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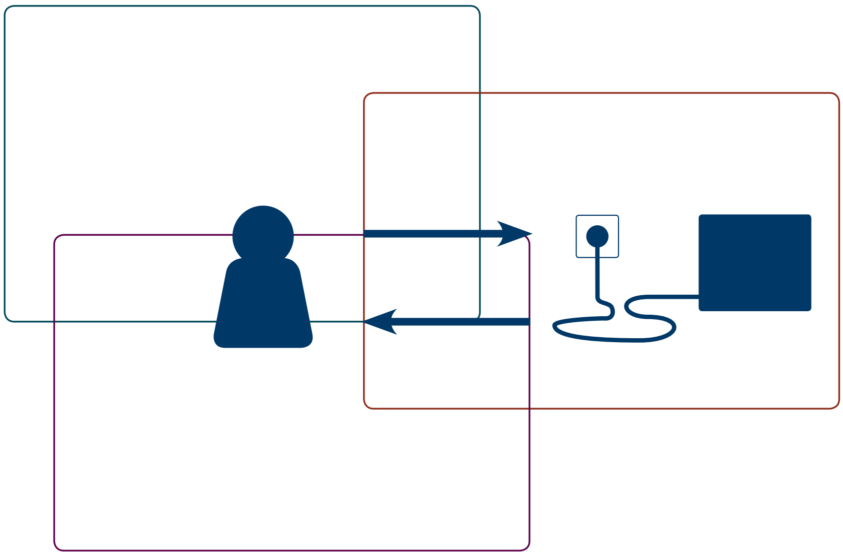

Predicting Energy Thieves

The development process of a theoretical tool to identify potential risks for energy wastage during the usage phase of products.

Master of Science Thesis in Industrial Design Engineering

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Preface

This report is a result of a thesis for Industrial Design Engineering at Chalmers University of Technology, Sweden, in collaboration with a company. Due to the confidentiality of the industry agreement, the name of the company cannot be disclosed. In this report, the process and research that has been conducted to address the usage phase of energy using products will be depicted.

The thesis has been under the guidance of three mentors, to whom I would like to express my warmest gratitude to: **Marianne Karlsson**, for her academic know-how and spot-on-the-dot advice, pushing me to believe in my method. **My second mentor**, for her warm personality and passion for sustainability, who has throughout the process provided me with sound advice, inspiration and helped to set limits for my ambitions. **My third mentor**, for her inspiring and encouraging words, always having the time to meet with me and welcoming me into the company in the best possible way.

I would also like to express my sincere thank yous to: **my family, friends and dogs**, for the continuous support and affection. I would also like to thank a few colleagues whose names cannot be mentioned in this thesis.

Abstract

With a predicted increase in household energy consumption and appliances as the most rapidly growing energy consuming category within the household sector, there is a growing recognition that increased energy efficiency alone cannot address the problem. Instead, to achieve substantial energy reduction, there is a need to not only understand and address user behaviour during the usage phase of products, but also to approach a larger group of users including those who are not motivated to behave in a sustainable manner.

In this thesis, the user's influence on the usage phase of products has been investigated to examine what factors affect the energy consumption and result in energy wastage. This was accomplished through a survey to determine users' understanding of energy using products and an extensive case study of a household product. In the case study, a series of energy measurements based on usage data from data logger readings showed that the energy consumption to perform a specific user goal could greatly vary between users. A set of qualitative studies was performed to understand the reasons why.

Based on an analysis of the survey and case study, it could be concluded that energy wastage could be attributed to (i) users' understanding of the product and its energy usage, (ii) how users use the product in their context of daily use, partly as a consequence of the technical function and design of the user interface, and (iii) the choice of technology related to the effectiveness of the product's technical design. It was also concluded that there was a need to create a common user understanding of when energy using products consume energy or not as well as to design products that are intuitively used as energy effectively as possible. The fact that several of the users in the case study had developed certain usage habits, many of them not optimal from an energy perspective, emphasises the importance to develop products that are designed either to cue the right habits or around existing. It is in designing a product, that the interaction between user and product is ultimately shaped and as a result also future habits. We need to know what behaviour is desired from an energy perspective and design accordingly. In order to do so, we need to understand what factors we need to design out of the product.

A set of generic design principles and recommendations – Three Approaches to Energy Effective Products – has therefore been created to address how products can achieve the lowest possible energy consumption. In addition, a theoretical tool – Energ-ability – has been developed with the purpose to systematically identify potential energy wastage as a result of the user-product interaction. This multi-disciplinary tool is intended to support product developers with different disciplinary backgrounds in creating a common understanding of the product and its potential energy impact during the usage phase. With this insight, product developers should have a better ability to improve products already during early development phases and thereby prevent the products from using unnecessary energy during the usage phase.

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Introduction

1. Background

The background to the thesis will be presented below.

1.1 Household energy consumption

Climate change has during the past years become a prime source of concern. Without preventive measures on a global level, it could have a serious impact on human life and the environment all over the world. In order to avoid the worst impact, it is therefore important to start minimizing the changes that are occurring in our climate. One way is by stabilising the C02 level; ideally by 2050, an 80% reduction of our current level emissions would be required (Stern Review, 2006). There has become an increasing awareness of utilising the global energy resources in a better way to reduce these emissions; this includes reducing the usage of fossil fuels, which accounts for approximately 66% of the global electricity production (International Energy Agency, 2008).

The household sector accounts for 29% of the global energy consumption and the OECD countries mainly rely on electricity and natural gas as the source of energy. The global household energy consumption has between 1990 and 2005 increased by 19%. This is mainly attributed to the use of appliances, which has been identified as the most rapidly growing energy consuming category within the household sector (see Fig. 1). The increased energy usage related to appliances is mostly ascribed to an increasing ownership of small appliances. Within 19 member countries of the International Energy Agency (IEA) in the same period of time, the electricity use for household appliances increased by 57%, accounting for approximately 59% of the total electricity use in households in 2005 (IEA, 2008). By 2020, the IEA have estimated that the electricity consumption of appliances will have increased with 25% compared to 2000 (Almeida et al, 2006). As most types of appliances operate on electricity (Wood & Newborough, 2002), improvements in their use of energy can play an important part in the reduction of emissions.

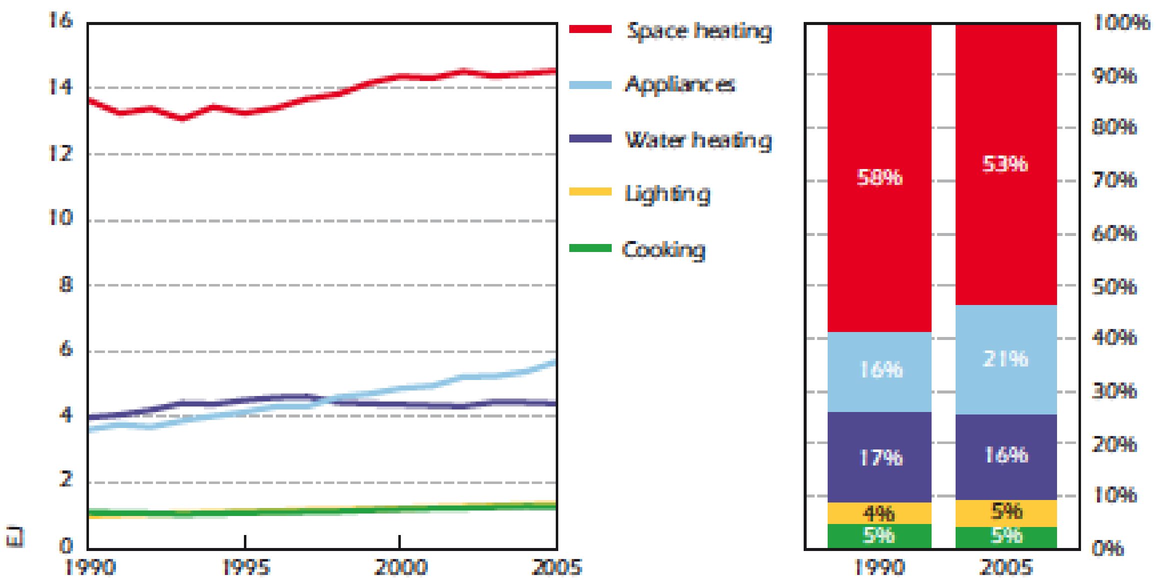

Fig. 1. Household energy use by end-use in the 19 member countries of the International Energy Agency (IEA, 2008)

1.2 New approach to energy reduction

One way of addressing the increasing global energy consumption is from a technological perspective in which the overall energy efficiency is improved. The possibility of reducing the environmental load of a product has however technical limitations (Pascual et al, 2003). In addition, these measures have little impact on the product usage phase, which is largely determined by consumer behaviour and is, for many electronic consumer goods, the phase having the largest environmental impact (Lockton et al, 2008). The way with which a household uses energy may vary greatly even when the appliances are identical; studies in the Netherlands, United States and UK have shown that approximately 26-36% of the household energy consumption is determined by user behaviour (Wood & Newborough, 2003). There is therefore a growing recognition of the need to tackle this challenge through product-led interventions by having a more user-centered approach to sustainability where focus is put on the interaction between user and product. Tang and Bhamra (2008, p.183/2) suggest that it is necessary to have a "better understanding of what users do with, and how they interact with products as well as the hidden factors behind the daily decision-making process".

2. Objective

The objective of the thesis has been to, with focus on the interaction between user and product, investigate ways of integrating sustainability into the domestic appliances of a specific company for the development of the next level sustainable products.

2.1 Purpose

The main purpose of the thesis was to answer: 'How can sustainable usage be integrated into the domestic appliances of the company?'. Focus was put on identifying new ways of achieving energy reduction during the usage phase and was addressed by examining:

» How can energy using products be designed to change the daily interaction with its users and encourage them towards sustainable behaviour?

» How can energy consumption differ during the usage phase and what aspects can lead to energy wastage?

Focus was put on one product and the final solution set sight on being a source of sustainable design inspiration.

2.2 Limitations

Energy wastage will be examined in relation to the user goal that is to be achieved, in other words the desired end result provided by the product and that the user would like to obtain. Why the user may wish to achieve this goal will not be examined, nor will energy wastage that may arise from misuse through poor maintenance be examined. All legislative documents that will be addressed within this thesis are from the European Union as this is where the company is situated.

3. Approach

The thesis has evolved in four main phases in which the initial phase strongly influenced the subsequent phases (see Fig. 2). Each phase has been characterised by an explorative as well as iterative process, and has also had a convergent character.

3.1 Phase 1. Frame of reference

The initial phase started with a wide objective but as the knowledge grew, became more concentrated and eventually helped to further define the scope of the thesis. A theoretical study was conducted during which current literature within the field of sustainable behaviour was examined. From this, it was concluded that in order to tackle the increasing household energy consumption, energy-saving should be made easy for a wider target group. In other words, it had to address others than those who were specifically in their everyday life already taking actions to reduce their energy consumption. Literature also pointed out the complexity of energy using products, including the multitude of power modes and the inconsistency of elements used in the user interface. In addition, it was also realised that the methods and tools that address sustainable usage was limited. In fact, there was no existing theoretical method that examined the user-product interaction during the usage phase to identify what aspects could lead to energy wastage. Thus, the important conclusions of this phase was to conduct an in depth investigation of the user-product interaction during the usage phase in two ways: firstly, by investigating the user's understanding of energy using products, and secondly, by obtaining deeper insights in the actual usage of a chosen carrier product. From the results of this investigation, a method to identify energy wastage during the usage phase would be developed.

3.2 Phase 2. Preliminary work

To better understand the current portfolio of the company's domestic appliances, an internal analysis to study the existing products was performed. The analysis helped to determine the carrier product and also pointed out that there was a different level of understanding for low power modes among the product developers. In addition, the analysis showed that there were several aspects of the user interface of energy using products that needed to be further explored. An online survey was therefore created to address the user's understanding of energy using products. With its 234 respondents, it contributed with interesting results, suggesting that one way of reducing energy wastage would be through creating a common understanding for energy using products.

3.3 Phase 3. Case study

The case study of the carrier product was divided into several consecutives stages. Once having established an understanding for the product, a theoretical analysis was performed to look into what aspects could lead to energy wastage during the user-product interaction. Data logger readings from the carrier product that had been logged in a specific number of households were studied and showed that the time it took users to perform a specific user goal could widely vary. From this information, user profiles were created and energy measurements were conducted to examine how much the energy consumption could differ. The conducted energy measurements showed that energy wastage could be attributed to the possible usage ways allowed by the product, but also to the actual system design of the product itself. This was followed by nine qualitative user studies in households to among others understand what factors could influence the time it takes the user to perform the user goal. In these user studies, observations were conducted as well as an energy context mapping session, which was specifically developed for the purpose to enable a more interactive way of interviewing the users. This in order to identify their habits that could not be seen or understood during the actual user study. The insights gained from the case study as well as the online survey from the previous phase resulted in the identification of three ways to achieve energy reduction in energy using products.

3.4 Phase 4. Method development process

In the last phase, a theoretical method to examine how energy wastage in energy using products could be identified and examined during the usage phase was developed. The method, which was named the Energ-ability Tool, evolved from the results of the previous phases and the development process was extremely iterative. In this phase, it was also realised that in order to fulfil

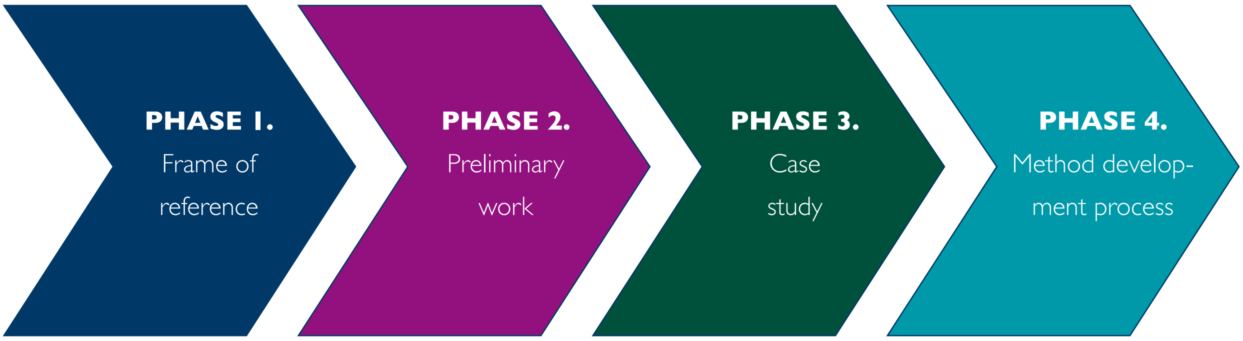

Fig. 2. The four main phases of the thesis project

the given objective and make the Tool easy to understand for the people at the company, there was a need to create a general understanding for the Tool. This lead to the development of the 3 Approaches to Energy Effective Products, which consists of a set of generic principles and recommendations of how energy wastage can be prevented in energy using products. These approaches were compiled in a handbook as an easy-to-read deliverable for the company. The handbook also provides with insights from the online survey as well as the case study. It further contains an introduction to the Energ-ability Tool and a glossary of the terminology for energy using products, including low power modes. Conceptual ideas of how to address the identified energy wastage of the carrier product were also developed during this phase.

Frame of reference

4. Introduction

In this phase, an extensive theoretical study was conducted in which literature was examined. The information that was obtained helped to further define the scope of the thesis.

4.1 Aim

The aim of this phase was to obtain a deeper understanding for the globally increasing household energy consumption and the measures that had been undertaken to address this problem. Another aim was to understand how a sustainable user behaviour can be encouraged.

4.2 Process

This phase started with a thorough and extensive literature study to examine the situation of the increasing household energy consumption. Many of the articles mentioned the problem of low power modes in energy using products, but did however not provide sufficient knowledge of these. It was considered important to obtain a general understanding for the terminology used for energy using products. International standards as well as regulatory documents of the EU were therefore studied. Although the international standard IEC 62301 includes new definitions for power modes, this standard is still under scrutiny and may therefore not be referred to. Thus, the definitions of the power modes that have been used in the thesis are based on those given by the European Union. To not only obtain clarity, but also to address the existing lack of power mode overviews, the power modes were divided into four main categories. The power modes have been categorised into categories, which have been given generic names that are commonly used in the terminology of energy using products. A matrix was thereafter created in which the power modes were linked with their respective functions, features and legislation (see ***Appendix I***).

The matrix was discussed and revised in discussion with an employee from a specific department of the company for validation.

An extensive literature study within the field of sustainable behaviour was also conducted. Focus was put on the seven design intervention strategies formulated by Bhamra et al in 2008 to obtain a deeper understanding for the ways with which products can create a behavioural change. The decision to focus on these strategies was based upon the fact that they were the most elaborate of the theories for achieving a sustainable usage.

5. Energy using products

Energy using products is in this thesis a term used to describe products that require energy from a mains power source to perform one or more functions. The product can be connected to the mains either through a permanently attached cord, or through an embedded rechargeable battery that is charged in an external power supply (EPS) or by an external charger.

5.1 Power modes

A power mode is a condition or state of an energy using product that characterises its power consumption and functionality. A product can have several power modes and will stay in a power mode for an indefinite time until it is activated into another power mode, either by the user or by the product itself through an automatic control. In the past years, the complexity of energy using products has increased; from simply having an ON and OFF mode, these products have been moving towards multiple power modes (Lawrence Berkeley National Laboratory, 2002) and with different designations.

In 2005, the International Electrotechnical Commission published an international standard, IEC 62301, providing with a method of test to measure the power consumption of standby power (Energy Efficient Strategies P/L, 2010). In this standard, standby was defined as the “minimum power level while connected to mains”. Standby became a commonly used term for low power modes and it is only recently that it is becoming clear that energy consumed in low power modes can be attributed to power modes other than the minimum one (Nordman et al, 2009). This definition was therefore revised and a range of new definitions for power modes were presented in a second version of IEC 62301 (Energy Efficient Strategies P/L, 2010). This standard could when it is officially published bring more clarity and a better understanding for low power modes.

5.1.1 Categorisation of power modes

The power modes have in this thesis been divided into four categories depending on its type of power source supply and energy consumption (see Fig. 3). These power mode categories include:

» **Disconnected mode.** Product is not connected to a power source and is therefore not consuming any energy.

» **Low power modes.** Product is connected to a power source and will either consume a low amount of electricity or none at all for a given functionality.

» **Low power modes for products with an EPS.** Product is connected to a power source through an EPS and will consume a low amount of electricity for a given functionality.

» **Active modes.** Product is connected to a power source and consumes energy to fulfill one or more of the main functions of the product.

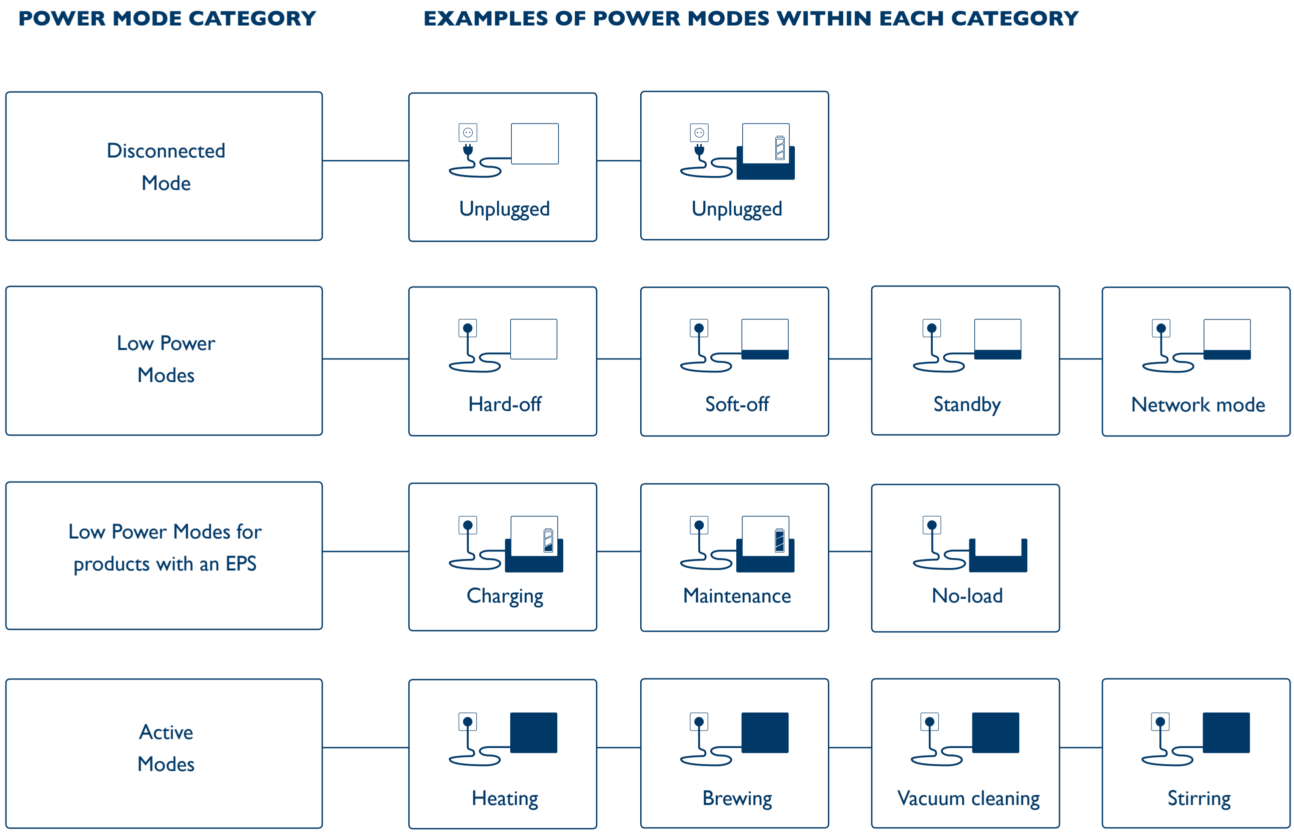

Fig. 3. Overview of the power mode categories

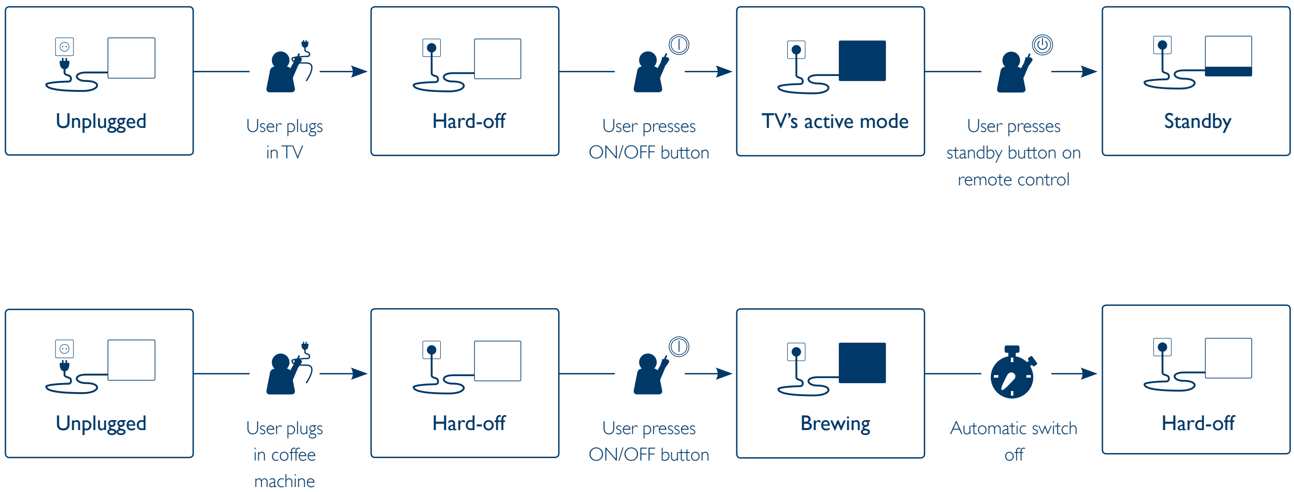

Fig. 4. Examples of power mode transitions. Top: a TV. Bottom: a dripfilter coffee machine

Each power mode category can in turn consist of a variety of power modes. See ***Appendix I*** for further information of each power mode and their respective functions, features and legislation. Two different examples of transitions between different power modes of a product are given in Fig. 4.

5.1.2 Low power modes

Power modes within this category use a low amount of energy to power a specific functionality.

Standby. This power mode consumes energy to power a reactivation function and/or a continuous function. The latter provides with information or an indication of the status of the product on a display. A reactivation function enables a product to be activated into another power mode through for example a remote control or internal sensor (Official Journal of the European Union, 2008). There is a wide range of domestic appliances with standby power and despite its rather low power range of 1-17 Watt, the environmental impact is considerate in regards to the total amount of appliances with built-in standby power within each household. An average home in Europe, Japan, Australia or North America is equipped with 20 devices continuously on standby (Ellis, 2007). 30-40% of the energy that an appliance uses during its life-cycle can constitute of standby power (Energimyndigheten, 2007). The total amount of household energy that is lost to standby mode lies between 5-10% and accounts for approximately 1% of global CO_2 emissions (Ellis, 2007).

Off-mode. This power mode does not provide with any function, but it can include an electromagnetic compability filter or an indicator showing that the product is in off-mode (Official Journal of the European Union, 2008). The off-mode can in turn be divided into either soft-off, in which the product will consume a low amount of electricity, or hard-off, in which the product does not consume any electricity at all (Lawrence Berkeley National Laboratory, 2002). In a study performed by the EU, it was determined that the number of products containing a standby and off-mode power functionality was estimated to 3.7 billion within the EU. The resulting energy consumption was approximately €6.4 billion. By 2020, the number of these products is expected to increase by 24% to 4.6 billion (Intertek, 2009).

Network mode. This power mode is commonly addressed as network mode. In the 'Guidelines accompanying Commission Regulation (EC) No 1275/2008', it has been referred to as 'networked standby' and has been suggested to mean a power mode that has a reactivation function that enables a product to be activated into another power mode through a network signal. The presence of network modes in products is expected to grow rapidly over the coming years as many products will be connected to a network in the future. The power mode is complex and cannot be addressed by the definitions of standby (Nordman et al, 2009). There is therefore currently an ongoing study to establish a regulation for network modes.

5.1.3 Low power modes for products with an EPS

For products with an EPS, which is connected to the mains, the following low power modes are used specifically: charging, no-load, and maintenance mode (see ***Appendix I*** for definitions). External power supplies are becoming another source of concern; it is estimated that approximately 17TWh of electricity consumption is lost annually to power conversion as well as the no-load mode, and by 2020, it is estimated to increase to 31TWh (Official Journal of the European Union). In a household survey examining the electricity consumption of battery-powered consumer electronics, it was determined that only 15% of the total energy consumed was used for battery charging. The remaining was lost as heat during maintenance (75%) and no-load mode (10%) (McAllister and Farrell, 2006).

5.2 Future trends

IEA has assessed that standby power will in the future be the fastest growing electricity consumption by end-use (Almeida et al, 2006) in which domestic appliances will be a strong contributory factor. A study on standby power consumption concluded that in the future, the purchases of new appliances will grow and 70% will have a built-in standby mode (Ross & Meier, 2002). Whether this 70% is only attributed to standby can be questioned due to the evolvement of its definition. What can be concluded is that there will in the future be an increasing rate of energy using products with multiple power modes. This will be a result of:

- » Increasing communication and networking between products (Almeida et al, 2006)
- » More products with automatic controls such as sensors (Lawrence Berkeley National Laboratory, 2002)
- » More products with external power supplies (Lawrence Berkeley National Laboratory, 2002)
- » More complex products with additional functions such as large multi-colour displays (Gruber & Schlomann, 2006)

5.3 User interface

The user interface for energy using products can include a combination of manual and automatic controls, and power mode indicators in which symbols, coloured LED lights, displays, as well as audio and tactile indicators can be used. In indicating the different power modes, there is often a lack of consistency in the user interface, not only when comparing different types of product, but sometimes also within the same type of product. Even though many products have power management features present in their interface, studies identified that these were often used incorrectly or not at all due to the complexity, inconsistency and confusion that they were associated with. The energy saving potential that these features have were therefore lost (Lawrence Berkeley National Laboratory, 2002). There are standards focusing on single aspects of the user interface such as indicators or symbols, but no standard covering the entire user interface. A first attempt to create one was funded by the Public Interest Energy Research Program of the California Energy Commission and conducted by

Lawrence Berkeley National Laboratory. The research led to that an IEEE standard for 'User Interface Elements in Power Control of Electronic Devices Employed in Office/Consumer Environments' was published in 2004.

5.3.1 Symbols

The graphical symbols used to indicate different power modes that are in accordance to the international standards are presented in ***Appendix II***. Of these, the standby and ON/OFF symbol are of particular interest (see Fig. 5).

Fig. 5. Left: ON/OFF symbol. Right: Standby symbol

The ON/OFF symbol is used for hard-switches to show that the product is not using electricity, whereas the standby symbol is used for soft switches to indicate that the product is consuming electricity. An issue that was brought up by Lawrence Berkeley National Laboratory (2002) was the distinction between the ON/OFF and standby symbols. The symbols are to their appearance rather similar and user studies in the US show that the standby symbol has come to be associated with the term 'power', 'on' or 'power on'. The ON/OFF symbol can also be associated with these terms. In the new IEEE standard for user interface elements, it was therefore suggested that a crescent moon symbol should be used to indicate a low power mode, including standby, and that the standby symbol should used as a generic power indicator (IEEE 1621, 2005).

5.3.2 Colour

Colour can be used to communicate the power mode that the energy using product is in, often through LED lights. The ANSI/VITA 40-2003 is a status indicator standard that is generally applicable to products using lights to convey status information to the user. Another standard is the CEI IEC 73, "Basic and Safety Principles for Man-Machine Interface, Marking, and Identification" (Hartley, 2010). Based on these two standards, an attempt to categorise the usage of colour in appliances was summarised in a table that can be viewed in ***Appendix III***. Red is used to communicate a fault of some kind. However the colour red along with green is often used to show that the appliance is in active mode. A reason mentioned by Lawrence Berkely National Laboratory (2002) is that red was the cheapest, most available and energy-efficient colour at the time when LED lights started to be used as indicators. They further state that sometimes even the colours blue or white are used as indicators for the same mode.

6. Users and energy use

Energy has according to Wallenborn et al (2009, p.8) been "abundant, cheap and invisible". This can make it difficult for users to relate to and understand energy consumption. Studies have shown that that users are not aware of how much energy their appliances were consuming (Bharma et al, 2008; Brook Lyndhurst, 2007) and that users have a poor perception of which products were consuming the most energy (Elias, 2007; Brook Lyndhurst, 2007). Abrahamse et al (2005 in Ai He & Greenberg, 2008) put attention on the fact that users do not necessarily use products in the most energy efficient ways and another author points out that users are not aware of any detail of energy-saving options (Brennan, 2006 in Gruber & Schlomann, 2006).

In the article 'Sustainable Use. Changing consumer behavior through product design', Bhamra et al (2008, p.3) write that: 'It has been recognised that although consumers express strong concern about the environmental and social impacts of their activities, their action do not reflect their concerns'. One reason mentioned by Tang and Bhamra (2008, p.183/2) is that: "Environmental benefits of the wider global community, compared with the individual desires, are not strong enough to motivate a different lifestyle". This could be explained by the fact that many users have difficulties in relating the outcome of their behaviour to a global context, which makes it hard for them to draw parallels between the way they are using a product and the possible impact it could have. Many educational interventions such as information campaigns have therefore not been successful as they often relate to environmental aspects from a global perspective (Lilley et al, 2005).

7. Measures to reduce energy

The common way of tackling the increasing energy consumption has been through education and technical development. The latter has been pushed by legislation.

7.1 Regulatory measures

Numerous regulations address the issue of increasing energy consumption through the establishment of minimum efficiency requirements. The EU are among others addressing the increasing energy consumption through implementing policies to set minimum requirements of efficiency and clear labelling of the energy usage of appliances (European Commission, 2009).

The European Parliament and the Council of the European Union have established a directive with ecodesign requirements for energy using products. Two of the implementing measures of this Directive are the regulation EC 1275/2008, and the EC 278/2009. These regulations have a two-phase entry implementation, the first phase on April 27th, 2010, and the second phase on April 27th, 2011. The EC 1275/2008 is applicable for all the company's products with a mains connection including those with external power supply (Internal company presentation). The requirements demand that the power consumption shall not exceed a certain limit for the standby and off mode respectively. See ***Appendix I***. In Phase 1, all products must, unless inappropriate for intended use, have a power mode that follows the power consumption limits of low power modes. In Phase 2, which is to be implemented in 2013, all products must, unless inappropriate for intended use, have a mechanism or switch that enables the product to go into off/standby or another mode that meets the power consumption limits of off/standby. They must also have a power management system that automatically switches it to a low power mode unless it is inappropriate for intended use (Official Journal of the European Union, 2008). For products with an EPS, limits to power consumption for the maintenance mode are in Europe given in EC No. 1275/2008, whereas for no-load and charging, limits are given in EC No. 278/2009. Exempted from the latter are the low voltage EPS in which the voltage and current output of the power supply is lower than 6V and 550A respectively.

For the active mode, which for most products is the power mode that uses most energy, there is no legislation providing with limits to power consumption. Energy labelling can however be seen as addressing this. The energy efficiency of a product is rated in different classes, with A+++ being the most energy efficient, and G being the least efficient.

7.2 Technological measures

There exists a variety of technical solutions to reduce the energy consumption of products during and after usage. These mostly aim at improving the overall energy efficiency. Legislation and voluntary agreements have helped in pushing the industry towards developing more energy-efficient products through their limits for low power modes. In the report 'Worldwide Trends in Energy Use and Efficiency' (2008), IEA however concluded that there still remains a large potential for further energy savings through increased energy efficiency. As an example, the energy consumption related to standby power can be significantly reduced. According to Ellis (2007), it is technically feasible to reduce standby power by as much as 90% without worsening the features. Companies, such as Fujitsu Siemens, have gone so far as to tackling the standby issue by simply eliminating energy consumption from standby and OFF-mode with their 0-Watt display and PC (Fujitsu, 2010). Other solutions implementable within the product itself include having a hard switch, power management system, or using alternative power sources such as a photovoltaic cell or battery to power the standby function (Mohanty, 2002). For products with an EPS, it has been suggested to replace these alternatives with corded solutions, but the portability of the products would then be lost.

In addressing users who tend to leave their charger plugged in, there are several types of technical solutions. Timers can switch off when the battery is fully charged and batteries can be optimised to minimise overcharging. Despite this, simple battery chargers, which can be both inefficient and have constant power consumption, are often preferred due to their lower initial costs (McAllister and Farrell, 2006).

7.3 Educational measures

Governments and environmental organizations have been advocating users to buy more energy efficient products through information campaigns and energy labelling of households appliances. Schlomann (2010) mentions that in some countries, such as Switzerland and the Czech Republic, the purchasing has been promoted through subsidies. An interesting observation, which was made when googling for ways to reduce energy consumption, was that the commonly seen energy-saving advice on the internet included "unplug your product" or "use a power strip to switch off your product". In other words, the most recognised way to control energy consumption of products was through the purchase of an additional device. These included power strips with a hard switch, timers or devices monitoring energy usage and sensing when to power them down when not in use. Another recommendation was for users to buy a meter to determine if their product is using energy continuously. The implication of this advice is that users cannot trust their products. This is not in any way out of the ordinary as many products on the market today lack a hard switch, and there is therefore no option other than pulling out the plug to ensure that no electricity is being consumed (Mohanty, 2002).

7.4 The counteractive factors of increased energy efficiency

Energy wastage in energy using products has mostly been associated with and addressed in low power modes, which have become a growing area of concern, particularly given the development towards 'comfort functions' such as displays, sensors and network communication. Although Woodall and Bates (2009) mention the given trend towards an increased purchase rate of energy efficient products, this can alone not solve the predicted increase in energy consumption that will be faced in the future. Significant improvements in energy-efficiency have had a counteractive role in the growing trend of increasing household energy consumption. The IEA (2008, p.3) however acknowledges that "the current rate of energy efficiency improvement is not nearly enough to overcome the other factors driving up energy consumption".

Firstly, energy efficiency has not been sufficient enough to balance the significant growth in number, size and features of electrical appliances (Herring and Roy, 2007). With a steadily increasing global population, appliance ownership is rising, which is affected not only by income growth and the increasing diversity of appliances (Almeida et al, 2006), but also by the growing trend of decreasing average household size; a single person household consumes approximately 60% more energy than a two-person household (Roberts, 2008).

Secondly, despite that a common way for a user to reduce energy consumption is by changing to more energy-efficient products, this does not necessarily result in lower energy consumption; on the contrary, it can give rise to a rebound effect in which the money that consumers save on energy-efficient products can instead lead to increased usage or be spent on other products and services (Herring and Roy, 2007). An interesting finding from a press release of a report published by the Joint Research Centre of the European Commission in 2007 was that "as older equipment is updated in a household, it is still often transferred to other parts of the home instead of being replaced, thereby contributing to greater electricity consumption".

8. Design for behavioural changes

Technical and educational measures may not be sufficient to achieve significant energy reduction given the previously described limitations. This knowledge confirms what was suggested in the introduction, that product-led interventions may be an alternative way to reducing the energy impact in the usage phase of products, and will thus from hereon be the focus of this thesis. In the words of Bhamra et al (2008, p.2): 'Products, as the interface between consumers and consumption activities, can give immediate and direct responses to users' operations: how it is perceived, learned, and used. Designing a product means designing a user experience with the product, which also determines the compound impacts of this experience'.

Within product-led interventions, Lilley et al (2005) distinguish between three potential approaches:

» Eco-feedback, based on informing users of the impact of their behaviour.

» Scripts and behaviour steering, based on providing products with 'scripts' or directions on how they should be used.

» Intelligent products and systems, based on products having more control over its functioning.

In a further developed model, Bharma et al (2008) define seven different design strategies. The authors have categorised the strategies according to three elements considered important for behavioural change: intention, habits and control (see Fig. 6). These strategies have different levels of power in decision-making between the user and product. In the strategies that are categorised under 'intention', the power lies more in the hands of the user, whereas in the strategies that are categorised under 'control', the power to create a behavioural change lies more with the product itself.

8.1 Three elements of behavioural change

The three defined elements of behavioural change will be described below.

8.1.1 Intentions

Intentions are affected by attitudinal, social and affective factors (Bhamra et al, 2008).

Attitudinal factors. Attitude refers to the sometimes evaluative behaviour or outlook upon which a user may have on an object (Moore, 2001 in Faiers et al, 2007). In the model of Bharma et al (2008), the factors have been determined as the level of knowledge or the beliefs that a user holds. These factors influence the way which a user may understand an issue or product and how a user will act or be motivated to act. The level of knowledge can in turn be affected by income, education, cultural background, geographical context, etc.

Social factors. Social factors influencing a user's intention include norms, roles and self-concept. Norms can refer to what a user may perceive as normal or ought to

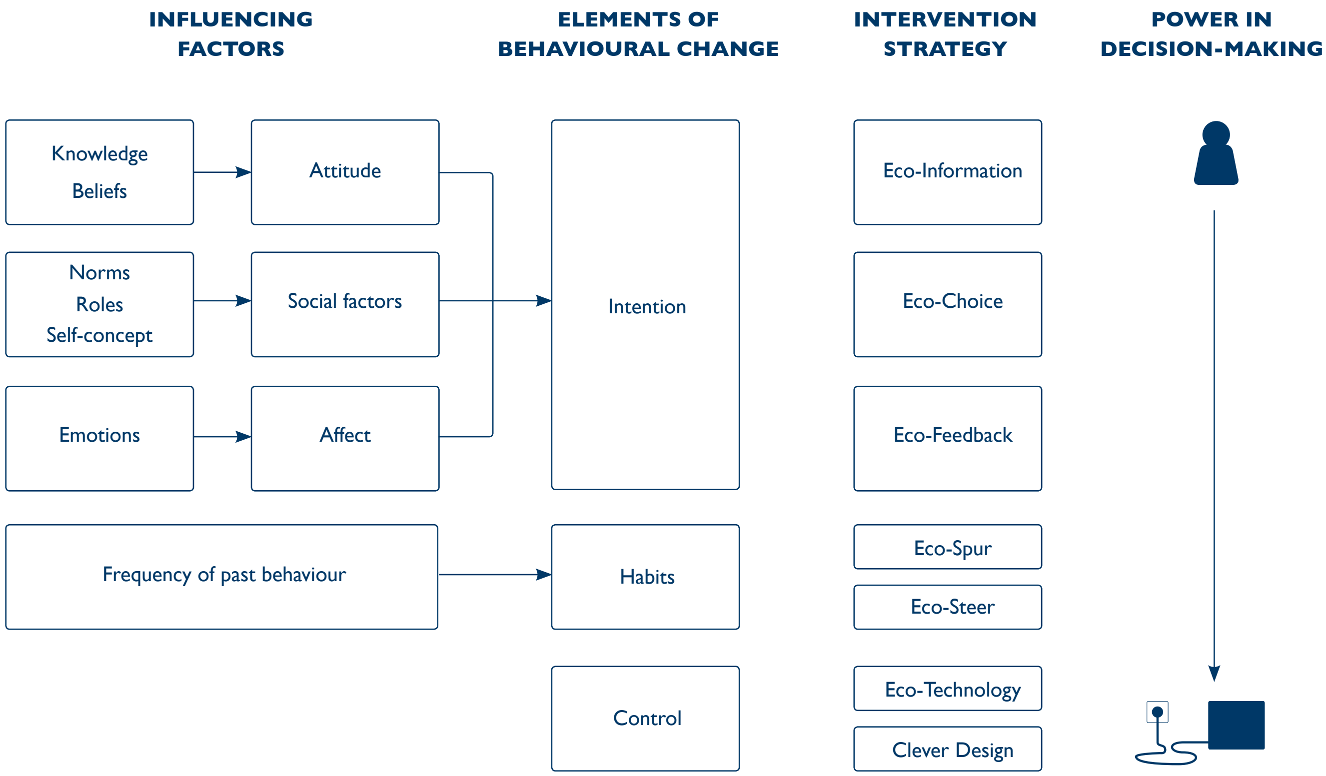

Fig. 6. Elements of behavioural change linked with the seven design intervention strategies, based on the model by Bhamra et al (2008)

be done in a certain situation, but it can also be based on what others are doing in a similar situation. According to Schwartz's 'Norm-Activation Theory', norms arise from "an awareness of the consequences of one's actions and the ability and willingness to assume responsibility for those consequences". The inclination to change a user's behaviour is greater when the user is aware of the negative consequences and also more inclined to accept responsibility for these consequences (Jackson, 2005). Lockton et al (2008) mention social proof as a way of persuading users to be more sustainable by comparing a user's energy consumption with that of other users. This approach could lead to reduced energy consumption, but there is also a risk that the opposite occurs, in which a user may feel that they have to consume as much energy as others. Roles are related to what a user may consider as appropriate behaviour in regards to the social position a user may have in a specific context, whereas self-concept refers to the view that users have upon themselves and the goals that they should pursue. How users perceive themselves is important in the sense of how they should or should not behave (Jackson 2005).

Affect. In the Triandis model, Jackson (2005) has interpreted affect as being an unconscious contribution to our intentions, in which users in specific situations react instinctively. Decision-making can be based on emotional responses and need therefore not be a deliberate process; according to Jackson (2005), Damasio has proposed a model in which the process of making a decision is influenced by physiological triggers within the body, which give positive or negative feelings and thereby creating biases towards specific options. These triggers can either be instinctive or have been accumulated through habits. Imbuing an emotional value to a product could therefore affect the way users feel and use their product. According to Linden & Thelander (1997), products that users are more emotionally involved with are usually better taken care of, thereby also lasting longer (Lilley et al, 2005).

8.1.2 Habits

Habits arise through repetition and reinforcement, which in turn are affected by frequency and strength respectively (Jackson, 2005). The way with which a user reacts to a specific situation can either be a conscious decision following a deliberate and rational decision-making process, or it can be subconscious, in which users respond instinctively, indicating that they must not always be aware of something in order to react in a certain way (Heijs, 2006a in Pettersen & Boks, 2008). Habits play an important role in the decision-making in everyday life; studies have shown that they make up for approximately 45% of the everyday actions that occur on a nearly daily basis and often in the same location (Verplanken & Wood, 2006 in Bhamra et al, 2008). In regards to this aspect as well as the high degree of automation that habits entail, Jackson (2005) concludes that breaking these routine behaviours can be difficult. Habits are according to Andersen (1982 in Jackson, 2005) created in a three stage process. Firstly, in the declarative stage, where information regarding a specific choice or action must be processed. Secondly, in the knowledge compilation stage, the information must lead to a new action and be translated to a new habit. Lastly, the procedural stage ensures that the habit is locked in.

Sauer et al (2003a) state that with low complexity products, it is harder to modify user behaviour than when compared to high complexity products, which have a higher level of automation, more functions and easier maintenance. This is especially true for products within the domestic environment. Habits are developed more easily with low complexity products as users are usually not trained in how to use them. Instead, these products are subject to a more skill-based learning in which users tend to teach themselves how to use them. Wiese et al (2002 in Sauer et al, 2003a) also mention that the lower the level of complexity, the higher the risk is that the user does not read the instruction manuals, which can instruct the user of best usage. High complexity products on the other hand are subject to a more knowledge-based learning in which users are more conscious about the decisions they make. This type of created behaviour is therefore easier to influence.

8.1.3 Control

Products in which the control lies more in the hands of the product than of the user does not rely too much on the mass consumer. They can therefore be a way to target users who are not committed to sustainability or who would not like to change or compromise on their lifestyles (Lilley et al, 2005). Changing user behaviour through control could however have unintentional effects as well as raise different moral and ethical issues. Using control as a mediator for behavioural change leads to a new product-user relationship. Lilley (2009) states that the relationship has long been characterised as being 'Master and Slave' in which the role of the product has been to serve the user. This relationship changes however when the control of the product lies more in the hands of the product. An interaction in which the product dominates over the user could be disconcerting if the user is accustomed to always making the decisions.

8.2 The seven design intervention strategies

Each of the seven design strategies for product-led interventions, defined by Bharma et al (2008), will be presented and analysed below.

8.2.1 Eco-Information

A strategy to "make consumables visible, understandable and accessible to inspire consumers to reflect upon their use of resources" (Bhamra et al, 2008).

A first step in creating awareness for energy consumption could be by making it more tangible to the user. One example is the Power Aware cord, in which electricity is visualised through different pulses and intensity of light. The short-term and long-term effect can however be questioned; once the novelty of a product wears off and becomes integrated in the everyday life, the product may no longer create awareness and be as eye-catching as it initially was (Backlund et al, 2006).

8.2.2 Eco-choice

A strategy to "encourage consumers to think about their use behaviour and to take responsibility of their actions through providing consumers with options" (Bhamra et al, 2008).

Providing users with choices can enhance the cause and effect, in which a user having to make a choice will reflect over their decision and be more likely to learn from and adapt their behaviour accordingly (Lilley, 2009). How the user makes a choice could however influence its cause and effect. Jackson (2005) mentions that choices can, according to the 'rational choice theory', be made by evaluating the expected outcome and choosing the alternative that is most beneficial to the user. The author also mentions that choices do not always have to follow a deliberate thought process, and the potential benefit of the cause and effect could thereby result in an undesirable behavioural change. Features that should enable the user to use a product in a more sustainable way are only beneficial to the environment if these features are selected and used by the user. This could be affected by the amount of choices given to the user. Too many choices or too much information can according to Jackson (2005), result in feelings of helplessness, which people in general try to resist as they like to feel in control of their lives. Lockton et al (2008) therefore mean that if there are several options that a user can choose between, the tendency for the user to choose the eco-friendly option will increase if it is easy for the user to select this option.

8.2.3 Eco-Feedback

A strategy to "inform users clearly about what they are doing and to facilitate consumers to make environmentally and socially responsible decisions through offering real-time feedback" (Bhamra et al, 2008).

Feedback has by many been advocated as a way of motivating people to change their behaviour. Appropriate feedback can help users to develop more accurate mental models (Lockton et al, 2008), helping them to understand the current situation and thereafter have the ability to make the right decision. The way the feedback is presented is thus important as it relies on the users' ability to relate it to their behaviour and to thereafter make the right choice. When, how, and what type of feedback are therefore important. Early studies by Senders et al (1952) have shown that feedback given during or immediately after the usage of a product is more effective as it enables users to more easily relate their usage to the product (Wood & Newbourough, 2002). This type of feedback give users the possibility to change their behaviour immediately after the feedback has been given (Lockton et al, 2008). Providing users with information does not however always imply that it will lead to an action (Darby, 2001, in Lilley, 2009) and many advocates emphasise the importance of also giving users an incentive to change. An often used argument to change behaviour that is mentioned in several articles is reduced energy costs and environmental impacts. However, on a study by Gyberg and Palm (2007) of different actors trying to influence household's energy behaviour in Sweden, an issue that was brought up was the fact that the economic profit was often too small to create a change and the environmental benefits were not tangible enough for the users.

8.2.4 Eco-spur

A strategy to "inspire users to explore more sustainable usage through providing rewards to 'prompt' good behaviour or penalties to 'punish' unsustainable usage" (Bhamra et al, 2008).

The carrot and stick approach is another term often used to denote rewarding and penalising. The essence is that rewards should enhance certain behaviour, whereas penalising should deter a user from performing a certain action or behaving in a certain way. Rewards and penalties are a way of reinforcing behaviour either positively or negatively. Jackson (2005) mentions that some behaviourists suggests that this approach is a more effective way of achieving behavioural change than compared to exhortation and information. Positive reinforcements are an important determinant in establishing new habits; a new action that is seen as successful to the user will motivate the user to continue using the action (Jackson, 2005). Penalising could however be perceived negatively by the user and could discourage them from using the product again (Lilley, 2009).

8.2.5 Eco-steer

A strategy to "facilitate users to adopt more environmentally or socially desirable use habits through the prescriptions and/or constraints of use embedded in the product design" (Bhamra et al, 2008).

Scripting products with affordances and constraints could help make unsustainable behaviour automatic or impossible. Affordances are details or cues that show a user how a product should be used. Constraints used to create a behavioural change are also referred to as forcing functions, which are built into the system and refrain users from using products incorrectly. A known constraint is the poka yoke. This is a Japanese term for mistake-proofing, in which product defects are eliminated by preventing, correcting or drawing attention to human-errors (Lockton et al, 2008). These can include more preventative constraints, which prevent the user from performing an error. An example of this would be an interlock, where a user has to perform actions in a certain order, only being able to go to the next action if the previous one has been performed correctly. A typical example would be a microwave oven that does not start operating until its door is closed. A detective constraint is another type in which the user is alerted when a mistake has been made. Examples of this would be warning beeps (Robinson, 1997).

8.2.6 Eco-technical intervention

A strategy to "restrain existing use habits and to persuade or control user behaviour automatically by design combined with advanced technology" (Bhamra et al, 2008).

Products can be designed to correspond to the actual way the users use them (Wever et al, 2008) and those exerting more control over the user could be advantageous in certain contexts when users may not have the knowledge or concern to make the right decision. However, products performing an action at the wrong moment or in a too regular way could raise feelings of irritation, making users try to find ways of evading the persuasive features and thereby counteracting the intentions of the product (Lilley, 2009). The timeliness of interventions is therefore a crucial aspect when trying to influence the user (Fogg, 2003). Evidence also proposes that by varying the frequency and modality of intervention, irritation can be reduced (Arroyo et al, 2005 in Lilley, 2009). Adding a surprise factor to the product could satisfy the user in a way that removes annoyance, but also increases the emotional attachment, making the user not want to purchase another product. Another way of maintaining the user-product relationship would be through having a more interesting and evolving interaction (Lilley, 2009).

8.2.7 Clever design

A strategy to "automatically act environmentally or socially without raising awareness or changing user behaviour purely through innovative product design" (Bhamra et al, 2008).

Clever design enables users to continue with the same behaviour as they always have had. The extent to which persuasiveness can be applied in product design and the resulting effectiveness and acceptability may differ from user to user and must therefore be investigated. These type of products could however separate the cause and effect by moving the decision-making to the product, which may restrict the user's recognition of sustainability issues (Lilley, 2009). In that sense, such a product would not offer an incentive for the user to take responsibility of their actions (Lilley et al, 2005). On the other hand, in regards to users who are not motivated in behaving sustainably, this approach would be a way of reaching out to them so that they would not have to compromise on their lifestyle (Lilley et al, 2005).

9. Methods and tools for sustainable usage

The previous chapter has shown that there is, as Bharma et al (2008) point out, not one solution to creating behavioural change, but many. The authors further state that: 'To successfully integrate behavioural concerns into design practice, and to make this process repeatable, appropriate information and tools must be developed and incorporated into the design process' (2008, p.8). They also mention that their seven design intervention strategies can be used as a tool to inspire and enable designers to address user behaviour. Similarly, the 'Design with Intent Toolkit' aims to inspire designers that have been given a brief to create behaviour change in products (Lockton et al, 2008). The toolkit aspires to create design ideas through questions and examples that are divided into eight lenses, in which each lense represents a certain field of research, such as architecture (Lockton et al, 2010). To identify the influencing factors of user behaviour, which can provide input to the brief given to designers, Bhamra et al (2008) have advocated the importance of observational studies. On the other hand, there exists no theoretical method of how to provide this brief with the required information of what aspect in a product that needs to be addressed from a sustainable usage perspective.

Most methods within sustainable design analyse or improve the sustainability impact in the different phases of the life cycle such as the Eco Strategy Wheel or the Life Cycle Analysis. The latter examines the usage phase, but from a single pre-supposed user profile and does not examine the differences that could occur within. The awareness of the importance of a user-centered approach to sustainability in product development is relatively new, which could explain the lack of methods or tools that address ways of investigating a product during its usage phase in regards to its effect on energy consumption. An explanation that is given by Wever et al (2008, p.2) to the limited research conducted within the human side of the usage phase is the "traditional lack of cross-fertilization between sustainable product design research and human-focused design disciplines like user-centred design and interaction design".

10. Conclusions and implications for further work

An early conclusion that was made during the literature study was that the increasing purchase rate of energy efficient products can not alone solve the predicted increase in energy consumption. Not only will they have to counteract the expected increase of appliances, but also the rebound effect, in which users may end up using more energy with an energy efficient product. It was also realised that although energy wastage has often been acknowledged and addressed in low power modes, the complexity of energy using products could also play an important role. This was due to the multitude of power modes and the sometimes lack of consistency in the user interface. For users, energy reduction should not require additional products such as a power strip to control the energy usage. Moreover, many users ascribe the responsibility to the manufacturers. There is therefore a need to develop products that help the user to a more effective energy usage. This in order to not only overcome the counteractive factors of energy efficiency, but also to make energy reduction accessible to a larger group of users, including those who do not express an environmental concern or have the adequate knowledge. As a result, a target group for the thesis was established: 'Silent Green'. This was not an initial aim of the thesis, but was seen as a natural way of addressing the users who could benefit from products developed to enable sustainable usage. This target group was in discussion with one of the mentors named 'Silent Green'.

The study of the seven design intervention strategies showed that an important mediator of change would be through creating new habits with products. This would especially be important in domestic appliances as habits are harder to break with low complexity products. The important thing would be to create the right habits, and through repetitive usage, make these new types of behaviours rooted and instinctive. The study also indicated that different types of design solutions could be acceptable to different types of users. Intervention strategies in which emphasis is put on persuasiveness or making sustainable usage intuitive have been pointed out to provide with the possibility of reaching a wider range of users. Products having a higher level of persuasiveness could therefore be the means to address the 'Silent green'.

An important discovery during the study on design for behavioural change was that there were indeed tools to address user behaviour, but none to identify what aspect of the user-product interaction for which a behaviour change needed to be created. User studies have been recognised as a way to identify aspects such as habits that prevent a sustainable usage. Theoretical methods to investigate the usage phase have however not been identified, but could from a company perspective be beneficial as they are less costly. They do not require home placement tests, but instead enable a product to be investigated in an environment separate from its actual context of use. Such a method could not only be a cost-effective way of identifying the factors that can lead to energy wastage, but also provide a basis for developing products for the 'Silent Green'.

Based on the findings of the literature study, it was therefore concluded that in examining energy consumption and potential energy wastage during the usage phase, there were two aspects of the user-product interaction to pursue:

» To examine the user understanding of the user interface of energy using products
» To examine how the usage phase is influenced by users by conducting a study on a carrier product

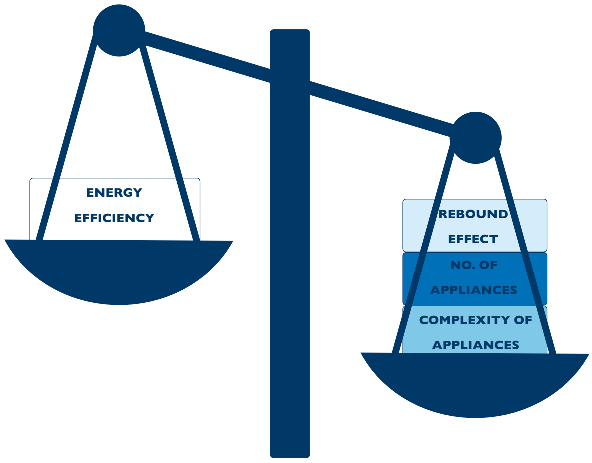

Fig. 7. The counteractive factors of energy-efficiency

The results of these two investigations would in turn form the basis for developing a theoretical method to identify energy wastage and what aspect of the user-product interaction for which a behaviour change needed to be created. This method would also be the means to explore how sustainable usage could be implemented in the domestic appliances of the company.

Preliminary work

11. Introduction

In the previous phase, the complexity of energy using products had been determined as one of the counter-active factors of energy efficiency. The complexity was partly ascribed to users' understanding of low power modes and the user interface of these products. In this phase, these aspects were further investigated through both a theoretical and empirical study.

11.1 Aim

This phase had three aims. Firstly, to assess the current portfolio of the company and determine a carrier product on which focus would be put in the subsequent phase. Secondly, to examine the market of product-led interventions aiming to achieve a behavioral change. The third aim was to conduct an empirical study to examine how users understand the user interface of energy using products.

11.2 Process

In this phase, a study on product-led interventions was conducted. A theoretical study to analyse existing products within the company was also performed and provided insights to which products had the most potential for improvement. This study also pointed out several aspects of the user interface that needed to be further explored. These aspects were among others investigated in an online survey that was developed specifically to examine the users' understanding of energy using products.

12. Analysis of existing products

Below follows an account of the internal analysis of the company's domestic appliances and the external analysis of product-led interventions.

12.1 Purpose

The purpose of the analysis was to examine and become acquainted with the current domestic appliances of the company. The analysis would identify possible areas of focus and help to determine a carrier product. Another purpose of the analysis was to examine the market for energy using products, which in different ways were trying to achieve a behavioural change.

12.2 Method

Low power modes had in literature been mentioned as a problem that had been addressed through both regulatory and educational measures. Therefore in obtaining an understanding for the domestic appliances of the company, and to have an idea of which product to focus on, a graphic overview was established. Each overview included the product categories and low power modes of each product (see ***Appendix IV - VI***). The overviews do not cover the entire product range, but is based on the information that was available at the time and in discussion with employees of the company. The information was gathered from test reports, user manuals and product data sheets. (For a detailed analysis of the products, see ***Appendix VII***). In examining the market for product-led interventions, the internet was used. To distinguish between the ways by which the identified products and concepts were aiming to create a change in behaviour, they were categorised according to the seven design intervention strategies described in the previous phase.

12.3 Results

The results of both the internal and external analysis will be described in the following sections.

12.3.1 Product overviews

The product overviews of the show a wide variety of products consuming energy when not in use. From a deeper analysis of the products, the following conclusions were made:

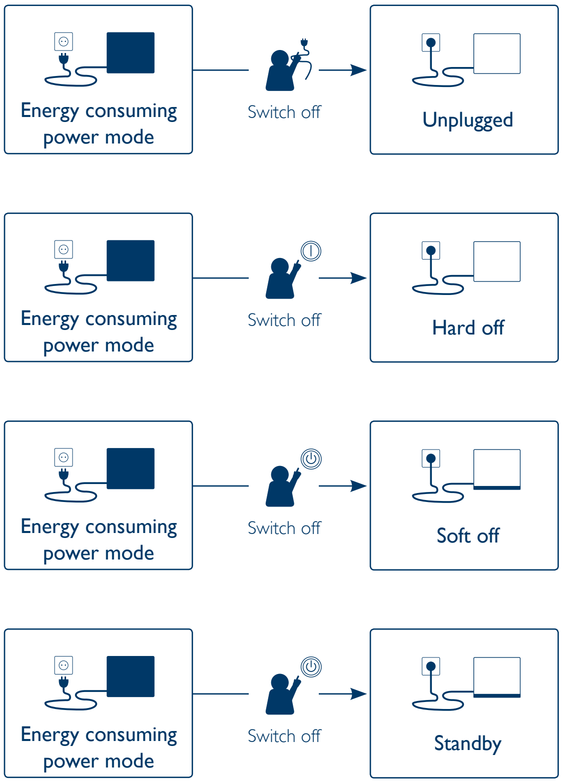

Fig. 8. Four identified ways of switching off

- Products with low power modes do often not have a solution enabling or encouraging users to prevent energy consumption in low power modes. In other words, the user must unplug their product to ensure that there is no usage of energy.
- Switching off has different meanings. When switching off a product, it does not necessarily mean that the product will no longer be consuming electricity (see Fig. 8).
- Switching off has different visual feedback. When switching off a product and it is still consuming energy, some products provide the user with feedback in the form of an indicator light, whereas other do not (see Fig. 9). In case of a present indicator showing the current power mode, there was an inconsistency in the colour used to communicate a specific low power mode.
- ISO-standard for symbols is not followed. For certain products, the ON/OFF symbol was used on despite the fact that they consume off-mode electricity when having been switched off with this button. In addition, the crescent moon symbol was not observed in any of the products and none of the employees of the company had seen the symbol before.
- Products can still be using energy after an automatic switch off.

Another interesting observation made during discussions with company employees was that there appeared to be a different level of understanding for the low power modes. This could be ascribed to that a specific low power mode could include many different types of functionalities and that the power modes could have different definitions.

12.3.2 Potential carrier product

In an internal document of the company, the annual energy impact of a variety of products had been investigated from a single user perspective, but also in regards to the total volume of sales in which the global implications of the energy consumption during and after use had been determined. This information showed that the impact of a specific product could increase drastically in relation to the volumes of sale.

12.3.3 External analysis

In examining the market of energy using products, it was observed that few attempts have been made to create products aiming to reduce energy consumption through product-led interventions. As previously mentioned, the main way of controlling the energy consumption of products was through the purchase of an additional device. An overview of products and concepts within each of the seven design strategies was created (see ***Appendix VIII***). As is mentioned by Lofthouse and Lilley (2008), most of the products are conceptual and those that are commercially available are few. There is however a growing assortment of meters focusing on providing feedback on household energy consumption. Many home meters are able to synchronise with computers, enabling users to get a better overview over their energy consumption through for example comparing their results from one month with previous months.

Certain products such as washing machines and dishwashing machines were found to have an eco button, enabling the user to wash their things in a more eco-friendly way. This feature was however not observed in any other products. Common for many of the products and concepts identified within the design strategies was the usage of colour as an indicator for energy usage; it was used to indicate actual energy consumption, actual cost of electricity, and variations of energy production. Different colour combinations were however used. The home meter 'Home Joule' used a traffic light sequence to indicate the different cost levels of electricity. The 'Wattson' on the other hand uses a blue, purple and red combination, with blue used to indicate a lower electricity consumption than normal and red as higher than normal. The 'Power-Aware Cord' uses blue due to that user tests showed that blue light was perceived as representing electricity current. Other ways of providing users with visual feedback was through variations of pattern size. This shows that there is no 'standard ' way of using colour to communicate energy related aspects.

13. Survey

The analysis of company's domestic appliances had pointed out that there were aspects of the user interface that needed to be addressed, including a possible misperception of when a product is or is not consuming energy. This was therefore further investigated in a survey.

13.1 Purpose

The purpose of the survey was to gain insights in the general user understanding of energy using products. Focus was put on the user interface to determine whether it could be a cause of energy wastage. The aspects that were addressed included users' perception of the ON and OFF of a product, and what elements of the user interface that help users to determine when a product is switched off.

13.2 Method

Below follows an account of the method of approach.

13.2.1 Developing the survey

In order to be able to gather information as well as to reach out to a wide range of people, it was determined that an online survey would be the best medium of achieving this. Surveys can have a non-structured or a structured form. The advantage of the latter is the ease with which the data can be analysed (Karlsson, 2005). A fixed response questionnaire, which is an example of a structured survey, was therefore chosen for this survey. It consists of a list of questions in which the respondents are provided with a number of responses for each question (Jordan, 2001). Different questions with fixed responses were developed to address the different aspects of the user interface that was to be investigated. These questions grew in number and were gradually reduced to only include 16 of the most essential. According to Jordan (2001), it is important to not only provide a complete range of possible responses to ensure that there is a response that the respondent can agree with, but also to use a simple language to make certain that the questions are fully understood. The formulations of the questions and responses were therefore discussed with the mentors and rephrased numerous times in order to be as clear as possible. To clarify to the respondents that energy using products required electricity for their functioning, the term 'energy using products' was

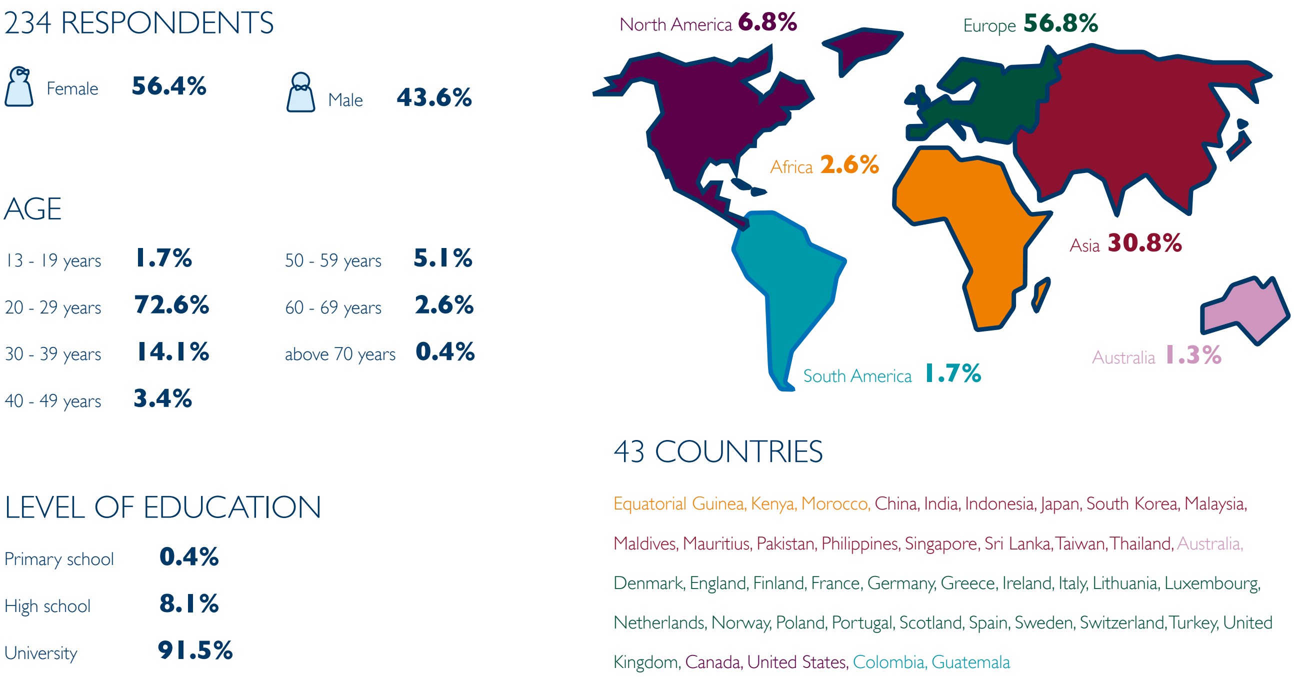

Fig. 10. Demographics of the online survey

substituted with 'electricity using products'. In addition, four different types of energy using products were referred to in two questions. This was to enable the respondents to relate the questioned functionality to a commonly known product.

13.2.2 Executing the survey

The online survey was created through 'Free Online Survey' and the 16 questions in the online survey were presented on two separate pages. (See ***Appendix IX*** for the survey questions). The link to the survey was sent to friends and relatives through email and social networks and they were encouraged to send it to their acquaintances. The respondents participating in the survey can therefore be considered as a result of combining a 'convenience sample' with a 'snowball sample'. The survey was open for response during one month.

13.2.3 Analysing the survey

In total, 247 respondents performed the online survey. Nine respondents had however only submitted the questions on one page and these were therefore not taken into consideration during the analysis. The gender distribution was rather even with 56.4% female and 43.6% men, and the respondents came from 43 different countries (see Fig. 10 for demographics). The results were looked upon from 2 sets of parameters: age and gender, in which the percentages were based on the total amount of women, men, and age group respectively. In other words, when 75% of women replied to a certain question, it corresponded to 75% of the total amount of women who participated in the survey. In the age-group 13 to 19 years, there were only 4 respondents. Furthermore, there was only one respondent above 70 years. These were thus not included in the final analysis as it was thought that it would be misgiving. Due to the wide spread of nationalities, this was decided to not be a parameter for the analysis. An attempt to categorise the results depending on the continent of the country was also not found to be relevant as countries within

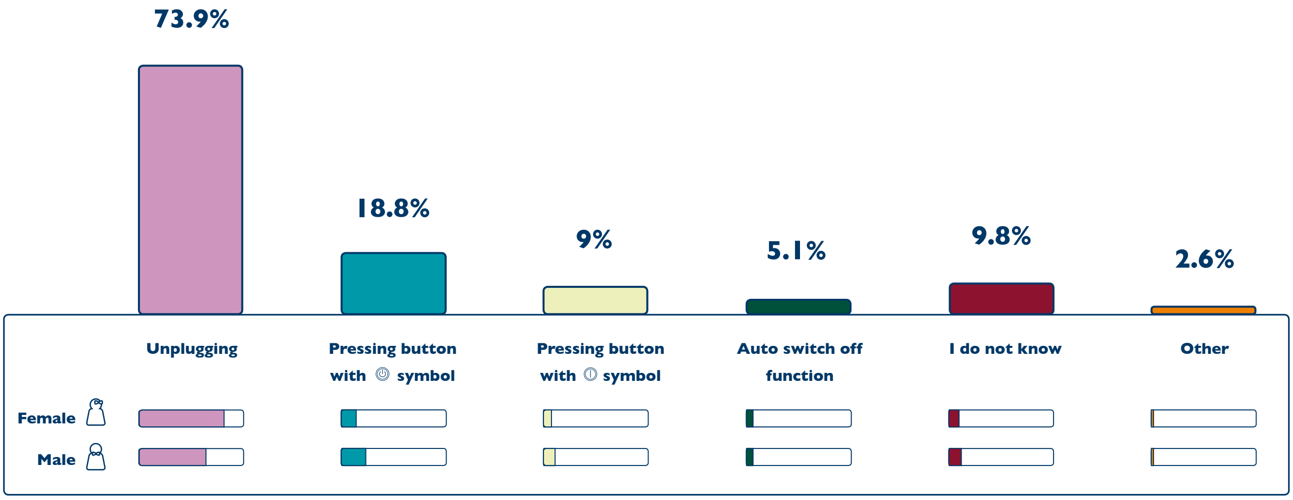

Fig. 11. Question: When are you certain that your product is not consuming electricity?

each continent may not be representative of each other. All the questions except for one were analysed and summarised into a histogram. The question that was not analysed was the one that addressed the usage of colours as an indicator in the user interface. This was due to that the possible responses to the question had been programmed incorrectly in the survey.

13.3 Results

The analysis of the survey will be presented below. See ***Appendix X*** for detailed results.

13.3.1 Means of ensuring zero electricity consumption

The majority of the respondents (73.9%) were certain that a product would not be not consuming any electricity after having unplugged it (see Fig. 11). Approximately 58% of all the respondents chose this as their only alternative. 9.8% of the respondents did not know which alternative to choose and most of these respondents were above the age of 40. An interesting result was that 94.9% of the respondents seemed to be aware that products with an auto switch-off consumed electricity when switched off and that more people were certain that a product was not consuming any electricity when pressing the button with the standby symbol. The latter verifies the research conducted by Lawrence Berkeley National Laboratory stating that many people associate the standby symbol with power ON and OFF. When looking at the age group 20 to 29 years, it was observed that 20% of these respondents were certain of zero electricity consumption when using the standby symbol, and only 5% were certain with the ON/OFF symbol. This could be an indication of that younger generations of people have been more exposed to this symbol than the ON/OFF symbol. The survey also showed that a larger part of the respondents (97.8%) associated standby with electricity consumption (see ***Appendix X***). None of the respondents chose the 'I do not know' alternative, indicating that the term standby is widely recognized and related to electricity consumption.

The respondents appeared to prefer different types of switching off solutions depending on the product (see Fig. 12). Approximately 55.1% of the respondents preferred to switch off a TV by themselves, but preferred the dish-washing machine, micro-wave and coffee-machine to have an automatic switch off (44.0%, 44.4% and 36.3% respectively). A large percentage of users

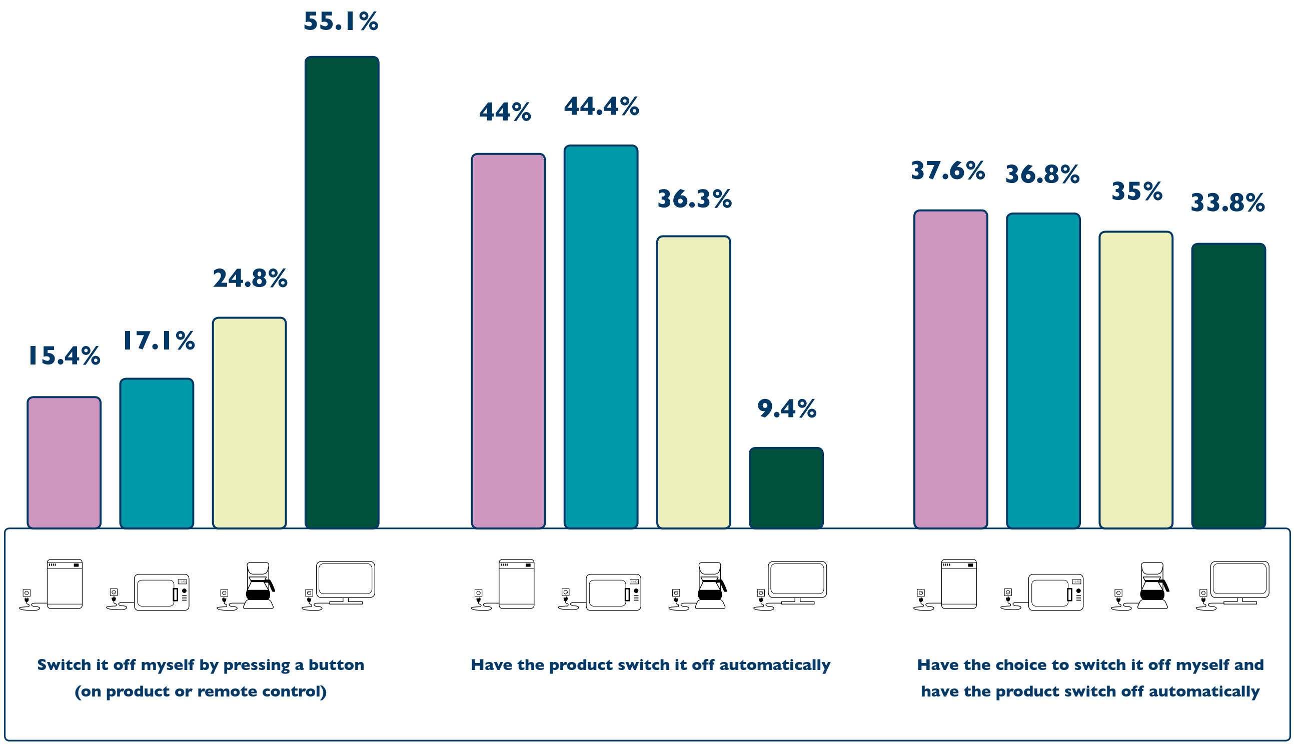

Fig. 12. Question: How would you like to switch off the following products after use?

stated that they would like to have the choice between switching off themselves or having the product switch off automatically.

13.3.2 Understanding 'switched off'

The majority of respondents (57.7%) believed that a product would not be consuming electricity when switched off, whereas 38.5% believed it to still be us-

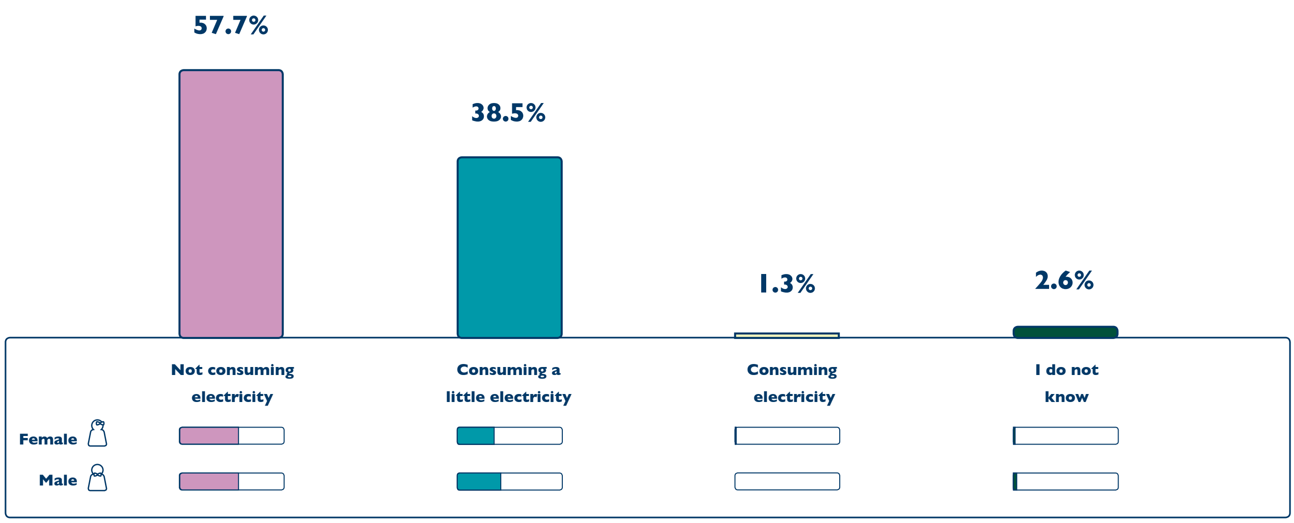

Fig. 13. Question: What does it mean when a product is switched off?

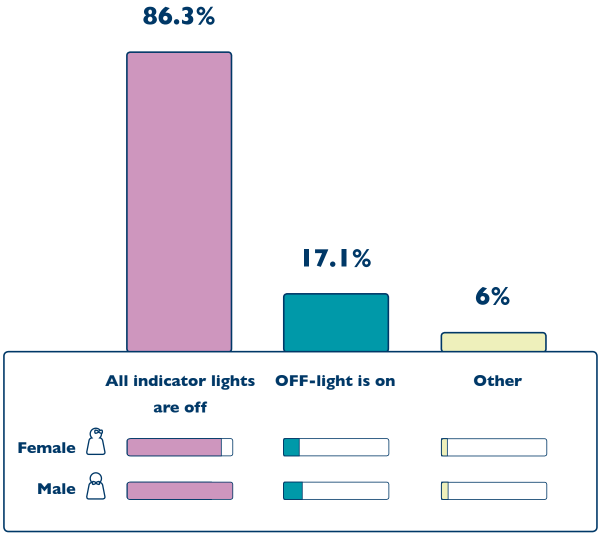

Fig. 15. Question: When are you certain that your product is switched off?

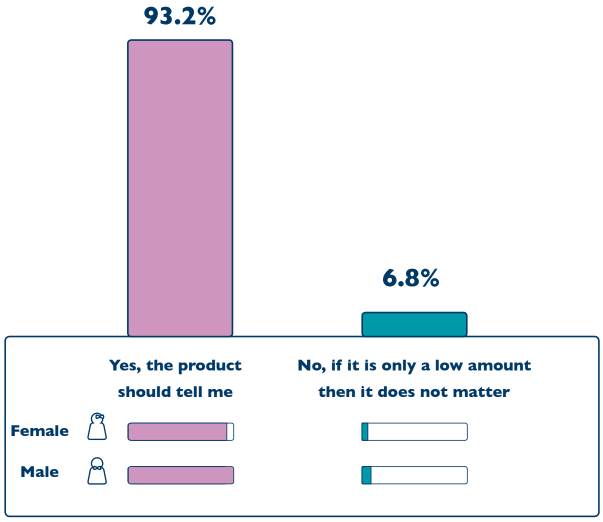

Fig. 16. Question: If a product is consuming a low amount of electricity, should it tell you this through for example a small indicator light?

ing a low amount of electricity (see Fig. 13). A thought-provoking observation was that 57% of all respondents with a university background believed that it would not be consuming electricity. Approximately 86.3% of the respondents were certain that a product was switched off when all the indicator lights were off (see Fig. 14). 76.5% chose this as their only option. A number of respondents (17.1%) were certain that the product was not using energy when the OFF-light was on, an option that more men than women chose (15.7% men compared to 5.3% women). In the 'Other' category, most consumers stated that the product had to be unplugged for them to be certain whereas one respondent mentioned "when the machine turns silent".

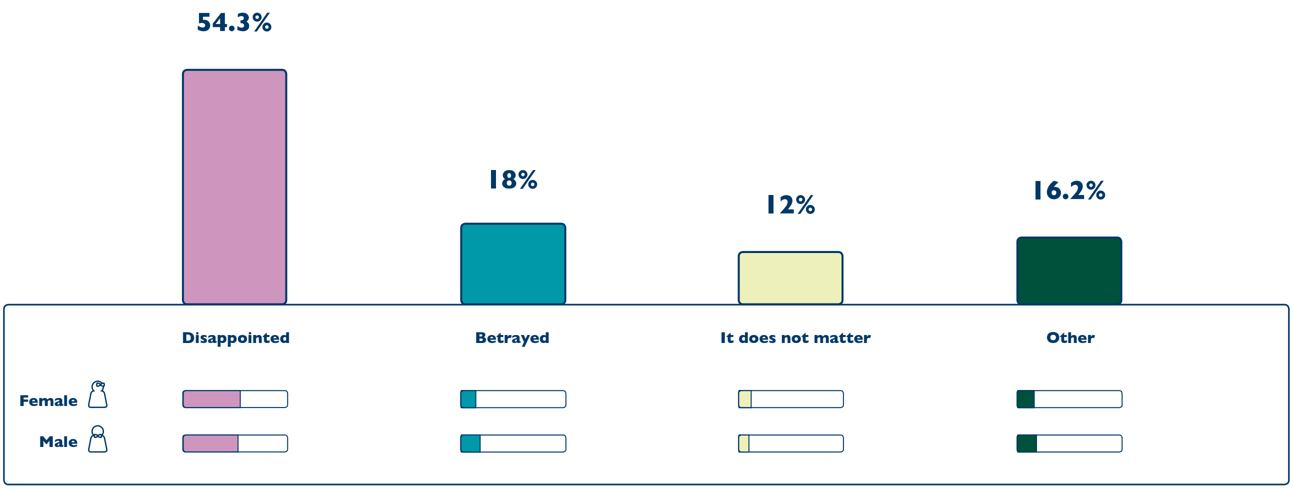

Fig. 14. How would you feel if you switch off a product and you later find out that it is still consuming a low amount of electricity?

13.3.3 Acceptance of low electricity consumption

The majority of respondents (93.2%) stated that they wanted to know when their product was consuming a low amount of electricity and implied that this should be communicated by the product (see Fig. 15). The survey also showed that disappointment (54.3%) and betrayal (18.0%) were emotions that the consumer would feel if they later found out that a product would still be consuming electricity after having been switched off (see Fig. 16). In the 'Other' category, 0.9% expressed themselves as being surprised compared to 3.4% that would not feel surprised. Another 3.4% expressed the words angry, annoyed, bothered, concerned, frustrated, irritated and resigned. A few comments in the 'Other' category include:

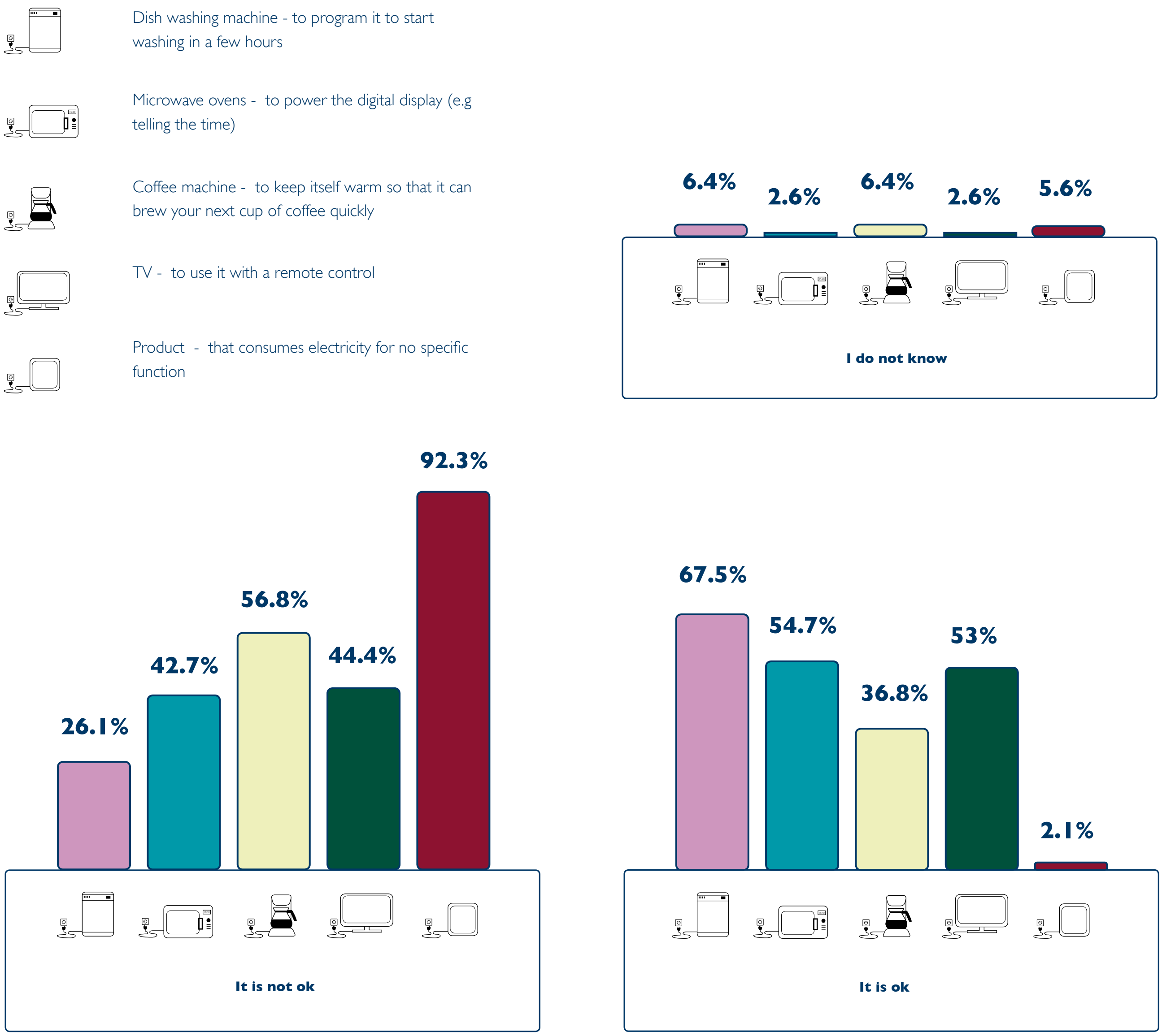

Fig. 17. For which products is it ok for you that a low amount of electricity is being consumed when they are not in use?

"Bothered, but feels a hassle to do anything as taking in and out the plug is inconvenient... especially for products that we use daily...".

"I know that most appliances draw current when not in use so I unplug most appliances when they are not in use. I can live with those I don't unplug drawing current (since it's my choice)."

"If it was standby for a feature I frequently use I wouldn't mind."

"It is an accepted truth by me."

The survey also showed that the acceptance for low electricity consumption differed depending on the functionality that it was intended for. (See Fig. 17). The results showed that the acceptance was high for a timer function in a dish-washing machine, a digital clock in the micro-wave and for the TV. For the latter, the acceptability however seemed to decline with the age group. For a product consuming electricity for no specific reason, the unacceptability was high, approximately 92%.

13.3.4 Motives and beliefs for reducing energy consumption

The two main motives for the respondents to reduce the energy consumption of their products were 'environmental concern' (85.0%) and 'lowering the energy bill' (81.2%). (See ***Appendix X***). Of the combinations of motives, 'lowering energy bill' and 'environmental concern' had the largest percentage of respondents, followed by 'lowering energy bill', 'environmental concern' and 'prolonging lifespan of product'. For the latter, 14% more men than women found prolonging the lifespan of their products important. The two respondents who expressed no motive for energy reduction were male and in the age group 20 to 29.

Around 25% of the respondents believed that it was their own behavior that could lead to the most energy savings (see Fig. 18). Approximately 70% of the respondents however believed that it was the product itself in which most energy savings could be achieved, either through the purchase of an energy efficient product, choosing an eco-option or having products switching themselves off automatically after use. In the other category, most of these respondents stated that they wanted to have a combination of the different alternatives and one respondent proposed that "I should not buy any products". In a question addressing the usage

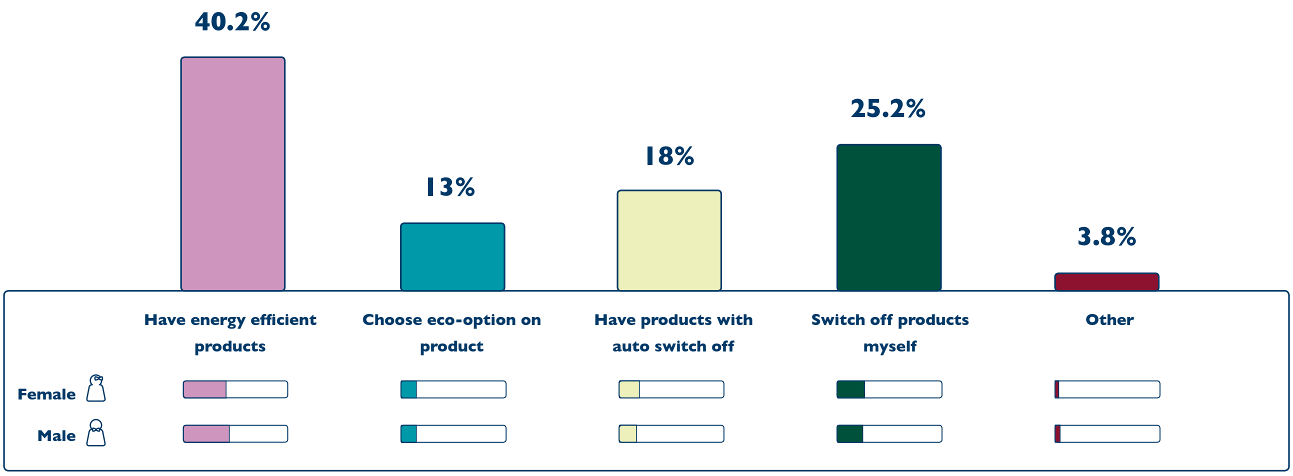

Fig. 18. Which of the following do you think could save you the most energy?

of an eco-button, the majority of respondents thought that there would be no difference in performance, the energy consumption would be better and that there would be no difference in the time it took for the product to perform its function.

14. Conclusions and implications for further work

The analysis of company's domestic appliances pointed out that there were several aspects of the user interface that could lead to that users do not not having a correct understanding of products' energy usage. This was confirmed in the survey, which did not only show that respondents were uncertain whether a product was or was not consuming electricity when switched off, but also revealed that for many the only way to be certain that a product had zero energy consumption was to unplug it.

From the results of the survey, it can be concluded that one means of achieving energy reduction can be through 'product honesty', in which a common understanding for energy using products is created. This could for instance be the ability to distinguish between when a product is or is not consuming energy. Without this 'energy understanding', there is a possibility that energy wastage can occur, which the users are not aware of. In addition, they will not have been provided with the possibility to take action. If on the other hand the user is provided with this information, a first step to creating the right habits can be taken. A need for 'product honesty' was further emphasised in the survey where a majority of the respondents expressed that they wanted to know when their products were consuming a low amount of electricity and would feel disappointed or betrayed if they did not know this.

The survey has further shown that the usage of the standby and ON/OFF symbols has not been sufficient to create an understanding for when a product is or is not using energy. In addition, for many respondents a common indication of a product being switched off was when the indicator light of the product was off. One way to address this issue could therefore be by making sure that energy consumed after a product is switched off is communicated through for example an indicator light. This could emphasise the difference between the standby and ON/OFF symbol. Such a solution could also be complemented by providing the users with an option to switch off into a hard-off. In other words, the user would then not have to go to the extent of unplugging the product. The results of the survey further suggested that respondents preferred different switching off solutions depending on the product, and that the acceptance for low electricity consumption differed depending on its functionality. This implies that these are two aspects of the user-product interaction that could be investigated and taken into consideration in the development of products.

The survey confirmed that users had a greater belief for products to achieve energy reduction rather than they themselves through changing their own behaviour. This data can be seen as emphasising the need of product-led interventions and that do not compromise on the lifestyles of users or demand them to take action. Considering this and that the external analysis showed that there were few products on the market that targeted energy reduction from a behavioural perspective, there may be a market opportunity to develop products that help users to a more energy effective usage.

During the analysis of company's domestic appliances, it was shown that there were different interpretations of the low power modes among the different employees involved in the product development process. If the power modes are not well understood among the employees, it can then be assumed that it cannot be expected that the users will understand them. This suggests a need to create a common understanding for not only the users but also the employees. The analysis further determined the carrier product of the case study. This decision was made in discussion with the mentors and the findings from the internal analysis in which certain aspects of its user interface were found to be interesting to pursue. Moreover, the energy impact in regards to its annual volume of sales was found to be significant.

Case study

15. Introduction

In this case study, energy wastage in the usage phase of the carrier product was investigated. Theoretical as well as empirical research was conducted.

15.1 Aim

The objective of the case study was to explore how the carrier product is used in real life, to identify and understand the factors that lead to energy wastage. The investigation was limited to examining the usage phase relative to a specific user goal determined for the carrier product. Focus was put on pursuing the following three questions:

» What aspects of the user-product interaction can lead to energy wastage?
» How can the energy consumption differ depending on the way of usage?
» Why does the energy consumption differ between users?

15.2 Process

The case study was divided into four separate stages, each with a different process and focus regarding the user-product interaction. In the first stage, an understanding for the product was obtained and was thereafter followed by a theoretical study of the possible energy wastage that could occur during the usage phase. In the third stage, energy measurements were conducted to investigate how much the energy consumption could differ depending on usage. In the last stage, an answer to why the energy consumption could differ was sought.

16. The product

Below follows an account of the first stage of the study.

16.1 Purpose

The purpose of this stage was to obtain a deeper understanding for the carrier product with focus on the user-product interaction and technical functioning during usage.

16.2 Method

To understand the history of the carrier product, its intended future, and technical functioning, semi-structured interviews were conducted with product developers from different departments. Internal documents were also studied. For an initial understanding of the different user actions required during the usage phase, user manuals, interacting with the product to gain personal experience, and observations were performed. For the latter, three employees were observed, as well as one person in a home environment. With this information, a Hierarchical Task Analysis (HTA) was conducted. (See ***Appendix XI***) This is a method that is commonly used to examine tasks in which the tasks performed by a user to achieve a goal are broken down into different steps and can be viewed at different levels of detail. The hierarchical break-down into lower levels continues until a level that is suitable for the analysis is acquired (Kirwan & Ainsworth, 1992 in Bligård & Osvalder, 2009). For a holistic overview of the user actions and the technical functioning of the carrier product, a User-Technical Process Model was created and elaborated further. (See ***Appendix XII***). This model can be used to visualize the relationship between a user's action and the technical function of a product. It examines how the user and technical system interact with each other to create a joint system. The model has emerged from a need to combine these two because many products only obtain their whole functionality together with the involvement of the user. In other words, it is through the collaboration of these two that a particular goal is achieved. The two main components of the user-technical process are the user process and the technical process. These are in turn divided into two sub-components respectively. The user process consists of mental activities and user actions, whereas the interface functions and technical constitute the technical process. These components are placed parallel to each other to illustrate the interaction (Janhager, 2005).

16.3 General description

The following text has been removed entirely with reference to the confidentiality of the industry agreement. What is important to bring forth is that in the analysis to understand user actions in the interaction with the product, it was determined that they could be divided into two categories: primary and secondary actions. Primary actions lead to a change of power mode and secondary actions are performed within a power mode. This categorisation will be used throughout the thesis.

16.4 Discussion and conclusion

The first stage of the case study further emphasised a conclusion that had been drawn in the second phase of the thesis project, that there was indeed a need to create a shared understanding among the product developers for the product's user-product interaction. During this stage, it was realised that several important aspects of the user-product interaction were found to not always be clear or understood. This included the terminology used for the power modes of the carrier product and the power consumption during and after use. It was thus concluded that this realisation needed to be considered in the method development process.

17. Initial analysis on potential energy wastage

Below follows an account of the initial analysis of potential energy wastage in the user-product interaction.

17.1 Purpose

The purpose of this stage was to further examine the user-product interaction of the carrier product and identify hypothetical energy wastage factors and if possible, investigate its theoretical affect on the energy consumption. The focus was on energy wastage that arises due to how a user uses the product relative to the given user goal. It would not examine actions that are not performed correctly and lead to that the product prevents itself from functioning.

17.2 Method

Energy was first looked upon from a basic physical perspective to understand potential factors that could affect the amount of energy consumed. Energy wastage factors, both existing and hypothetical, were thereafter determined through analysing the data logger readings and conducting a theoretical usage analysis. From the data logger readings, a set of user profiles was created from which the theoretical energy impact was calculated.

17.2.1 Analysing the data logger readings

To gain insights in the usage of the carrier product, the internal document was studied. This document summarised the information provided by data logger readings from a specifically developed logging device that had been placed in products in a specific number of households. From the data logger readings, existing energy wastage factors could be determined. The raw data from the data logger readings was thereafter examined to further investigate and obtain more intrinsic knowledge.

17.2.2 Conducting the theoretical usage analysis

To investigate the hypothetical energy wastage of primary and secondary actions, the possible patterns of use for performing the user goal were analysed. This analysis first occurred with help of a set of cards specifically created for the purpose. Each card corresponded to a specific action or operation that had been determined in the Hierarchical Task Analysis. The cards were placed in different sequences to investigate alternative patterns of use and potential outcomes if a specific action or operation had been forgotten (see ***Appendix XIV***). From this analysis, flow charts depicting different sequence possibilities of performing an action were created (see ***Appendix XV***). The identified energy wastage factors from the data logger readings and the theoretical usage analysis were placed in a matrix. The questions regarding the user-product interaction that arose during the analysis were also included (see ***Appendix XVI***).

17.2.3 Determining the user profiles

From the information provided by the data logger readings, four different user profiles were created to examine how the energy consumption could differ depending on the time it took to perform the user goal (see Fig. 22). Three of the profiles were created from the average of the minimum, average and maximum logged time from the data logger readings. One user profile was an ideal fictive user, whose way of usage would lead to that the product was used as ideally as possible. This user profile constituted the basis with which the other three profiles could be compared.

17.2.4 Determining the theoretical energy impact

The theoretical energy impact of the four user profiles was calculated with help of energy values available from the company (see ***Appendix XVII***).

17.3 Results

The results of the initial analysis on potential energy wastage will be presented below.

17.3.1 Energy consumption from a basic physical perspective

One way of determining the amount of energy used in energy-using products is with the formula:

E=Power x time

From this equation, it can be concluded that time is an important parameter, which can in the user-product interaction be affected in two ways: firstly, the time it takes the product to fulfil a certain function, and secondly the time it takes before the users perform a specific action. The amount of power that is applied in a product can depend on the function that the product needs to fulfil.

17.3.2 The frequency of use

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17.3.3 The theoretical energy impact

The following text has been removed entirely with reference to the confidentiality of the industry agreement

17.4 Conclusion

The data logger readings showed that the product can time-wise be used differently as it is designed in a way that allows the user to choose when to perform specific actions. The calculations showed that the longer it took to perform these actions, the larger the amount of energy that was consumed. The theoretical usage analysis identified that the pattern-of-use could have an effect on the energy consumption, but also identified a number of hypothetical energy wastage factors that could occur in the secondary actions.

18. Understanding the energy impact

In this stage, energy measurements were conducted to investigate the energy impact.

18.1 Purpose

The purpose was to examine how the energy consumption could differ during the usage phase depending on how a user uses the product. Focus was put on two main points of investigation:

1. How the energy consumption can differ during the user phase depending on:
   - » Effect of usage time
   - » Frequency of use on an annual basis
   - » Assumed distribution frequency

2. How effective the product is in its usage of energy

18.2 Method

The energy measurements were based on the four user profiles and a set of energy usage scenarios that were created. The distribution of the power and energy consumed was analysed from a systems perspective, in which the entire usage was investigated. By looking at the usage in its totality instead of an isolated part of it, it is easier to discover energy losses that can occur. The power and energy consumption was also analysed for each power mode in order to increase the understanding for the product functioning as well as the factors that lead to energy wastage.

18.2.1 Measurements

The measurements were performed with five carrier products and conducted with a power meter, Yokogawa WT300, and a programmable power source, Elgar SW5250W. (See Fig. 26 for test set-up). The measurements were conducted with 230V and 50Hz, which are used in the power systems within Europe, and the data of the energy and power consumption was logged with a two second frequency.

18.2.2 Energy usage scenarios

The four following energy usage scenarios were created for the energy measurements:

- » Effect of usage time
- » Frequency of use on an annual basis
- » Distribution frequency

18.2.3 Conversion effectiveness

One way of examining a product's technical inefficiency and determining the products with the greatest potential for improvement is by comparing its efficiency to a theoretical minimum energy use (Elias, 2007). This was assumed to be an appropriate approach in determining the effectiveness of the carrier product regarding its usage of energy. This approach is usually denoted as the 'conversion efficiency', but has in this thesis been designated as the 'conversion effectiveness'. The use of the word 'efficiency' created confusion among certain product developers as they related this word with an isolated part of the system, which in the carrier product had a high efficiency. One product developer proposed the word 'effectiveness', which could be used to provide with a measure of the extent of achieving a user goal. This term was proposed to several developers, and was found to be more fitting. From here on, the conversion effectiveness will thus be used. This term will give a % of how effective the product is in achieving the user goal by comparing the minimum theoretical energy required to fulfill a user goal with the actual amount of energy that the product uses to fulfill this goal.

The conversion effectiveness of the carrier product was examined for two energy-using scenarios: Effect of usage time, and Distribution Frequency. The calculations were performed by comparing the measured energy values from the energy measurements with the minimum theoretical energy.

18.3 Results

The following text has been removed entirely with reference to the confidentiality of the industry agreement.

18.4 Conclusion

The energy measurements showed that energy wastage could occur due to two factors: (i) possible ways of using the product that is allowed by the system design; (ii) and the function of the system design itself. The energy measurements for the energy usage scenarios showed that the way with which the users can use an appliance could have an impact on the energy consumption due to that:

» Product allows for variations in the amount of time to achieve the user goal
» Product input can affect the energy consumption
» Energy required to achieve a user goal is affected by frequency of use and its distribution frequency
» Product uses energy when not it use

The conversion effectiveness emphasised the fact that even when the product was used as ideally as possible in relation to what is possible with the technical functioning of the system design, the effectiveness of the product was still low. This was attributed to:

» Product is not optimised for the user goal and uses more energy than necessary for the user goal

19. User studies

At this stage, user studies were performed. The process and outcome will be described below.

19.1 Purpose

The purpose of this study was to gain deeper insights of the user-product interaction and understand why and which of its aspects may result in energy wastage. The focus was on finding an explanation for the occurrence of the identified energy wastage that was attributed to the possible usage allowed by the system design, but also to examine whether there were other aspects of the interaction that can lead to energy wastage.

19.2 Method

Nine user studies were performed to collect qualitative data from users in their home environment. These users were selected to include a broad range of different users with respect to gender, age, household type, profession, and level of education. The length of experience with the product differed from 1.5 to 10 years. The user studies consisted of the following:

» **Observation**. To observe the users' pattern of use and context of use when performing the user goal.
» **Energy context mapping session**. To further understand the user-product interaction by examining the pattern of use, other non-product related actions during usage, emotions, and perception of energy consumption during usage. It also aimed to understand the distribution frequency.
» **Questionnaire**. To obtain background information of the users.

To prevent biased answers, the participants were informed that the focus of the user study was the user-product interaction. Energy consumption was not mentioned. Of the nine user studies, two were performed simultaneously as the participants were from the same household. In three of the studies, other members of the household were present, but were not directly involved in the study. The focus in the analysis of the results from the user study was to obtain qualitative data and not on linking the results with the demographic data. This decision was based on the fact that nine users were not enough to be able to draw such conclusions.

19.2.1 Observation

As a first step of every user study, each user was asked to perform a specific user goal with the carrier product in their home environment. This was thought to give a more informal start to the user study and according to Jordan (2001), observing users in the environment that they usually interact with their product is one way of increasing the validity of the collected data. Having the observation constitute the initial part of every user study was thought to make the usage of the carrier product be more present in the minds of the participants. In addition, aspects of the user-product interaction that had been observed could be referred to at a later point in the study. Each observation was combined with a 'think aloud protocol' to gain further insight in the user's interaction with the product. In a 'think aloud protocol', users can perform specific tasks and are asked to speak aloud about their thoughts and feelings when interacting with the product (Jordan, 2001). The entire process was video-filmed.

19.2.2 Energy context mapping session

An energy context mapping session was specifically developed for the user studies. The purpose of it was to enable a more interactive way of interviewing users to analyse their interaction with and understanding of the product. It also aimed to identify user habits that could not be seen or understood during the actual user study. The session was developed to make the user feel less exposed as understanding why users do something in a certain way can be a sensitive topic. The session was inspired by the method of context mapping. This is a generative user study technique used to elicit contextual information of the factors that influence the experience of using a product. It aims to not only gain an understanding for what users know, feel and dream, but also to reveal tacit knowledge or latent needs, which often can determine the user experience and are for users often hard to express (Visser et al, 2005).

The energy context mapping session consisted of two different templates, each on a separate A3 paper. The users could with different sets of stickers express aspects of their interaction with the product on the templates. This a general principle of generative techniques where users can articulate and become aware of their experiences through creating artwork, such as collages and drawings (Stapper & Sander, 2003 in Visser et al, 2005). The two templates acted as a basis of discussion and was combined with a semi-structured interview to gain as many insights as possible from the user. A semi-structured interview can be seen as a combination of an unstructured and structured interview. In an unstructured interview, the participants are given open-ended questions, whereas in structured interviews, participants are asked to choose a response from for example a pre-defined set of categories. As it is important that the issues that are to be addressed In a semi-structured interview are clear to the interviewer and can be prompted to ensure that they are covered (Jordan, 2001), a list of topics to be addressed during the interview was therefore present. The entire session was recorded in order to facilitate the analysis of the data.

Template 1 aimed to create an understanding for the users' distribution frequency (see ***Appendix XXII***). Template 2 consisted of four different timelines. Each timeline represented an aspect of the user-product interaction that needed to be understood and had its own set of stickers (see ***Appendix XXIII***). On the first timeline, the user had to place 'action stickers' in the order which they performed the user goal. The idea was that the user should place the actions according to the actual time it took for them to perform their actions, but some of the users found it difficult to understand the concept of creating a time interval. It was also realised that the actual timing of the actions was not important; the important aspect was to distinguish between the actions that were performed consecutively, and the actions that took time before they were performed. If the user would perform other actions while using the product, they were asked to place 'other action stickers' on the second timeline. On the third timeline, the users were asked to depict their different feelings during the usage with the help of the 'emotion stickers'. The aim had been to identify whether the emotions could differ depending on when they were using the carrier product and how this could affect the usage. This was however not brought forth in this study and is therefore not part of the results. On the final timeline, the users had to place 'percentage of energy consumed stickers' in relation to the actions that they performed.

19.2.3 Questionnaire

A questionnaire with open-ended questions was created to obtain demographic data as well as information about the participants' usage of the carrier product (see ***Appendix XXIV*** for an overview). This questionnaire was handed to the users once the user study was finished.

19.3 Results

The following text has been removed entirely with reference to the confidentiality of the industry agreement.

19.3.1 Conclusion

The user studies showed that it was possible to use the carrier product in many ways, which was reflected in the differing patterns of use for the nine users. It also showed that several users developed certain usage habits around the system design of the product of which some were not optimal from an energy perspective. Another conclusion drawn is that the way the system design of the product is made can make it possible to use the product in an erroneous way where the user will obtain an end result that is not desired.

Different aspects of the examined user-product interaction could explain the occurrence of the identified energy wastage factors and can be summarised as following:

Timing and pattern of use

» Timing in relation to the sequence with which actions are performed can increase the energy consumption

User positioning

» Users are not always positioned by the carrier product during usage and this can lead to that it takes them either a longer time before they return to the product, or that they forget to return

Context of use

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User understanding & perception of energy

» Users do not know that the carrier product consumes standby energy because the light of the standby button is off when the product is switched off

» Users understand the energy consumption of the product differently depending on background knowledge

20. Conclusions and implications for further work

The case study of the carrier product has shown that one and the same product can result in different levels of energy consumption. The energy wastage can be attributed to the way with which the user may use a product and the habits that are developed partly as a consequence of the technical function of the product. Differences in energy consumption can to a certain degree also be affected by the context of use and to the user's understanding of the product and its energy usage, partly through the design of the user interface. The latter was in the user studies to a certain extent reflected in that most users were not aware that the product was consuming energy after having been switched off. This finding emphasises what had been concluded from the survey, that there is in fact a need to create a common understanding for when energy using products consume energy or not. The case study has also shown that even when the product is used as ideally as possible by a user, the product is still not very effective in its usage of energy. It is thus important to not only ensure that a product is as energy effective as possible, but also to provide users with a correct mental model of a product's energy usage and to consider how users may use a product in its context of use. In order to address energy wastage in energy using products, it was therefore concluded that three aspects need to be considered for integrating sustainable usage in the development of products:

» Product honesty. Creating a common and basic understanding of energy using products
» User perspective. Designing for context of use and user needs
» Technical perspective. Designing an energy effective product with technical solutions

The method or approach that evolved during the course of the case study has shown that the influence on the usage phase could be investigated through a What, Why and How approach in which energy wastage was identified, the reasons for why it occurs was examined, and that these insights could act as a basis for finding ways of how to solve them. In order to develop a method to theoretically examine the usage phase in energy using products, it is important to identify the factors that can lead to energy wastage in order to find ways of designing around user habits or simply designing for the right habits from the start.

Method Development Process

21. Introduction

The findings from the previous phases lay the foundation for developing the theoretical method.

21.1 Aim

The main aim of this phase was to develop a theoretical method assessing the usage phase of energy using products to identify and understand the underlying reasons of energy wastage that can occur as a result of user-product interaction. The method evolved through a further investigation of the case study and survey findings with help of a What, Why and How approach aiming to answer three main questions:

» What presumptive energy wastage can occur?
» Why does the energy wastage occur?
» How can the energy wastage be solved?

These questions were primarily looked upon from a user perspective, where factors in the user-product interaction that can be affected by or influence the user were examined. The questions were secondarily looked upon from a technical perspective, in which the focus was on examining energy wastage that arises due to the actual system design. The sub-criteria was to establish:

1. A guideline for conducting an in-depth study of an energy using product with the same approach that had been undertaken in the case study
2. A deliverable for the company providing an overview of a product's energy wastage and where the focus for improvement should be put
3. A holistic overview of a user-product interaction to create a common multi-disciplinary understanding for a product
4. Develop ideas for a redesign of the current product based on the findings of the case study

21.2 Process

The iterative method development process consisted of five stages: Literature study, Further analysis, Developing the basis, Further development, and Final development. In the first stage, a literature study was conducted and helped establish a set of criteria to steer the development of the method. In the second stage, the energy wastage factors identified in the case study and online survey were further analysed to investigate potential generic dimensions on which the method could be based. These were categorised and the underlying reasons for their occurrence were examined. In the third stage, the foundation of the method was developed in which the questions for examining presumptive energy wastage and a visual basis for the examination was created. Ideas for how to combine these into one method were evaluated and one was further developed in the fourth and fifth stage. Throughout the entire process, ideas of how to solve the energy wastage of the carrier product were thought of and integrated in the final stages. Other products of the company were also analysed and the input from this analysis was given to the different stages of the development process.

22. Literature study

Below follows an account of the literature study.

22.1 Purpose

The purpose of this study was to become acquainted with how theoretical methods could be structured and to also find inspiration in developing the method.

22.2 Method

Theoretical methods evaluating the usability of a product and probability of human errors in the user-product interaction were studied. This in order to obtain an understanding of the ways by which methods could investigate presumptive energy wastage and approach a product from a What, Why and How approach. In addition, literature on ecodesign tools were studied to identify what aspects should be taken into consideration during the development of the method. Reference cards as well as check-lists and matrixes used in different usability methods were also examined to see how the method could be structured and visualised.

22.3 Results

The results will be explained below.

22.3.1 Analysis of theoretical evaluations of usage errors

The article 'Metoder för att undersöka brister i samspelet mellan människa och maskin' by Bligård and Osvalder (2009) was studied in detail in which information of Cognitive Walkthrough (CW), Enhanced Cognitive Walkthrough (ECW), Systematic Human Error Reduction and Prediction Approach (SHERPA), Action Error Analysis (AEA), Predictive Human Error Analysis (PHEA) and Predictive Use Error Analysis (PUEA) were described. It pointed out that in examining presumptive errors or problems in user-product interaction, methods are often goal-oriented and that the starting point of the described methods was a Hierarchical Task Analysis (HTA) in which the tasks required to fulfil the user goal were determined. The HTA was thereafter used as a basis to identify and examine presumptive errors. An important aspect that the authors of the article point out is that a HTA only describes one way by which a user can obtain a goal. As the ways by which a user can achieve a goal can be multiple, it is important to keep this in mind and assume the most common way of reaching the goal. Another common denominator for the methods was that definitions of the target group and context of use were required as a basis for the investigation of presumptive errors. Many of the methods had a question-based approach and these questions were studied regarding their formulations and how they examined presumptive errors. In the methods described by Bligård and Osvalder (2009), the questions were task-oriented and directed at operations, nodes, and/or functions in the HTA. In examined usability checklists, the questions were often formulated in a way that provided with a yes or no answer. In examining the process and questions used in the methods, it was realised that many of these were detailed in their investigation and therefore time-consuming. The tasks were at times broken into too small details and in addition, the questions posed during the analysis were not always relevant for every determined task.

In identifying the underlying reason for the occurrence of a problem, an important observation was that several methods had a way of categorizing the identified problems into types. In the ECW, the problems were categorized into five types according to whether they were caused by the user or by the product, such as lack of given clues or placement of text and icons. In SHERPA and PHEA, every determined operation in the HTA was classified into five categories: action, retrieval, checking, selection, and information communication. For each of these categories, there existed a list of potential problems. The PUEA uses the same list to identify the errors, but also attempts to categorise the reason behind the problem and relates this to: lapse, slips, rule based mistakes, knowledge based mistakes, and violation.

A problem that the ECW and PUEA had identified and tried to address was the need of a clear and understandable overview of the conducted analysis. Both methods therefore developed a way to present the results of their analysis in matrices. An important part of the ECW matrix included an attempt to grade the severity of an identified problem and determine its occurrence probability to see where the focus should be put. In the PUEA matrix, an interesting point is that it brings in the consequence of the problem and leaves room to address how the problem can be solved in terms of how the product provided the user with recovery or prevention possibilities.

22.3.2 Analysis of requisites for ecodesign tools

Most of the tools currently used in ecodesign focus on the design stage after the product specification has been set, i.e after parameters such as functions and properties are determined. Hardly any of the tools within ecodesign are suitable for the early stages of design. In addition, current tools within ecodesign demand a large volume of data, which often cannot be provided in the pre-specification stage as the available data is of poor quality (Karlsson & Luttropp, 2006). The early stages of product development are however critical and environmental aspects must be integrated here as research indicates that 80-90% of a product's economic and environmental costs are determined in the early stages of the PDP (Council,1997, in Sherwin and Evans, 2000). Early integration has resulted in the most significant reductions in the environmental impact of products as design changes at the stage prior to the specification being set prevents quality problems after manufacturing (Bhamra and Evans, 1999). During the pre-specification stages, the knowledge of the product is rather small, but at the same time there is a greater degree of design freedom as nothing has yet been settled (Luttropp & Lagerstedt, 2006).

Tailor-made solutions have been identified as a key factor to successful implementation of ecodesign as well as the usage of common language and knowledge between those involved in the process (Pascual, Boks and Stevels, 2003). However, many of the tools currently used in ecodesign were initially designed for engineers (Lofthouse in Lofthouse 1994) and Sherwin and Evans (2000) mention that these often contain very specific quantified data on the impacts of certain types of manufacturing processes, which are not relevant to industrial designers. Differences in background and training of different disciplines can give rise to language barriers and affect general problem solving and communication. Communication and shared knowledge are vital aspects of the product development process, and can have a large impact on the project performance. Rauniar et al (2008) concluded that a process based on shared knowledge enables a greater understanding of each others strengths and thus maximises the knowledge resources of the team members and reduces development time and costs as well as glitches, which occur when requirements of the product do not meet up with those of the consumers.

22.3.3 Analysis of reference cards

Reference cards were studied in terms of how they structured information and made it easily accessible to understand. The IDEO method cards, a set of 51 cards depicting different methods that can be used in a design process to better understand the end-user (IDEO, 2010), were studied in particular as well as numerous reference cards available on the internet for creating web sites. A characteristic for many of the reference cards was the way with which large amounts of information was categorised in generic dimensions, which made it easy to find the information that was of relevance for the user using the cards. Some of the reference cards for web site creation were however so detailed that they resembled a glossary. When examining the IDEO method cards, one of its advantages was the fact that for every project, only the cards relevant to the specific project could be selected and utilised. In addition, the cards could evolve and grow in number over time.

22.4 Discussion and implications

The literature study gave rise to a set of criteria to guide the development of the method. Firstly, a basis from which presumptive energy wastage could be examined was necessary. From the analysis of theoretical evaluations of usage errors, it was realised that this basis could be achieved by defining the goal that the user would like to achieve with the product, and the required actions for this achievement. Secondly, presumptive energy wastage in a product could be examined through a question-based approach. In the development of questions, it would be important to examine ways of optimizing them so that only relevant questions would be asked.

The analysis of ecodesign tools established two additional criteria. Firstly, that the method should be performed by a multi-disciplinary group to combine the know-how of developers with different backgrounds, and secondly that the method should not only be used for existing products but also for conceptual. The latter could be beneficial as it is easier to implement a change to the design and to a lower cost in the early stages of product development.

The literature study gave rise to the idea that the severity and probability of an identified problem could be interesting to integrate into the method. The study further emphasised the importance of having a clear overview of the analysis and brought ideas of potential method formation and structure for the next stage.

The notion to investigate whether the identified energy wastage could be categorised into generic dimensions or problems types from which other products could be analysed originated from the study on the reference cards.

23. Further analysis

The Further analysis will hereby be presented.

23.1 Purpose

The focus of this analysis was to determine the What, Why and How of energy wastage.

23.2 Method

The analysis was divided into two parts. The first part investigated the What and Why by examining the factors leading to energy wastage that had been identified in the case study and survey. These factors were studied in order to see how they could be categorised into generic dimensions from which the method could be based. In examining the energy wastage from a user and technical perspective, each perspective was compared with an ideal situation (see Fig. 36 for an overview of the process). In other words, within each perspective the following was studied:

» **User perspective**. The user actions were studied based on an ideal usage given the actual system design to identify the factors that could be affected by or influence the user

» **Technical perspective**. The technical functioning of the system design was studied based on a comparison with an ideal system. This was determined to correspond to one that only uses the amount of

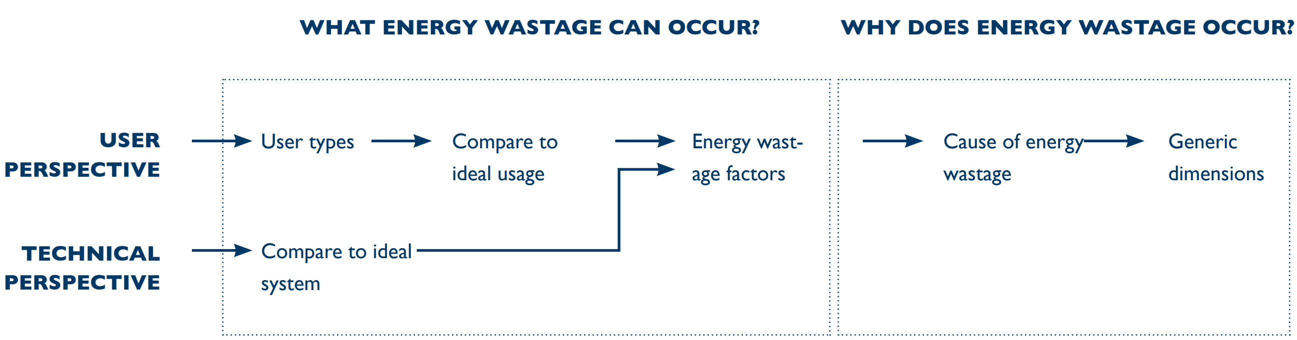


Fig. 36. Overview of the What & Why process

energy that corresponds to the minimum theoretical energy to fulfil a user goal

In the second part, the How was investigated in which ways to solve the energy wastage were examined. This continued throughout the entire method development process.

23.2.1 Analysing the What and Why from a user perspective

The identified ways of using the carrier product were used as a basis to further investigate the user actions. The first step in establishing an overview of the user actions that could lead to energy wastage was to determine all the different ways of performing a specific action identified from the user studies. These were all written down on separate Post-its and were denominated as user types. In order to identify the user types associated with energy wastage, the most energy-efficient way of performing the user goal in terms of the timing and sequence of the required actions in relation to the power modes was determined. An ideal user type was determined for every action and the user types that did not perform an action the ideal way were considered as an erroneous user type (see matrix in ***Appendix XXVIII***). The essence of the fault in the error was thereafter determined and categorised into energy wastage factors, which depict generic incorrect user actions that could lead to energy wastage. The occurrence of these energy wastage factors in other domestic appliances was also investigated and included in the matrix. These factors had been established by analysing and discussing with employees the technical functions and user interface of the appliances.

In identifying the fundamental reasons for an energy wastage factor, the erroneous user types depicted in the matrix in ***Appendix XXVIII*** were related to the identified reasons behind the cause of error. This was first done with Post-its on an A3 paper and thereafter created into a matrix. The occurrence of the energy wastage factors were thereafter traced to a higher level of cause and categorised into the following initial generic dimensions: product related, timing option, user positioning, user perception, and context of use. The initial generic dimensions corresponded to the conclusions drawn from the case study. In pursuing an even higher level of cause, the following question was posed:

> *'Why will the user not perform their actions in the most energy efficient and ideal way?'*

The fundamental reasons behind the occurrence of an energy wastage factor was as a result traced to four generic dimensions that were not directly caused by the user, but instead by the product (see ***Appendix XXIX***).

Analysing the What & Why from a technical perspective

The basis for investigating the product from a technical perspective was the research behind the conducted energy measurements. The technical functioning of the system design was examined to identify the factors that lead to energy wastage that the user could not influence. In comparing the design of the carrier product to an ideal one, which only uses the minimum theoretical energy to fulfil a user goal and does not use energy other than for fulfilling a user goal, two simple energy wastage factors were established. To establish the fundamental reasons giving rise to the identified energy wastage factors, the conclusions drawn from determining the conversion effectiveness during the energy measurements were investigated further. As these reasons were product specific, they were therefore pursued to a higher level of cause for their occurrence and rephrased to become more generic in their formulations (see ***Appendix XXX***).

23.2.2 Investigating the How

Idea generations of how to solve the identified energy wastage factors from the case study were conducted throughout the method development process (see ***Appendix XXXI***). Ideas were brainstormed around the seven design intervention strategies, but also discussed together with product developers of the company.

23.3 Results

The results of the analysis will be depicted below.

23.3.1 The What and Why analysis from a user perspective

Energy wastage factors caused by actions that users perform in their interaction with a product and that can lead to energy wastage can be seen in Fig. 37. The analysis of these factors resulted in four generic dimensions to which the fundamental reasons behind the occurrence of an energy wastage factor can be ascribed: user interface, context of use, system design and product honesty, which refers to how honest the product is in communicating the energy consumption of the product. The common denominator for these generic dimensions is that the occurrence of the energy wastage factor is not directly attributed to the user.

In a further analysis of the four generic dimensions, it was concluded that they interrelate with each other and that the user interface acts as the main link between them. It was also concluded that energy wastage from a user perspective can be a result of how well the product is communicating to the user in relation to its context of use, actual energy consumption, and the habits that are created depending on the system design. The aim of the interface is therefore to provide the user with the right information, which can be communicated through three main interface elements (see Fig. 38):

» When the action should be performed
» How the action should be performed
» Feedback of a performed action

The analysis of the case study had shown that if a user

ACTION IS PERFORMED AT THE WRONG TIME
» Action is performed later than intended within the same power mode
» Action is performed in another power mode

ACTION IS PERFORMED WRONGLY
» Wrong action for intended use
» Wrong combination of actions
» Wrong amount of objects

ACTION IS NOT PERFORMED AT ALL
» Following actions can be performed but user may not obtain the desired end result
» None of the following actions are performed and the product will after a certain period of time change to a lower power mode
» The usage of an interface element does not match the user's expectation of the outcome (eg. symbols, automated power modes)

ACTION CAN TAKE MORE TIME TO PERFORM THAN INTENDED
» The length of time to perform the action is affected by the required object's placement in relation to the product
» Action may be double-checked to ensure that it has been performed
» Wrong power setting

Fig. 37. Overview of energy wastage factors from a user perspective

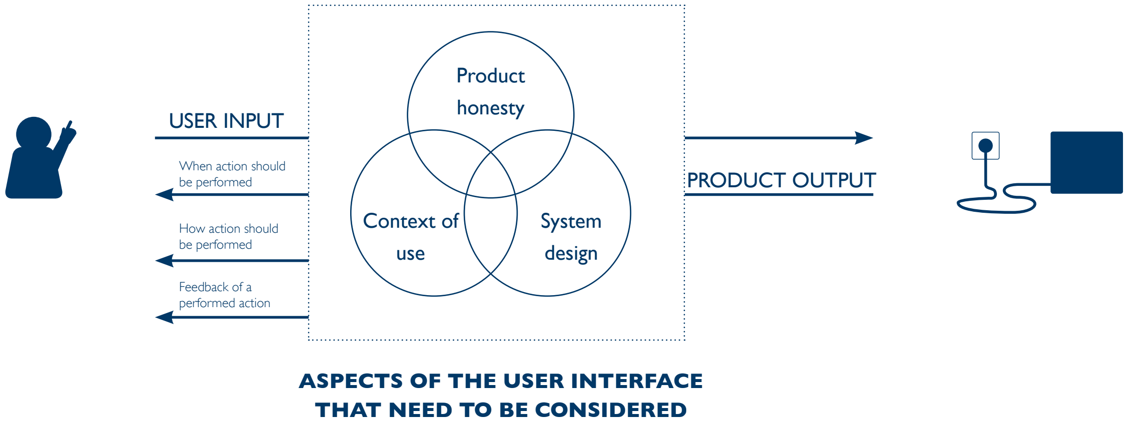


Fig. 38. The role of the user interface in the user-product interaction

does not know when to perform an action, they may not perform the action at all or may perform it at a later point in time. If a user does not know how to perform an action, the action can for example be performed wrongly whereas if a user does not receive feedback when he has performed an action, he may not know that the action has been performed. A lack of feedback can also give the user a wrong impression of the product's energy consumption and the user will therefore not have a correct mental model of the product. Thus, these three interface elements can guide the user to the right usage, whereas inadequate interface elements or a lack of one of these can, depending on the context, give rise to energy wastage. It is however important to keep in mind that the presence of the three interface elements may not be necessary for all user actions as too much information provided by the product is not always eligible.

23.3.2 The What & Why from a technical perspective

The energy wastage factors that were identified when determining the factors of the system design that lead to energy wastage were:

» Product uses more energy than the minimum theoretical energy to achieve user goal
» Product uses energy when not in use

The fundamental reasons for the occurrence of these factors have been removed with reference to the confidentiality of the industry agreement.

23.4 Conclusion

The Further analysis showed that the energy wastage that had been identified during the survey, user studies and energy measurements could be pursed further and categorised into generic dimensions by examining a product from its ideal usage but also an ideal system. It also showed that the majority of the reasons for the occurrence of energy wastage could be attributed to the product. From a technical perspective, it is ascribed to the fact that a product is not effective in its energy usage. From a user perspective, energy wastage is a result of how the information provided by the user interface was adapted to contextual factors and technical constraints, but also to how honest it was in communicating the energy consumption of the product. In other words, energy wastage can be prevented if the right product is developed, which is a product that uses only the energy that is needed to fulfil a user goal, and provides the user with the right information which, depending on the situation, can consist of three interface elements communicating: When the action should be performed, How the action should be performed, and providing Feedback of a performed action.

24. Developing the basis

Below follows an account of the development process for creating the basis of the method.

24.1 Purpose

The purpose of this stage was to focus on two of the criteria that were established during the literature study: (i) to have a set of questions to predict possible energy wastage; (ii) to have a basis from which the questions of presumptive energy wastage could be posed.

24.2 Method

The development of the method in this stage was divided into three main parts. The focus of the first part was to create a Question Basis for examining energy wastage from a user perspective. In the second part, a visual basis of a product's user-product interaction was elaborated upon. In the third part, concepts were generated to see how the Question Basis could be combined with the visual basis.

24.2.1 Developing a Question Basis from a user perspective

Questions on presumptive energy wastage factors were developed from the matrix in ***Appendix XXVII*** and ***XXIX***, but also from studying other domestic appliances. The questions were written down on Post-its and placed on several A3 papers. From the large quantity of determined questions, there arose a need to simplify the process of questioning the product under investigation. Questions were grouped and re-grouped and these attempts gradually led to three categorisations.

24.2.2 Developing a visual basis of investigation

To begin with, the visual overviews that had been created for the carrier product during the case study were elaborated further. These overviews resulted in the idea of a visual model for each of the different user profiles to show the difference in energy consumption in relation to how they were using the product. However, as the large differences in energy consumption are usually time-related and a potential difficulty in visually assigning the small and specific details to their impact on to the energy consumption, this idea was forsaken. Instead, the idea of using one overview to show that there could be a potential difference in energy consumption grew. This idea coincided with the criteria that had been established in the literature study: that a basis from which presumptive energy wastage could be examined was necessary, and that this basis would show the entire user-product interactions necessary to achieve the user goal. This basis could also be used to make the user-product interaction clear to developers with different backgrounds and roles in development work. The idea was therefore expanded further upon into an Energy Overview.

The Energy Overview started with elaborating on the relationship between the power modes and user actions. As a transition of a power mode is caused by a user action or automatically by the product itself, a need to visualize the connection between these two aspects arose. Different ways of visualizing this was developed (see ***Appendix XXXII***). In finding ways of visualising these connections, an initial inspiration was found from the interaction model of the company. For confidentiality reasons, the model in its original form was not permitted to be included in this thesis. The Energy Overview gradually evolved into a holistic view of the user-product interaction providing a visual overview of power modes, power distribution, length of time, user actions and the three main interface elements that had been determined in the Further analysis.

24.2.3 Concept generation and evaluation

During the parallel development of the Question Basis and Energy Overview, the idea of combining these two emerged. The combination was considered appropriate as the Energy Overview showed the basic aspects of the user-product interaction upon which the investigation could be based. In determining how these could be combined together with the criterion of how to present the results of the analysis, different ideas were generated and resulted in two concepts. These were evaluated and one was chosen for further development.

24.2.4 Evolvement of the 3 Approaches to Energy Effective Products

During the Further analysis, the idea of having a set of principles and recommendations for products that could guide product developers to a more effective usage of energy but also to help create new energy effective products grew forth. This idea evolved into the "3 Approaches to Energy Effective Products", which describe three ways of how a product could achieve the lowest energy consumption. The principles of each of the 3 Approaches were based on the conclusions drawn from the case study and survey. The recommendations were developed from the ideas of how to improve the carrier product but also through discussions with various developers at the company, and by studying products that were found to be sustainable.

24.3 Results

The results of this stage will be described below.

24.3.1 Question Basis from a user perspective

As previously mentioned, the questions were categorised in three different ways. In the first categorisation, the questions were grouped according to two of the generic dimensions for the occurrence of an energy wastage factor: user interface and context of use. The questions within the user interface category were in turn categorised according to which interface element they were associated in order to pinpoint which interface element that needed to be addressed. The questions related to the system design, which was the third fundamental reason for energy wastage, did not have its own category but were instead integrated into the other questions. This decision was taken partly due to the strong relationship between the different reasons for energy wastage factors, but also in an attempt to reduce the number of categories.

In the second categorisation, the questions were categorised after the two action types: primary and secondary, which had been determined during the case study. This categorisation evolved from the fact that considering the variety of different energy using products, there is a wide range of possible user actions, and by categorising the questions according to the type of user action, only questions relevant for each action type would be posed. During the categorisation, there arose an awareness that the action types could be elaborated further upon. The user actions of three different products were therefore determined and analysed further.

In the third categorisation, the power modes were also divided into types as it was realised that the character of a power mode was dependent on whether it was consuming energy or not, but also by what it was that determined the length of time a product spent in a power mode (see Fig. 39).

Several measures were taken to simplify the Question Basis. To reduce the amount of text, abbreviations as well as a colour code were assigned to distinguish between the different power mode and action types. For the three interface elements, three different symbols

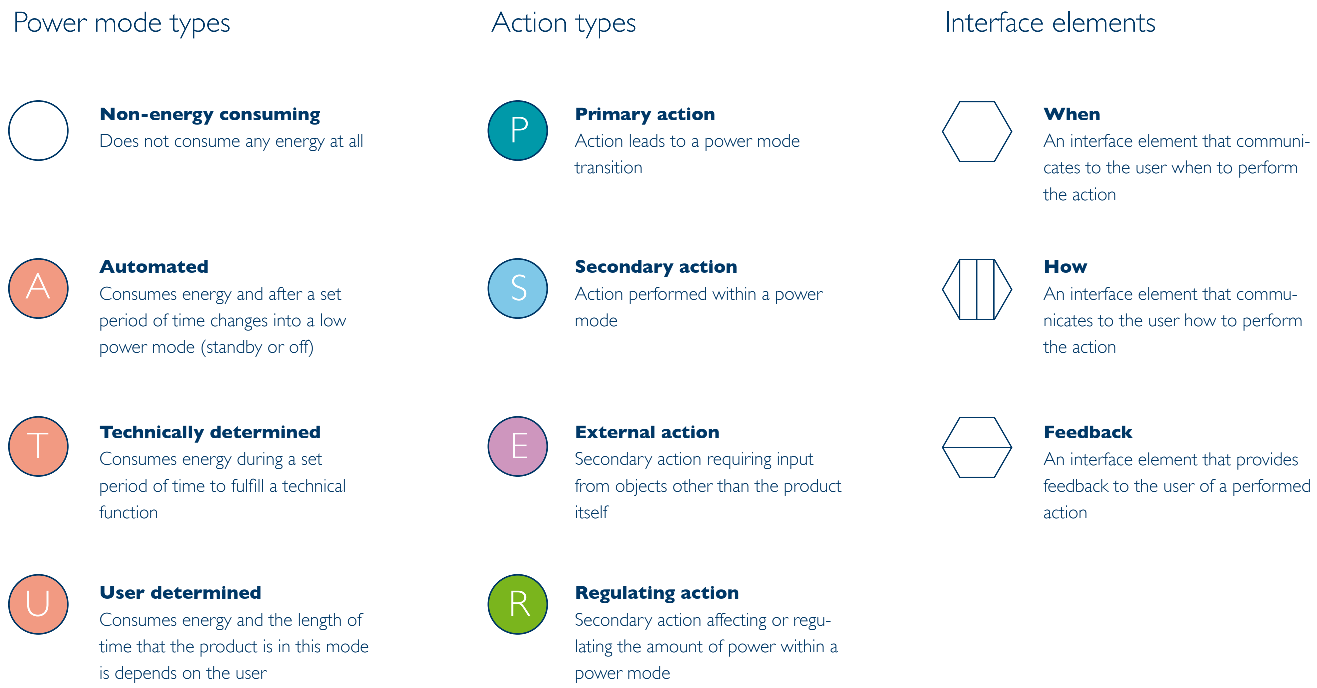


Fig. 39. Overview of power mode, action and interface element types.

were developed an assigned to each one (see Fig. 39).

24.3.2 *Energy Overview*

The Energy Overview developed into simple and separate timelines depicting the power consumption, length of time, power modes, user interface elements, primary actions and secondary actions. These timelines were placed parallel to each other to indicate the relationship between them (see Fig. 40). A parallel placement enabled the power distribution to be shown in relation to the user actions and power modes. This was found to be a good way of making it clear where in the process of usage most energy is consumed. A timeline ascribed to the time aspect aimed to give a better perception of the length of time spent in a specific power mode and to also complement the power consumption timeline. The Energy Overview was also further developed to show the relationship between power modes, user actions and the three main interface elements (see Fig. 41).

24.3.3 *Evaluation of concepts*

The two concepts that were developed are as follows (see ***Appendix XXXIII***):

» **Concept 1**: Integrating questions in the Energy Overview itself

» **Concept 2**: Energy Overview, question cards and a matrix to fill in the results

In Concept 1, different matrix solutions were among the concepts that were thought of. By looking at the Energy Overview, the participant could easily see where the potential problems lay. However, an overview like this not only looked complex but would also be complex to use. In addition, it could give the product developer an incorrect impression of where the actual problems lay, as it did not show the probability of the problem occurring or the consequence of the problem.

For Concept 2, different cards were produced to examine how they could be structured and to test different

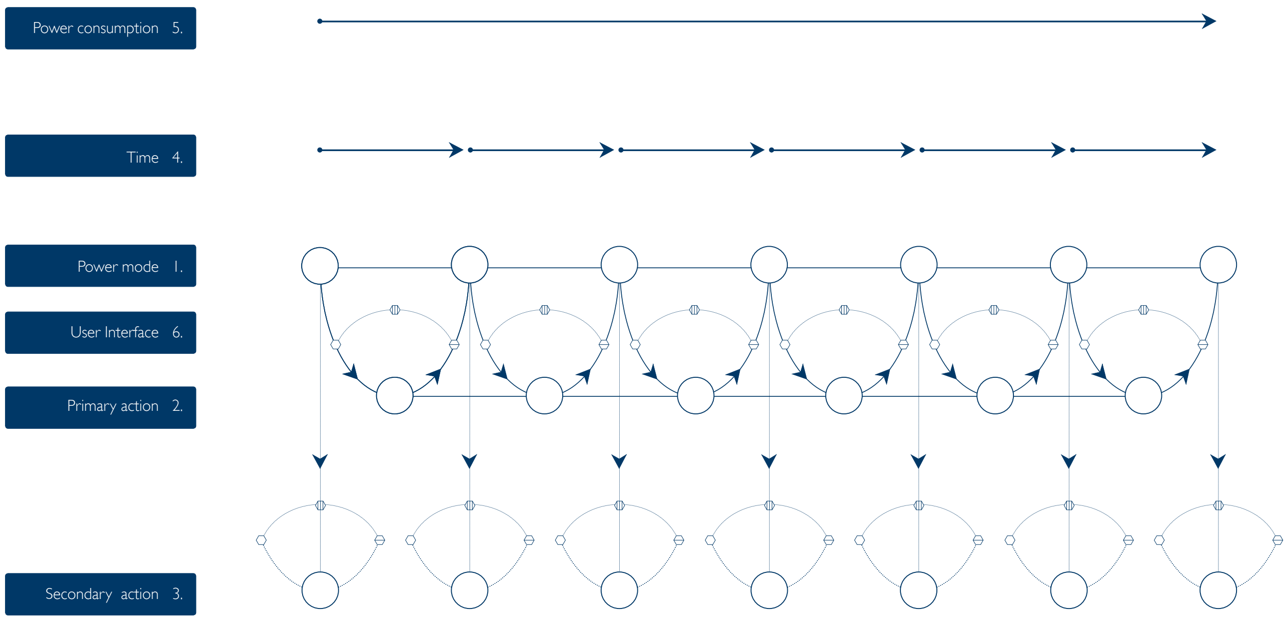


Fig. 40. Template for the Energy Overview

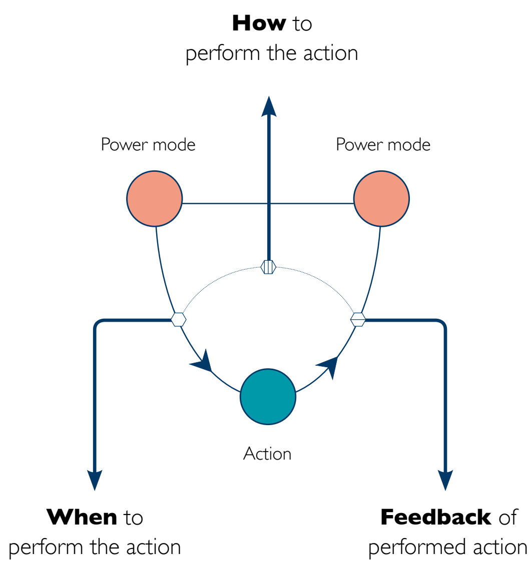


Fig. 41. A part of the Energy Overview that can be used to depict how a product with its interface elements can make the user perform an action that causes a power mode transition

ways of formulating the questions. It was realised that there was a possibility to develop the question cards in a way so that only the cards relevant to the specific product under investigation could be selected and utilised. The colour code that had been developed for the Question Basis could for example be used for this. In addition, the cards could evolve and grow in number over time. Another discovered benefit when comparing the concepts was that only the identified energy wastage that had been determined during the analysis would be summarised in the matrix. It was concluded that Concept 2 was the best idea to continue with. It was, however pointed out that these cards, even though they were simply formulated, were too abstract for product developers. The given examples made it difficult for them to relate a potential described problem with a product and it was therefore suggested that the cards should include a specific example from the case study to make the questions more understandable.

24.3.4 The 3 Approaches to Energy Effective Products

The 3 Approaches to Energy Effective Products consists of a set of principles and recommendations of how a product can achieve the lowest energy consumption. The approaches include 'Product honesty', 'User Perspective' and 'Technical Perspective'. Until now, the focus of the method development process had been on investigating energy wastage from a user and a technical perspective. Product honesty can be seen as a part of the User Perspective, but was found to be so important that it required an approach of its own. The principals and recommendations that were developed for each approach are general in their denomination as these evolved to be applicable to a wide range of energy using products.

24.4 Conclusion

In this stage, the basis for the method was established. Questions for examining energy wastage from a user were developed and the Energy Overview, a visual basis for the method, was also established. In the final part of the stage, the entity of the method basis was determined. The method would consist of three important parts: the Energy Overview, a Question Basis, and a Matrix in which the results of the analysis could be summarised.

25. Further development

In this stage, the Energy Overview and the Question Basis were further elaborated upon.

25.1 Purpose

The purpose of this stage was to develop a way for the product developer to create an Energy Overview, and to create cards for examining the What and Why of energy wastage from the user perspective.

25.2 Method

In this stage, cards instructing how to create an Energy Overview and to analyse energy wastage were developed and tested.

25.2.1 Energy Overview

In the Further analysis, potential energy wastage had been investigated by comparing a product to an ideal way of using it. This approach was seen as successful and assumed to be a way with which energy wastage could be examined in other products. Thus, the aim of the Energy Overview was to determine and make explicit the most energy-efficient way of usage and thereafter investigate the possible deviations from this. The Energy Overview from the previous stage was improved and a template that the product developer could use to create an overview of the product was developed. A set of instructive cards were thereafter created.

25.2.2 Cards for analysing energy wastage

The Question Basis for the user perspective was used as a foundation to develop cards examining the What and Why of energy wastage. It was decided that each question should have a separate card.

25.2.3 Testing the method

A test version of the method was created and tested on a product. As a result, several areas of improvement were identified, but the positive aspects of the method were also made clear.

25.3 Results

The results of this stage will be presented below.

25.3.1 Energy Overview

A template as well as a set of cards instructing how to make an Energy Overview of a product was developed (see Fig. 40 and 43). The instructive cards depicted a step-by-step approach to determine the user goal and define the determined user actions and power modes into action and power mode types. The cards also guided the product developer to put all the information together in the template. "Type stickers" were also made (see Fig. 44). These were based on the colour code and abbreviations that had been assigned to the different power mode and action types, and could be placed on the template to distinguish between them.

25.3.2 *Cards for analysing energy wastage*

The information provided in each card was divided into three parts (see Fig. 45):

» Triggering question to examine energy wastage
» Consequence in terms of energy wastage
» An example for further understanding the question

The cards were categorised according to action type and interface elements.

25.3.3 *Evaluating the testing of the method*

The Energy Overview was found to be useful for creating an understanding for the different aspects of a product's user-product interaction. The initial step of the method was however slightly confusing for the product developer. In this step, the most energy efficient way to use the product was to be determined. Thus, with this feedback it was decided that determining the user goal and all the required actions had to be

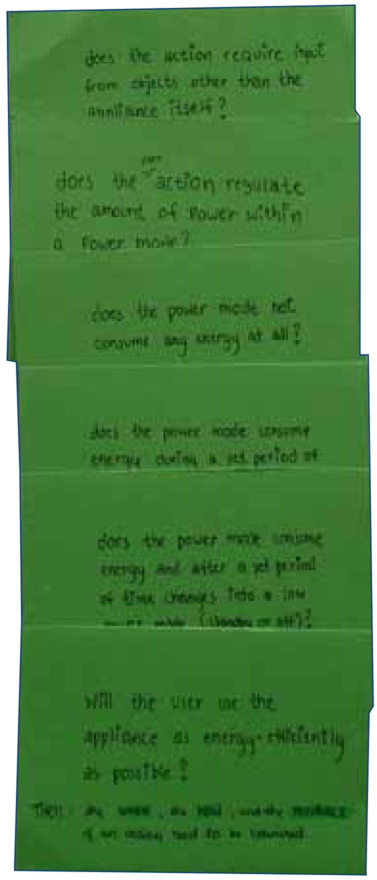


Fig. 43. First version of instructive cards

rephrased to avoid confusion. It should no longer be about determining the most energy efficient usage, but instead the intended way of achieving a user goal. The usage of this phrase was considered more appropriate as product developers will most likely easier relate to it. It was also concluded that the rephrasing would not affect the outcome of the analysis as the analysis examined deviations from a specific way of usage.

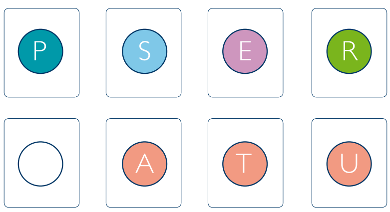


Fig. 44. Above: "Types stickers" for actions. Below: "Types stickers" for power modes.

26. Final development

In this stage, the method was completed. It was also decided that the method that was being developed was not to be referred to as a 'method' but instead

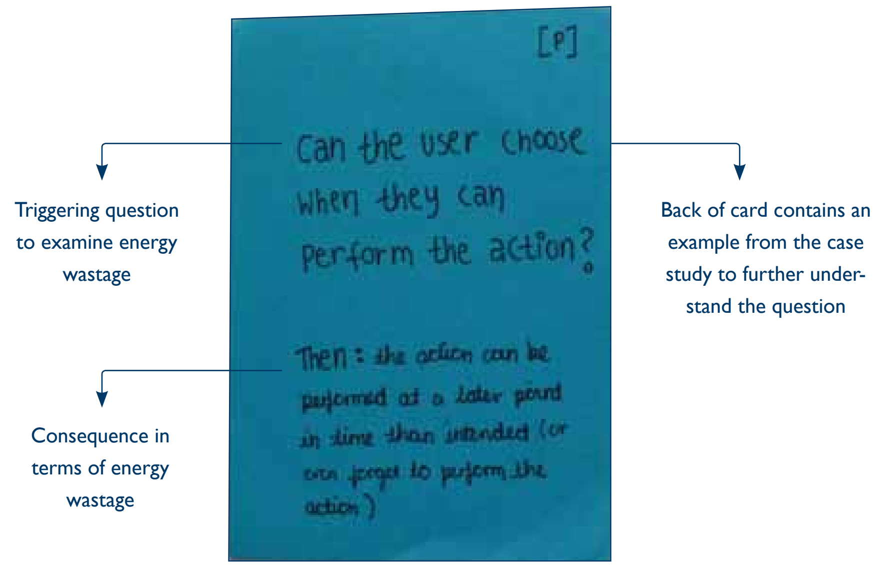


Fig. 45. Example of a card analysing energy wastage

as a 'tool'. This decision was based upon the fact that the word 'tool' felt lighter and less intricate than the word 'method'. Upon the suggestion of a mentor, it was named the 'Energ-ability Tool'. This name was found appropriate considering that the case study, survey and method development process had evolved with focus on usability from an energy perspective.

26.1 Purpose

The purpose of this stage was to finalise the tool and test it with a group of product developers. This would partly be achieved by expanding the method to encompass a What, Why and How approach, but also by aligning it with the 3 Approaches to Energy Effective Products and developing a Matrix to summarise the results of the analysis.

26.2 Method

The results from the previous stage were not only elaborated further, but also expanded to be more in line with the 3 Approaches to Energy Effective Products. Additional cards to analyse energy wastage from a Technical Perspective and Product Honesty were developed. All cards were determined to be an A6 in order to contain all the necessary information. A handbook introducing the 3 Approaches was also created and a workshop was held to evaluate the Tool.

26.2.1 Energy Overview

The instructive cards for the Energy Overview were elaborated further upon. The formulations of instructions and the layout were evaluated and improved. Consistency was a key element, in particular for the layout and wording used.

26.2.2 Cards for analysing energy wastage

The cards created in the previous stage were further improved and the number of cards was reduced as some of the cards addressed the same matter. Cards addressing energy wastage from a product honesty perspective as well as a technical perspective were also created. In developing the cards to investigate a product from a technical perspective, it was realised that many of these questions required detailed information that could not be obtained without conducting in-depth energy measurements. In addition, it was realised that in order to investigate a product from a technical perspective, there had to be a basis from which the analysis could proceed. The undertaken approach in the Further analysis in which the energy wastage was investigated after having determined the product's conversion effectiveness was seen as appropriate. This decision was backed up by the fact that companies often have a measure of the amount of energy used by the product and would therefore have an estimated value that could be used for the basis of analysis. The Question Basis for the analysis from a technical perspective therefore evolved into developing instructions of how to calculate the conversion effectiveness and developing triggering questions to examine whether or not the energy usage was optimal. To address the sub-criteria that was determined in the beginning of the method development process, to provide guidelines for in-depth studies of energy using products, cards for this was also developed.

26.2.3 Summarising results of the analysis

In the initial development of the Matrix, a short brainstorming session was held to identify which factors related to energy wastage should be included. Among these were how severe the impact of an energy wastage factor would be and the probability of its occurrence. These two combined could give an indication of which aspects of the user-product interaction that would have the highest impact on the energy consumption. Ideas for evaluating these were developed but in discussion with a mentor, the idea was discontinued. It would not only require information from detailed energy measurements but also of different users' knowledge and abilities, which would not always be readily available. The remaining factors that were found to be relevant were thereafter translated into a matrix. The Matrix was kept simple and also aligned with a What, Why and How structure to enhance the link to the analysis of energy wastage. During the development of the Matrix, it became evident that there was a need for two matrices: one in which energy wastage could be ascribed to a user action, and one in which it could be ascribed to the power modes of a product. This conclusion was based on the fact that when investigating a product from a technical perspective, it makes more sense to examine and evaluate the product function within a specific power mode. This is due to that not all user actions, such as an external one, will necessarily result in the activation of a certain function of the product. In addition, when conducting energy measurements, it is easier and more efficient to investigate and determine the differences in energy impact within a power mode rather than to each and every user action.

26.2.4 Creating the handbook

During the further development of the Tool, it was realised that there was a need to have an introduction to the topic of energy wastage related to products. This could give the product developers more background knowledge before performing the Tool. A handbook was therefore developed.

26.2.5 Testing and evaluating the Tool

A workshop was held with a group of 5 company employees to test and evaluate the Tool by using it to examine a product. To enhance the relevance of the workshop for the participants, but also to maximise the information that could be extracted for the product under investigation, the group only included people whose work was related to the product. In addition, the group had been composed to be multi-disciplinary .

The workshop took place in the 'Creative room', a room with a more creative and relaxed atmosphere. All of the participants, except for one, had attended the final presentation during which the 3 Approaches had been introduced. The one who had not been there was

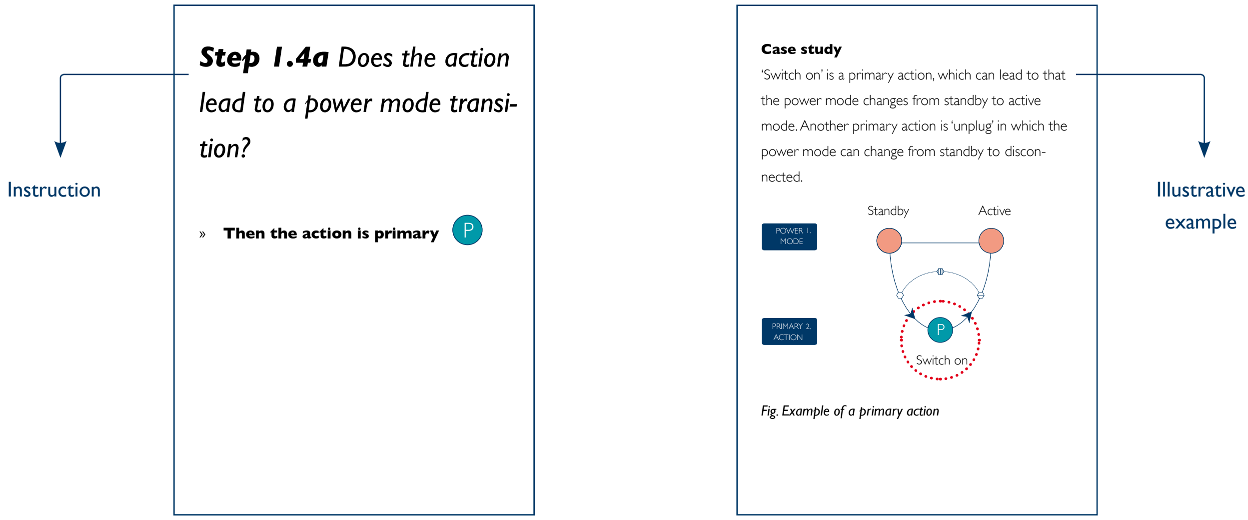


Fig. 47. Example of a card that helps the product developer to create an Energy Overview

instead sent an overview of the Approaches so that all participants would be on the same level and were aware of the goal of the Tool. Two sets of Tool cards were available and the Energy Overview template as well as the Matrices were pinned to the wall. In order for the participants to have a reference throughout the process, the Energy Overview and Matrices from the case study were put up on a residing wall.

26.3 Results

The results of the final stage will be presented below.

26.3.1 Energy Overview

The instructive cards for the Energy Overview evolved into 9 specific steps required to create the overview. The steps consisted of instructions or a question written on the front of the card, and an illustrative example from the case study written on the back of the card (see Fig. 47). These cards together with a set of "type stickers" would help the product developer to create an Energy Overview of a product on the template (see Fig. 40). See the cards in ***Appendix XL***.

26.3.2 Cards for analysing energy wastage

The cards were developed to be more in line with the 3 Approaches to Energy Effective Products. The information on these cards, were also aligned with a What, Why and How structure (see Fig. 48). In addition, the colour code that had been developed for the action types was also assigned to the cards in an attempt to create a clearer linkage between the cards and the Energy Overview. This would also enable the product developer to easily see which cards could be used to question a specific action of the product. The guidelines that were developed for conducting an in-depth study of an energy using product were based on the conducted case study and consisted of two steps: how to conduct user studies in terms of observations and energy context mapping sessions, and how to conduct energy measurements. See the cards in ***Appendix XL***.

26.3.3 Summarising the results of the analysis

Two matrices were developed to summarise the results of the analysis. In one Matrix, the identified energy wastage could be assigned to user actions, whereas in the other Matrix, it could be ascribed to the power modes of a product (see Fig. 49). The Matrix for power modes has an additional column in which information of the energy impact obtained through detailed energy measurements could be placed.

26.3.4 The handbook

The handbook that was developed for the product developers at the company was distributed as an easy-to-read deliverable of the thesis project. It presented the 3 Approaches to Energy Effective Products as well as more detailed information on the case study and online survey. It also included a glossary with common terms used in the area of energy using products.

26.3.5 The workshop

During the workshop, several interesting observations were made. Firstly, that low power modes of energy using products are complex and not well-understood by people involved in product development of these products. This was reflected by the fact that several of the participants were not aware of that there was an off-mode in the product and the reason for its presence. The results of the workshop were summarised in a matrix and an Energy Overview and sent to the participants (see ***Appendix XXXIV - XXXVI***).

The Tool was found to be useful to identify possibilities for improvements and was seen as a new way of looking at a product. It also managed to pinpoint current dilemmas with the product.

The participants were positive to the Matrix and in particular liked the fact that it was possible to note down the energy impact as they believed this could help to steer or motivate people in the right direction, i.e. to focus on the aspects that could really save energy. One participant therefore enhanced the importance of making use of real logged data. Another participant suggested an additional column to the Matrix in which it could contain suggestions of who would pursue a certain matter and how it could be pursued. This could for instance be a specific person or department. This was found to be a good idea and was added to the results that were sent out to the participants.

Fig. 48. Example of cards analysing energy wastage from a user perspective

Action	*Action type*	WHAT energy wastage can occur?	WHY does the energy wastage occur?	HOW can the energy wastage be solved?

Power mode	*Power mode type*	WHAT energy wastage can occur?	WHAT is the energy impact?	WHY does the energy wastage occur?	HOW can the energy wastage be solved?

Fig. 49. Matrices for summarising the results of the analysis

One participant expressed that the Tool was complex for the first time users and that it required the presence of an expert. This could be agreed upon as it took time to read the cards and many steps of the process were therefore verbally explained. The workshop took longer than expected. The required time had been estimated to an hour, but it required an additional 30 minutes. One participant mentioned that it would be much faster if she would do it a second time. A large part of the time was spent on creating the Energy Overview. Perhaps what could be done to reduce the amount of time could be to have an Energy Overview already prepared for the workshop that the participants could look through before attending and that could be initially discussed in case there was anything that was not clear. The focus of the workshop would then be to analyse and come up with solutions. This could however eliminate the learning effect. Another observation made during the workshop was that it could be useful to divide the "type stickers" into two separate sheets: one for power modes, and one for actions, to make it more easy to distinguish between the different types. In addition, it could also be good to have a reference sheet showing an overview of the different action and power mode types and to divide the power consumption timeline into sections to facilitate for the user to see the difference in power consumption depending on which power mode it is in.

An area of concern prior to the workshop had been the categorisation of action and power modes into types, i.e. whether or not this would require too much of the participant. During the workshop it was observed that the way they were categorised seemed to be understandable and straightforward. One user however initially thought that something was odd when not all the different power mode types were present in the product. It would thus be important to enhance that different types of products will have different types of product modes and not all products will have all product mode types.

The discussion that evolved during the workshop was found to be useful for creating a common understanding for the product and sharing insights among the different departments. It would however have been advantageous to have had a person from marketing and an electronics engineer present, the latter to understand the electronics within the product. Perhaps it could also be interesting to include someone whose work was not related to the product. This could not only bring another perspective to the analysis of the product, but also generate more out-of-the-box ideas to reducing energy wastage.

Results

27. Introduction

The results of this thesis will be presented below. These include the 3 Approaches to Energy Effective Products, an Energ-ability Tool and suggestions for improving the carrier product.

28. The 3 Approaches to Energy Effective Products

The 3 Approaches to Energy Effective Products is a set of approaches aiming to address how products can achieve the lowest possible energy consumption during the usage phase through three areas of focus: Product honesty, User perspective and Technical perspective (see Fig. 50). Each approach has a set of generic principles and recommendations of how energy wastage can be prevented to fulfil the purpose of each approach (see Fig. 51). These approaches may overlap, but are here treated as separate issues.

The 3 Approaches to Energy Effective Products can act as a guideline and a source of inspiration for people involved in the product development process. It is developed as a reaction to an identified need to make energy saving simple and accessible to a wider range of users, i.e. the 'Silent Green' target group, which includes both users who do and do not express a concern for the environment, and those who are and are not motivated or have the knowledge of how to achieve energy reduction in the usage of products. These 3 Approaches strives to guide product developers to develop products that enable sustainable usage from the beginning. They not only suggest that products should be designed in a way that enables them to achieve the lowest possible energy consumption for each and every of its user goals, but also that product developers should find ways of designing around user habits or simply creating the right habits from the start.

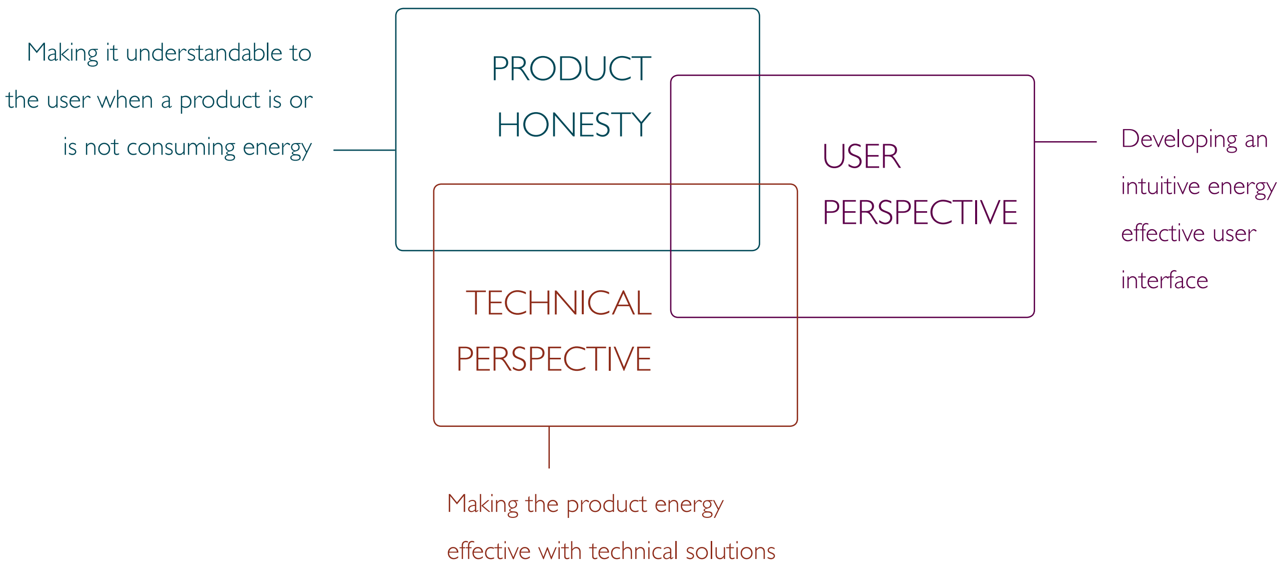


Fig. 50. The 3 Approaches to Energy Effective Products

APPROACH	PRINCIPLE OF APPROACH		RECOMMENDATION
PRODUCT HONESTY	**No.1**	The user will know when the product is ON and when the product is OFF	» All energy using power modes should give an indication communicating that the product is consuming energy
	No.2	The user does not have to unplug the product to make sure no electricity is being consumed	» All products should give the user the option to switch the product off with a hard-switch
USER PERSPECTIVE	**No.3**	The product is developed to intuitively be used as energy-effectively as possible	» Investigate how the product can be used as energy-effectively as possible and with this information, develop a user interface requiring minimum thought and effort of the user » Inform the user of best usage
TECHNICAL PERSPECTIVE	**No.4**	The product is developed to use the minimum theoretical energy to fulfill all of its user goals	» Examine the product from a systems perspective to identify the energy losses that occur » Strive to achieve the minimum theoretical energy when the product is in use by developing use-only-the-energy-you-need products, changing to effective technology, and/or reducing energy losses » Strive to achieve zero energy consumption when the product is not in use by eliminating low power modes, replacing power source, and/or improving the efficiency of the power supply

Fig. 51. Overview of the 3 Approaches and its principles and recommendations

28.1 Product honesty

Product honesty aims to create a common understanding of energy using products by firstly making it visually clear when a product is or is not using energy, and secondly, by always providing the user with the possibility of switching off a product into a hard-off. Creating a consistency across energy using products can help users to create a correct mental model and make them be confident regarding the outcome when switching off a product. In this way, a trustful relationship between user and product can be built and the user does not have to doubt or be unsure of whether the product is consuming energy or not.

28.2 Technical Perspective

The Technical Perspective strives for products to be as effective as possible in their usage of energy by only using the amount of energy necessary for fulfilling a specific user goal. This can be achieved if the product strives to reach its minimum theoretical energy when in use, and by not using energy when the product is not in use. The latter has in products often been present as 'comfort functions', in terms of enabling easy reactivation or a certain aesthetic "look" to a product. This approach does not in any way propose that comfort should give way to energy effectiveness, but instead urges to find other innovative technical solutions that can achieve the same comfort level.

28.3 User Perspective

The User Perspective states that an intuitive user interface should be developed to enable users to use the product as energy-effectively as possible with minimum thought and effort. By examining aspects of the user-product interaction that can give rise to energy wastage and/or taking into consideration user habits and context of use, the user interface can be developed to prevent unsustainable usage. The User Perspective also suggests that users should be informed of the best usage by integrating advice in the user manual or quick-start guides.

28.4 The handbook

The handbook of the 3 Approaches to Energy Effective Products presents the 3 Approaches by summarising the findings of the case study and survey. It strives to inspire those reading it to think differently about the development of products and to create an initial understanding for factors that can lead to energy wastage during the usage phase. The handbook also contains a glossary of commonly used terms for energy using products to address the need of a common language in multi-disciplinary teams. A complete matrix of the power modes, their functionality, features and external as well as internal regulations can also be found in the handbook.

29. The Energ-ability Tool

The Energ-ability Tool examines an energy using product from the 3 Approaches to systematically identify potential energy wastage that can occur during the usage phase (see Fig. 52 for an overview of energy wastage factors). Prior to using the Tool, it is recommendable for the participants to read the Handbook to become acquainted with the 3 Approaches.
The Tool is intended for a multi-disciplinary team and to be used in the early phases of product development. It aims to support product developers with different disciplinary backgrounds in creating a common understanding of the product and its potential energy impact during the usage phase. With this insight, product developers should have a better ability to develop products that are designed either to cue the right habits or around existing.
The Energ-ability Tool consists of three different stages: Define, Analyse and In Depth. The first two stages are theoretical and provides the possibility to analyse a product when the option to assess them in home environments does not exist. The third stage provides with an in-depth guideline to conduct more extensive user studies of existing products in home environments as well as how to conduct detailed energy measurements (see Fig. 53 for an overview of the Energ-ability Tool). The participants will for each stage examine a product through a set of A6 cards. These cards will also assist

APPROACH	PRODUCT HONESTY		USER PERSPECTIVE				TECHNICAL PERSPECTIVE
GENERAL ENERGY WASTAGE FACTORS	The user does not know when the product is or is not consuming energy	The user has to unplug the product to ensure that no energy is being consumed	**User Interface** The user does not receive the right information from the product			**Context of use** The product may not be adapted to where it is being used	The product uses more energy than the minimal theoretical energy to fulfill a user goal
			User does not know WHEN to perform an action	User does not know HOW to perform an action	User does not receive FEEDBACK of performed action		
SPECIFIC ENERGY WASTAGE FACTORS	The product uses energy without the user knowing	User may leave the product plugged in	User does not perform action at right time or does not perform it at all	User can place wrong amount of objects	User has to double-check that an action has been performed	Action can take longer than expected	The product uses energy when the product is not in use
			Action can take longer than expected	User chooses the wrong combination of actions	User does not understand automated power modes		The product is not effective in fulfilling a user goal

Fig. 52. Overview of energy wastage factors from the 3 Approaches

	Stage 1. DEFINE	**Stage 2. ANALYSE**				**Stage 3. IN DEPTH**	
AIM	DEFINE an energy overview	WHAT energy wastage can occur?	WHY does the energy wastage occur?	HOW can the energy wastage be solved?	NEXT STEP	WHAT is the energy impact?	WHY does the energy wastage occur?
TOOL CARDS	Step 1.1-1.9 Creates an Energy Overview of the product by linking user actions, user interface, power modes, time, and power consumption	Step 2.1 Investigates energy wastage that can occur due to that the product does not comply with the Product Honesty Principles			Determines potential follow-ups to verify or further investigate the identified energy wastage through for example energy measurements or focus groups	Step 3.1 Guidelines for conducting detailed energy measurements	Step 3.2 Guidelines for conducting user studies to obtain a deeper understanding of user habits by investigating how a user is using a product
		Step 2.2 Investigates energy wastage that can occur due to that the product does not fulfill the User Perspective Principle by analysing user actions, user interface and context of use					
		Step 2.3 Investigates energy wastage that can occur due to that the product does not fulfull the Technical Perspective Principle and thereby uses more energy than required to fulfill a user goal					

Fig. 53. Overview of the Energ-ability Tool

the participants to fill in the results in three templates, which will be the deliverables of the analysis.

29.1 Stage 1. Define

In Define, an Energy Overview of the product is created to establish a common understanding for the user-product interaction and its energy consumption. It brings together and shares the product knowledge of different departments to facilitate communication between them and to also create a good basis of discussion to which all can contribute. Once the user goal of the product being investigated has been determined by the participants, an overview of the product that links user actions, user interface, power modes, time and power consumption will be put together on a given graphical template. A set of instructive cards will step by step guide the participants through this stage and also help them to categorise the power modes and user actions that are present in the product into types (see ***Appendix XL***). To distinguish between the different power mode and action types on the graphical template, a set of stickers can be used. (See ***Appendix XXXIV*** and ***XXXVII*** for two examples of the Energy Overview).

29.2 Stage 2. Analyse

In the Analyse stage, presumptive energy wastage is examined for each of the 3 Approaches through a set of instructive cards (see ***Appendix XL***). The cards will examine whether the product fulfils the principles of each approach by examining whether certain energy wastage factors exist. In the Product Honesty approach, energy wastage is examined depending on the ease of understanding and ensuring zero energy consumption, whereas in the User Perspective, it is examined in the user interface and context of use. For the Technical Perspective, energy wastage is examined after having determined the conversion effectiveness of the product. For each approach, the What, Why and How will be examined, in other words:

» What kind of energy wastage can occur
» Why does the energy wastage problem occur
» How can the energy wastage problem be solved

The results of the examination can be filled in two separate matrices. In Matrix I, the energy wastage is ascribed to the power modes, whereas in Matrix II, it is ascribed to the user actions. In both matrices, the 'Next step' can also be determined in which potential follow-ups to verify or further investigate the identified energy wastage can be depicted (see ***Appendix XXXV - XXXVI*** and ***Appendix XXXVIII - XXXIX*** for examples of the matrices).
There are two ways of approaching the What, Why and How. For Product Honesty and User Perspective, the energy wastage factors will be examined with help of the Energy Overview. The latter will show the participants the power mode and action types of the product, and this will determine which cards should be used. The cards are colour coded in accordance with the power mode and action types. As a result, only the cards relevant to the product will be used. Each card is structured to contain a question, explain the potential energy wastage factor, provide with an example of the energy wastage in a product to create an understanding for its occurrence, and offer suggestions of how the energy wastage could be solved. The Technical Perspective has a different way of approaching the What, Why and How than the other two approaches. Once haven determined the conversion effectiveness, the cards will help continue the investigation in three consecutive steps. The first step examines what aspects can lead to that the product may use more energy than the minimal theoretical energy. The second step requires detailed knowledge of the product functioning to understand the occurrence of energy wastage. The third step consists of two sets of recommendations for how energy wastage could be solved in low power modes and other energy using power modes respectively.

29.3 Stage 3. In depth

The In Depth stage can be performed to complement the Analyse stage and contains two separate guidelines for conducting:

- Detailed user studies in home environments
- Energy measurements to determine the energy impact of the usage phase

The guidelines summarises the undertaken approach of the case study and require both time and access to real users in their context of use as well as a lab with proper measurement equipment.

The guidelines for conducting the user studies includes recommendations for obtaining a deeper understanding of user habits by examining how they are using the product through user observations in home environments and conducting energy context mapping sessions. The guidelines for conducting energy measurements provides instructions of how to create user profiles and user scenarios to investigate the effect of the distribution frequency on the energy consumption as well as the annual energy consumption, and also to establish macro-scenarios. (See ***Appendix XL***).

30. Conceptual ideas for the carrier product

The following text has been removed entirely with reference to the confidentiality of the industry agreement.

Discussion

31. Introduction

Below follows a discussion on the work and how it has achieved its objective, as well as reflections on the process and results. Further recommendations have also been included.

32. Achieving the objective

The thesis project started with one objective and two research questions. In regards to the evolving character of the project, an additional reseach question emerged together with a number of sub-criteria.

32.1 Main purpose

The main purpose of the thesis project was to investigate the following: *"How can sustainable usage be integrated into the domestic appliances of the company?"* and provide the company with a solution that would set sight on being a source of sustainable design inspiration. This has been found to be addressed through the 3 Approaches to Energy Effective Products and the Energ-ability Tool that were developed during the project. These meet the objective in different ways. The 3 Approaches provides general principles and recommendations of how products can become more effective in their usage of energy, setting an aim of what a product should strive to achieve. The Energ-ability Tool is on the other hand the means of investigating what aspects need to be addressed to enable sustainable usage.

32.2 Research questions

In the thesis project, the focus was to identify new ways of achieving energy reduction during the usage phase. This was firstly examined through two questions that were determined in the beginning of the project. The first question: *"How can energy using products be designed to change their daily interaction with users and encourage them towards sustainable behaviour?"* was first of all addressed in Phase 1. It was then concluded that product-led interventions with a higher level of persuasiveness could be the means for addressing this. The question was further pursued in the Phase 2, where the internal analysis of the company's domestic appliances as well as the online survey pointed out that an important aspect of energy using products would be that they provide users with a correct mental model of a product's energy usage. The case study emphasised that in order to design products enabling sustainable behaviour, it would be vital to not only ensure that a product uses only the energy that is needed to fulfil a user goal, but also to understand the product's context of use and the possible ways that a user may use the product. The insights gained from these phases gradually shaped the 3 Approaches, which can be seen as answering the first research question. Additionally, a further analysis of these insights in Phase 4 concluded that energy wastage could be prevented if the user is provided with the right information through the user interface of the product. Depending on the situation, the information that the product should communicate would be: When the action should be performed, How the action should be performed, and providing Feedback of a performed action.

The second question: *"How can energy consumption differ during the usage phase and lead to energy wastage?"* was addressed in Phase 2, 3 and 4. The survey suggested that energy wastage could arise due to complexity of the user interface. In the case study, the deep dive into the data logger readings and energy measurements showed how the energy consumption could differ whereas the user studies helped to understand why these differences could occur. In Phase 4, the insights gained from the previous phases were further analysed and indicated that the occurrence of energy wastage could mostly be attributed to the product. This is not only a result of that the product is not effective in its energy usage, but also due to how the information provided by the user interface is adapted to contextual factors and technical constraints, and how honest it is in communicating the energy consumption of the product.

During the thesis project, an additional research question was established: *"How can energy wastage be identified in other energy using products"*. This question was addressed in Phase 4 and resulted in the Energ-ability Tool.

32.3 Sub-criteria

In Phase 4, four sub-criteria were established in addition to the research question. The Energ-ability Tool answers three of the four sub-criteria. One criteria was to provide a holistic overview of a product to create a common multi-disciplinary understanding for its user-product interaction. This was addressed by the Energy Overview. Another criteria was to provide with an overview of a product's energy wastage and where the focus for improvement should be put. The matrices in which the results of the analysis is to be written answers this criteria. The third criteria was to create a guideline for conducting an in-depth study of an energy using product with the same approach that had been undertaken in the case study. One part of the Energ-ability Tool contains a set of cards that describes this process. The fourth criteria was to develop conceptual suggestions for a redesign of the carrier product. These suggestions were a part of the previous chapter.

33. Process

This thesis project was conducted individually, which in itself was a new experience as one of the main characteristics of Industrial Design Engineering is to perform extensive projects in groups. A benefit of working in groups is that ideas can be discussed on the same level of knowledge of a project. In this thesis, the decisions that determined the continuation of the project could only be individually based. Nonetheless, during the entire project there was always valuable support and possibilities to discuss with the mentors and people from the company, which was of great help.

33.1 Phase 1 - Frame of reference

This project started with a broad objective formulated around the growing awareness for a need of a more user-oriented approach of the usage phase of energy using products. It was difficult to know what the end-result presented to the company would be, but the time and effort allocated in this phase was helpful in defining the scope of the thesis. It was realised that to address the global increase in household energy consumption, the largest possible group of users had to be targeted. In what appeared to be a rather drastic and daring decision, the longer the thesis project progressed, the more sense this proposal made. What initially was thought of as a self-experienced complexity and perplexity of energy using products was found to experienced by others as well. Several friends who had responded to my survey contacted me to say "Wow, your survey really made me start thinking about products". This feedback helped me to realise that the thesis was on the right track.

In the early stages of the project, it was also realised that in answering the objective, the focus would be on identifying aspects of products that could be addressed by a behavioural change and finding a way to identify and examine these. This realisation determined the form of the end-result: a theoretical method. It was also early in the thesis decided that product-led interventions with a high level of persuasiveness were required to address the increasing household energy consumption. This can be seen as a rather loose formulation as persuasiveness can be applied in different ways. With time, this evolved through the obtained insights during the thesis project into the 3 Approaches.

33.2 Phase 2 - Preliminary work

In the internal analysis of the company's domestic appliances, it had been determined that the usage of colour in the user interface was not always consistent. How users perceived this was therefore a part of the investigation in the online survey. However, due to errors when programming, the given results could not be analysed correctly. This was unfortunate as the results could have been interesting.

33.3 Phase 3 - Case study

It could be claimed that the method applied in Phase 3 corresponded to a method for identifying and examining energy wastage. There were however a few aspects that could have been done better. During the project, the importance of having quantitative data to convince employees of the company was emphasised on a few occasions. For the nine user studies of the carrier product, despite that 4-5 qualitative studies have been determined to be enough to draw a conclusion, more user studies could have brought forth other interesting insights and could have brought a stronger credibility to the work. The user studies could have been complemented by conducting a quantitative survey specifically on the user habits and understanding of the carrier product, and more recent data logger readings could have increased the validity of the findings. However, both the available time and data had to be used as efficiently as possible.

The specifically developed energy context mapping session was found to be a good way of interviewing the users on their usage. The depicted user emotions during the usage did not on the other hand contribute with significant insights. The emotional aspect could perhaps be more useful if the user instead was creating a usage diary over a long period of time. This could help understand whether a certain action could be influenced by a certain context of use. More emotionally related questions could have also been asked during the user studies, such as how would they feel if they later found out that the product was using standby energy when switched off, to better tie this together with the survey findings. These questions were however not posed in order to not bring this kind of product-specific information out in the light.

33.4 Phase 4 - Method Development Process

The method development process was the hardest of all phases of the thesis project. Translating the findings of Phase 3 and 4 into a method was a long and tedious process. The data was re-analysed numerous times and despite the many attempted categorisation expeditions, it always ended up where it had started. Little by little, progress was made. It was only afterwards, when in detail describing the method development process, that it was realised that the process and its many iterations had made sense after all and had brought forth many interesting thoughts.

The initial focus of the method had been on the user and its role in the usage phase, but during the course of the project, it was realised from the findings of the energy measurements that the system design had a significant role in determining the energy impact of a product. These findings were therefore taken into consideration in Phase 4 and used to develop the Technical Perspective. It is not as elaborative as the development of the User Perspective, but this was not the aim. It was although found to be so important that it could not be excluded.

The method development process may have lacked in evaluative methods to determine or confirm decisions taken, but can partly be explained by the evolving character of the process. Unlike a product development process, the focus was not on generating different concepts but instead on how to analyse and categorise the data to see how it could be applicable to other products. The findings and conclusions from each stage of the method development process were supported by the mentors and helped to set the pre-requisites for the subsequent stage. In a way, this approach can also reflect the ways of the company, in which there is not always time to conduct these type of evaluations and that the acquired knowledge can be used to make the right decisions.

34. Results

The thesis project has not only showed that low power modes are a problem that needs to be addressed further in the future, but has also pointed out that there must be an understanding of how users use products and its potential effect on the energy consumption. The results of the thesis have focused on this and will be reflected upon below.

34.1 The 3 Approaches to Energy Effective Products

The 3 Approaches to Energy Effective products aim to guide and be a source for inspiration in developing products that enable sustainable usage. It could also be regarded as a gradual means of achieving lower energy consumption by being taking into consideration in future product road maps. Through a step-by-step implementation in product portfolios, it could eventually phase out products that are not effective in their energy usage. The 3 Approaches could also be used as a way of communicating to the users. Companies could promote themselves as designing their products to be used as energy effectively as possible.

34.2 The Energ-ability Tool

The Energ-ability Tool does not only identify and examine the user-product interaction for presumptive energy wastage in the usage phase. It has also tried to address other aspects that have been brought forth during the thesis project, such as creating a common understanding of the product among the employees. Regarding the extent to which one can use the results of the Energ-ability Tool, this will most likely depend on whether the analysis was performed on a conceptual or an already existing product. Many of the suggestions to improve the carrier product were found to create too much of a change for the user. This implies that there is a fine balance in how much can be changed in the interface or functioning of an already existing product without changing the user experience too much. Users will already have a way of using the product and if a re-design of the product compromises on the functionality or the comfort factor, users may not be satisfied and the company would therefore not be willing to conduct a re-design. Therefore, the Tool may be better utilised for conceptual products where there is a greater possibility of creating the desired habits from the beginning.

35. Recommendations

This thesis project has shown that the way products are designed, in terms of the technology that is present and the user interface that is designed around it, can shape the user-product interaction and thereby also future habits. Energy using products are becoming more and more complex and the number of products as well as the global household energy consumption is expected to increase in the future. If consideration is not given to the potential energy wastage that can occur as a result of the product design, products will continue to be designed in ways that allow unnecessary energy to be consumed during the usage phase. This can be prevented and requires an industry driven change in which companies of electronic consumer goods take a greater responsibility to reduce the impact of their products during the usage phase. This can be done not only by making the usage of energy using products simple, but also by bringing an added sense to them by being as energy effective as possible in their use.

As a first step, it is recommended for the electronic consumer goods industry to reflect upon the 3 Approaches and consider how they can be implemented in future road maps. Many companies are today already conducting extensive user research through data loggers, home placements tests, and focus groups. As a second step, it is highly recommended to integrate into these research methods an energ-ability perspective from which user insights can be elicited and used for designing the energy effective products of the future. A third recommendation is to educate product developers with different educational backgrounds of the different power modes. Product developers with more knowledge of for example the functions of the different power modes can better understand the implications of their design choices. As a fourth recommendation, as the 3 Approaches is merely an initiator, it can be elaborated further to provide more detailed recommendations for the electronic consumer goods industry. For example further research on how consumers perceive energy using products through colour and light indicators could be conducted. Similarly, to increase the relevance of the Energ-ability Tool it is also recommended to conduct a series of extensive user studies on a variety of different product types to enable a more complete Tool.

Reference

Almeida, A., Fonseca, P., Schlomann, B. (2006) ***Residential Monitoring to Decrease Energy Use and Carbon Emissions in Europe***. In: European Commission Institute for Environment and Sustainability. Energy efficiency in Domestic appliances and lighting. Proceedings of the 4th international conference Eedal'06. UK, 21-23 June 2006, European Communities: Luxembourg

Backlund, S., Gyllensvärd, M., Gustafsson, A., Ilstedt Hjelm, S., Mazé, R., Redström, J. (2006). ***STATIC! The Aesthetics of Energy in Everyday Things***. DSR Wonderground Conference, 1-4 November, 2006

Bhamra, T.A., Evans, S. (1999). ***Integrating Environmental Decisions into the Product Development Process: Part 1 The Early Stages.*** Ecodesign '99. 1st International Symposium on Environmentally Conscious Design and Inverse Manufacturing, Waseda University, Tokyo, Japan

Bhamra, T.A., Lilley, D., Tang, T. (2008). ***Sustainable Use. Changing consumer behavior through product design***. Changing the change. Design Visions Proposals and Tools. Conference Torino 10-12 July 2008. p234-246

Bligard, L., Osvalder, A. (2009). ***Metoder för att undersöka brister i samspelet mellan människa och maskin - Enhanced Cognitive Walkthrough (ECW) och Predictive Use Error Analysis (PUEA)***. Institutionen för produkt- och produktionsutveckling, Avdelning Design & Human Factors, Chalmers Tekniska Hogskola, Göteborg, 2009

Brook Lyndhurst 2007. ***Public Understanding of Sustainable Energy Consumption in the Home. A research report completed for Department for Environment, Food and Rural Affairs***. September 2007.

Elias, E.W.A. (2007). ***The Potential for Domestic Energy Savings through Assessing User Behaviour and Changes in Design***. EcoDesign 2007: 5th International Symposium on Environmentally Conscious Design and Inverse Manufacturing, 10-13 December 2007, Tokyo, Japan

Ellis, M. (2007). ***Fact Sheet: Standby Power Use and the IEA "1-watt Plan***" [Internet] Available at: http://www.iea.org/papers/2007/standby_fact.pdf [Accessed 17 February 2010]

Energimyndigheten (2007). ***Har du stangt av på riktigt?*** [Internet] Malmo: Elanders Berlings. Available at: http://213.115.22.116/System/TemplateView.aspx?p=Energimyndigheten&view=default&cat=/Broschyrer&id=11c4d6c7fa764029be6de7f9476a1b84 [Accessed 17 February 2010]

European Commision (2009). ***Energy: Energy Labelling of Domestic Appliances.*** [Internet] Available at: http://ec.europa.eu/energy/efficiency/labelling/labelling_en.htm [Accessed 16 February 2010]

Fujitsu (2010). ***Green Innovations***. [Internet] Available at: http://ts.fujitsu.com/products/0watt.html [Accessed 16 March 2010]

Gruber, E., Schlomann, B. (2006). ***The Current and Future Electricity Demand of Appliances in German Households***. In: European Commission Institute for Environment and Sustainability. Energy efficiency in Domestic appliances and lighting. Proceedings of the 4th international conference Eedal'06. UK, 21-23 June 2006, European Communities: Luxembourg

Gyberg, P., Palm, J. (2009). ***Influencing household's energy behaviour – how is this done and on what premises?*** Energy Policy37, p.2807–2813

IDEO (2010). ***Method cards for IDEO***. [Internet] Available at: http://www.ideo.com/work/method-cards [Accessed 22 July 2010]

International Energy Agency (2008). ***Worldwide Trends in Energy Use and Efficiency. Key Insights from IEA Indicator Analysis.*** [Internet] Available at: http://www.iea.org/papers/2008/indicators_2008.pdf [Accessed 9 February 2010]

Intertek (2009). ***Eco-Design Directive (EuP): Analysis of the Standby/Off Mode Implementing Measure.*** [Internet] Available at: http://sweden.intertek-etlsemko.com/about-intertek/white-papers/details/26/ [Accessed 22 February 2010]

Hartley, C. (2010). ***Colors***. [Internet] Available at: http://www.av40.org/AV40Site/Colors.html [Accessed 22 March 2010]

Jackson, T. (2005). ***Motivating Sustainable Consumption- a review of evidence on consumer behaviour and behavioural change***. A report to the Sustainable Development Research Network. Centre for Environmental Strategy, University of Surrey, United Kingdom

Janhager, J. (2005). ***User Considerations in Early Stages of Product Development - Theories and Methods***. Doctoral Thesis, KTH Industrial Engineering and Management, Stockholm

Joint Research Centre for the European Commission (2007). ***Electricity consumption growing in spite of efficiency drive says EU report.*** 2007-07-13. [Internet] Available at: http://europa.eu/rapid/pressReleasesAction.do?reference=IP/07/1091&format=HTML&aged=0&language=EN&guiLanguage=enjuly%2029th%202010 [Accessed 29 July 2010]

Jordan, P.W. (2001). ***An Introduction to Usability.*** Taylor & Frances Ltd, Padstow UK

Karlsson, M. (2005). ***"Lyssna till kundens röst" Kurskompendium Produktutveckling- Behov och Krav.*** Götebprg: Institutionen för product- och produktionsutveckling, Chalmers Tekniska Högskola

Karlsson, R., Luttropp, C. (2006), ***EcoDesign: what's happening? An overview of the subject area of EcoDesign and of the papers in this special issue***. Journal of Cleaner Production 14 (15-16), pp. 1291-1298

Lawrence Berkeley National Laboratory (2002). ***The Power Control User Interface Standard.*** Consultant Report for California Energy Commission, Pier (Public Interest Energy Research Program). [Internet] Available at: http://eetd.lbl.gov/controls/publications/pubsindex.html [Accessed 22 Feb 2010]

Lilley, D. (2009) ***Design for sustainable behaviour:: strategies and perceptions.*** Design Studies. Elsevier Ltd

Lilley, D., Lofthouse, V., Bhamra, T. (2005). ***Towards Instinctive Sustainable Product Use.*** Presented at the 2ns International Conference: Sustainability Creating the Culture, 2-4th November 2005, Aberdeen Exhibition & Conference Centre, Aberdeen

Lockton, D., Harrison, D., Stanton, N. (2008). ***Making the user more efficient: Design for sustainable behaviour*** (Preprint version). International Journal of Sustainable Engineering. Taylor & Francis

Lockton, D., Harrison, D., Stanton, N. (2010). ***Design with Intent: 101 Patterns for Influencing Behaviour Through Design***. [Internet] Available at: http://www.danlockton.com/dwi/Main_Page [Accessed 10 March 2010]

Lofthouse, V. (2004). ***Investigation into the role of core industrial designers in ecodesign project.*** Design Studies 25 (2), pp. 215-227

Lofthouse, V., Lilley, D. (2008). ***Design for Behavioural Change. An Engineering Subject Centre Mini project Award 2008 End of Project Report***. Loughborough University. [Internet] Available at: www-staff.lboro.ac.uk/.../Design_for_Behavioural_Change%20-%20end_of_project_report.pdf [Accessed 10 March 2010]

Luttropp, C., Lagerstedt J. (2006), ***EcoDesign and The Ten Golden Rules: generic advice for merging environmental aspects into product development***. Journal of Cleaner Production 14, pp1396-1408

Mohanty, B. (2002). ***Perspectives for Reduction of Standby Power Consumption in Electrical Appliances.*** Published in Guidebook on Promotion of Sustainable Energy Consumption: Consumer Organisations and Efficient Energy Use in the Residential Sector for United Nations ESCAP. ST/ESCAP/2207. [Internet] Available at: http://www.unescap.org/esd/energy/publications/psec/guidebook-part-two.htm [Accessed 10 March 2010]

Nielsen, J. (1993). ***Usability Engineering***. Academic Press

Nordman, B., Siderius, H.P., Harrington, L., Ellis, M., Meier, A. (2009). ***Network connectivity and low-power mode energy consumption.*** Presented in EEDAL Conference (Energy Efficiency in Domestic Appliances and Lighting) in June 2009, Berlin, Germany

Official Journal of the European Union (2008). ***Commission Regulation (EC) No 1275/2008 of 17 December 2008 implementing Directive 2005/32/EC with regard to ecodesign requirements for standby and off mode electric power consumption of electrical and electronic household and office equipment***. (OJ L 339).

Official Journal of the European Union (2009). ***Commission Regulation (EC) No 278/2009 of 6 April 2009 Implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for no-load condition electric power consumption and average active efficiency of external power supplies***. (OJ L 93/3)

Pascual, O., Boks, C., Stevels, A. (2003), ***Communicating eco-efficiency in industrial contexts: A framework for understanding the (lack) of success and applicability of eco-design***. IEEE International Symposium on Electronics and the Environment, pp. 303-308

Rauniar Rupak, Doll William, Rawski Greg, Hong Paul (2008). ***Shared knowledge and product design glitches in integrated product development***. Int J. Production Economics 114, pp 723-736

Roberts, S. (2008) ***Demographics, energy and our homes.*** Energy Policy 36. p4630-4621.

Robinson, H. (1997). ***Using Poka-Yoke Techniques for Early Defect Detection.*** Paper presented at the Sixth International Conference on Software Testing Analysis and Review (STAR'97) [Internet] Available at: http://facultyweb.berry.edu/jgrout/pokasoft.html [Accessed 12 March 2010]

Ross, J.P., Meier, B. (2002). ***Measurements of whole-house standby power consumption in California homes.*** Energy 27, p.861-868

Sauer, J., Wiese, B.S., Ruttinger, B. (2003a). ***Designing low-complexity electrical consumer products for ecological use***. Applied Ergonomics 34 (2003), pp521-531. Elsevier Ltd.

Sauer, J., Wiese, B.S., Ruttinger, B. (2003b). ***Ecological performance of electrical consumer products: the influence of automation and information-based measures.*** Applied Ergonomics 35 (2004), pp37-47. Elsevier Ltd.

Schlomann, B (2010). ***SELINA – Standby and Off-Mode Energy Losses In New Appliances. Measured in Shops. Actions and policy instruments.*** IEA-APP-EU International Standby Workshop

Sherwin,C. and Evans, S. (2000). ***Ecodesign Innovation: Is 'Early' Always 'Best'?*** IEEE International Symposium on Electronics and the Environment, pp. 112-117

Stern Review (2006). ***Stern Review: The Economics of Climate Change*** [Internet] Available at: http://siteresources.worldbank.org/INTINDONESIA/Resources/226271-1170911056314/3428109-1174614780539/SternReviewEng.pdf [Accessed 9 February 2010]
Tang, T., Bhamra, T.A. (2008) ***Understanding Consumer Behaviour to Reduce Environmental Impacts through Sustainable Product Design***. In:Undisciplined! Design Research Society Conference 2008, Sheffield Hallam University, Sheffield, UK, 16-19 July 2008

Visser, F.S., Stappers, P.J., v.d. Lugt, R., Sanders, E.B.N. (2005). ***Contextmapping: experiences from practice.*** CoDesign , Vol 1. No.2 June 2005, p119-149. Taylor & Francis Group Ltd

Wallenborn, G., Prignot, N., Rousseau, C., Orsini, M., Vanhaverbeke, J., Thollier, K., Simus, P. (2009). ***Integration of Standards, Ecodesign and Users in energy-using products "ISEU"***. Final Report Phase 1. Brussels: Belgian Science Policy 2009 (Research Programme Science for a Sustainable Development) [Internet] Available at: http://www.belspo.be/belspo/ssd/science/Reports/ISEU-Report%20Phase1-DEF.pdf

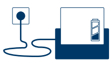
Wever, R., van Kuijk, J., Boks, C. (2008). ***User-centred Design for Sustainable Behaviour.*** International Journal of Sustainable Engineering, Vol. 1, No.1, 2008

Wood, G., Newborough, M. (2002). ***Dynamic energy-consumption indicators for domestic appliances: environment, behaviour and design.*** Energy and Buildings 35 (2003) pp821-841

Woodall, G., Bates, J. (2009). ***How the Recession and a Targeted Energy Efficiency Marketing Program Can Create a Greener Economy and Benefit Energy Utilities***. Rockbridge Associates [Internet] Available at: http://www.rockresearch.com/Energy-Efficiency-Programs.php [Accessed 28 March 2010]

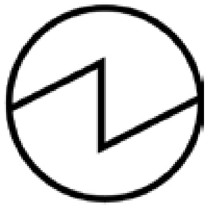
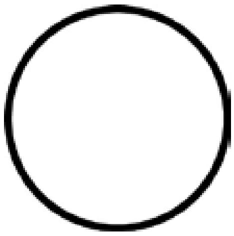
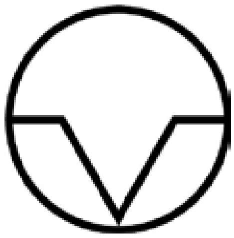
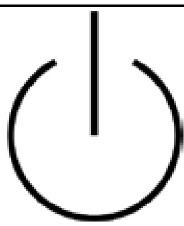
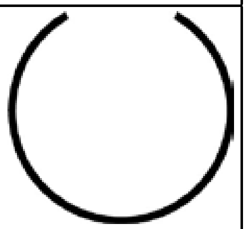
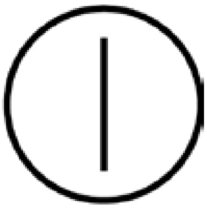
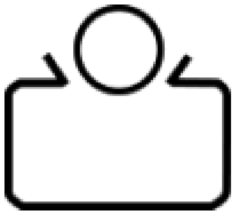
Appendix

Appendix I. Overview of power modes

CATEGORY	POWER MODE		FUNCTION	FEATURES
Disconnected mode	Unplugged		Not providing with any function	Disconnected from power supply
Low power modes	OFF		Not providing with any function	Hard switch with ⏻ symbol
			Not providing with any function	Indicator showing OFF-mode, soft switch with ⏻ symbol
			Providing function that ensures electromagnetic compability	EMC filter, soft switch with ⏻ symbol
	Standby		Reactivation function- enables product to be activated into another power mode	Remote switch/control, internal sensors, timers, indication of function, soft switch with ⏻ symbol
			Continuous function - indicates information or status of product	Information or status display, clocks
	Network		Providing reactivation through network signal	LAN, USB, RS-232C, WiFi, HDMI, infra-red other than that of remote control
Low power modes for products with an EPS	Charging		Battery is charging	Product is either in the charging station or connected to an external charger
	No-load		Not providing with any function	Product is not connected to the charging station or external charger
	Maintenance		Providing function to avoid discharging of battery	Product is fully-charged and connected to either a charging station or external charger
Active mode			Providing one or more of the main functions	

LEGISLATION	INTERNAL GUIDELINES
	The text has been removed in reference to the confidentiality of the industry agreement.
(EC) No 1275/2008 By 2010: < 1W By 2013: < 0.5W	
(EC) No 1275/2008 By 2010: < 1W (without display) < 2W (with display) By 2013: < 0.5W (without display) < 1 W (with display)	
(EC) No 1275/2008 By 2010: < 1W By 2013: < 0.5W NB. There is an ongoing study to establish more specific regulations for network modes.	
(EC) No 278/2009 By 2010: different average active efficiency limits depending on P_{out} By 2013: different average active efficiency limits depending on P_{out} and EPS type (AC-AC, AC-DC or low voltage)	
(EC) No 278/2009 By 2010: < 0.5W $(0<P_{out}<250)$ By 2011: < 0,5W (for all AC-AC) < 0.5W $(P_{out}>51W)$ < 0.3W ($P_{out}<51W$ for AC-DC and low voltage EPS)	
(EC) No 1275/2008 By 2010: < 1W By 2013: < 0.5W	

Appendix II. Graphical symbols

"ON" (power) **IEC 5007, JTC1 001** To indicate connection to the mains, at least for mains switches or their positions, and all those cases where safety is involved.		**Electric energy** **ISO 0232, JTC1 008** To signify any source of electric energy, for example on devices starting or stopping the production or use of electric energy.	
"OFF" (power) **IEC 5008, JTC1 002** To indicate disconnection from the mains, at least for mains switches or their positions, and all those cases where safety is involved.		**Pause; interruption** **IEC 5111, JTC1 011** To identify the control device by means of which the run (e.g. of a tape) is interrupted by means of a break mechanism and mechanical disconnection from the driving mechanism which continues to run.	
Stand-by **IEC 5009, JTC1 010** To identify the switch or switch position by means of which part the equipment is switched on in order to bring it into the standby-by condition.		**Ready** **ISO 1140, JTC1 009** To indicate the machine is ready for operation.	
"ON"/"OFF" (push-push) **IEC 5010, JTC1 003** To indicate connection to or disconnection from the mains, at least for main switches or their positions, and all those cases where safety is involved. "OFF" is a stable position, whilst the "ON" position only remains during the time the button is depressed.		**Save; economize** **IEC 5581** To identify a control whereby an economy program becomes activated, for example, to save energy or water. *Note – The percentage of economizing may be indicated in the figure.*	

Note: In IEC 13251, the definition of 5010 ON/OFF ends with "Each position, "ON" or "OFF" is a stable position.

IEC numbers are from IEC 60417. ISO numbers are from ISO 7000. JTC1 numbers are from ISO/IEC 13251.

Source: Lawrence Berkeley National Laboratory, Environmental Technologies Division. ***ISO/IEC/JTC1 Graphical Symbols for Office Equipment*** *[Internet] Available at: http://eetd.lbl.gov/Controls/overview/symbols1.pdf*

Appendix III. Colour

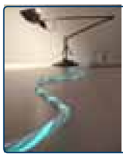
COLOUR	CEI IEC 73 [1]	ANSI/VITA 40-2003 [2]
GREEN	Normal" state of equipment or a "normal" condition of a process.	"OK", "normal", "satisfactory operation", "active", or "in service".
AMBER	"Abnormal" state of equipment or an "abnormal" condition of a process	"Attention" or "service action required".
BLUE	"Mandatory significance", i.e., to indicate something that is associated with a required action.	"Service action allowed"
WHITE	Has no meaning	Provide an aid to locating a particular system or subassemblyIn order to make the locator indicator be more noticeable, it uses a distinctive FAST BLINK that is very different from the SLOW BLINK used by other indicators.
RED	"Emergency" or "dangerous condition"	"Out of service", "major fault", or "critical fault".

[1] ANSI/VITA 40-2003 is a status indicator standard that is generally applicable to products using lights to convey status information to the user.

[2] CEI IEC 73, "Basic and Safety Principles for Man-Machine Interface, Marking, and Identification".

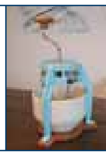
Source: Hartley, C. 2010. ***Colors****. [Internet]. Available at: http://www.av40.org/AV40Site/Colors.html.*

Appendix VIII. Seven design intervention strategies



POWER-AWARE CORD
Visualising electricity use through pulses, flows and intensity of light

ELECTRICAL SEPHAMORE
Visualising variations in energy production during the day

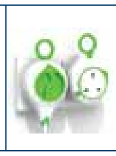


TYRANNY OF THE PLUG
Blender powered by human energy to create reflection on power

ECO-INFORMATION

WATTBLOCKS
Master step switch enabling all connected appliances to switch off

ENERGY LOCK
Provides feedback on energy usage and enables user with one switch to switch off unneccessary appliances



VAMPIRE PLUG
Mechanical timer where user sets how long a product should charge before it switches off

ECO-CHOICE

WATTSON
Displays actual household energy consumption and cost with numbers and colour

HOME JOULE
Displays actual household energy consumption and real-time cost of electricity

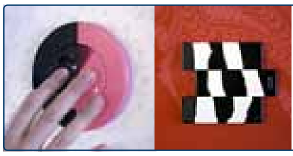
ENERGY AWARE CLOCK
Displays actual household energy consumption through size of pattern and colour

ECO-FEEDBACK

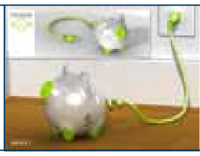
FLOWER LAMP
Rewards user when energy usage is low by unfolding its petals and thereby giving more light

FLOWER POD
Electronic flower that grows or wilts in relation to the level of energy consumption

ECO-SPUR



PUZZLE SWITCH
Designed to enhance understanding of ON/OFF and to encourage user to switch off through their built-in desire for order



POWER-HOG
Children can user their appliances for 30 minutes by feeding pig with coin

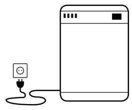
ECO-STEER

ERRATIC RADIO
Radio frequency and volume can change depending on the amount of appliances that are in usage

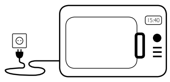
ENERGY CURTAIN
Window shade collecting solar power during day and emitting light during evening

ECO-TECHNICAL

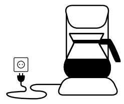
Appendix IX. Questions of the survey



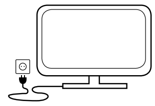
Dish-washing machine



Micro-wave oven



Coffee machine



TV

SURVEY ON ELECTRICITY CONSUMPTION OF HOUSEHOLD PRODUCTS

My name is Sophie Thornander and I am a student of Industrial Design Engineering, Chalmers University of Technology, Sweden. I am working on my Master's thesis on electricity consumption of household products and need your help to answer 16 questions about products that are powered by electricity (the questions are distributed over two pages). In this survey, the word 'product' will only refer to a product that is powered by electricity through a cord that is plugged into a wall socket. Examples of such products are dish-washing machines, micro-wave ovens, coffee machines and TV:s.

1) What is your gender?

» Female
» Male

2) What is your age?

» below 12 years
» 13 - 19 years
» 20 - 29 years
» 30 - 39 years
» 40 - 49 years
» 50 - 59 years
» 60 - 69 years
» above 70 years

3) What is your level of education?

» Primary school
» High school
» University

4) What is your nationality?

» *A drop down menu listing the countries of the world*

5) What does it mean when a product is switched off?

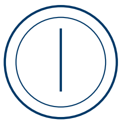
» The product is not consuming electricity

» The product is consuming a low amount of electricity

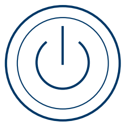
» The product is consuming electricity

» I do not know

6) In which of the following situations are you certain that a product is not consuming any electricity?



Symbol A



Symbol B

» I have unplugged the product

» I have pressed the button with symbol A

» I have pressed the button with symbol B

» The product has an Auto Switch OFF function and switches itself off automatically

» I do not know

» Other (Please Specify):

7) If you would like to switch off the following products after use, which kind of solution would you prefer?

	Switch it off myself by pressing a button (on product or remote control)	Have the product switch it off automatically	Have the choice to switch it off myself and have the product switch off automatically	It does not matter
Dish-washing machine	○	○	○	○
Micro-wave oven	○	○	○	○
Coffee-machine	○	○	○	○
TV	○	○	○	○

8) When are you certain that your product is switched off? You can choose one or more of the following options:

» All the indicator lights are off

» The OFF- light is on

» Other (Please Specify):

9) How would you feel if you switch off a product and you later find out that it is still consuming a low amount of electricity?

» Disappointed

» Betrayed
» It does not matter
» Other (Please Specify):

10) If a product is consuming a low amount of electricity, should it tell you this through for example a small indicator light?

» Yes, the product should tell me it is consuming electricity.
» No, if it is only a low amount of electricity then it does not matter.

11) Buttons or small indicators on products can light up in different colours when they are in use. What do you think the product is telling you when a button or indicator lights up with the following colours?

	Product is ON	Product is OFF	Product is in standby-mode	Something is wrong with the product	Does not mean anything (e.g. it is only used for decoration)	I am colour blind and can-not distinguish this colour	Other (Please Specify):
Green	○	○	○	○	○	○	○
Red	○	○	○	○	○	○	○
Yellow/orange	○	○	○	○	○	○	○
Blue	○	○	○	○	○	○	○
White	○	○	○	○	○	○	○

12) Imagine you have a product with an eco-button. This button could be a new button on the product or replace an existing button on the product. If you press this button, what would you expect?

	Better	No difference	Worse
The performance of the product will be...	○	○	○
The total energy consumption will be...	○	○	○
The time it takes the product to perform its function will be...	○	○	○

13. Some products have a standby mode. What does this mean to you?

» The product is not consuming electricity
» The product is consuming a low amount of electricity
» The product is consuming electricity
» I do not know what standby mode means

14) Some products can consume a low amount of electricity when you are not using them. This could be because they have a certain function that needs this electricity. For which of the following products is this ok for you?

	It is ok	It is not ok	I do not know
Dish-washing machine that you have programmed to start washing in a few hours	◯	◯	◯
Micro-wave oven with a digital display (e.g telling the time)	◯	◯	◯
Coffee-machine that is keeping itself warm so that it can brew your next cup of coffee quickly	◯	◯	◯
TV that you can use with a remote control	◯	◯	◯
Product that consumes electricity for no specific function	◯	◯	◯

15) What would be your main motive for reducing the energy consumption of your products? You can choose one or more of the following options:

» Lower my energy bill
» Environmental concern
» Prolong the lifespan of my products
» I have no motive
» Other (Please Specify):

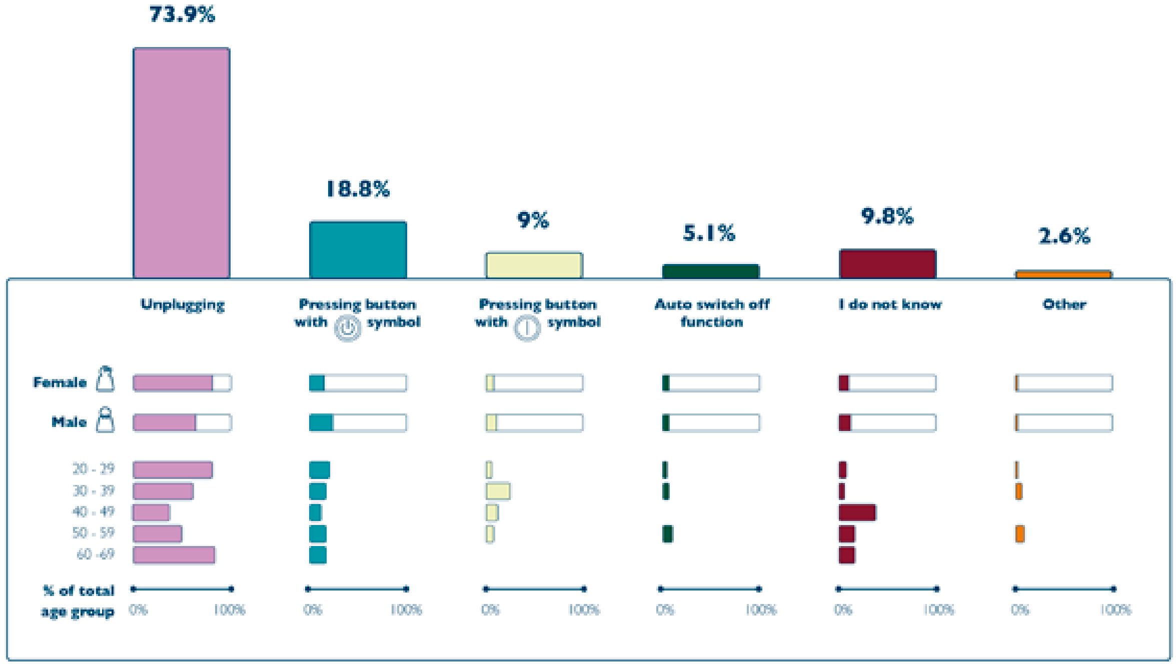
16) If you wanted to reduce the energy consumption of your products, which of the following do you think could save you the most energy?

» I would have products that are energy efficient
» I would choose the eco-option (e.g. eco-button) if my products have such an option
» I would have products that switch off automatically after use
» I would switch off my products when they are not in use
» Other:

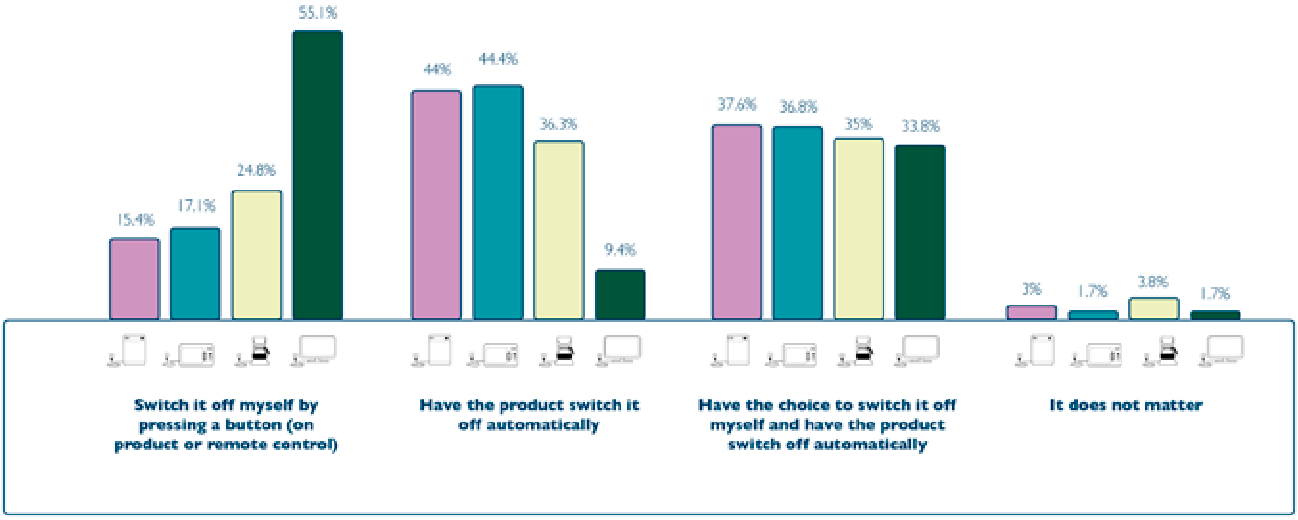
Appendix X. Results of the survey

5) What does it mean when a product is switched off?

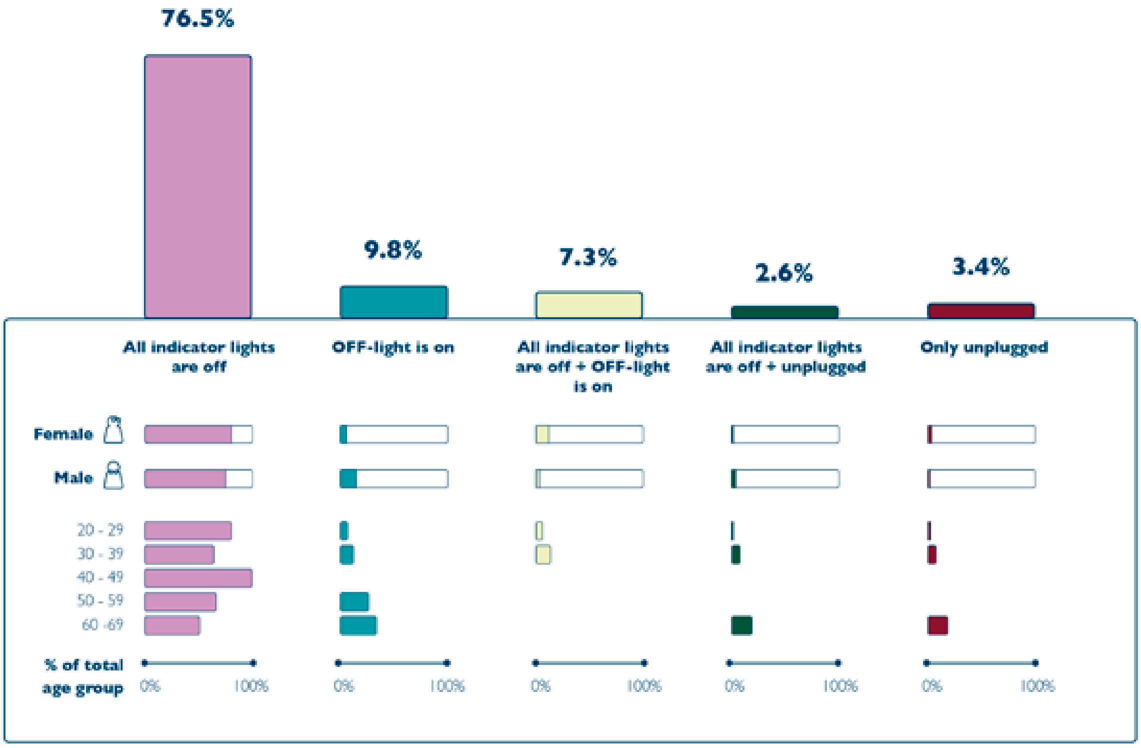
6) In which of the following situations are you certain that a product is not consuming any electricity?



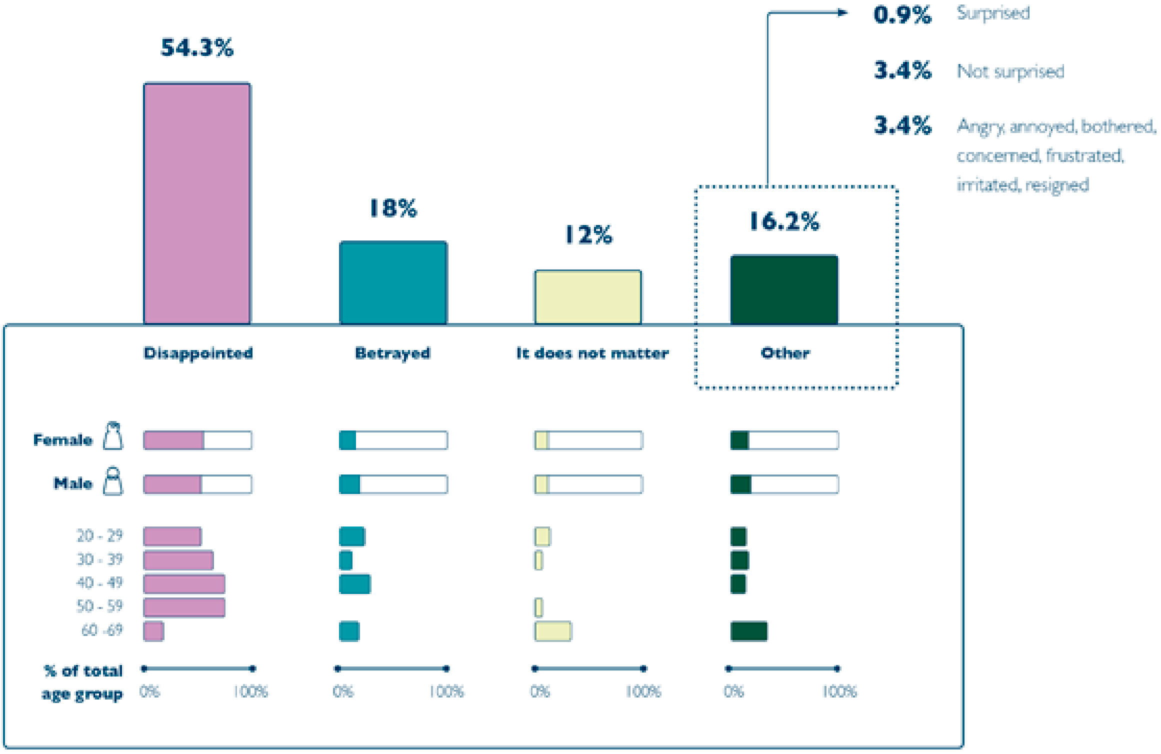
7) If you would like to switch off the following products after use, which kind of solution would you prefer?



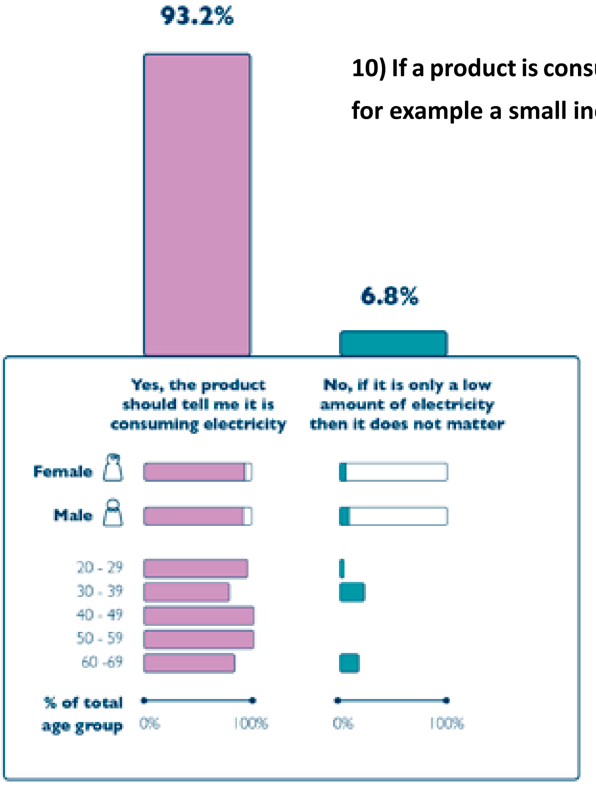
8) When are you certain that your product is switched off? You can choose one or more of the following options:



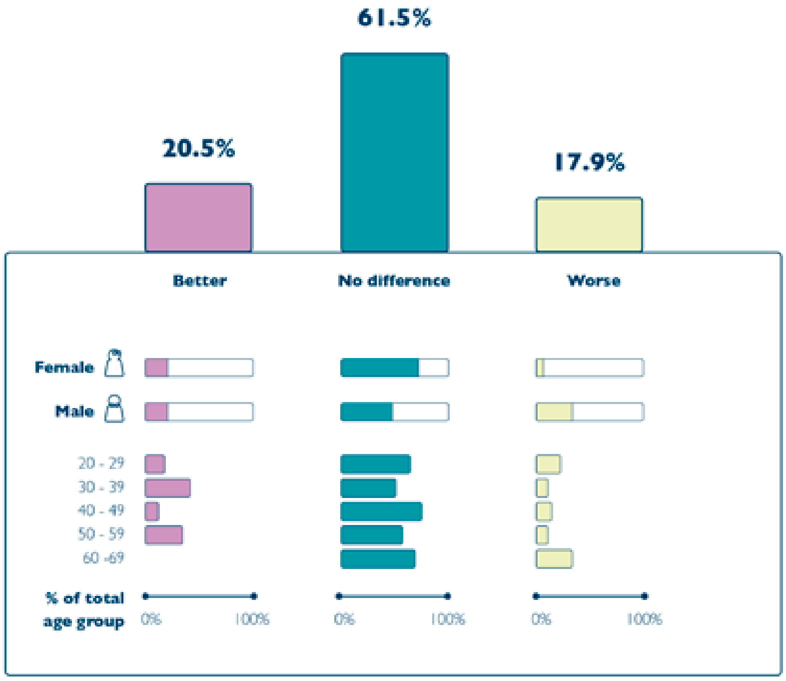
9) How would you feel if you switch off a product and you later find out that it is still consuming a low amount of electricity?



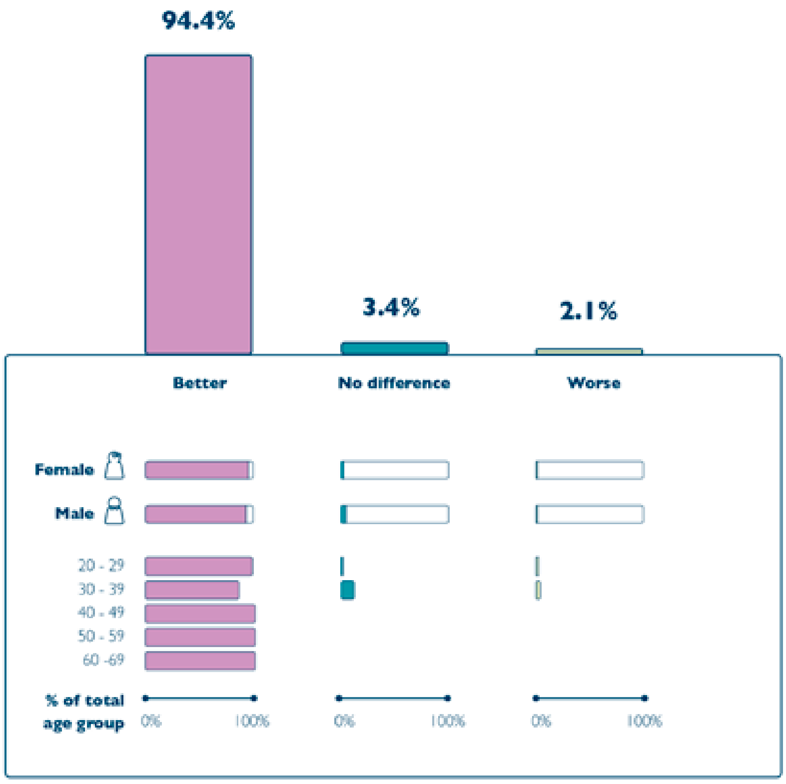
10) If a product is consuming a low amount of electricity, should it tell you this through for example a small indicator light?



12) Imagine you have a product with an eco-button. This button could be a new button on the product or replace an existing button on the product. If you press this button, what would you expect?



a) The performance of the product will be...

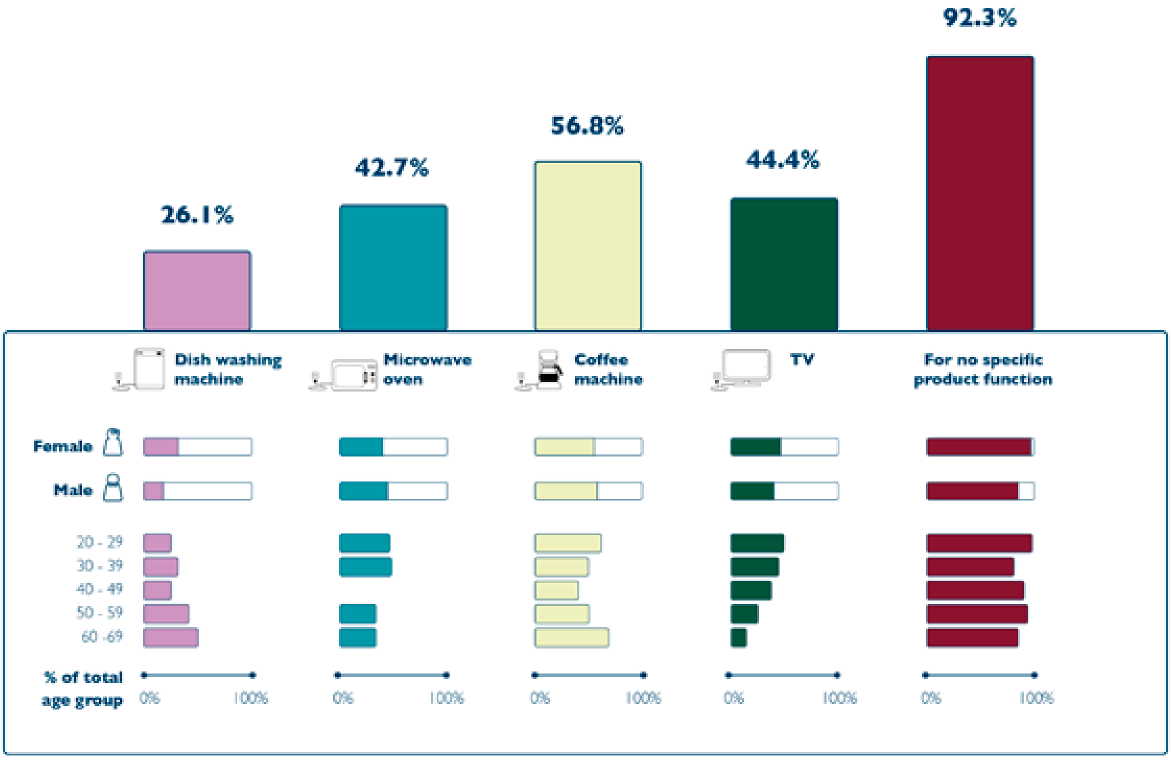


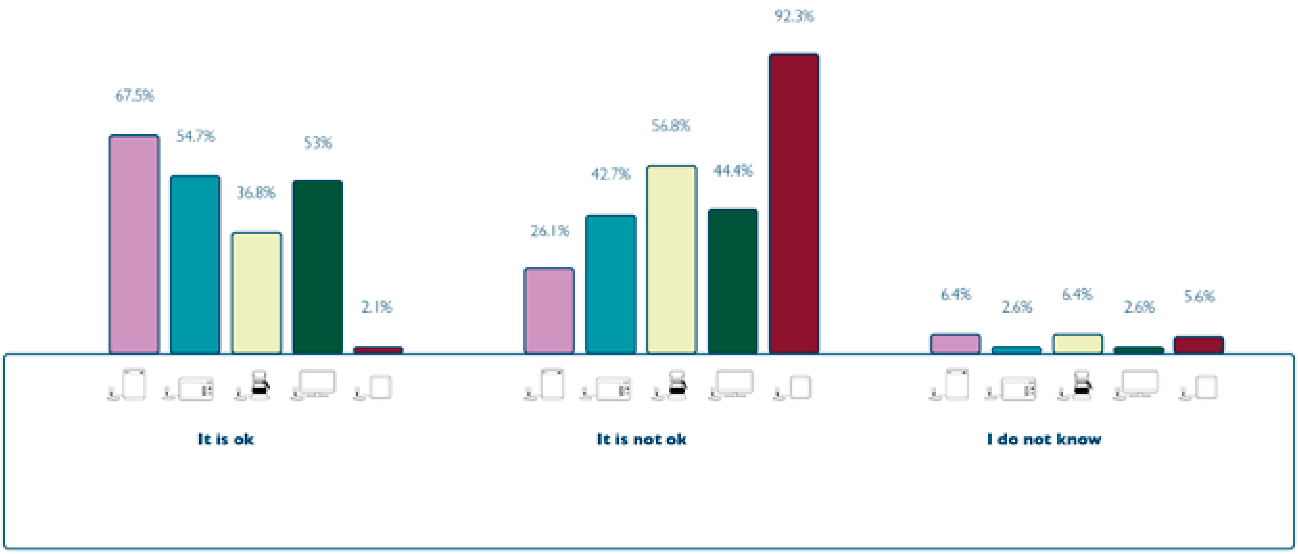
b) The energy consumption of the product will be...

c) The time it takes the product to perform its function will be...

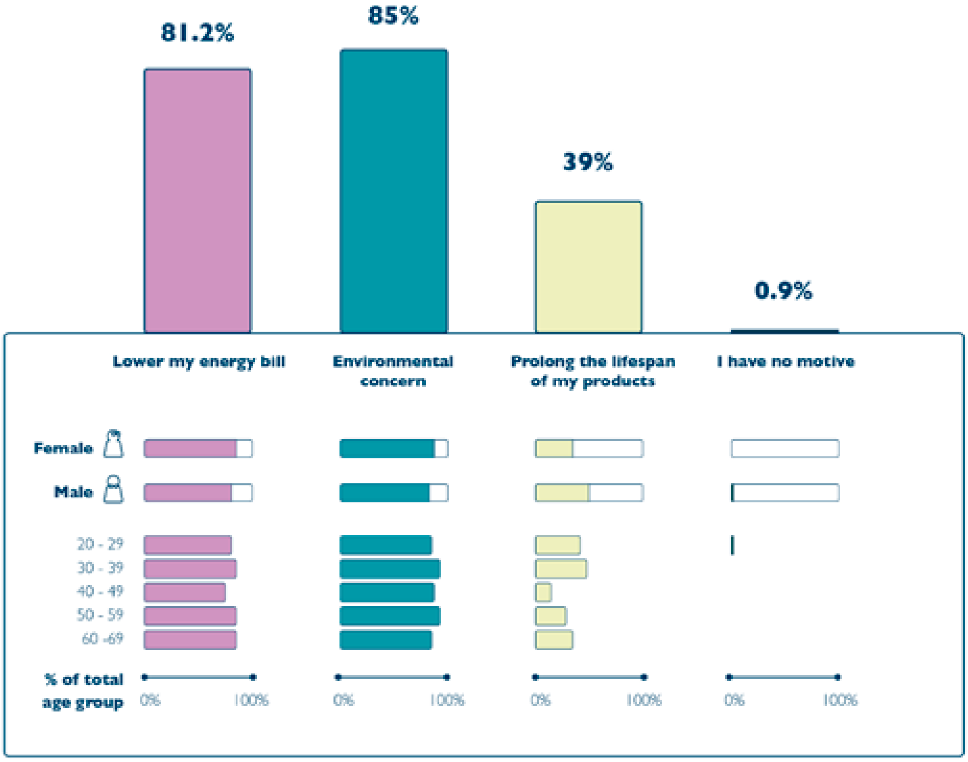
13. Some products have a standby mode. What does this mean to you?

14) Some products can consume a low amount of electricity when you are not using them. This could be because they have a certain function that needs this electricity. For which of the following products is this ok for you?

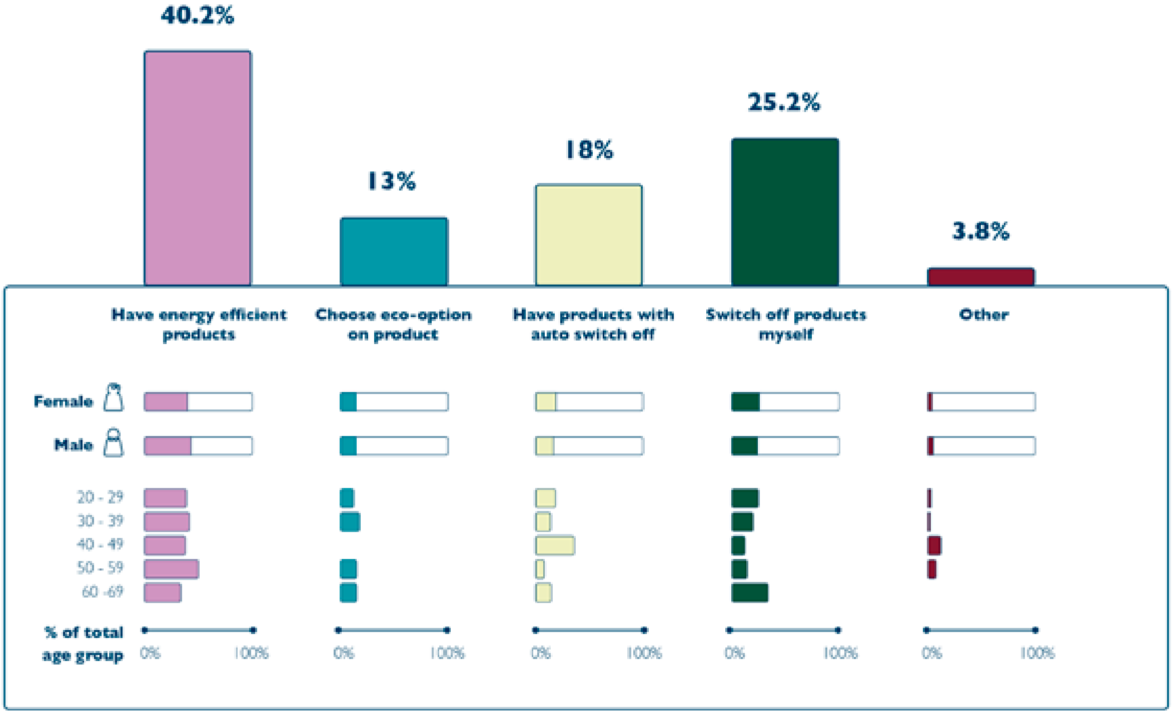




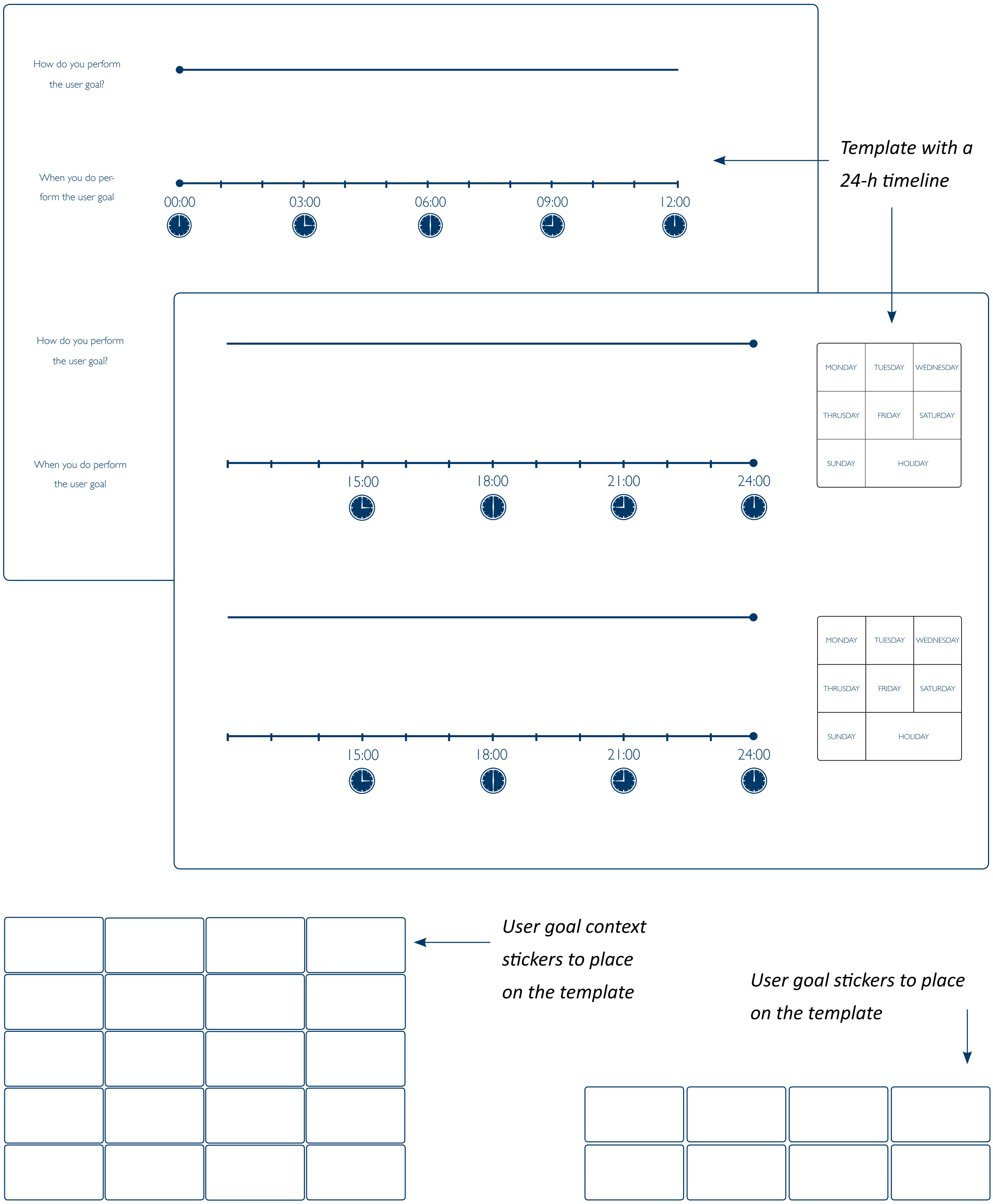
15) What would be your main motive for reducing the energy consumption of your products? You can choose one or



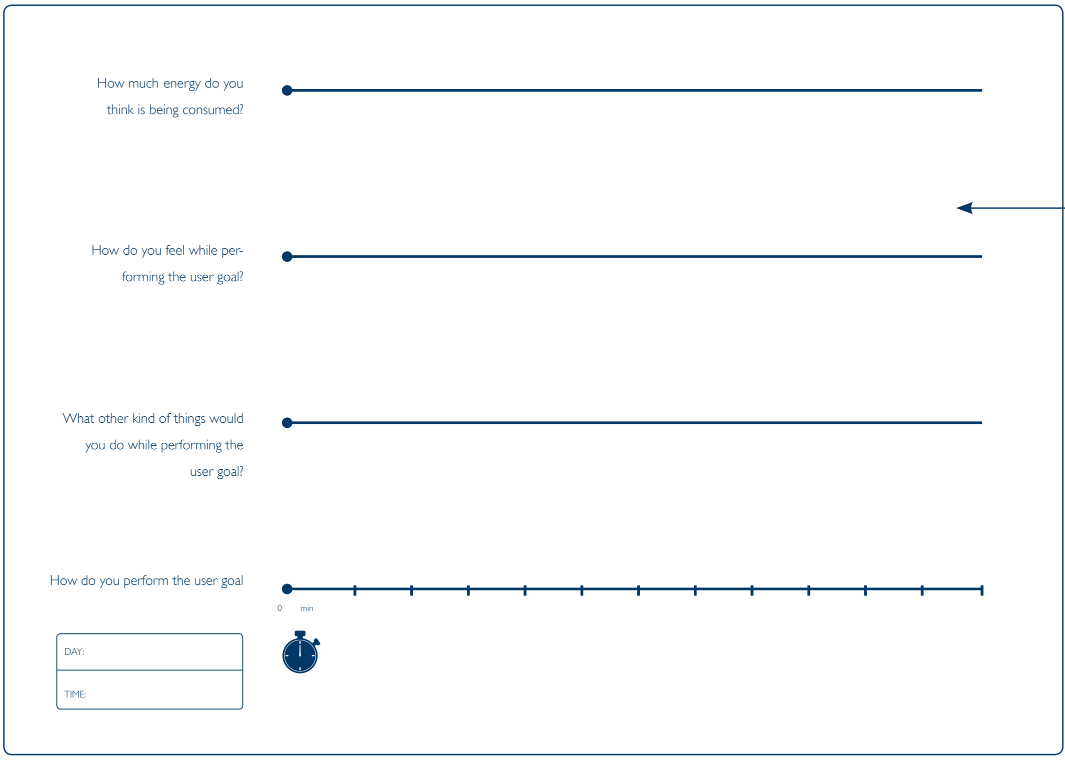
16) If you wanted to reduce the energy consumption of your products, which of the following do you think could save you the most energy?



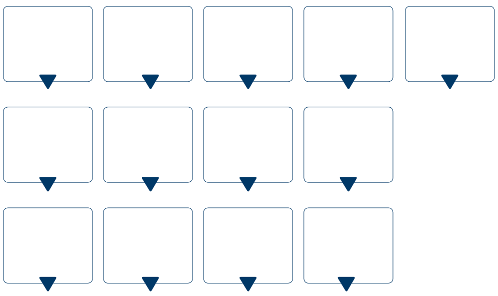
Appendix XXII. Energy context mapping session I



Appendix XXIII. Energy context mapping session II

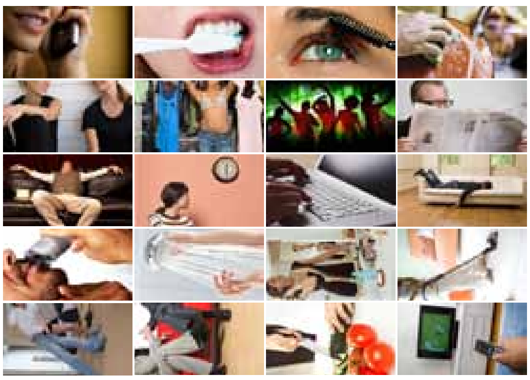


Template with 4 different timelines



Action stickers

Emotions stickers



Other action stickers

Percentage of energy consumed stickers