock-up of the product was made, as well as a fully interactive simulation running on a touch-screen (see Figure 7).

By constantly putting the user centre stage using these methods, the resulting product *Greeny*™ exhibited improvements not only in the user interface (focusing on essential functions including calculations in terms of financial cost – which is easy to understand by users), but in the physical set-up of the product as well. Additionally, more appeal and engagement to the product were designed in using, for example, LEDs whose light intensity increases as the measured energy use increases, enabling the product to be monitored with a single glance. The final aesthetic properties of the product aimed at reassuring users that they would in fact be able to use the product as intended.

A final usability test was done in a laboratory set-up, comparing between the original energy meter and the redesign. On the redesigned energy meter users were on average 4 times quicker when performing tasks than on the old device, making much less use of the manual when using the *Greeny*™ (see Figure 8 for the final design). Finally, with the old product three out of five test participants were not able to measure the energy use of an electric kettle within the maximum amount of time, whereas with the *Greeny*™ all participants were able to complete the tasks.


*Figure 8. The final design of the Greeny™ Energy Meter.*

## 10. Discussion

The case study clarifies the potential of one of the strategies (eco-feedback) and emphasizes the importance of user-centred design when aiming at reducing environmental impact during the use phase.

This paper presents an approach to deal with the behavioural aspects of the environmental impact of products in their use phase. When energy use efficiency is already high and close to the theoretical minimal energy use desired, an alternative or supplement to traditional engineering approaches is required (see Elias (*et al.* 2007) for a discussion). This approach is provided in the form of changing the user behaviour.

For sustainable behaviour inducing products to fulfil their potential of lowering environmental impact they of course need to be bought instead of alternative products. However, research shows that there is only a limited percentage of consumers willing to buy sustainable products only because they are sustainable, and prepared to compromise on functionality somewhat. The percentage that is willing to proactively change their lifestyle is even smaller. This stresses the importance for understanding product users when looking for solutions that are perceived by users as non-intrusive and with a high usability.

It is relevant to acknowledge that required levels of usability are not universal. A well-known sustainable product, the human powered radio, is a good example of this. In a third-world context the effort-result ratio is very favourable while in a first-world context the same ratio is unfavourable, meaning the product can not escape niche status.

Understanding the user logic is essential in a user-centred approach. Jelsma (2006) proposes a methodology utilizing contextual interviews. However, these may not be productive in cases where the objective is to prevent socially undesirable behaviour, as people will say what they feel they should do rather than what they actually do when interviewers are not present. This effect was apparent in research into littering behaviour. Jelsma already encountered this when people were unwilling to be filmed while loading their dishwasher with dirty dishes. They only agreed to be filmed during a dry-run, using clean dishes. Hence compromises in research methodology may be required. Hence Jelsma's suggestion of using contextual interviews may not always be the most suitable. However, as section 4 and the examples and case study have clarified, there are multiple methods available from the user-centred design field to incorporate the user in the design process, differing in costs, time-consumption and the suitability to identify socially undesirable behaviour. Which method is most suitable in a specific project will have to be determined by the design team.

## 11. Conclusion

For many products the use phase contributes significantly to the total environmental impact of the product's life cycle. This impact is partly determined by user behaviour. There is a potential for designers to influence this behaviour in a more sustainable direction. Designers can follow multiple strategies to achieve this, as this paper has identified: *functionality matching, eco-feedback, scripting and forced functionality*. The effectiveness of these strategies will differ from product to product, but will depend on the required (certainty of) the achieved environmental improvement and the acceptable intrusiveness or forcefulness of the strategy on the user's behaviour.

In all strategies the inclusion of the final user in the design process is key. The existing field of user-centred design can provide tools and methods to the field of design for sustainability to realize this potential.

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