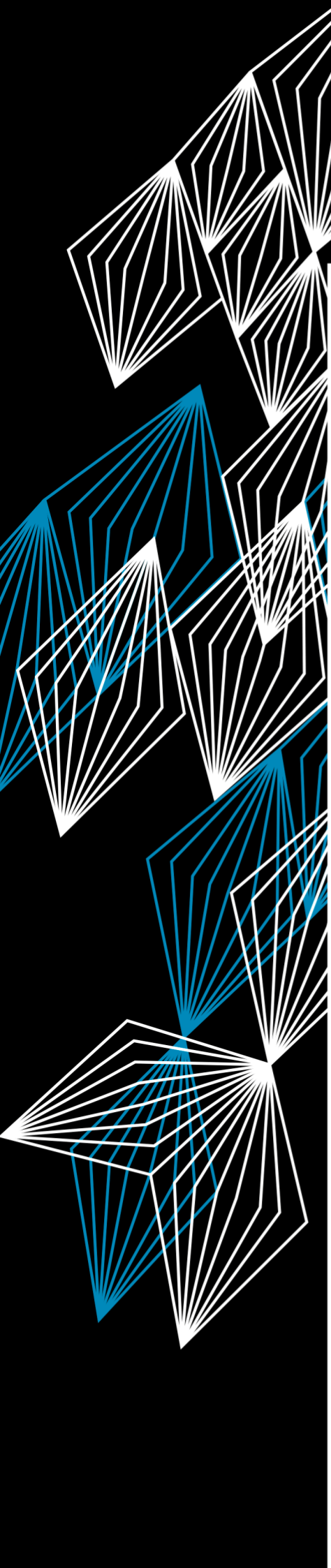

Bachelor THESIS

An energy awareness campaign for the UT-community

Creative Technology

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Abstract

This objective is constructed by the UT because an objective is to reduce the CO_2 footprint by 49% in 2030. The department Campus and Facility Management (CFM) is responsible for the CO_2 emission. To realise a reduction in CO_2 footprint, CFM is automating buildings and makes buildings more durable. However, 40% of the CO_2 consumption is due to human behaviour and cannot be reduced by automating buildings. To decrease the CO_2 footprint, the UT-community needs to behave differently. By applying the Trans Theoretical Model of behavioural change, it is possible to change the individual's behaviour.

This research focusses on the first three stages of this model, which in the end, is aimed to create awareness among the UT-community. To create awareness among the UT-community an Energy Buddy as campaigning tool was developed. This Energy Buddy was developed using exploratory design approaches through different idea generation methods. The Energy Buddy is a buddy of an individual and monitors the individual's electricity consumption.

The Energy Buddy is designed with the aid of requirements, which have been derived from interview with CFM and the UT-community. Furthermore, elements from the state of the art research and the Transtheoretical Model have been integrated into the requirements. With the aid of scenario-based design, architectural diagrams and a flow-chart the method of the Energy Buddy has been clarified.

According to the electricity consumption the Energy Buddy changes its emotional state, makes sounds, shows signs, shows gestures, vibrates, glows and shows signs. These interaction methods are implemented in such a way that the requirements are met.

The Energy Buddy was tested with the aid of a usability test which consists of an observation and a survey. The Energy Buddy was tested among the target-group and is appreciated. Especially the interaction and triggering resulted in a personalized Energy Buddy which was appreciated by the participants. With the aid of a statistical test, the Energy Buddy was proven to increase awareness among the UT-community.

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List of Acronyms

CFM Campus and facility management

UT University of Twente

TTM Transtheoretical Model

EB Energy Buddy

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1 Introduction

This thesis has the goal to realize an awareness campaign for the UT-community regarding energy consumption. The client is the campus and facility management (CFM) of the University of Twente (UT). In the first part of this introduction, the importance of climate change will be highlighted, followed by the importance for the UT. To reach the goal, some problems are described in the challenges and objectives section. These problems result into one research question and multiple sub-questions. In the end the complete overview of this report is described.

1.1 Situation

Climate change is world's biggest global threat of the 21st century. It is likely that everyone who is living now or will be born in this century has to deal with these effects. A temperature rises between 1 and 4 degrees, sea level rise between 18-59 cm, melting ice between 28-79 cm and deforestation are examples and visualize the importance of these effects[1]. To decrease these effects climate focused investments regarding, for example reforestation, safe water supply, disaster risk management needs to be taken care of [2].

Therefore, the University of Twente aims at reducing their CO_2 footprint by 49% in 2030 [3]. To reduce the CO_2 footprint, the University, for example, automated climate control systems. This resulted in buildings which act on the presence and needs of the users. This subsequently resulted a lower energy consumption, however, this also resulted in automated behaviour of the students and employees [4]. The users are used to enter buildings which have automated climate systems, e.g. the lights, water and heating is adjusted for them. This has the negative side-effect of students and employees becoming less conscious about their energy consumption and don't manage their heating, light or water consumption at the University.

To facilitate the CO_2 reduction, the University of Twente set-up a task-force called the SEE (sustainability, energy & environment). The SEE reduces the footprint facilitating an organizational to reduce the energy consumption on the UT. To even further decrease the energy consumption, the SEE needs the UT-community to consume less energy. However, the SEE doesn't know yet how-to make them aware and decrease their energy consumption.

The challenge is to provide the UT-community with the insight in the problem regarding energy consumption. The UT-community consists of everyone who uses facilities of the UT, for instance students who use the library facility at the UT. To create awareness, they need an insight in what they can do, to have a positive effect on the energy consumption and to motivate them to change their behaviour.

To improve awareness the UT-community must be approached, a campaign is suitable for this since many people can be approached easily without a lot of effort.

1.2 Challenges and objectives

The main challenge of this project is to increase the awareness around energy consumption. The UT-community is broad, from visitors to students and employees, the awareness campaign has to fit this broad target group. Besides this, changing people's behaviour is not easy. Therefore, the Trans Theoretical Model of behavioural change (TTM) will be applied. The TTM is developed by Prochaska and consists of 6 stages of change. The goal of Prochaska's model is to guide the intervener to change the user's stage from the first stage to the final stage. To realize awareness, it is necessary to move the users from the pre-contemplation to the preparation phase [5].

In the current situation people aren't aware of the problem and have no intention to become aware, the people are in the pre-contemplation phase. With the intermediate step of realizing that people enter the contemplation phase, in which they have intention but are not yet ready, it is possible to enter the preparation phase. In the preparation phase the people have intention and are ready for behavioural change and are thus aware.

This model is used in the health sector to motivate people to change their behaviour into a healthier life. It is already applied to people with behavioural problems regarding smoking, drug-use and alcohol [6]. Besides these behavioural problems with health it is also applied in people' financial situation [7]. Therefor this method is applicable for changing behaviour regarding energy consumption since it is a guideline for changing behaviour.

1.3 Research questions

To ensure an increase in the awareness regarding energy consumption, a research question has been set up:

- How to develop an energy awareness campaign for the UT-community?

To realize this question the following three sub-questions have been set-up:

  - How to activate people to move from the pre-contemplation to the contemplation phase?
  - How to motivate people to the preparation phase?
  - What are the main elements to provoke the phase transition?

1.4 Outline

In chapter 1 the introduction of the report is described. In Chapter 2 of this thesis the background research is explored, consisting of a literature review and state of the art. In the literature review important aspects for the design of a campaign are described. In the state of the art section these aspects are elaborated with some examples of campaigns. In chapter 3 the methods and techniques that are used in this project are described. In chapter 4 the ideation phase is described, which results in an intended product. This product is further specified in chapter 5. After the specification, it is possible to realize the product, which is described in chapter 6. When the product is realized, it will be evaluated in chapter 7. This thesis will conclude with a conclusion, which is situated in chapter 8.

2 Background research

In the background research, firstly the literature review will be explained. In the literature review important characteristics, requirements and components are described. Secondly, a state of the art research will be conducted. In the state of the art, other campaigns will be investigated to discover what can be learned from these campaigns.

2.1 Literature review

In the literature review, three different topics for a good campaign will be discussed. Firstly, different requirements for a campaign will be investigated, secondly components for a campaign and success & fail factors. By investigating these different topics, the shape of a campaign will become clear.

2.1.1 Requirements for a good campaign

During this research the definition campaign is limited to influencing campaigns. With influencing campaigns, marketing campaigns which aim to increase profit or publicity are excluded. With influencing campaigns, the topic of influence or direction is irrelevant.

The requirements for a good campaign are essential since the impact of the campaign can depend heavily on that. Pearson [8] states the following requirements: generate objective, make a hierarchy, consider priorities, generate content, these requirements are on a more abstract level. These requirements are corresponding to the more specified requirements dedicated by Lee [9] and Rice [10]. Lee [9] states the following requirements: identify; background information, subgroups, priority areas, campaign goals, critical stages and consider psychological theories like credibility, incentive, appeal and repetition [9]. While Rice [10] states requirements in order of execution during the campaign [10]:

1. Describe plan
2. Conduct situation analysis
3. Target audience
4. Set: Behaviour objectives and goals
5. Identify: Barriers, benefits and competition
6. Positioning
7. Set -up: Marketing mix
8. Describe evaluation plan
9. Budget
10. Plan to implement

Due to time and budgeting limits, not every requirement can be considered. All the different requirements are in the same scope, therefor the most appeared requirements are important. These requirements are: describe plan, target audience, conduct research, prioritize, consider psychological theories and finally the implementation of the campaign.

2.1.2 Components to start campaign

Only considering requirements is not enough to ensure a solid campaign which will result in behavioural change. The designer of the campaign needs to follow specific patterns and consider different implementation techniques for the campaign. Bryant [11] states that the researcher has to decide between two different approaches, namely prevention versus promotion approaches [11]. He adds that the designer has to think about the message content, whether this is informational or persuasive. Coffman [12] disagrees and states that the campaign must be focussed on either individual behaviour change or a public will campaign [12]. According to Rice [10] the designer of the campaign must split the campaign in two phases, the preproduction research phase and the production testing phase [10], these phases are already integrated in the research.

Adhikarya [13] suggests that the designer must split the campaign into strategy development planning and campaign management planning [13]. Atkin [10] does elaborate more on different components, according to his research, designers have to think about the approach whether the campaign should be prevention or promotion oriented. Furthermore, the designer has to think about the message content, whether this should be informational or persuasive [14].

The most researchers split the campaign into two sections in which the designer has to focus on, Rice [10]and Adhikarya [13] both exposure the phases of execution and can be applied as the same. These phases are already integrated in the structure of this research. The other researchers; Bryant [11] and Coffman [12] assign different topics and have all to be considered. The components guide the designer towards the setup of the campaign, the designer needs to implement these components to start a successful campaign. Atkin [14] strengthens the prevention versus promotion and informational versus persuasive of Bryant. The individual behaviour changes versus public will change of Coffman also needs to be considered. Hereby it must be considered that the targeted audience is the UT-community and that this differs from the individual behaviour change or public will change approaching technique. The UT-community can be approached with an individual behaviour change or public will change.

2.1.3 Success & fail factors for a campaign

The campaign can be influenced by different factors and each factor can have a negative or a positive impact on the campaign. Each campaign is built-up from various different factors, which all lead to another outcome. These factors can contribute and make the difference between a successful or a fail campaign. According to Bryant [11], the designer should include elements of the following theories [11]:

- Gratification
- Transtheoretical model
- Theory of reasoned action
- Social cognitive theory
- Self-efficacy
- Health behaviour model
- Extended parallel process model
- Elaboration likelihood model

These success and fail factors are of importance since they highlight behaviours of people. By considering these factors the people are more likely to change their behaviour. The success and fail factors provided by Bryant will be considered during this research.

2.1.4 The Transtheoretical Model

As described in chapter 1, and strengthened by Bryant, the transtheoretical model of behavioural change (TTM) will be applied to ensure behavioural change. The TTM is developed by Prochaska and consists of six different stages; the pre-contemplation, contemplation, preparation, action, maintenance and termination [5]. Each stage is described as the following:

Pre-contemplation

During this first stage people are unaware, uninformed, unwilling and/or discouraged to change their behaviour. They do not have the insight that their behaviour is problematic or produces negative consequences. People inside this stage do not have any intention to act within the upcoming 6 months [5].

Contemplation

People inside the contemplation stage acknowledge that their behaviour may be problematic. Therefor these people have the intention to change their behaviour within the upcoming 6 months. Furthermore, they are more thoughtful and are considering more practical pros and cons of changing their behaviour. Nevertheless, people inside this stage are still ambivalent towards changing their behaviour [5].

Preparation

Inside the preparation stage people are ready to act in the immediate future. The individual aims to develop and commit to a plan. Individuals in this stage intend towards behaviour change and believe that this can lead to reduce the problems [5].

Action

in the action stage, people have a different behaviour and intend to improve their behaviour. People are still learning and adapting their behaviour to improve their behaviour, the behaviour is not yet part of everyday routines [5].

Maintenance

In this stage, the individuals have sustained their behaviour for over 6 months and intend to stay in this stage. The individual do not have to pay attention to their new acquired behaviour, it is part of their routines. However, the people have to pay attention to prevent a relapse [5].

Termination

In this stage, people do not have desire to return to their undesired behaviour, they are sure that they won't relapse. However, this stage is rarely reached because people stay in in the maintenance stage [5].

2.1.5 Applying the Transtheoretical Model

The goal of this research is that the UT-community reaches the preparation stage. To realize a change in behaviour, people have to move from the pre-contemplation to the contemplation, where after people have to move from the contemplation to the preparation stage. To realize this, it is key to motivate people to change their behaviour. Most technologies use the "one-size-fits-all" solution, "providing the same feedback to differently motivated individuals at different stages of readiness, willingness and ableness to change" [15]. Therefore, Greenberg created a motivational framework based on the TTM. The motivational framework consists of motivational goals and recommendations providing the researcher information how technologies can reach these goals [15].

Pre-contemplation

Individuals inside the pre-contemplation stage can be reluctant, resistant, resigned, or rationalizing. They are missing knowledge about the problem and do not want to consider change. The goal is to "plant the seed", giving the individual moderate amounts of information about the problems regarding energy consumption. To do so three recommendations are given [15]:

1. Provide personalized feedback, this feedback needs to consist of both the benefits as the consequences of the unwanted behaviour. The benefits and consequences need to be presented in relation with the individuals' values in a neutral and non-biased way.
2. Refer to social norms in a descriptive and injunctive normative way.
3. Give the user personalized feedback of some small energy actions which can be taken to realize a lower energy consumption.

Contemplation

During this stage people have acknowledged that their behaviour is a problem. They are open for new information; however, they are not ready for action. The positive and negative effects of the individual's behaviour are equal to each other. To motivate people to change their behaviour it is necessary to "tip the balance". There are four recommendations to apply for tipping the balance [15].

1. Provide personalized feedback consisting of the pros of their sustainable energy behaviour and the cons of negative non-sustainable energy behaviour. The pros should emphasize to the positive effects on the individual's quality of life, preferably in relation to what they value. The cons should be presented in terms of losses in relation to what they value.
2. Communicate discrepancies between individuals' pro-environmental attitude and their corresponding behaviour. Encourage a change towards a more sustainable behaviour.
3. Provide some examples of small energy actions which users can perform to encourage larger energy actions in the future.

The provided tips in the pre-contemplation section are necessary to motivate from the pre-contemplation to the contemplation phase. The tips in the contemplation section are needed to motivate people from the contemplation to the preparation phase.

2.1.6 Conclusion

The requirements, components, success & fail factors and the aspects needed for the TTM can be seen in table 2.1. This table gives an overview of the aspects which have to be considered during the development of the product.

Requirements	Components	Success & fail factors	Pre-contemplation	Contemplation
Consider psychological theories	Prevention versus promotion	Extended parallel process	Provide both the pros and cons of personalized behaviour	Provide individual with pros of “good” behaviour and cons of “bad” behaviour
Conduct research	Informational versus persuasive	Health behaviour model	Refer to social norms	Communicate discrepancy
Target audience	Public will versus individual behaviour change	Elaboration likelihood model		Provide small energy actions
Prioritize		Self-efficacy		
Implementation		Social cognitive theory		
Describe plan		Theory of reasoned action		
		TTM		
		Gratification		

Table 2.1 Overview of integrated subjects

The aspects in the requirements section are primarily aimed to develop a plan of action and to have a logical reasoning embedded in the campaign. Since the campaign is part of the thesis, there is a plan of action, therefor these requirements will be considered throughout the research. Furthermore, the psychological theories are considered throughout the research, however not fully-integrated due to the time limitations. With the exception of the TTM, the TTM will be embedded in this projects because this is stated in section 1.2. To embed the TTM in the project, the aspects inside the pre-contemplation and contemplation will be integrated.

The components are also of importance due to their binary approach. Therefor it is key to discover what type of campaign is desirable. This will be identified in the state of the art research.

2.2 State of the art

There are a lot of campaigns worldwide, each with its own characteristics and originated idea. The diversity in these campaigns is large, this results in different positive and negative aspects in each campaign. This enables the possibility to learn from these campaigns. Positive aspects can be applied and negative aspects can be prevented. During this state of the art research campaigns regarding: behaviour, energy consumption and awareness will be looked at. The components, described the literature review, will be shortly highlighted.

2.2.1 Campaigns to change behaviour

For campaigns to change behaviour two campaigns are looked at, firstly a campaign to change behaviour regarding meat consumption and secondly a campaign to change people's behaviour surrounding speed limits.

The strong point of this campaign is the use of Arnold Schwarzenegger, he is an activist in regarding meat consumption. At the moment eating meat has a manly/strong image while Arnold Schwarzenegger is a vegan. With this he takes away one of the subversive effects that eating meat is manly and necessary for a healthy living. In figure 1 is Arnold Schwarzenegger talking into the camera about the catastrophic effects of eating meat.

Furthermore, in the campaign, the climate change is predominantly assigned to meat consumption, there is connection given with the cause and effects. Lastly, other causes of climate change are being mentioned, such as traffic or energy consumption [16].

Another campaign is changing people's behaviour for traffic safety. In this campaign a car accident occurs. Seconds before the car crash the video will play in slow-motion in which the drivers of the cars are talking with each other, trying to still prevent the accident. In the campaign is developed by the New Zealand's transport agency and is aimed to shift speeding drivers with a message about human fragility and the inevitability of mistakes. The developers also aimed for a reminder that reducing violations is part of a safe system, enforcement may be needed to encourage compliance and ultimately reduce harm [17]. An image of two persons talking to each other about the speeding, just seconds before impact, is visible in figure 2. The campaign firstly assigns the consequences of the behaviour and secondly aims at compassion. In the right car a child is present, who will die in the campaign, due to this the viewer will sympathize with the personalities in the campaign

Meat

Figure 1 Less meat less heat campaign

[16]

Traffic safety

Figure 2 Traffic safety campaign

[18]

2.2.2 Campaigns regarding energy consumption

This campaign is developed by the European Union. In the beginning of the video some examples of energy waste are given, where after the main character provides the viewer actions which limits the energy waste. The video continues by showing the catastrophic consequences of not changing behaviour. With this the main character forms a community which prevents climate change by performing small actions and induce limiting energy waste. In this campaign is clearly visible that aspects of the TTM are integrated. In figure 3 the main character replaces a light bulb with a CFL.

Energy

Figure 3 Campaign regarding less energy consumption

[19]

2.2.3 Campaigns regarding creating awareness

The last two analyses will be performed regarding awareness, the first campaign is developed for awareness regarding health, the second campaign regarding bullying. The mental health awareness campaign, visible in figure 4, has been launched by the city of Wales. Its intention is to change the mentality around the citizens to start thinking about each other. Being there for someone is highlighted in the campaign, the city hopes to increase healthier citizens. The campaign shows various problems with the mental health nowadays and provides some actions which individuals can perform. The second awareness campaign assigns bullying, the campaign is visible in figure 5. This campaign was developed by Safeschools, this is a brand which helps creating safer and more inclusive schools around the world [20]. The campaign shows children, who tell facts about bullying. In the campaign is highlighted who bullies, what the effects are and where the bullying occurs. Both campaigns asses the current problems of the behaviour and give tips about action which the users can perform.

Health

Figure 4 Campaign for improved health

[21]

Bullying

Figure 5 Less bullying campaign

[22]

2.2.4 Conclusion

In table 2.2 all the different campaigns are described on the rows and the scoring criteria are described on columns. For each campaign it is stated which scoring criteria it matches. The matching criteria consists of the different components. The different components are whether the campaign needs to be prevention versus promotion, informational versus persuasive or public will versus individual behaviour change.

	Energy saving	Health	Less Meat	Traffic safety	Bullying
Prevention versus promotion	Promotion	Promotion	Promotion	Promotion	Promotion
Informational versus persuasive	Persuasive	Persuasive	Persuasive	Persuasive	Informational
Public will versus individual behaviour change	Individual behaviour change	Individual behaviour change	Individual behaviour change	Individual behaviour change	Individual behaviour change

Table 2.2 Overview of applied components

It is clearly visible that the majority of the campaigns use the same approaching technique. All the campaigns have a promotional approach towards the viewer. Therefor a promotional campaign will have better impact than a prevention-oriented campaign. The bullying campaign is mostly informational, while the other five campaigns are persuasive. This indicates that a persuasive approach will have a bigger impact to the viewer than an informational campaign. Lastly, it is key to determine whether the campaign needs to be oriented on individual behaviour change or public will. All the campaigns are oriented towards individual behaviour change, therefor the campaign will also be oriented on individual behaviour change.

Furthermore, the state of the art research provided valuable information regarding the aspects which are needed to be integrated. In the Less meat Less Heat campaign, subversive effects are assigned, there is a relation given between the cause and the effects. The traffic safety campaign shows that sympathize is a way to approach people and the campaign shows the effects of the undesired behaviour. In the energy consumption campaign, examples of energy waste are provided together with actions which can be performed. In the health campaign examples of action which viewers can perform are provided. Also the bullying campaign assigns the effects of bullying.

In the state of the art research, the focus is on campaigning video's. These video's enable to determine how the components, set in the literature review, should be met. Nevertheless, a campaign is not restricted to a video. In section 2.1, the requirements, components and success & factors have been developed. These aspects need to be integrated in the campaign. By integrating these aspects, campaigns can range from advertisements, to a video or a product.

3 Methods and techniques

In this chapter of the thesis, an overview of the used methods and techniques will be given. The methods and techniques are described shortly, together with the application in this project. Firstly, in section 3.1, the selected design process, is explained. In section 3.2 the requirements elicitation will be explained, followed by an explanation of the requirements classification. This chapter will end with an explanation of the used evaluation techniques.

3.1 Creative Technology Design process

For this thesis, the Creative Technology design process is applied and has a central position throughout the thesis. It is used as guideline for the design of this awareness campaign. It has been introduced by Mader and Eggink [23]. With the aid of iteration the designer adjusts the needs of a product to constantly changing factors. The model consists of four phases: Ideation, Specification, Realisation and Evaluation. Each phase follows from one another and there is the possibility to take a step back. In each phase there is a constant analysis of the product design, together with the involvement of the stakeholders in mind. During the ideation and specification phase there is an influence between the user needs/stakeholders request and the technology and the creative idea itself. A visual representation of the Design Process for Creative Technology can be found in figure 6.

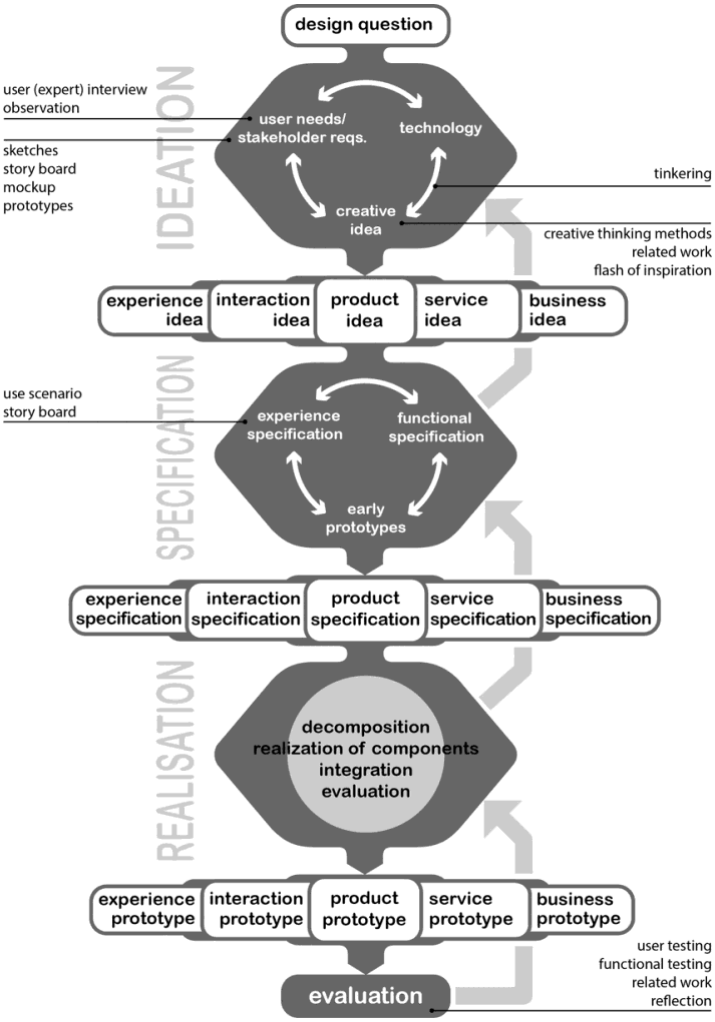


Figure 6 Design process for Creative Technology

3.1.1 Ideation

The goal of this phase is to ensure that there will be an idea for a product. The product idea can originate from three possible starting points, the user needs/stakeholder requests, a technology or from a creative idea. After the starting point, by iteration through the different points the final design will be reached.

During the iteration, with the aid of different low-fi concept prototypes like mind maps and sketches, these concepts are discussed with the stakeholders. These discussions will be done by using interviews and brainstorm sessions, these are important during this phase since they provide the design guidelines for the envisioned product. Furthermore, the provided information strengthens the iteration process and therefor stimulates the process towards the final design. This information induces different preliminary requirements which needs to be prioritized. The MoSCoW method (Must, Should, Could, Won't have) is used to categorize these requirements, so the different requirements will become clear and feasible to develop.

3.1.2 Specification

During the specification phase, the envisioned product is further refined with the aid of feedback loops. These feedback loops are necessary because these enable the possibility to integrate the necessary aspects, which arise during the development of the product.

In the specification phase, firstly the functional requirements will be derived from research. Where after, with the aid of scenario-based design, non-functional requirements will be derived. The specification phase will end with the architecture of the envisioned product to clarify the relation between the different elements.

3.1.3 Realization

Once there is a feasible specified concept of the envisioned product, the realization phase begins. During this phase there is an iteration between the early prototypes, refined requirements and the architecture of the envisioned system. The requirements, which are specified in the specification phase, are guiding the realization. After the first realization, there is a feedback loop by checking if all the requirements are met. After this realization the designed product has its final design and is ready for the stakeholder evaluation.

3.1.4 Evaluation

During this final phase, the final product is being evaluated. With the aid of usability tests and interview with clients and the UT-community, the designed product is being evaluated. Besides the evaluation of the clients and UT-community, the researcher evaluates the functioning elements of the product. The evaluation is aimed to check whether the goal of this research has been accomplished.

3.2 Requirements elicitation

To elicit requirements, some methods and techniques will be applied. Firstly, the interview technique will be explained, where after the stakeholder identification and analyses methods is explained. Lastly, the brainstorm technique will be discussed.

3.2.1 Interview techniques

An interview gives the interviewer the possibility to gain more in-depth knowledge about the stakeholder. This information can help get insight into the expectations of the stakeholder and what requirements they might have. During an interview one person questions another person or group about a subject. In general, there are three possible interview techniques, the structured, semi-structured and unstructured interviews[24].

Structured

In a structured interview the interviewer determines the questions on beforehand. During the interview the questions will be asked in a particular order and the interviewee answers these questions in that particular order. It is key to strictly follow the questions described in advance and not elaborate on different topics that occur during the interview.

Semi-structured

During a semi-structured interview, the interviewer will prepare questions to structure the interview. However, it is possible to elaborate on topics which seem relevant during the interview. This enables the interviewer to ask in-depth questions or ask about other topics that are relevant. The interviewer is free to ask everything, but the predetermined questions guide to a coherent interview.

Unstructured

During an unstructured interview the interview doesn't prescribe the interview questions. The conversation will be guided by both the interviewer and interviewee.

During this thesis the semi-structured interview will be used. This enables the possibility to answer the prescribed questions, but also to ask in-depth questions which might be necessary or occur during the interview.

3.2.2 Stakeholder identification and analysis method

A broad range of different stakeholders are related to this project, a stakeholder is a person or party with interest in the project. The stakeholders are affected by decisions or can contribute to a certain decision [25]. To ensure that all the different stakeholders are part of this thesis and are being analysed in a structured way the Stakeholder Analysis toolkit of the Manchester Metropolitan University will be used [26]. For each stakeholder there will be described what their interest in the project is, what is needed from them together with the possible risks that each stakeholder may entail. Lastly the stakeholder's role will be explained.

Furthermore, Sharp states that the different stakeholders can be categorized in four different groups; the users, developers, decision-maker and the legislators[25].

- Users: are people, companies or groups who will interact with the product.
- Developers: are people who build, maintain or manage the product. This group is working on the development and maintenance of the concerned product.
- Decision-maker: this group are often people on management positions. These people are closely involved with the development of the product.
- Legislator: This group provides guidelines for the intended product. Most of the times this group consists of companies or government agencies.

The group is of importance during the research to distinguish them in their role. Each group has a different point of view towards the project, this is important for the project because each group has a different influence, added value or role. Therefor the group is added to the Stakeholder Analyses toolkit of the Manchester Metropolitan University in table 3.1.

Stakeholder name	Stakeholder interest	Added value	Stakeholder role	Group

Table 3.1 Stakeholder Analysis Toolkit

After all the different stakeholders are identified, together with their interest and role, the stakeholders will be divided depended on their interest and power. To do so, the power versus interest matrix of Mendolow is used [27].

This grid divides stakeholders into four different sections based on their interest and their power. On this grid the power of each stakeholder is on the y axis and the interest of each stakeholder is on the x axis. The power means how much power that particular stakeholder has in relation with the project. In the design process, the power indicates the perceived ability to persuade, induce, adjust, coerce, thus influence the outcome of the designed product. The interest section means how interested a particular stakeholder is in the outcome of this project. A visual representation of the grid is given in figure 7.

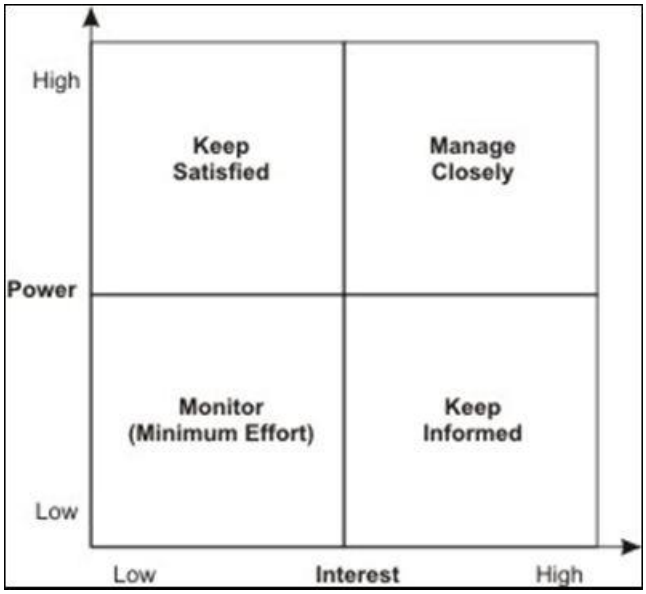


Figure 7 Power / Interest matrix by Mendolow

In figure 7, there are four different boxes in which stakeholders can be located, depended on their level of power and level of interest. These are the following:

- Minimum effort (low power and low interest), low effort needed and just monitor & inform occasionally.
- Keep informed (low power and high interest), keep this group informed but no close collaboration needed.
- Keep satisfied (high power and low interest), the wishes of this group need to be satisfied.
- Key stakeholders (high power and high interest), with this group there must be a close collaboration during the project.

3.2.3 Brainstorm technique

To generate ideas and combine strong aspects, brainstorms have to be conducted with the different stakeholders and individually. There are several brainstorm techniques, of which the most well-known are[28]:

Mind Mapping

Mind mapping is an example for an individual brainstorm session. In this technique one word is placed on a piece of paper, after which related words are connected to that word. This results in a graphical appealing structured way of words that are related to each other. Advantages are that the graphical representation and ideas are organized and stimulates interaction and elaboration. A downside is that it is time consuming and can be chaotic.

Free-form (unstructured)

After initializing the topic of the brainstorm, the participants express their ideas. It is crucial that these ideas are collected without criticizing, changing or evaluating these ideas. When the group has run out of ideas, the brainstorm session is over. An advantage is that people are stimulated by ideas or group members, however the session can be dominated by a single or a couple of persons.

Round Robin (structured)

During this brainstorm session, the participants express their creative ideas at their turn only. This creates a followed order of people expressing their ideas. When everyone has run out of ideas, the brainstorm session has ended. This brainstorm type results in an equal chance of for everyone to express their ideas, however the waiting and structured approach might turn into a loss of ideas. Furthermore, the mentioned ideas influence the participants and the participants influence each other, which might result into a limited frame of generated ideas.

Nominal Group Technique

This is a structured brainstorm technique in which the participants firstly write down their creative ideas. When everyone is done, the ideas are discussed in the group. Where after the participants rank their own ideas, after which the ideas are discussed again. At the end, the whole group will vote with a voting system and dedicate the top generated ideas. This technique enables the participants to participate freely. A downside is that this technique is time-consuming and that interaction is fixed, diminishing ideas generated by others.

Pencil and Paper (silent)

The individuals will form a group and write down their creative ideas. These ideas are than passed to another member of the group. This member will than write down his/her association with that idea. This technique enables a lot of freedom and creativity because there won't be feedback on ideas. However, there isn't any verbal communication and therefor there isn't a synergistic process.

For this project, two individual brainstorm sessions will be held. The first one is held to generate ideas. For this brainstorm session a free-form (unstructured) type of brainstorm will be used. This brainstorm technique is possible to do alone, secondly it is possible to create a lot of ideas in a relatively little amount of time. For the 2nd brainstorm session, the mind

mapping technique will be used. Mind mapping will be used because this type of tool enables to structure the generated ideas, make them more vivid and create depth. Lastly, both these brainstorm techniques are able to structure well and communicate to the different stakeholders.

During this project, also two group brainstorm sessions will be held. For both brainstorm sessions the free-form (unstructured) technique will be applied. With this technique it is possible to generate a lot of ideas which is necessary in the first brainstorm session. In the second brainstorm session this approach is applicable since it is possible to discuss the generated ideas and combine them. Combining different aspects is, according to Wilson [29], essential for good brainstorming. By applying metaphors or improving the existing ideas, the existing ideas can be extended, create new creative ideas or ideas can be combined [29].

3.3 Requirement classification

The interviews and brainstorm session elicit requirements; however, these requirements are arbitrary and not clear. To order these different requirements, the MoSCoW technique will be used, which will be explained in section 3.3.1. To clarify the non-functional requirements, scenario-based and storyboards will be applied, these are explained in section 3.3.2 and 3.3.3 respectively. To clarify the functional requirements and visually represent the functions of the envisioned product, an architectural diagram will be made together with a flow-chart and functional diagram, explained in 3.3.4, 3.3.5 and 3.3.6 respectively.

3.3.1 MoSCoW

The information gathered during the interviews will be input for the preliminary requirements classification. To ensure that there is an ordered list of these requirements the MoSCoW method is applied [30]. MoSCoW stands for 'must have', 'should have', 'could have' and 'won't have'. The first group, "the must haves", are requirements which are essential for development of the envisioned product and these requirements must be implemented. The second group is the "should have" group, these requirements are not essential but are nice to have and should be implemented. The "could have" requirements are nice to implement but, it is not necessary to implement, thus these requirements could be implemented. The last group is "won't have", these won't be included into the campaign, these are therefor in the won't have group. By using the MoSCoW approach the requirements are categorized on priority level. In table 3.2, a template of the categorization with the use of MoSCoW is given.

Order	Requirement
Must	-
Should	This requirement should be implemented
Could	-
Won't	-

Table 3.2 Example of the MoSCoW technique

After applying the difference in categories, requirements are assigned whether these are functional or non-functional. Firstly, there are the functional requirements, these describe what the system must do, thus a function of the envisioned product. Secondly there are the non-functional requirements, these are not part of the system but describe what the functions intend to realize.

3.3.2 Scenario-based design

During the development of a product, the product has an intention of use. However, it is not explicitly clear how the intended system should work in relation with the user. Scenario-based design is a family of techniques in which the use of a future system is concretely described. By applying the scenario-based design during the development process, the intention of use is being clarified. Scenario-based design is an example of an user-centred approach, it changes the focus of the system operations to the interaction between the user and the product. A scenario-based design consists of narrative descriptions of the envisioned usage, in combination with a variety of ways to guide the development of the system that will enable these experiences [31].

Scenario-based design furthermore enables the researcher to communicate the usage possibilities and concerns among the different stakeholders. Rosson [31], made a framework which the designer has to apply to make a successful scenario. In figure 8 an overview of this framework is visible, in which the scenarios serve as a central representation throughout the development cycle.

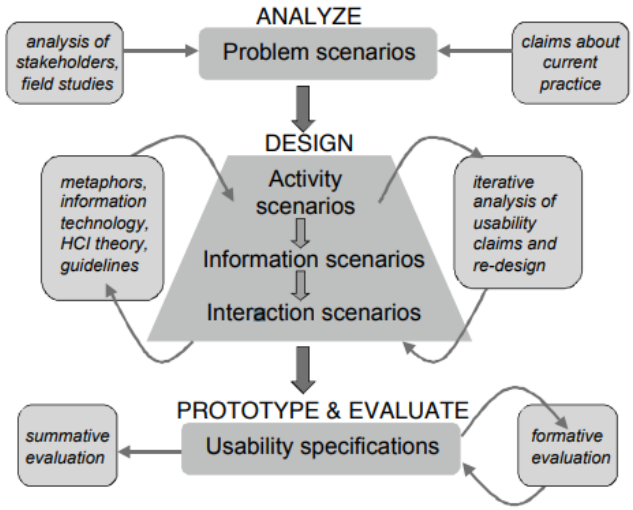


Figure 8 Framework for scenario-based design

The applied scenario-based design consists of two different sections. Firstly the persona will be described to highlight the current situation and introduce a usage situation, where after a scenario will be portrayed. The scenario describes the actions of the user in relation with the envisioned system.

3.3.3 Storyboard based design

Rosson [31] adds that the usage of storyboards in relation with the scenario enriches the possibilities of the scenario and storyboard. Orr [32] adds that a combination of data research studies, combined with developments experience, provides insights into “what works best” for the intended system [32]. The guidelines set-up by Orr, are broad, however should be considered during the development of the storyboard. Hereby he states that this depends on the used hardware, software, intension of use, learning skills, stakeholders, complexity, content, resources and the targeted audience. By considering these elements, a storyboard can be created which communicates the goal, analyses decisions made by the designer, see discrepancies in the product and how the different elements work together. The storyboard will be made to clarify the relation between the user and the envisioned system.

3.3.4 Architectural diagram

The described storyboard design in combination with the scenario-based design provide the developer a clear overview of the interaction between the user and the intended product. To further specify the intended product, system architecture is used to provide an overview of the functionalities of the different elements. In the architectural diagram these different elements are connected to each other, creating a simple overview of a complex system.

To create this functional diagram, blocks and diagrams are used. The blocks mimic different functions at that particular abstraction level. The blocks are connected with arrows, on the arrows the transferred data is portraited. When a functional system has been developed, it can be decomposed into a lower abstraction level, due to which a more detailed overview can be made. By making another level of the functional diagram, the different sub-systems can be clarified and a detailed overview of the relation between each different sub-system with other sub-systems gets clarified. This process can be repeated until all the functionalities inside the different subsystems are clearly portrayed.

A finished architectural diagram provides a basis for the realization of the prototype. All the different elements and the connections are clarified, this helps the designer by combining the different elements of the envisioned system. Furthermore, the architectural diagram will be used in the evaluation of the functional requirements. The architectural diagram gives an overview of the embedded functionalities and whether these are working properly.

3.3.5 Flow-chart

A flow-chart is a diagram, consisting of multiple graphics and symbols in a structured sequence. There are four basic symbols in the flow-chart: start, process, decision and end. A flow-chart helps to understand how the system works. Furthermore, it operates as a blueprint, thus helps the programmer tackle arising issues more easily. Lastly, the flow-chart helps the designer in communicating the logic of the intended system [33].

A flow-chart is started with the start function, after which the sequence loop is started. The sequence loop is looped through and is the core of the intended product. In a flow-chart is precisely situated what the relation is between the input and output.

The flow-chart consists of a couple of decisions and processes which indicate unambiguously what the decision value is and what effect this has. This creates a path, depended on the input value, through the flow-chart. Each time this value changes and thus the path of the loop changes. The flow-chart is constructed in such a way, that there is only one direction which is possible depended on the input value. This creates a system in which there aren't any misinterpretations possible.

3.3.5 Functional diagram

A functional block diagram is a simple and graphical way to program any function together. It is an example of a: programmable logical control language. This is used for electrical devices with a microprocessor, in which the microprocessor controls inputs and outputs. In a functional block diagram, the functions are illustrated with a box, in the middle of the box, there is text which explains what the actual functionality is. There are lines towards and from the box, these illustrate the functions inputs and outputs, there might be several. A functional diagram helps the designer clarify the functions of the programmed code and communicate the functions. [34]

3.4 Evaluation method

After the envisioned product has been realized, the prototype needs to be evaluated. As stated in section 3.3.1, the requirements are divided into two categories, the functional requirements and non-functional requirements. Both types of requirements need to be evaluated and need different evaluation methods. Firstly, the functional requirements are evaluated, where after the (non-)functional requirements are evaluated with a user evaluation. The goal of both evaluations is to check if the prototype works properly and whether the envisioned product meets the requirements. The evaluation furthermore highlights possibilities for future research or improvement.

3.4.1 Functional evaluation

The functional requirements are generated to check whether the prototype functions properly. These requirements are about the functions of the prototype. These requirements are summarized in a table, where after it is possible to state if these requirements are met, partially met or not met. This method will be executed by the researcher solely, since the observations are unambiguously and objective. After the approval of the system by the researcher, the end users will evaluate the system.

3.4.2 Non-functional evaluation

After the approval of the researcher, the system will be tested by the end user. This test is performed to check whether the requirements regarding the intended product are met. This clarifies whether the interactions are clear, if there are functionalities missing, whether the prototype is acting as expected and lastly to check what the perceived influence is. Together, the non-functional evaluation facilitates the input for the researcher to check whether the non-functional requirements were met.

It is key that the test is performed among the target group of the envisioned product, in this case the UT-community. People inside this target group have other demographical statistics than outside this target group. By testing the product solely by people whom belong to this target group, representable result of the outcome of this evaluation can be expected.

User testing

User testing is a process in which the user tests the interface, method, interaction and influence of the product. The user tests this product to provide crucial feedback for the researcher to make recommendations and improvements for the product. Advantages of user testing is that it gives an impression of the experience, derives insights and feedback and identifies improvements. The most familiar types of user testing are [35]:

- Usability testing

  This test is held among real users to discover how they interact with the intended product. It helps to gain insights about the interaction between the user and the product and how the product can be adjusted to meet the requirements of the user. During this test the conditions of execution must be the same as the intended usage of the product. This method is relatively fast and cheap. This type involves both observing as to interview the participants. Participants need to be encouraged to think aloud and the observer may ask questions.

- Tree testing

This test is the simplest form of testing and the users are instructed to execute a specific sequence of tasks. Without mimicking the real situation, the tasks are performed and evaluated on their functioning only.

- Remote usability testing

During a remote test, a system is being tested on the screen of the participant. The participants screen and sound is being recorded. The software is than being tested by the participant on the participants computer, while the researcher watches along on a remote device.

- Open card sorting

In this test, participants are asked to sort navigation items to different categories, created by the participants themselves. The participants are structuring them according to their wishes and desires. This enables the researchers to discover the desired navigation architecture of systems.

- Closed card sorting

This method resembles the open card sorting. However, the categories are already described by the tester.

For this research the usability testing is most applicable since it is a designed, interactive prototype which interacts with its environment. Furthermore, this relatively easy realizable, provides crucial feedback and enables to discover the reaction and opinion of the user. To perform a usability test, the designer needs to develop a survey and needs to observe the users.

Observation

According to Ross [36], observation is the most important because it provides the most accurate information about people, their tasks, and their needs. Ross states: “To really understand what people do, you can’t ask them, you have to observe them.” Ross states several observation techniques, of which usability testing is one of them. This type of observation is most valuable because interaction is allowed, which increases the amount of valuable information that can be collected.

Survey

The usability testing is used to observe the user, however also consists of a survey. A survey highlights possible issues, options for improvements and clarifies how the system is being perceived. To gain these insights, a survey will be held with both quantitative as qualitative questions. These questions are asked on the performance and perceived influence of the product during the usability testing. By combining these different techniques, an elaborated evaluation report can be created. As described in section 3.2.1, a semi-structured interview will be held for this survey.

There are a couple of question types which could be performed, the most popular ones are[37]:

- Dichotomous questions
  Users have binary options to choose from, for example yes or no.

- Multiple choice questions
  Usually these questions offer three or more predetermined answer options, which the user can choose from.

- Checkbox questions
  These questions have the same layout as multiple-choice questions; however, the user can choose multiple.

- Rating scale questions
  With rating scale questions, users are asked to assess an issue on the basis of an already predetermined dimension, for instance 1 up to 10. The researchers must explicitly state what each particular number means.

- Likert scale questions
  Likert-scale questions range, for instance from strongly disagree to strongly agree. This type of questioning is used for measuring perceptions, attitudes and opinions, they are used to question the respondents about a new product release.

- Matrix questions
  Matrix questions consist of several questions in a row with a series of rating scale or Likert scale questions.

- Open-ended questions
  There aren't any redefined answers, the respondents supply their own answer.

- Demographic questions
  These questions are aimed to provide information regarding the background of the participant.

During this research four types of questions will be used. Firstly, demographic questions, to validate the respondents. Secondly, open-questions will be used, these questions aim to elicit an elaborate opinion of the users. Dichotomous questions will be used for questions in which two answers are possible. Lastly, to gain quantitative data, Likert-scale questions will be used, these questions aim to gather insights in the experience of the users. To check whether the product has influence on the awareness of the user, the perceived influence will be measured. In the survey, the end-users attitude will be asked before the prototype was demonstrated and after the prototype was demonstrated.

3.4.3 Statistical evaluation

To indicate whether the product influences the end user, the influence of the envisioned product will be measured. This will be done by measuring the end-user's attitude two times. The attitude will be measured before and after the product was demonstrated.

As described in section 3.4.2, Likert-scale questions will be used to acquire quantitative data. This data provides a mean before the product was demonstrated and a mean after the product was demonstrated. With the aid of a t-test, the obtained means will be compared [38].

The hypotheses will be that the mean before demonstration is equal to the mean after demonstration. The alternative hypotheses will be that the mean after demonstration is larger. By executing the t-test, the hypotheses can be accepted or rejected. Where after it is possible to conclude whether the product influences the end-user.

To compare two values among the sample, a two-sampled t-test will be applied. Secondly, an one-tailed test is required because the second mean is assumed to be greater than the first mean. The formulas to derive the t-value are given in appendix C.1.

From this formula, a t-value will be derived, this t-value has to be compared with critical value. Where after it is possible to accept or reject the stated hypotheses. This critical value is depended on the confidence interval and the degrees of freedom. For this test a 95% confidence interval will be used. This implies that with a probability of 95% the hypotheses will be accepted or rejected correctly. Depended on the number of participants, the degrees of freedom is being calculated. The degrees of freedom is calculated by adding n_1 and n_2 and subtracting 2. Depended on the degrees of freedom and the confidence interval, in the t-table the critical value can be found. The critical value will be compared with the obtained t-value, where after the stated hypotheses will be accepted or rejected.

4 Ideation

In this chapter the ideation phase will be described. At the end of this chapter there will be a final idea. During the construction of this final idea the design question is the starting point in this process. In the first part the stakeholder identification and analysis will be explained. Where after the requirements are elicited, these requirements are the input for the concept creation in section 4.3. At the end of this chapter a final idea is described.

4.1 Stakeholder identification and analysis

As mentioned in chapter 3, the different stakeholders have different influence on the project. Together the stakeholders influence the requirements of the campaign. therefor it is key to indicate the different stakeholders, and secondly analyse these stakeholders.

4.1.1 Stakeholder identification

In this project multiple stakeholders are involved, consisting of users, decision-makers and legislators. It is important to identify and analyse them since these groups have input regarding information or determine functional and non-functional requirements of the envisioned product. In table 4.1 the different stakeholders are identified and explained.

Stakeholder	Interest	Added value / risks	Role stakeholder	Group
Visitors Employees Students	More awareness prevents climate change and therefor the liveability on earth	Knowledge about current behaviour Creating a campaign which doesn't affect them	Sharing their behaviour and attitude regarding energy consumption	Users
Campus and facility management (CFM)	More awareness around energy consumption which might contribute to less energy consumption,	Knowledge about energy consumption Wrong information could be gathered + Creating a product which isn't feasible for them	Sharing their information and experience regarding energy on the University and referring to other projects to realize less energy consumption	Decision-maker
University	A more sustainable University in which students act responsibly	Process accompaniment Not in line with the goal of the UT	Sharing their knowledge and experience in the construction of a thesis and design of a product	Legislator

Table 4.1 Stakeholder identification

4.1.2 Stakeholder Analysis

In this section, the three mentioned stakeholders consecutively be analysed. Firstly, the Campus & facility management will be explained, where after the University of Twente is discussed and finally the UT-community will be described.

Campus & facility management

The Campus & Facility Management department is the client of this project. This group is represented by Brechtje Marechal and Henk Hobbelink. Brechtje Marechal is the policy officer of environment and sustainability at the UT, furthermore she is head of the task force: sustainability, energy and environment. She facilitates organisational measurements and steers the group. Henk Hobbelink is the contract of manager of CFM, he is also a member of the sustainability, energy and environment task-force. He is responsible of the implementation and execution of different measurements.

Both are representatives of the CFM; this stakeholder has a high interest and a high power. Their interest is high since this groups aims for a lower energy consumption and is responsible for that. The power is high since this group has executive tasks regarding energy consumption. This stakeholder needs to be managed closely to realize a successful product. The position of the stakeholder is positioned in figure 9, along with the other stakeholders.

University of Twente

The UT is interested to reduce the energy consumption and is represented by Richard Bults and Kasia Zalewska. This group is responsible for the organisation with the University and supports the contact between the student and client. Their main task is to overview the progress and adjust the progress or development where necessary. Since this group gives also the internal supervision, they are also responsible for the assessment and final evaluation. Their interest is relatively high since the goal of the UT is to realize a sustainable University. Their power is also relatively high since process and steering is provided by them and this group is decision-maker in the project.

Both the power and interest are lower than CFM's, since energy is not their main task on the University. The UT is a key player and therefor needs to be managed closely. The position of the UT in the power versus interest matrix is visible in figure 9.

UT-community

The UT-community consists of three different sub-groups, first of all the students, secondly the employees and lastly the visitors. These sub-groups are the aimed target group, it is important to split this group since each group has a different pattern. A student has other activities to perform, has other lines of reasoning and have another time schedule. This substitutes that they have a different behaviour regarding energy consumption. Furthermore, the interest of each sub-group is different, together with their attitude towards the UT and the goal of the UT at a larger scale. These sub-groups together are responsible for the energy consumption and are described separately:

- Employees

When there isn't a lockdown, employees spend a lot of time on the University and have designated working places. This is contributing to the energy consumption on the University. The campaign needs to approach this group to realize more awareness. To realize this, it is key that the employees understand the message. To ensure that the employees understand the message, the wishes and needs, needs to be considered. Therefor their interest is average, furthermore their power is relatively high because employees are strongly defended on the UT. The employees need to be kept satisfied. In figure 9 is the position of the employee's visible in the power / interest matrix.

- Students

The University of Twente provides education towards its students. These Students spend time on the UT, with the effect of energy consumption. Their power is high since the campaign needs to be adjusted to their needs and wishes. Without doing this the campaign might not be successful. This group has a lower interest since their connection and attitude is on a different scale than an employee, therefor the students are in the lower-left corner. This means that the students need to be monitored. The position of the students can be found in figure 9.

- Visitors

Visitors of the UT do not spend a lot of time on the University, don't have designated working places and their attitude towards the UT is different. During their visits their contribution to the energy consumption is negligible. Though this group isn't of high importance for the research, they should be considered since they are part of the community. Therefor their interest and power are low. Their positioning in the power versus interest matrix is visualized in figure 9.

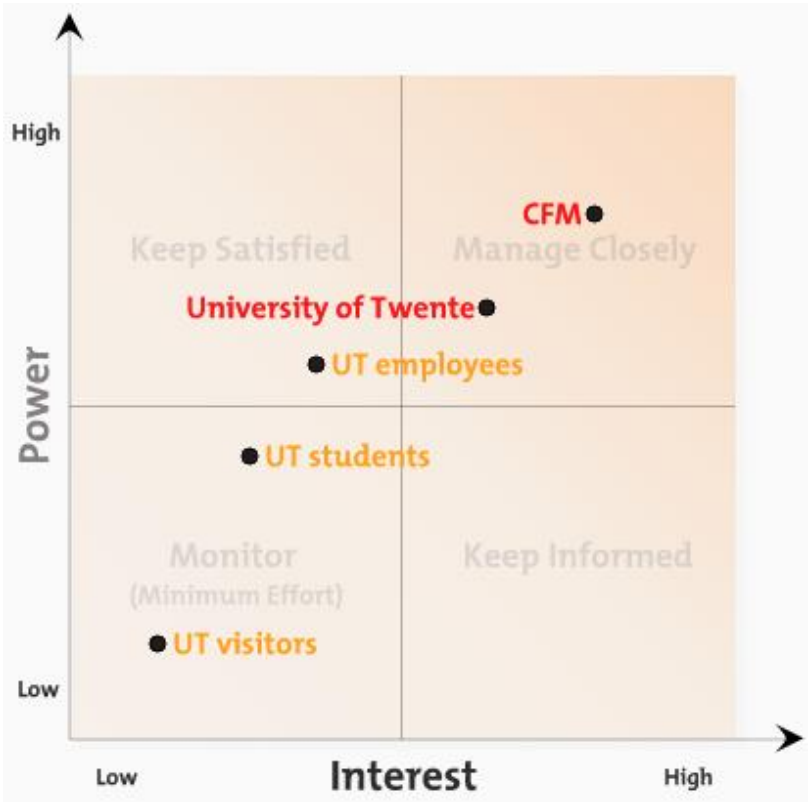


Figure 9 Stakeholder analysis: power versus interest matrix

4.2 Requirements elicitation

As explained earlier, stakeholders have wishes and needs which have to be met. To elicit their requirements, interviews will be held. One with Henk Hobbelink, a representative of CFM. Secondly, students have been interviewed. Where after the elicited requirements can be classified. These classified requirements will be input for the concept creation in the next section.

4.2.1 Interview client

The first interview session was held with Henk Hobbelink, he facilitates automated buildings and monitors energy flows. According to Hobbelink, there are five types of energy flows, these are, in order of influence on the CO_2 footprint: electricity, gas, warmth, cooling, water[4].

According to Hobbelink, buildings contribute to 60% of the CO_2 footprint while the users are contributing 40% to the CO_2 footprint. Besides the fact that users are contributing less, their share in the energy consumption may not be neglected.

Hobbelink adds that 25% of the CO_2 footprint is created by students and 75% by the employees. There are 11.740 [39] students registered at the UT while there are 3.317 [40] employees. Employees are contributing more since they have designated offices, are spending more time on the University and use laboratory.

According to Hobbelink, employees are the largest group which is wasting energy. The main reason is that employees do not consider energy as one of their tasks, therefor staff members are lazy in switching off devices. Hobbelink said:

> "This group isn't turning off lighting, isn't switching of computers even on Friday afternoons so the computer will stay on for the whole weekend and this group isn't turning off installations after usage. These installations are used for research, their power consumption is huge and start-up time may take 6 hours, for this reason installations won't be powered-off. There are a lot of PhD employees who are using these installations once in a while. None of these PhD employees is turning off the installation due to the large start-up time, while the installation is using a lot of energy."

This statement, clearly portrays the issue of the problem. Finally, Hobbelink adds that rewarding or punishing people are two elements which may be assessed to realize that the viewer of the campaign is adhering to the message.

4.2.2 Interview UT students

There are two interviews performed to gather knowledge about the behaviour of students. Both students are in their final phase of their bachelor[41] [42].

Both students indicate that they do not pay attention to the energy consumption surrounding their presence. Furthermore they are motivated to change their behaviour to consume less energy.

When lights are on or the thermostat is not at the preferred setting, both students switch on the lights and change the thermostat settings. One student adds that he also switches off the light and returns the thermostat settings when leaves the room. Furthermore, the students rely on the automation system of the University, both students added that they know that this system isn't applied in every building. One student even said that he is annoyed by water being wasted at restrooms, the power consuming billboards spread over the UT and lights which are on without a reason.

Both students claim that they are not aware of the University's energy consumption. Mainly because of the thought: "it is a University, with smart people, thus the energy must be regulated good and probably will be green". One student explains this by saying: "I'm not personally motivated to change my behaviour, however the Netherlands has to consume less energy, since I'm part of that, I want to change my behaviour". He primarily wants to adjust his behaviour at his home. One student thinks that this is due to two factors. The first influencing factor is money, the second influencing factor is responsibility. A lower energy consumption is resulting in a lower energy bill, therefor people are more likely to pay attention at their own residence. Furthermore, responsibility is lower at the UT because it is visited by many people, it is not the user's property.

The interviewed students claim to only use their own laptop which is consuming electricity and once in a while a beamer. One student uses devices like cutting machines, which are placed in the Designlab. He adds that there is always an employee present who is responsible for the machines and therefor assumes that the devices are switched off after usage.

Both students think their energy consumption is negligible, mainly because their only power consuming device is a computer, therefor these students don't know how to change their behaviour to consume less energy.

To discover what kind of campaign would be impactful to the students the campaign regarding energy consumption described in section 2.2.2 is shown. According to the students positive aspects are that the campaign shows concrete examples of actions which could be performed, it is easy to understand, focusses on one-target group: the families and what the effects of climate change are.

However, the focus on families was also resulting in frustration because, according to the student, companies and primarily industry is consuming much more electricity, thus this campaign is not addressing the real problem.

Other negative aspects where that the quality was low, it was kind of childish and that the length of the campaign was too long. Preferred changes were that the campaign needs to be shorter, more powerful and have one goal. One student adds that he wants to be compared with other people, by having insight in his consumption in kWh.

4.2.3 Preliminary requirements and classification

The interviews with the client and the University of Twente resulted into a list of requirements. These requirements are shown in table 4.2. These requirements are categorized by the MoSCoW method. Together with the requirement it is stated whether it is a functional or a non-functional requirement.

Category	Functional (FR) / Non-Functional (NFR)
Must have	
The campaign must refer to social norms	FR
The campaign must Provide individual with pros of "good" behaviour and cons of "bad" behaviour	FR
The campaign must communicate discrepancy about the energy behaviour and the desired energy consumption to the user	NFR
The user must be provided with concrete examples of actions which can be performed to decrease energy consumption	NFR
The campaign must be easy to understand for the UT-community	NFR
The units in which the data is represented must be recognizable for the viewer	NFR
The personalized information of the energy consumption must be in the context and perception of the viewer.	NFR
Both the pros and cons of personalized behaviour must be assessed.	FR
The data must be provided relating to its context	FR
The campaign must provide correct and up to date information	FR
The campaign must assess the issue around energy consumption concise	FR
The Energy Buddy must show effects of climate change	FR
Include a type of reward or punishment for the viewer	NFR
The campaign must have one goal	NFR
Focus on raising awareness regarding energy consumption	NFR
Should have	
The campaign should communicate the gain of less energy consumption	FR
The campaign should be oriented on persuading the individual on the gain of less energy consumption	FR
The campaign should be focussed on individual behaviour change	FR
The campaign should consist of one artefact	FR
Could have	
Be applicable in multiple contexts (i.e. office's, buildings, lecture rooms, campus)	NFR
Won't have	
-	

Table 4.2 Preliminary functional and non-functional requirements

4.3 Concepts

In this section, firstly several intended products are being devised. Where after these concepts will be discussed with the clients, which will result into good aspects for each concept. The good aspects will be made vivid with a mind map, where after the personality will be created. At the end of this chapter a final concept will be portrayed.

4.3.1 Concepts creation

The brainstorm method described in section 3.2.3 has been used to come up with a wide range of interactive applicable solutions. These different ideas are visualized in figure 10.

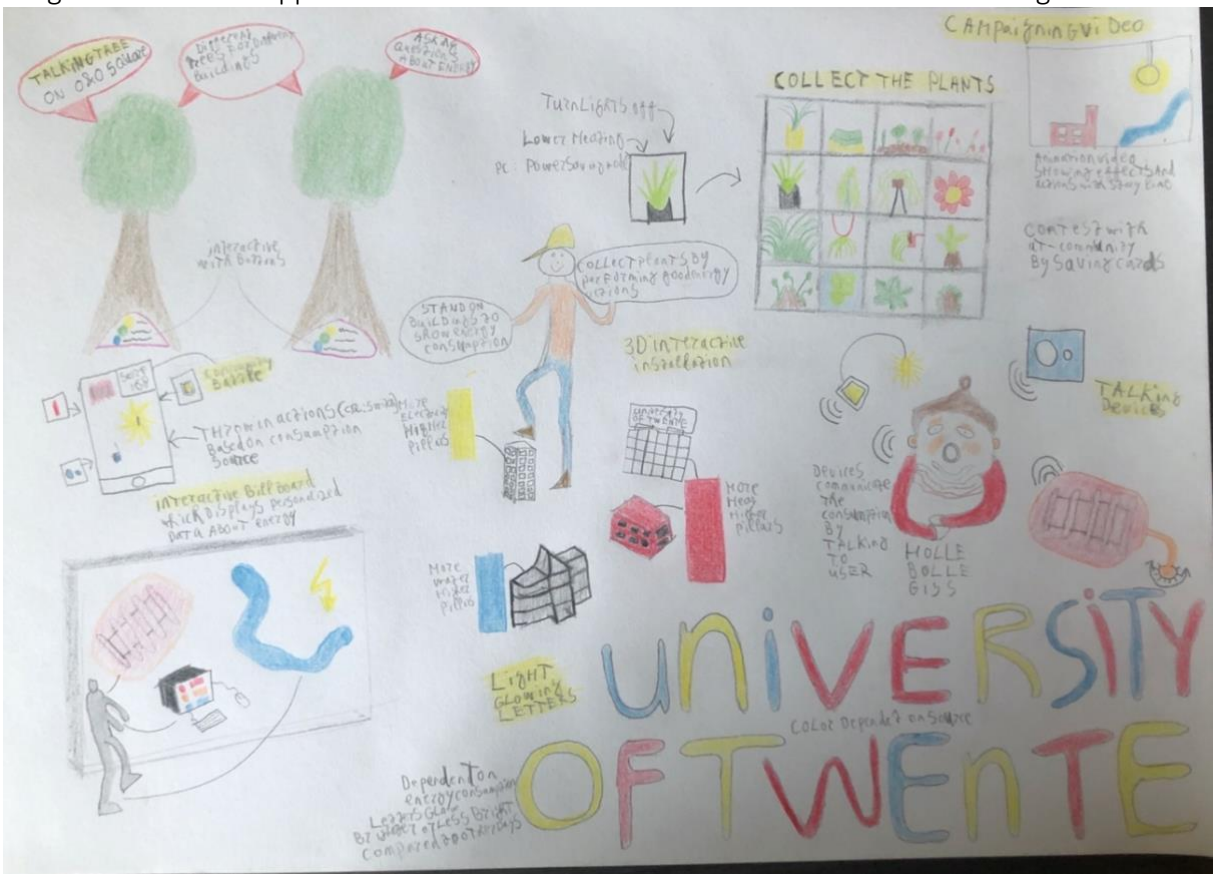


Figure 10 Idea concept sketches

The first ideated product is; two talking trees which are interacting with each other and with the user. The user interacts with buttons integrated in the tribe of the tree. According to the input, the trees start talking and discussing with each other and with the user.

A second idea was to create contest, in which you can earn plants to simulate a healthy earth. Cards can be collected by performing “good” behaviour, quizzes or inviting other members to the contest. The cards are plants which exist in nature and are intended to create a relation between nature and the user.

Thirdly an animation campaign video is possible, this animation campaign consists of a video which can be unrolled among the UT-community.

Furthermore, an interactive game can be developed, in this game the user gains insights in various forms of energy waste, for example turning lights on during daylight. In the game the player has to throw the applicable behaviour towards that wastage, for example turning the light off. The game enables the player to gain insights in their behaviour and what the desired behaviour is in a playful manner.

A related idea is an interactive installation on the UT. The installations consists of several buildings which represent the UT's buildings. By standing on a building, the user interacts with the installation. The installations shows the energy consumption of that particular building.

In the lower-right corner an interactive billboard is visualized, the billboard is in direct contact with the user and knows the consumption of the individual user. With this information the billboard shows discrepancies and relevant aspects towards the user.

An Energy Buddy is visualized in the middle-right, this device is integrated into energy consuming devices. Based on the energy consumption the Energy Buddy has an opinion about the user's energy consumption, it communicates this consumption towards the user.

The last idea is changing University of Twente letters. The letters change according to the electricity consumption of that day of a particular building or a particular user. For instance, the letters turn red when the energy consumption is high and turn green when the energy consumption is low.

4.3.2 Consultation with clients

As explained in section 3.2.3, during the second step of the brainstorm it is essential to highlight the positive aspects and combine the different creative ideas. Therefor these ideas were presented in separate interviews with the stakeholders; CFM and the UT.

CFM is most fond of the "save and collect the plants", "the game" and "Energy Buddy" [3]. CFM augmented their choice by explaining that these ideas enable the possibility of a contest between the different users. According to CFM this is necessary to realize awareness.

CFM added that it is undesirable to realize a product which is placed on a designated position. Hereby she refers to the talking tree, interactive billboard, changing UT letters and the interactive buildings.

The same ideas were also presented towards the representatives of the UT. The interactive billboard, Energy Buddy, interactive buildings, animation video and the changing University of Twente letters were most popular.

However, there are some implications regarding the changing UT letters. For example, this stand-alone object is not sufficient to make the users aware, the data represented is unfamiliar, the data presented can be vague and unclear and it is hard to personalize the data. The latter one also applies for the animation video.

The interactive billboard has the strong aspects that it is easily personalized and attracts the user's attention in a fun and interactive way. However, it is doubtable if this idea is realizable. The interactive buildings is also easily personalized, however according to the UT, a downside is that only data about buildings is being presented, and not the users' personal data.

Lastly, due to the personal approach, the energy buddy was appreciated. However, it is hard to integrate this appliance in every energy consuming device.

4.3.3 Combination of elements

The provided information from section 4.3.2 can be combined into a matrix. By combining these different ideas, it is possible to combine good aspects and increase the quality of the product.

For each interactive installation will be described on their appearance, method, placement, comparing and personalization. This is processed in table 4.3, where for each of the installation a description according to each aspect is described. The good aspects are highlighted in green. By combining these different an energy buddy seems promising, however aspects like sensing energy consumption and remembering the high scores have to be considered.

Concept Criteria	Save and collect the plants contest	Talking Tree On O&O Square	Interactive billboard	Energy Buddy	Game	Changing University of Twente letters	Interactive buildings	Animation video
Appearance	Cards of plants can be collected and these cards fit into an online collection card	A talking tree fake tree looking like a real tree with speakers and touch screen integrated.	A huge interactive billboard which displays information to the user	Interactable devices integrated in existing energy consuming products	A game for the mobile phone in which the user can throw energy aware actions to energy consuming situations	The letters of the UT change according to today's energy consumption	Small buildings which represent the UT buildings are placed together with pillars which	An animation video which can be released across the University
Method	The plants can be collected due to a raised awareness or joining online quiz questions	Users can press buttons on the tree trunk due to which information can be heard	The device senses energy consumption data and shows this to the user	By using the device, a speaker will tell a message regarding energy.	The game shows situations of wasting energy, the user has to throw as soon as possible the correct action	The energy consumption is translated to a colour's range, the letters change to the usage	The energy data of the pressed building is visualized through 3d pillars.	Showing information during the animation video towards the viewer
Placement	The plants can be saved in an online collection card	The tree can be placed on the O&O square due to which a lot the high number of visitors	The billboard can be placed on various locations throughout Enschede	The installation is embedded into many devices	The game is a mobile phone app	The existing UT letters	The installation can be placed on a busy area on the UT campus	On electronic devices owned by user
Comparing	There is the possibility to challenge each other online	When groups of people interact, the installation can compare the users	When multiple users are walking by, these users are being compared	When two times between a certain timeframe is pressed, the users can be compared	The users can compare with each other with the high score, the high score is based on correct throws	The days can be compared throughout the days and the buildings might correspond to a particular letter	The buildings can be compared by pressing two buildings at the same time	Not possible
Personalization	The collection card is connected to the card-number so the system adjust to your personal consumption	The tree can talk personalized data to the user	By collecting data, the billboard displays personalized behaviour	The current usage of energy is communicated towards the user	The user controls the game	No individual personalization, only the feeling of a community	The user decides which information is shown	-

Table 4.3 Description strong elements in different ideas

4.3.4 Vivid making

At this stage, the idea is vague and unclear, to forward the process mind mapping will be used. This is especially helpful since the intended product consists of various strong aspects which have to be combined. The mind map will have branches regarding its functionality, character type, appearance, information, connectivity, moods and aspects which are able to be integrated.

The mind map is given in figure 11 in which there are eight branches visualized. The green branch highlights the functionalities which the product might entail, which primarily consists of sensing capabilities. Below this branch the connectivity branch is situated, which expresses through which channels the device could perform. In the orange branch integrable aspects like the TTM, approaching type and psychological theories are visualized. In the blue/green branch different types of energy wastage is given. Examples of moods which the device can have are given the yellow branch. It is powerful for the device to have particular moods, resulting in a device which a user can relate to. Followed by the yellow branch is the informational branch, in which there are examples of information the device has to know/express. This information will aid the device in what information needs to be communicated towards the user. In the purple branch the appearance aspects are visualized. The last branch consists is highlighted in pink and consists of various character types.

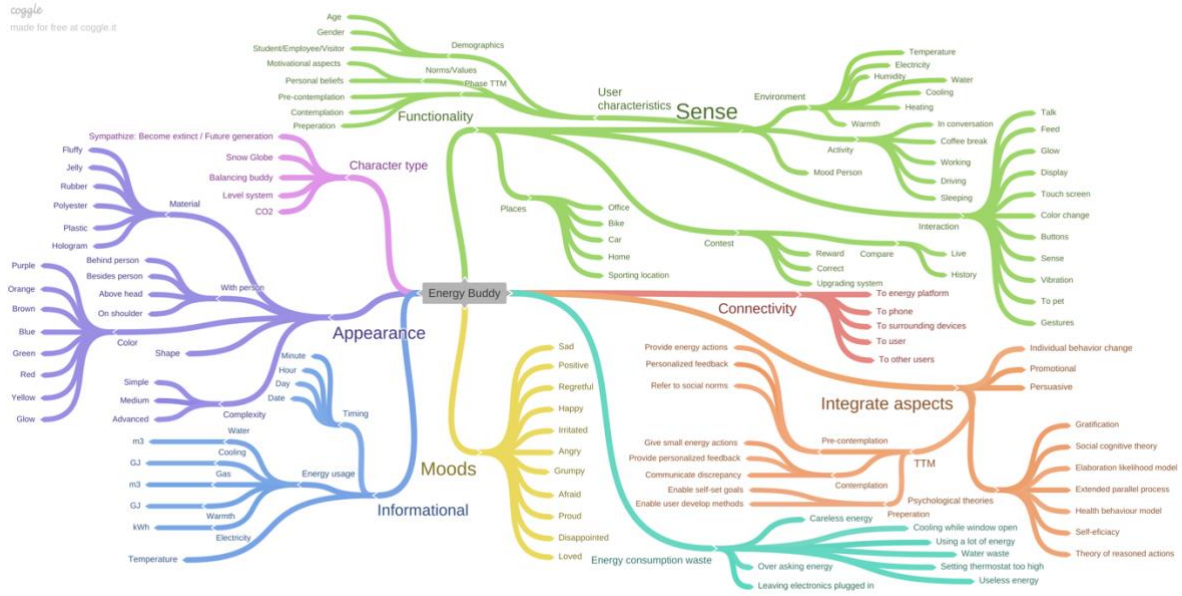


Figure 11 Visual mind map

The moods and character types are of importance because these aspects are in direct relation with the user. They both create “a personality”, which is necessary to approach the user in a personalized way. Therefore, it is key to create a system which has a personality.

4.3.5 Personality creation

The mind mapping phase resulted in some possible characters for the product. These character types are different on their idea, executional methods and interaction with the user. These aspects influence the personality of the system, the personality is of importance because it will be the foundation for communication. To get a better idea of what each character contents, these different characters are described shortly in this section.

The balancing energy

The balancing energy is a device around the user which is bilateral. He continuously flips from one side to the other, this can be positive vs negative but also aware vs unaware. Due to this (dis)-ability users feel for him but it is also very hard to satisfy the device. Inside the device a light strip is embedded, this light strip indicates on which side the current mood is.

The energy level

The energy level is an avatar which can level-up trough different phases. Each phase corresponds with a different attitude or behaviour regarding energy consumption. The avatar can have different types of appearance. The user sympathizes with his personal avatar and therefor wants to upgrade his avatar.

The snow globe

A snow globe, can be developed as wearable like an earring or bracelet. Inside this snow globe different forms are present, for example a small fire, a water stream and an energy bulb. Each object corresponds with an energy type and is influenced by its energy consumption.

The CO_2 Cloud

This cloud respondents the CO_2 emission of an individual. This cloud is hovering above the person and consists of the five different energy types. These energy types are represented in the cloud by areas, these areas are bouncing into each other, change in magnitude and size, this gives the cloud a dynamic appearance. Interacts with the user by dropping different kinds of particles onto the person.

Fearing the future or helping the children

The last idea is to realize an avatar which envisions a possible futuristic scenario in relation with future generations. This is done by creating an avatar consisting of a dinosaur, this dinosaur displays the possible effect of not changing behaviour: extinction. The child corresponds to the future generations which we influence and maybe even won't have.

These five different energy buddies have different appearances, these are given in appendix B.1. These where presented and discussed with Kasia Zalewska and Richard Bults. During the discussion aspects like interaction, possibilities, appearance and feasibility were assessed. According to them, the energy levels has the highest chance of success towards the UT-community. Mainly because the personality is related to the user's consumption and the user can sympathize with the character. The energy level will be the personality of the energy buddy.

4.3.6 Final concept

The Energy Buddy accompanies the user and monitors the energy consumption. According to the energy consumption the Energy Buddy communicates towards the user. The Energy Buddy needs to be designed in such a way that the user sympathizes with the Energy Buddy.

To enable the user to sympathize with the Energy Buddy the Energy Buddy needs to have some familiar capabilities, such as vibrating, gestures, signs, glowing, making sounds and different moods. By doing this, the user can relate with the Energy Buddy. By combining these capabilities, the Energy Buddy can communicate towards the user in various interaction types. Besides these interaction methods, the Energy Buddy also checks the users consumption over a certain time frame.

The moods are coherent with the user's energy consumption to indicate directly the current consumption towards the user. The moods enable the Energy Buddy to have different emotional states, and thus implicitly express an opinion about the consumption. The different emotional states are ordered consecutively. With the aid of various iterations, the four different moods are, in consecutively order: neutral, aware, annoyed and frustrated. Two examples of different emotions are visible in figure 14.

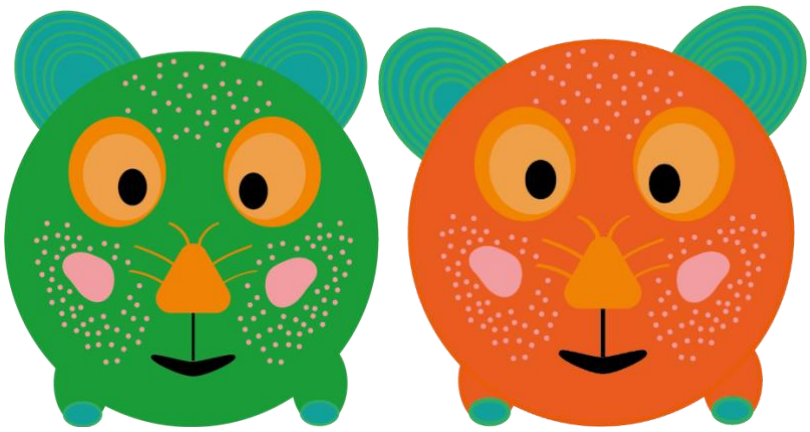


Figure 12 Two different moods of the Energy Buddy

Furthermore, the Energy Buddy vibrates when the emotional state is changing. By vibrating the user's attention is gently assessed. The gestures indicate what actions the user should perform, for instance switching of devices. The signs of the Energy Buddy will provide the personalized information regarding energy consumption. Furthermore, it enables the possibility to guide the user through the stages of the TTM.

Lastly, when the Energy Buddy detects a sudden increase or decrease in energy consumption, it will act proportionally. When the Energy detects an increase in energy consumption, a negative reaction is triggered by glowing to confront the user. The Energy Buddy will reward the user with a positive reaction when there is a decrease in electricity consumption. The Energy Buddy will use sounds to amplify the previous mentioned actions. For example, when the user switches off a device, the Energy Buddy might applause.

The Energy Buddy detects the energy consumption of the user with an energy meter. The device is places between the outlet socket and the appliances. The energy meter contentiously monitors the energy consumption and provides this towards the system Energy Buddy. Hereafter the Energy Buddy will be abbreviated to EB.

5 Specification

The final concept, created in chapter 4 and clearly described in section 4.3.6, is at this stage not yet realizable. In this chapter the final concept will be further specified. Firstly, by specifying the functional requirements, where after the EB is being personalized. With the aid of scenario-based design and storyboards the non-functional requirements will be developed. In the end of this chapter, the functional architecture and flow-chart of the system will be displayed. Which, all together, will result in a realizable product.

5.1 Personalization data

In this section functional requirements will be developed. To achieve this, firstly one energy data element will be chosen. Where after the energy consumption per building will be discussed, together with the energy consumption per time-frame. With the aid of the provided occupancy on the UT, it is possible to personalize the energy consumption and derive the functional requirements.

5.1.1 Choosing energy data elements

As described earlier, there are 5 types of energy consumption; gas, water, electricity, heat and cooling. Integrating each aspect will make the final-prototype complicated and extensive, those two aspects aren't beneficial for the feasibility and ease of use, therefor it is necessary to include a limited amount of energy consumption types.

The UT provides a dashboard which provides the gas, water, electricity, heat and water consumption [43]. By using the data provided by the UT, the CO_2 emission per energy element is calculated.

Firstly, for each energy type, the emission per quantity will be presented, this emission will be multiplied with the amount of consumption on the UT. The following formula is used to calculate the emission in kg CO_2.

$$CO_2 = Emission * Amount$$

The heat is created from a biomass central and the electricity is grey [4]. Therefor the applicable emission quantities have been applied to these elements. The CO_2 emission is presented in table 5.1. In appendix B.2 the data about the CO_2 emission per energy consumption type is graphically given. In both the appendix as in table 5.1 is clearly visible that electricity contributes to the vast majority of the UT's CO_2 emission. Therefore, the product will focus on the electricity consumption.

Element	Unit	Emission	Amount [43]	CO_2 emission In kg
Water	$1m^3$	0,298[44],	40.938	12.196
Gas	$1m^3$	1,89[45].	341.367	645.091
Heat	1GJ	25,8 kg[45],	31.801	820.130
Cooling	1GJ	23,3 [45],	26.757	623.275
Electricity	1kWh	0,649[46]	14.037.777	9.106.440.933

Table 5.1 Consumption and CO_2 emission per energy element of the UT

5.1.2 Electricity consumption on the UT

In figure 13 the total electricity consumption per building is visualized. This data is provided by the UT through the energy dashboard [43]. The buildings which use approximately 1% of the total electricity consumption are left out of scope in the figure. It is visible that the Carré, Horst and Nanolab buildings contribute to 67% of the total electricity consumption. In these buildings laboratory are present and education is given. In the Zilverling and Cubicus aren't any laboratory and solely education is given. These buildings use 3% or 2% of the total electricity consumption. The substantial difference in electricity consumption can be assigned to laboratory usage, this is confirmed by Henk Hobbelink. [4].

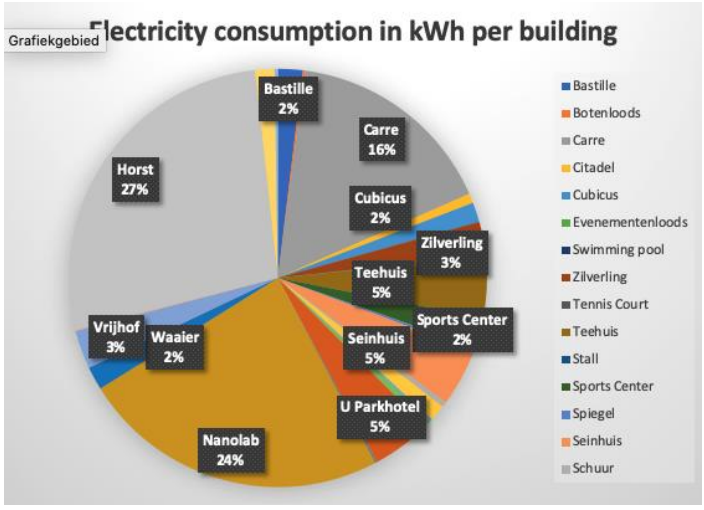


Figure 13 Electricity consumption per building

5.1.3 Electricity consumption per day

The UT's energy data dashboard provides the consumed energy per type and building, but also per time-frame [43]. This enables the possibility to abstract the data per minute, hour, day, month and year. In figure 14 the consumed electricity during one week is visible.

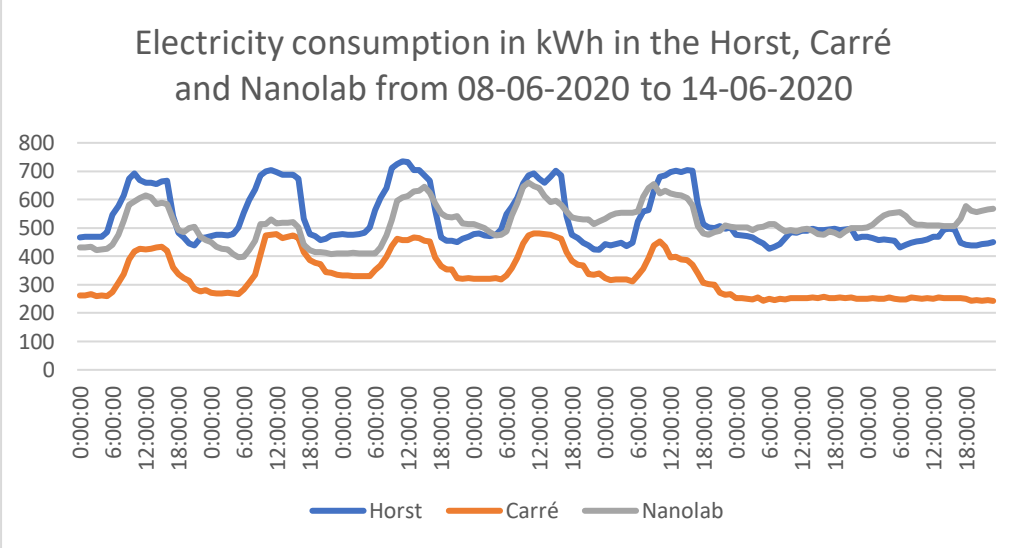


Figure 14 Electricity consumption during one week

The Horst, Carré and Nanolab have the same electricity consumption pattern over the week. In a conversation with Richard Bults it has been decided to continue with the electricity consumption of the Horst. By continuing with one building is easier to assign information to the EB. This doesn't influence the outcome of this project. Furthermore, by focussing on one building it still is possible to adjust the EB for the other buildings as well.

Generally, the higher electricity request starts rising from 07:00 and after 17:00 the request for electricity slowly drops. According to Henk Hobbelink the increase at 07:00 and decrease at 17:00 is due to the employees and students arriving at the UT [4]. According to Hobbelink this extra electricity consumption can be designated to the user's consumption.

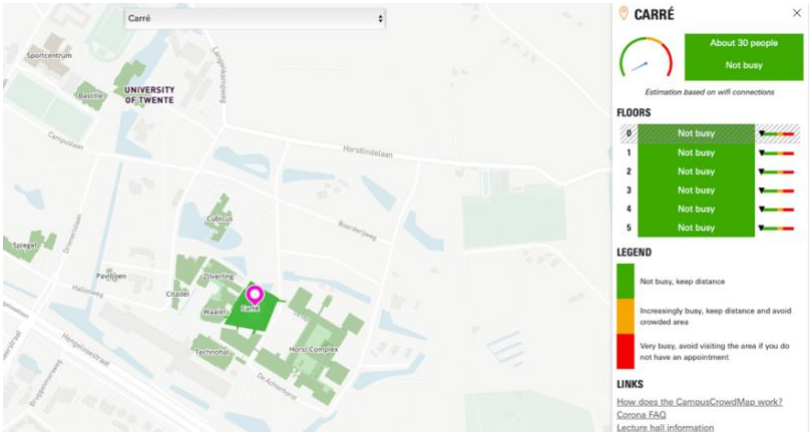
The user's consumption is thus the difference between 07:00-17:00 and 17:00-07:00. In table 5.2 the average kWh consumption of the Horst is given between 07:00-17:00 and between 17:00-07:00. This data is collected from 08-06-2020 up to 14-06-2020, and is representable for a normal working week. With the aid of a formula in appendix C.2 the user's consumption is calculated to be 188 kWh.

	Horst
07:00-17:00	669
17:00-07:00	481

Table 5.2 Consumption per building during different timeframes

5.1.4 Personalization electricity consumption

The UT launched the campuscrowdmap to provide the users of the UT information about the occupancy in buildings. In this map the crowdedness per buildings is visible. In figure 15 the layout of this website is visible[47]. The map displays all the different buildings on the UT. By clicking on a building, the buildings information is shown on the right. In this case, there are 30 people in the Carré. Furthermore, the occupancy per floor is given, in this case all the different floors are not busy[48].



Occupancy per building	Horst
10:23	686
12:05	727
13:56	699
15:37	500
Average	653

Table 5.3 Occupancy per building on 09-10-2020

Figure 15 Example of occupancy in the Carré

By collecting the data at various times about the building's occupancy on 09-10-2020 the number of visitors were gathered. The campuscrowdmap doesn't store any historical data, thus there isn't any data available from before the first lockdown. On 09-10-2020, there weren't any restrictions, the buildings was open for usage and the education was limited. Therefor the occupancy on 09-10-2020 was average during the COVID-19 outbreak. In table 5.3 the number of present persons is indicated, at the end, the average occupancy is given.

The average occupancy of the Horst is 653 people. this substitutes to a personal consumption of 346 Watt. With a CO_2 consumption of 0,649 kg CO_2 per watt this results to 0,23 kg CO_2 per user, per day. These calculated values will be us in the envisioned product. The calculations can be found in appendix C.3.

5.1.5 Functional requirements

The data provided in the previous sections gave insights in the energy consumption of the UT community. This enables the possibility to shift the functional preliminary requirements to functional requirements. The functional requirements are given in table 5.4. These requirements not only help to specify the design, but are also being used in the evaluation phase to evaluate the final prototype.

Category
Must have
The EB must be able to provide text messages to the user
The EB must communicate the user's electricity consumption to the user
The EB must show the average electricity consumption of the Horst
The EB must show the consequence of electricity consumption on climate change
The EB must show the gain of a reduced electricity consumption
The EB must ask the user to perform electricity saving actions
The users measured electricity consumption must be live.
The EB must be able to play sounds
The EB must notify the user when there is an increase or decrease in electricity consumption
The EB must emphasize increases or decreases of electricity consumption with the aid of sound
The EB must have different emotions which the user can relate with
The EB's emotions must be in conjunction with the electricity consumption
The EB must notify the user when the emotion of the EB changes
The information shown must be correct
The EB must visually emphasize a decrease or increase in electricity consumption
Should have
The EB should consist of one artefact
Could have
The EB could be portable to be used in different settings
Won't have

Table 5.4 Functional requirements

5.2 Personalization EB

As discussed in section 4.3.6, the emotion will interact with a couple of interaction methods. In this section, these interaction methods will be further specified. To achieve this, firstly the visual expression of the EB will be discussed, where after the audio expression will be treated.

5.2.1 Personalization visual appearance EB

Emotions

To enable the user to sympathize with the EB, the EB needs to have different emotional expressions, these are consistent to the user's electricity consumption. The emotions are constructed in such a way that they are recognizable to the user.

For a low electricity consumption, a neutral emotion has been developed. The emotion will seem neutral and have a blue colour. When the electricity consumption is adequate, the emotion will be aware. The aware emotion is yellow and visualized in an aware emotional expression. When the electricity consumption is excessive, the emotion will be annoyed. Therefor the emotion will seem annoyed, with an orange colour. When the electricity consumption is excessive for a dedicated amount of time, the frustrated emotion will appear, this emotion will seem frustrated with a red colour. When there is a decrease in electricity consumption, a positive emotion will be visible. This emotion will seem positive and have green colour. When there is an increase in electricity consumption, a glowing EB will be visible to confront the user. The four different emotions, the positive reaction and negative reaction are visualized in figure 16.

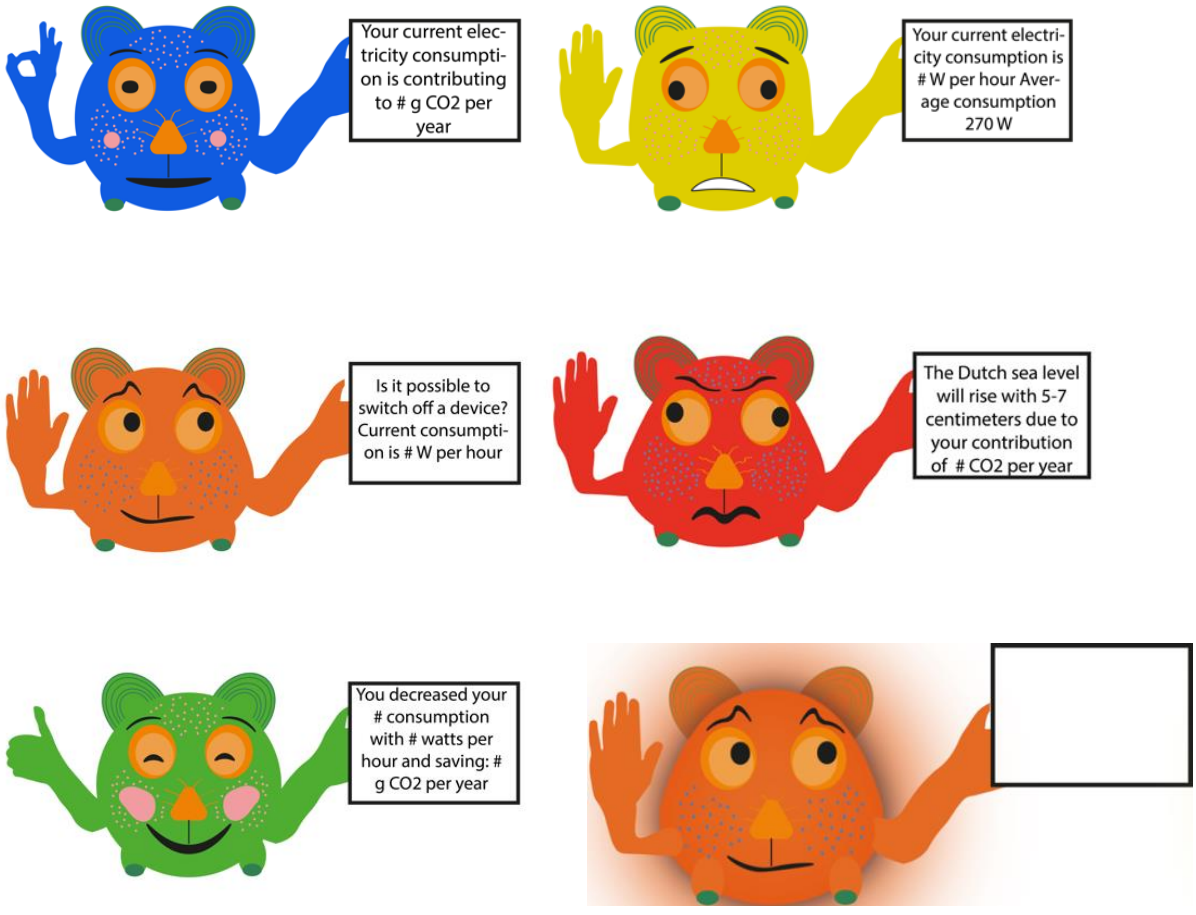


Figure 16 Different emotions Energy Buddy

Textural messages

The EB has four different emotions; neutral, aware, annoyed and frustrate. When the annoyed EB is annoyed for over a certain time frame, the EB gets frustrated. To indicate to the user how long the EB is frustrated, the emotion is split into frustrated 1, frustrated 2 and frustrated 3. Together with a positive reaction and negative reaction this results in eight different emotional expressions in which the EB should display a different text on the sign.

For each of the different emotional expressions a text has been developed, these are given in table 5.5. During the development of these texts, the requirements were taken into account. A "#" in the text of table 5.5, means that this is a variable which changes along with the usage and represent either a wattage or grams in CO_2 emission.

Negative	You increased your electricity consumption with # W per hour and contributing: # g CO_2 per year
Positive	You decreased your # consumption with # watts per hour and saving: # g CO_2 per year
Neutral	Your current electricity consumption is contributing to # g CO_2 per year
Aware	Your current electricity consumption is # W per hour Average consumption 270 W
Annoyed	Is it possible to switch off a device? Current consumption is # W per hour
Frustrated 1	Your current consumption is equivalent to # phone's charging
Frustrated 2	Ice caps are melting due to your contribution of # W per hour
Frustrated 3	The Dutch sea level will rise with 5-7 centimetres partly by your contribution of # CO_2 per year

Table 5.5 Text on signs

In appendix B.3 the wattage per hour for three typical household appliances is given. For example, a phone charger uses 8,5 watt per hour, when 100 watts is consumed the EB's text displays 12 phones. This translation from abstract data to recognizable data is used with for the text of frustrated 1.

Gestures

To highlight the opinion of the EB about the user's electricity consumption, the EB will have gestures. The gestures highlight the opinion of the EB in an unobtrusively manner. Three unambiguous gestures have been developed, the thumbs-up gesture, the "Pico bello" gesture and lastly the hold gesture. These three gestures have an unambiguous interpretation. A graphical representation of each of these gestures is given in figure 17.

Figure 17 Gestures Energy Buddy

The different gestures, textural signs, the glowing, positive reaction and emotions have been clarified. However, these are solely developed and are not yet in relation with each other. To clarify how the different emotions relate with each other, the EB's mood flow has been developed, visible in figure 18.

To ensure a smooth transition from one emotion to another emotion, several in-between emotions have been developed. These are situated between the previously described emotions which will act as states.

In the middle column the emotional states are consecutively ordered from neutral (blue), to aware (yellow), to annoyed (orange) and in the end to frustrated (red). The states neutral, aware and annoyed are depended on the electricity consumption. The frustrated state is depended on the time.

For each of these states it is possible to decay or progress to the adjacent state.

When there is a substantial decrease in electricity consumption, the EB will be positive, where after the EB will jump to the appropriate state. When there is a substantial increase in electricity consumption, the EB will start to glow, where after it will jump to the appropriate state.

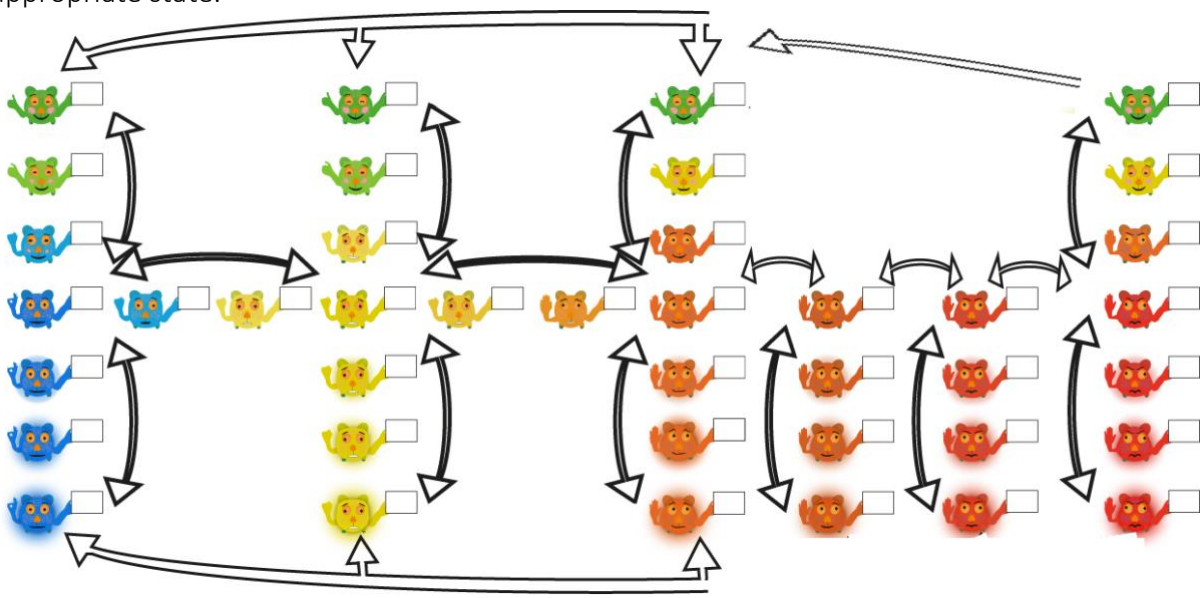


Figure 18 Energy Buddy's mood flow

5.2.2 Personalization audible effects EB

The EB needs to be able to play different sounds, these sounds are being played when there is a decrease or increase in electricity consumption. Therefor the sounds need to be both positive as negative. The positive sounds are: cheering, applause and a "winning" sound. For the negative sound effects; a whistle, horn and siren have been chosen. Each of these sounds have an unambiguously interpretation.

5.3 Scenario-based design

Scenario-based helps to get a better picture of how the user will interact with the EB. In the scenario fictional personas interact in typical usage situations with the EB. A scenario for a student has been made in which the student is studying in her dormitory. The scenario for an employee has been made who is working at his office.

The employees have a substantial influence on the electricity consumption and the number of students studying at the UT is high. While the electricity consumption of visitors and number of visitors is minimal [49], in combination with time-limiting factors a scenario for the visitor has not been made.

The two scenarios, each consist of three different sections. In the first section of the scenario the persona will be described. Herein the motivation of the persona is explained. Furthermore, in the scenario of the employee, the essence of the EB is being explained.

In the second section the actions of the user are described and how the EB responds to this. This creates a situation, in which for each possible action which the user can perform, the interaction of the EB is described.

In the last section a storyboard is visible, herein the numbers correspond with the numbers given in the scenario. In the storyboard the actions of the users are visualized together with the EB's interaction method. In figure 19 is the storyboard for the student given and in figure 20 the storyboard for the employee is given.

5.3.1 Energy Buddy Scenario – A day in the life of a UT-student

Persona

Julia is a 21 old female student who studies industrial design at the UT. She is currently in her final year of her bachelor. The majority of her lectures take place in the Horst building; however, it is hard for her to concentrate with a lot of people sitting close to her or walking behind her back. Therefor Julia studies at her dormitory on campus as much as possible.

At the end of the ergonomics lecture, Julia had a conversation with her lecturer about the UT's community electricity consumption. During that conversation Julia realized she is not aware of her influence on the UT's electricity consumption, neither in the lecture halls of the UT or her own dormitory. Julia knows that using electric electricity could have effects on climate change and is even worried about these effects. However, she never realized that her own behaviour could have impact on the climate change.

During the conversation with the ergonomics lecturer, he convinced her to try the new EB. The EB helps a UT community member to become aware of his/her electricity usage.

Julia is excited since she is curious about her electricity consumption, therefor she decided to use the EB that same evening. She borrows an EB at the service desk of the Vrijhof, which has a couple of EB's for the people whom are interested.

After a long lecture day, Julia is happy she can go home. The next day she has an exam which she really wants to pass, thus she decided to take a quick microwave meal and study the whole evening. When she walks outside the Horst the weather is boisterous and it drizzles. Along her journey towards her dormitory the drizzle turns into heavy rain, she arrives soaking wet at her dormitory. Julia parks her bike and walks inside the stairwell of her students complex, where she plugs the EB in the wall socket.

Scenario

1. Julia switches on the lights, where after the EB makes a sound and glows to indicate the increased electricity usage. The EB's state is neutral since the consumption is under four watts per hour. On the sign the CO2 contribution is visible and the gesture shows a "Pico bello" sign since the current consumption is very low.
2. Julia wants to start studying fast , thus she switches on her computer, hereafter the EB glows to indicate the increased electricity consumption and makes a negative sound to notify Julia. Since the electricity usage is increased significantly, the state becomes aware and the amount of consumed electricity on the sign adjusts. The sign indicates the current electricity consumption, together with Julia's average consumption.
3. She grasps a microwave meal and starts preparing this in the microwave. The EB again notifies Julia of her increased electricity consumption by glowing and making a sound. The emotional state changes from aware to annoyed accompanied with a vibration, the sign asks whether it is possible to switch of a device, the gesture shows a hold sign indicating to switch of a device.
4. Julia continues studying behind her desk while the meal is warming up inside the microwave. The EB remains annoyed during this time because the time-span to enter the frustrated state isn't reached yet. On the sign the EB asks whether it is possible to switch off a device, however for Julia this is not possible since she needs the computer to study and the meal isn't prepared yet.
5. After a while the meal is ready and the microwave turns off. The EB enters the cheerful state for a moment with a thumbs up gesture, a positive sound and the sign indicate the decreased electricity consumption and the amount of saved CO_2.
6. After Julia fetched her meal from the microwave Julia puts in the socket of her electric heater to warm her room. The EB glows and vibrates to indicate the increased electricity consumption. The EB enters the annoyed state again since the electricity consumption is high. The gesture assigns the hold gesture and the sign asks whether devices could be switched off. For Julia this is not an option since it is cold, and she wants to have a warm room to study in.
7. After one hour the heater increased the temperature in her room, however Julia still hasn't switched off the heater. The EB vibrates and changes to the frustrated state, hereby the sign communicates to Julia effects of electricity consumption on climate change.
8. Julia startles from this and switches off the electric heater. The emotional state of the EB is changing from frustrated to cheerful for a while. The sign indicates the amount of saved CO_2, decrease in electricity consumption, the gesture has the thumbs up and a positive sound is being played.
9. Slowly the EB state changes towards aware to indicate that Julia still uses electricity. On the sign Julia's current electricity consumption is visible together with her average consumption. While the EB remains in the aware state, Julia continues studying dedicated on her subject.
10. At the end of the evening she switches off her computer and lights which will result in a cheerful EB. The EB makes a positive sound, shows a thumbs-up gesture and assigns the saved CO_2 consumption together with her electricity consumption. Julia is convinced of the EB's purpose since the it reminded her to switch of her electric heater and notified her when she started to use electricity.

Storyboard

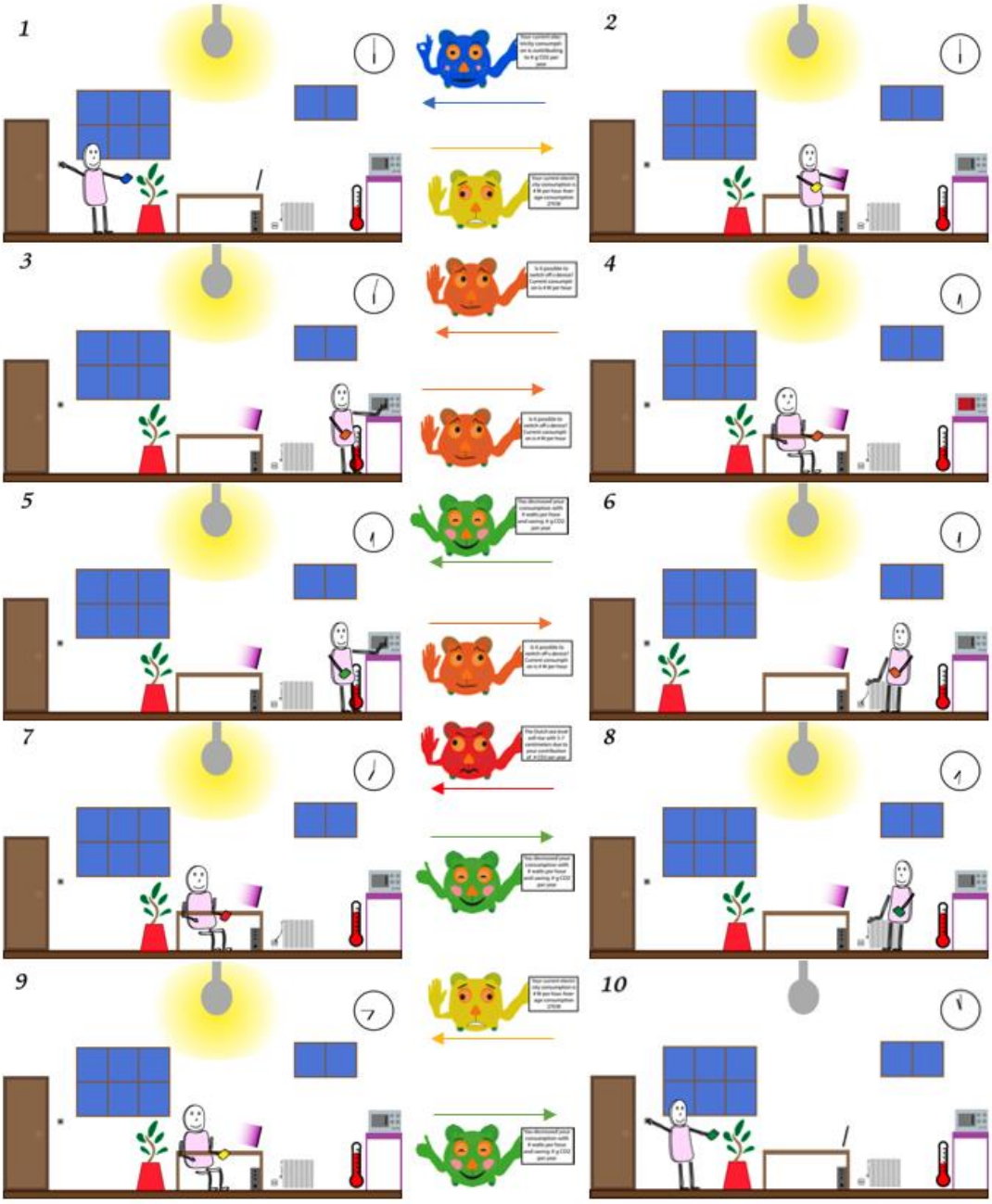


Figure 19 Storyboard UT student

5.3.2 Energy Buddy Scenario – A day in the life of an UT-employee

Persona

John is a 45-year-old male lecturer and researcher statistics at the University of Twente, he educates two days a week and researches three days a week. Each day he is biking from his home, which is in Enschede, towards the UT. He is biking because this is equally fast as a car, is good for his health and John knows that biking is better for the environment than driving. John is a smart person who pays attention to his lifestyle in relation with his influence on the environment. He eats vegetarian once in a while, has solar panels on his roof, limits his car usage and teaches his children to pay attention to the climate. He knows that it is inevitable to consume electricity, water and gas in this century.

Each day John arrives at 8 am in the morning, he parks his bike in the designated bicycle parking place in front of the Horst. He continuous his journey along the coffee machine in the hallway, the lights are on everywhere while there is almost no one present. When John nears his office, he walks past a laboratory machine which makes a low-monotonous sound. John even doesn't notice the device making the sound because the device is always running. John enters his office and switches on his computer. Throughout the day he uses many appliances inconsiderately, the lights, his computer, the printer, the coffee machine and also his phone, which he quickly charged before he cycles back home in the end of the afternoon. When John gathers his material at the end of the day he switches off his computer and walks out of his office without switching off the lights.

While he gets his bike the street lights on the campus are switched on. Since it is the early evening twilight John thinks by himself that this could have been postponed with 10 minutes, "that would've saved some electricity" he thinks. On his way back to his house John starts wondering about his electricity consumption at the UT. "Day in day out I carelessly use all kinds of devices without paying attention. 50% of these devices I even do not turn off, these devices are just running 24/7. At home I try to consume as least as electricity as possible, however when I'm at work there is no single thought that I should do something."

When John arrives at home he sees the solar panels on his roof and realizes that he is aware of his footprint in his home while he is not aware of his electricity consumption at his work. He decides that he also wants to be aware of his electricity consumption on the University. Therefor he picks up an EB at the Vrijhof, the Vrijhof has some EB's available for the community of the UT. The UT provides these EB's to make the UT-community aware of their electricity consumption

> The Energy Buddy is a small rectangular device with a speaker and screen integrated, the device has three sockets of which the electricity consumption is measured. On the screen the Energy Buddy is shown, the Energy Buddy has four different emotional states. The emotional states are neutral, aware, annoyed and frustrated. Each applicable state corresponds with a predefined electricity consumption range, for example a consumption of 0-4 Watt per hour results in the neutral state. Next, it emphasizes differences in states with vibrations, discourages extra electricity consumption by glowing and a sound. The Energy Buddy stimulates less electricity consumption with a positive reaction and a sound. Depended on the electricity usage the Energy Buddy shows signs with texts, for example the gains in CO2 consumption, the extra electricity consumption and facts about electricity consumption in relation with the actual consumption. When a user consumes excessive amounts of electricity for a longer time period the Energy Buddy responds proportionally. Finally, the Energy Buddy shows gestures to indicate desired actions. The UT-community member plugs-in the devices he/she uses and depended on the consumption the Energy Buddy interacts with the aid of a vibration, sound, emotion, signs or glowing.

Scenario

1. The next day the EB is present at John's office on the UT. John enters his office; the lights are off because the sun is shining brightly. Meanwhile the EB is neutral since there isn't any electricity consumption and this is the beginning state of the EB. On the sign the current influence on the CO_2 emission is visible. The gesture indicates "Pico bello", since there isn't electricity consumption.
2. When John switches on his computer the EB beeps to alert John of his action. The EB starts glowing, vibrating and changes its emotional state. The emotional state shifts from neutral to aware since there is electricity consumption. The EB glows since the electricity consumption is raised, it starts vibrating because the EB changes its emotional state. On the sign which the EB holds the current electricity consumption is given in relation with John's average electricity consumption. The gesture changes from "Pico bello" to a hold gesture indicating to stop consuming more electricity.
3. After a while John switches on the lights in the ceiling even though it is sunny outside. The EB makes a negative sound to alert John of his action. The EB vibrates to indicate that the emotional state has changed to annoyed and glows to alert John of his increased electricity consumption. The gesture remains the shape of a hold gesture which indicates that the John has to switch off devices. On the sign the EB asks whether it is possible to switch off a device.
4. For John switching off a device is not ideal at that particular moment, for the examination of his paperwork he needs to have extra lighting. While the annoyed state of the EB is active, a colleague of John is entering the office for a small work meeting. John and his colleague keep discussing about this relevant topic.
5. Both John and his colleague are interested in the subject, thus the time is going rapidly and after 15 minutes since the annoyed state was entered, the EB gets frustrated. The EB alerts John and his colleague with a vibration, accompanied with the vibration the sign indicates the raise of the Dutch sea level partly by the effects of electricity consumption.
6. John and his colleague are triggered by the EB and John switches off the lighting. The EB enters the cheerful state for a moment, the EB plays a positive sound, shows a thumbs up gesture and on the sign the saved electricity consumption and saved CO_2 contribution are visible.
7. For the colleague this is good moment to continue working at her own office. After one minute the emotional state becomes aware again since John still consumes electricity. The EB changes the text on the signs, showing John's current electricity consumption.
8. When John is leaving his office to go to home, he switches off the computer and the EB gives a positive emotion towards John. A positive sound is being played, the gesture shows the thumbs-up and the sign shows the decreased electricity consumption together with the amount of saved CO_2.

   John is enthusiastic about the EB and decides to use the EB every day. Slowly he bonds with the EB and listens to him quicker and quicker. Since the EB alerts every time John starts using a device, John's gets aware of his electricity consuming devices.

Storyboard

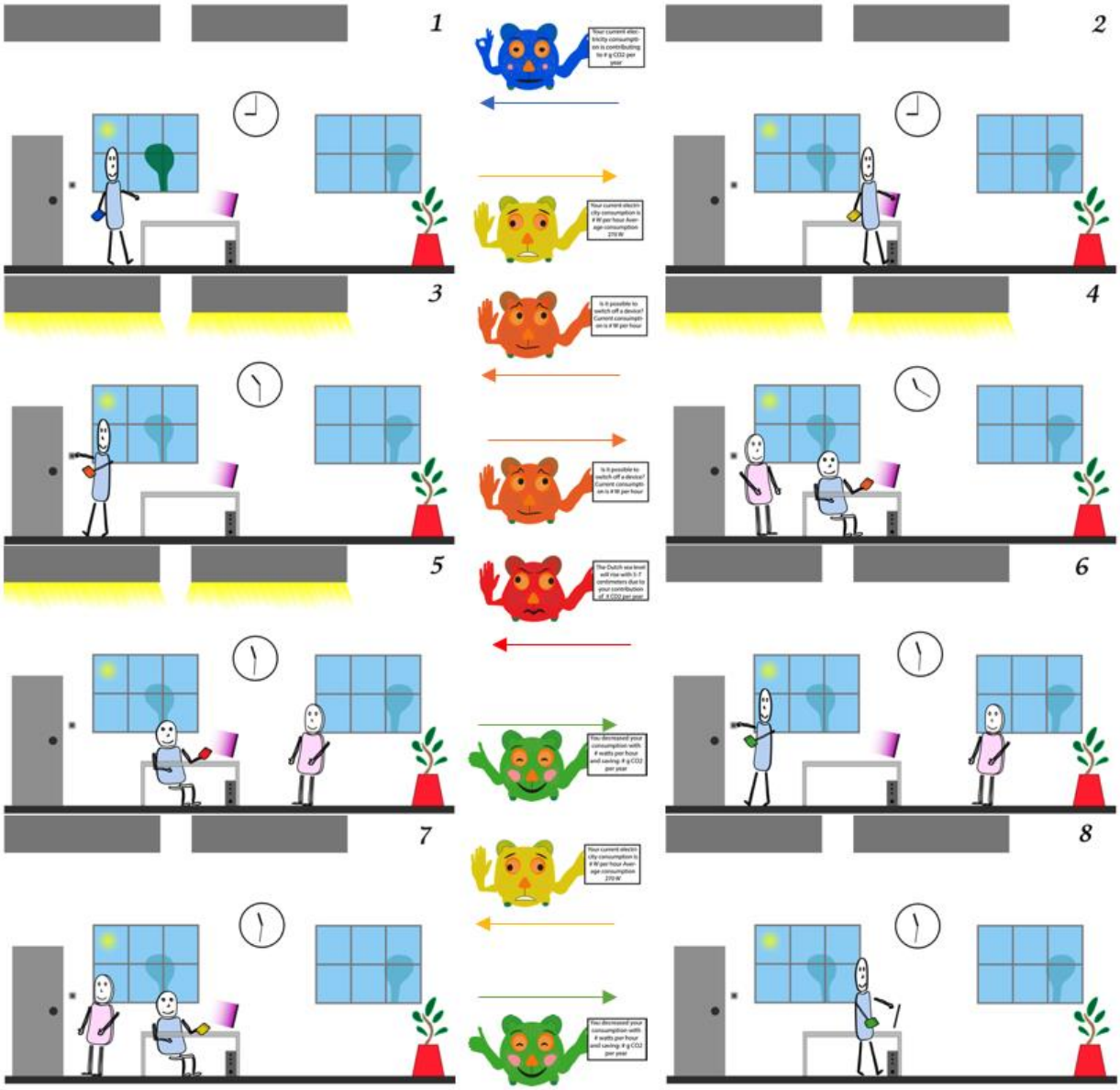


Figure 20 Storyboard UT employee

5.3.3 Non-functional requirements

The scenario-based design results in non-functional requirements which the EB has to achieve. These non-functional requirements are visualised in table 5.7. The non-functional requirements are, as stated earlier, ordered by the MoSCoW method. In the evaluation phase the non-functional requirements will be evaluated whether these are met. In order to judge them individually the requirements are numbered.

Number	Category
	Must have
1	The visual communication of the EB must be recognized by the user
2	The EB must show electricity consumption in the context of the user
3	The function of the EB must be Implemented efficient
4	The functions of the EB must be implemented concise
5	The EB must be appealing
6	The EB must raise awareness for electricity consumption
7	The EB must have one goal
	Should have
8	The EB should communicate in terms of gain rather than losses
9	The EB should reward the user for “good” electricity behaviour
10	The EB should indicate “bad” electricity behaviour towards the user
11	The EB should be convincing rather than descriptive
12	The EB should be focussed on individual behaviour change
13	The EB should raise the sense of responsibility regarding electricity consumption
	Could have
	-
	Won’t have
14	Evoke the impression that electricity consumption isn’t allowed

Table 5.6 Non-functional requirements

5.4 Architecture

In this section, firstly the system's architecture will be explained. In the architecture part the elements of the EB will be visualized and how these relate with other elements. Secondly, with the aid of a flow-chart the working method of the EB will be explained. The goal of this section to get a systematic overview of the systems functioning.

5.4.1 Architectural diagram

Firstly level 0 is described, when level 0 is decomposed into lower level, level 1 is created. Level 1 consists of 4 different sub-systems which individually will be explained. In figure 21 the architectural overview of the EB in relation with the user visualized. This is the most abstract level of the system, it only portrays the main function and their relations to another., In this abstraction level the input is clearly defined, together with the output.

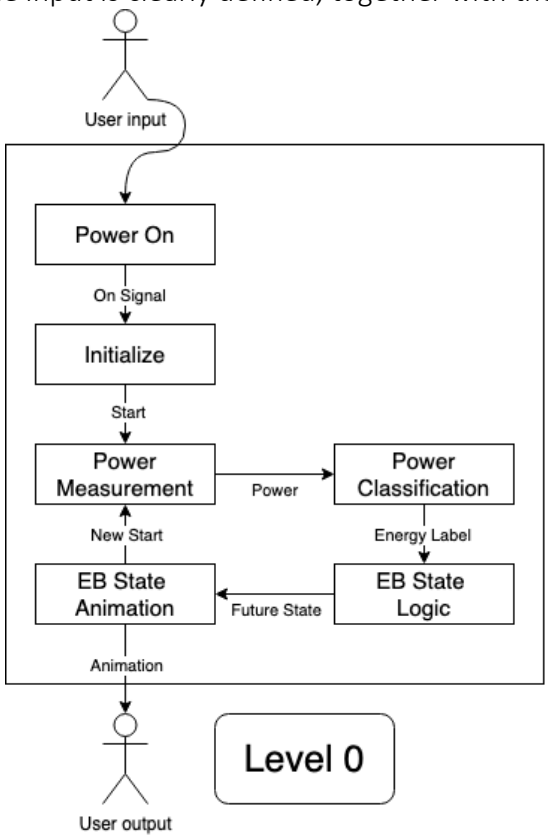


Figure 21 Architectural diagram Level0: Energy Buddy

The input for the EB is turning on the device, after the device is started up, the EB starts acting. There are four functions which are: "Power Measurement", "Power Classification", "EB State Logic and "EB State Animation". Inside the Power Measurement function the EB triggers the user's current electricity consumption. The Power will be passed through towards the Power Classification. Depended on the Power, the Power Classification, classifies the Power. The Power Classification forwards the appropriate Energy Label towards the EB State Logic. The EB State Logic processes the Energy Label, and forwards the appropriate Future State. The Future State is the input for the EB State Animation, which will Animate the corresponding animation towards the user and trigger a new loop. Each of these different functions can be decomposed into more specific functions. By decomposing the different functions, a lower abstraction level is achieved.

Level 1A: Power Measurement

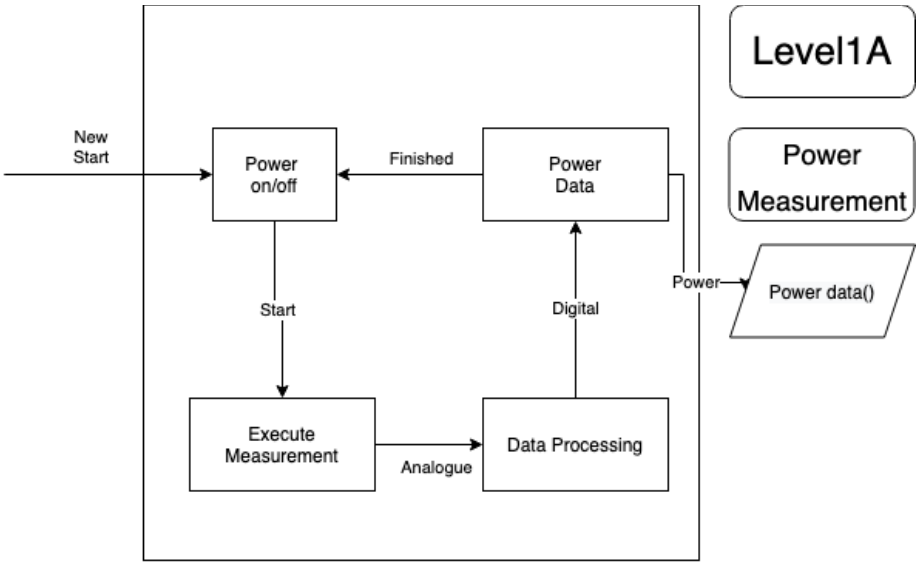


Figure 22 Architectural diagram Level1A: Power Measurement

In figure 22, the Power Measurement function starts with an Execute Measurement function. The Analogue data is derived and passed through to the Data Processing function, the Data Processing function processes the Analogue into Digital. The Digital format is thereafter passed to the Power Data function. The Power Data Function receives the Digital and ensures that it is send to the Power Data function.

Level 1B: Power Classification

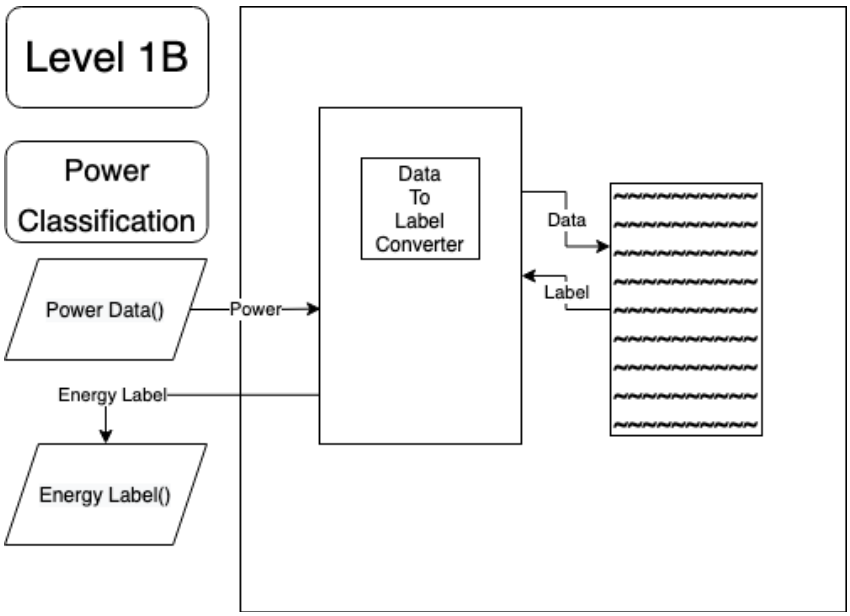


Figure 23 Architectural diagram Level1B: Power Classification

The Power Classification function receives the Power from the Power Measurement function, this is visible in figure 23. Depended in on the Power, the Power Classification classifies the Power into an Energy Label. The Data To Label Converter inside the Power Classification converts the Power into Data. Thereafter, the Data To Label Converter compares the Data with a pre-defined list of values. Depended on the Data, the corresponding Label is prescribed. Finally, the Energy Label is passed through to the EB State Logic.

Level 1C: EB State Logic

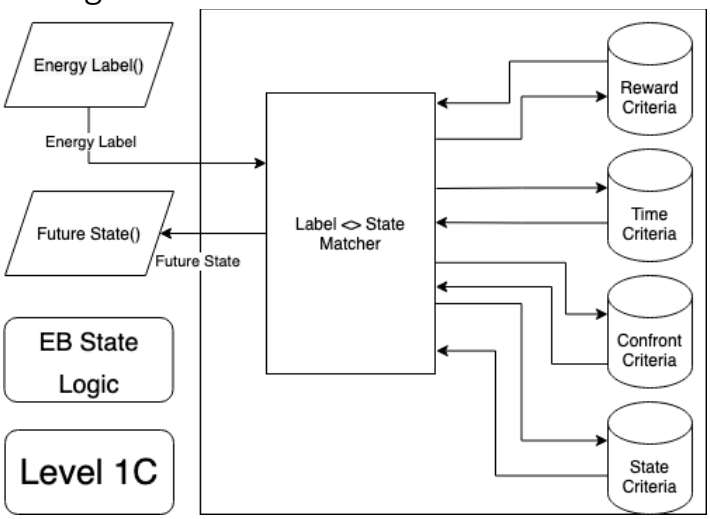


Figure 24 Architectural diagram Level1C: EB State Logic

In figure 24, the Energy Label is sending the Energy Label to the EB State Logic, in which the Label<>State Matcher matches the Energy Label with a state. To do this, the EB state Logic has a pre-defined database for the Reward Criteria, Time Criteria, Confront Criteria and the State Criteria. Depended on the Energy Label and the databases, the Future State will send to the EB State Animation.

Level 1D: EB State Animation

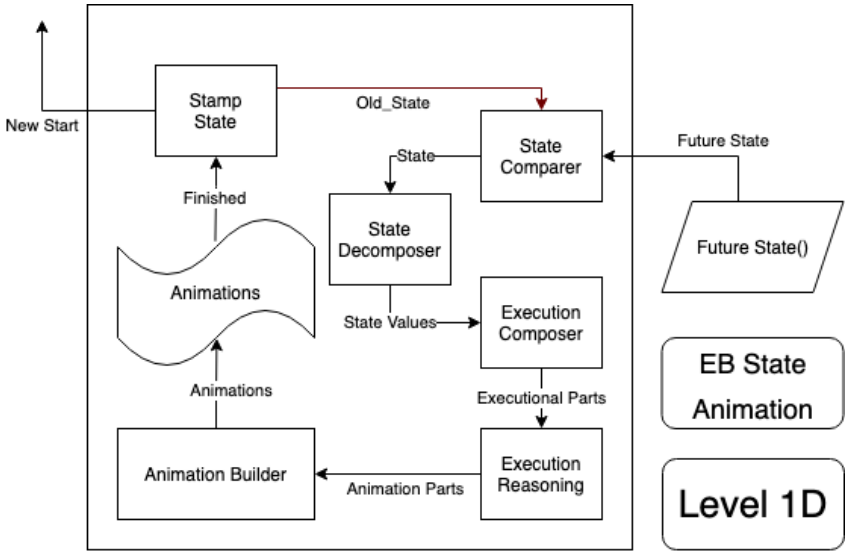


Figure 25 Architectural diagram Level1D: EB State Animation

In figure 25, The Future State function is sending the Future State to the State Comparer. The State Comparer gathers the Old_State, which is highlighted in brown, and compares the Old_State with the Future State. The State Comparer forwards the State to the State Decomposer, which decomposes the State into State Values. The State Values is received by the Execution Composer, which makes Executional Parts. Where after the Execution Reasoning logics the Animation Parts, which is passed through the Animation Builder. The Animation Builder sends the Animations towards the Animations, which plays the animation. When the Animations is finished, the State is being stamped and a New Start is sent back to the Power Measurement function.

Level 1:

These sub-systems need to be integrated into the system as a whole. To clarify the relation between the function of each sub-system and the system as a whole, the different sub-systems are combined in figure 26.

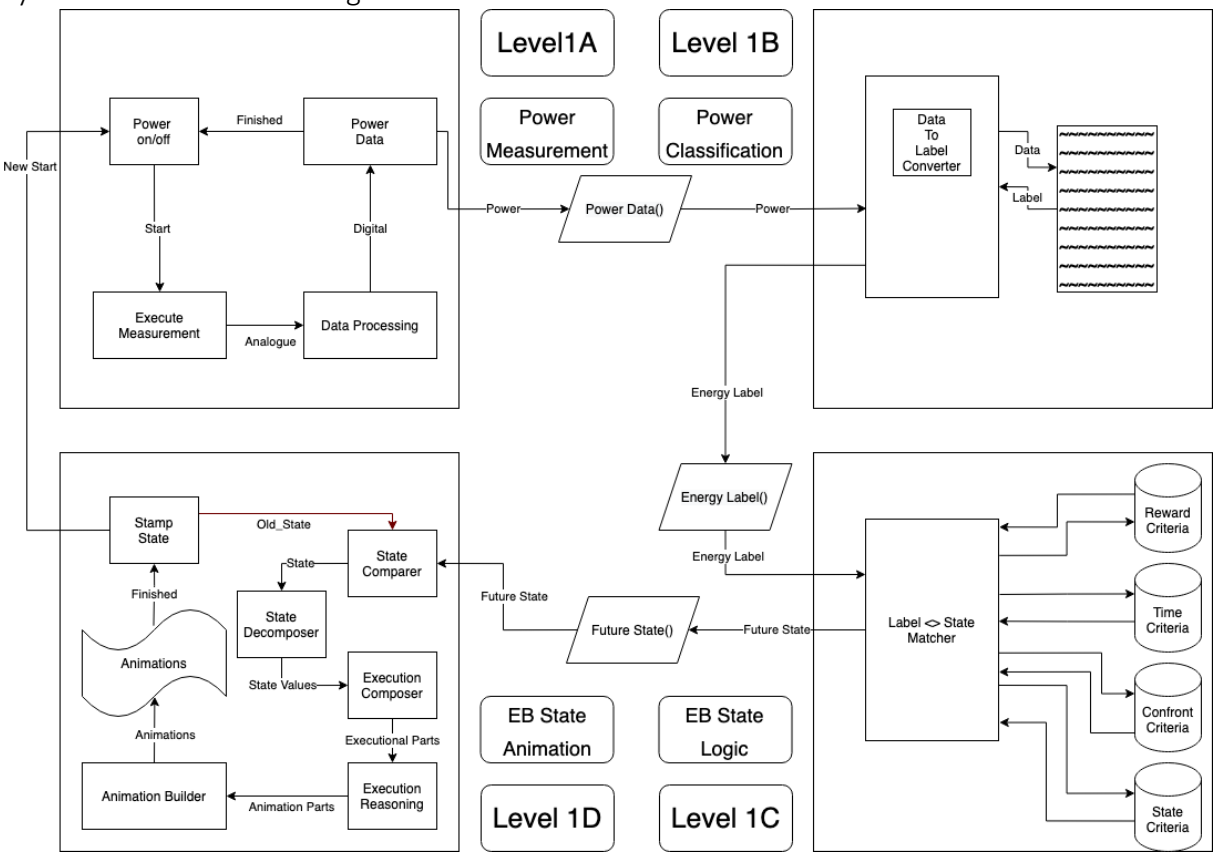


Figure 26 Architectural diagram Level1

5.4.2 Flow-chart

The flow-chart, which is visualised in figure 27, visualize the flow of the EB. The flow-chart provides insight of the separate sequential steps of the EB system. The flow-chart precisely describes the actions which have to performed, depended on different inputs.

The flow-chart displays each separate sequential step and how this step influences the flow of the EB. Each step has one dedicated function and decides what the successive step is going to be, where after this is being executed. The flow has a binary method and always returns back into the loop.

The sequential steps of this flow-chart depend on the amount of electricity consumption and the time component. These values are derived through various iterations in which the product was tested. The electricity consumption <4 belongs to a minimal electricity consumption, <99 to a substantial electricity consumption and >99 to an excessive consumption. To illustrate; powering a desk lamp solely remains <4, while a desk lamp plus a phone charge is approximately 10 watts, thus the electricity consumption is substantial. Charging a laptop with external monitor and desk lamp is approximately 90 watts, this relatively high, but not yet excessive. When, the user charges a laptop, desk lamp and two external monitors the electricity consumption is >99, thus excessive. These values can be altered to the desires s of the designer.

When the annoyed state has been entered, the time function is going to function. For the first 20 seconds the annoyed state is active, between 20 and 40 seconds the frustrated 1 state is active, between 40 and 60 seconds the frustrated 2 state is active and above 60 seconds the frustrated 3 state is active. These time points are quickly follow-up on each which is necessary for the usability test, nevertheless these can be altered to other altered to the desires of the designer. For example, the time component can easily be changed to 15 minutes, which is stated in the scenario-based design

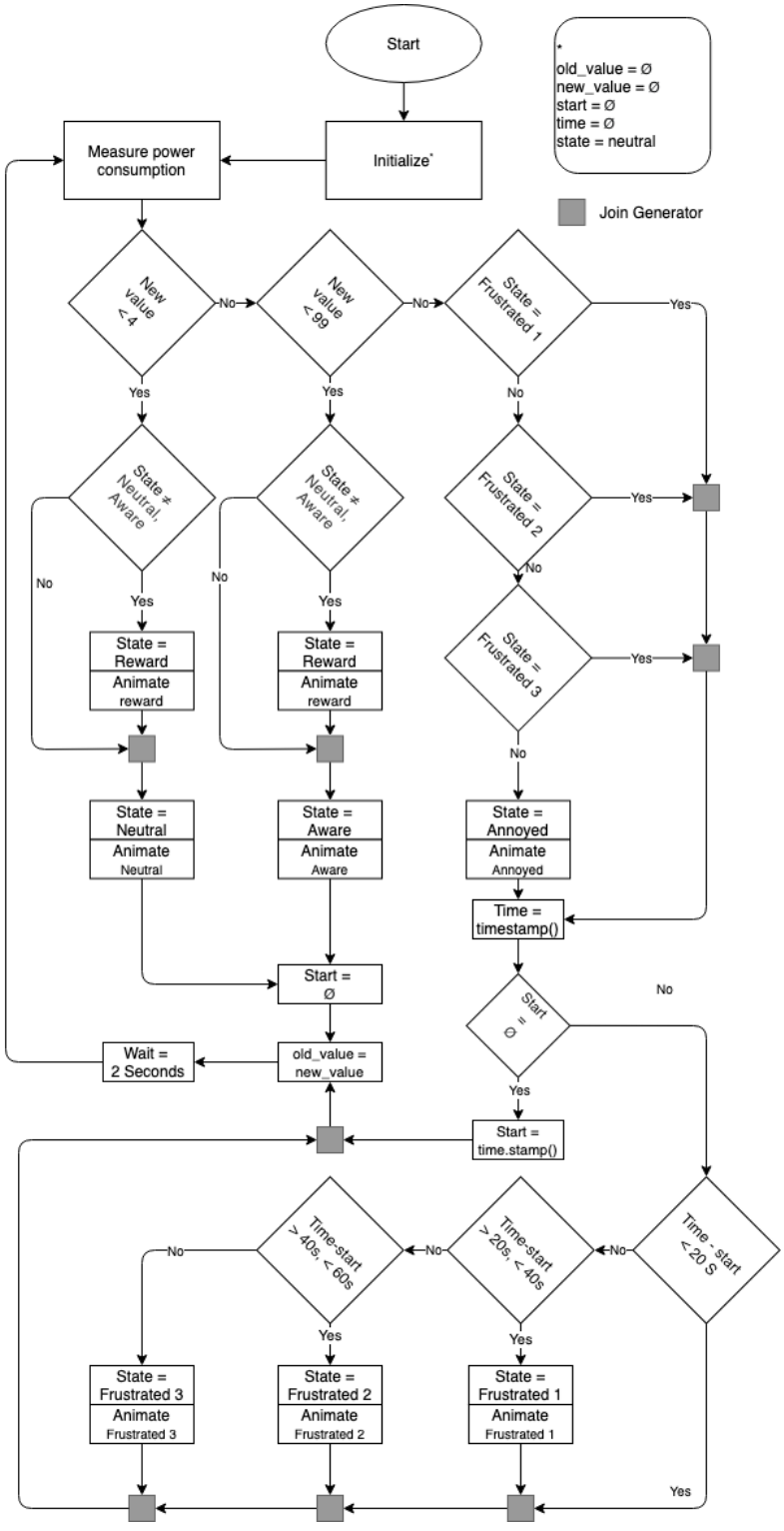


Figure 27 Flow-chart Energy Buddy

6 Realization

To create an EB, various software and hardware have to be used. In this chapter the construction progress will be explained. Firstly, by explaining the chosen hardware and secondly the chosen software. Followed by section 6.3, in which an overview of the EB is given and in section 6.4 the final prototype given. At the end of this chapter, the functional requirements are evaluated.

6.1 Tools

The EB has to interact with the user in various different ways. Various interactions have to be embedded and need to communicate with each other. Therefore, a suitable OS has to be chosen where after it is possible to discover which software is needed.

6.1.1 Operating system

There is a numerous amount of power sensing devices available. However, limited of these devices have an option to acquire the power consumption in an open format. The most applications visually represent the power consumption, thus the data can't be acquired. This is necessary because the EB needs the collect the power data in raw format. This limited the number of available devices to a CT-sensor.

The CT stands for current transformer. When electricity flows through the wiring, it creates a magnetic field. This magnetic field fluctuates proportionally with the consumed electricity. The current transformer senses the magnetic field and proportionally transforms the current into analogue values.

The analogue values need to be transformed with an AC-DC converter. An AC-DC converter, converts analogue current to direct current. An Arduino has an AC-DC converter integrated and has the possibilities to the data. However, an Arduino doesn't have the possibility to display visual graphics. The visual graphics are needed to communicate the different emotional states. Therefor the Arduino needs to be connected to another device. Four operating systems can be applied, these are: Linux, macOS and Windows and Raspbian[50]. The first three are operating systems (os) on dedicated computers, thus are assumed to be the same:

- A dedicated computer:
  This is a dedicated system which can run on Windows, Linux and MacOS. The EB can be displayed through the screen which the computer has. The advantage is that the program is easily exchangeable, however the EB is displayed on the user screen, therefor the user might discard the EB.

- Raspbian:
  Raspbian is an os which is free to download on the official website. The OS needs to be placed on a device, the most popular is the Raspberry Pi Model B. A downside of the Raspberry Pi is that it is an extra device and solely has computing power.

The discussed systems differ in executional methods. The EB on a computer is resulting in less screen space, which not desired. Raspbian has the possibility to run the EB on a separate device. Therefor the operating system Raspbian will be applied. Due to the outputs of the Raspberry Pi, it is possible to attach external devices like a screen and speaker, these need to be connected in order to show the emotions, signs and gestures and play the sounds.

6.1.2 Software

The Raspberry Pi needs to run an operating system from an SD-card. To place an operating system on the SD-card, Raspberry Pi imager needs to be used. Before-usage, an SD card needs to be formatted with the aid of an SD-card formatter. Where after it is possible to use the SD-card and, subsequently be able to run the operating system. On the operating system the code of the EB needs to be situated. Python will be used to code the EB because Python works well with a Raspberry Pi, furthermore Python has a numerous amount of external libraries, which can infinitely be combined. One external library is Tkinter, which enables Python to show graphical images, therefor Tkinter needs to be used to show the graphical images. There are various software programs available which support Python, PyCharm is the most popular. PyCharm is popular due to it's native usage, therefor PyCharm will be used to code EB. To enable the EB to play sounds, the sounds have to be converted, an online audio tool can be used, in this case audio online-convert has been used. Lastly, Adobe Illustrator has been used to graphically give the EB an appearance.

6.2 Engineering process

Firstly, the Raspberry Pi operating system has been installed onto the Raspberry Pi, where after the LCD screen needs to be connected to and installed on the Raspberry Pi, therefor the LCD screen needs to be connected to the Raspberry Pi and settings inside the Raspberry Pi needs to be adjusted. The LCD screen occupies all the output pins of the Raspberry Pi.

Because all the output pins are used by the LCD screen, the speaker has to be connected to the Arduino. Because the Arduino doesn't have enough processing power, the sounds need to be stored on an external SD-card which is connected to the Arduino.

Besides a speaker, the CT-sensor needs to be connected to the Arduino. A power strip consists of three wires; a neutral, a ground and a positive wire. Because the CT-sensor proportionally senses the magnetic field created by current, the current created by power consumption needs to be clamped onto the neutral or positive wire. Therefore, a power strip is cut open to uncover these wires and clamp the CT-sensor on it. Hereby must be noticed that each individual CT-sensor has its own characteristics in terms of voltage and current, which have to be taken along into the code. Depended on these values the code interprets the received analogue data differently, thus influences the send digital data. The Arduino code can be found in appendix E.1

The Arduino transmits the power consumption towards the Raspberry Pi, where the Python code receives the power consumption. The Python code, processes the data and acts according to the flow-chart. The code is situated in appendix E.2.

6.3 Overview

To clarify the functions of the Arduino and the functions of the Python code, a functional diagram is visualized and explained in section 6.3.1. Where after an overview of the used hardware is given in section 6.3.2. The hardware overview and software overview together simulate the mould of the final prototype.

6.3.1 Functional diagram

The operating structure of the EB is visually given in a functional diagram situated in figure 29. Herein each function of the EB is situated and how this function relates to another function. The functional diagram clarifies the programmed functions of the Arduino and Python.
Firstly, Arduino measures a power consumption and transmits towards Python. To detect whether the user switched on or off a device, thus whether the system should reward or confront the user, a value comparison function is needed. Secondly, the Energy Label is developed by the value Classification, the Energy Label is input for the EB state comparison function. Depended on the Energy Label and the EB old state, the EB state comparison function is executed, which decides whether the states should be changed. Where after the EB determine state function checks whether the time was active. Dependably, the EB state logic functions are executed. These functions need to be programmed that they decide how the animation should be played. This is depended on the previous state and future state, and thus fluctuates. The corresponding animation is sent to the EB execute logic function, which executes the animation. All these functions are situated in the Python code to act accordingly.

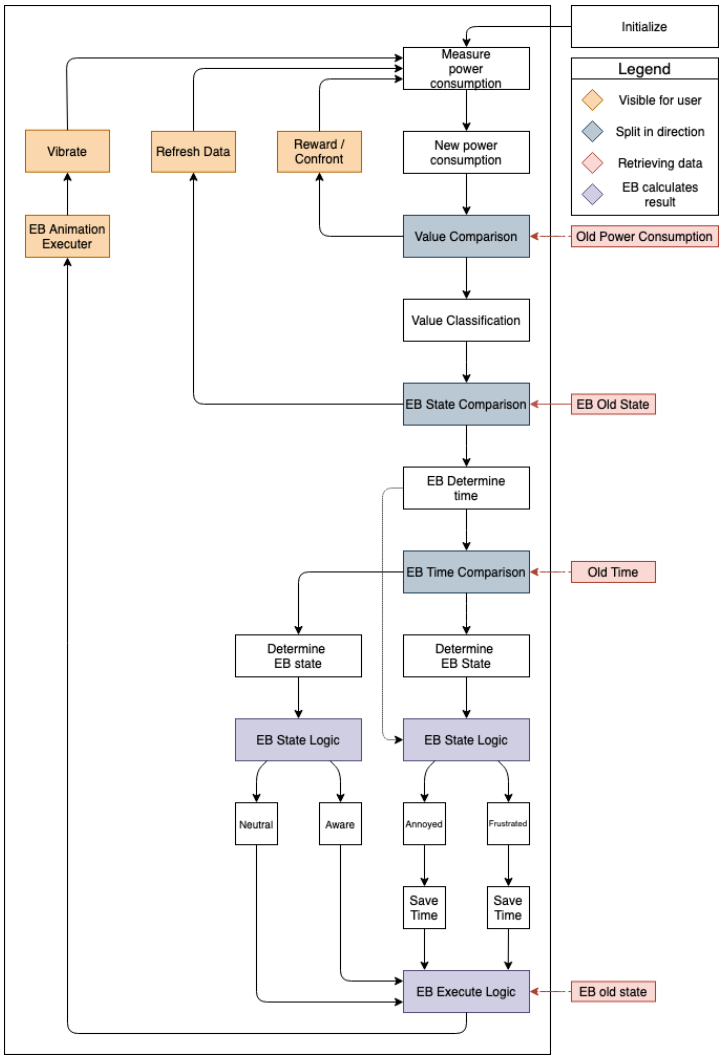


Figure 28 Functional diagram

6.3.2 Overview Hardware

An overview of the connected hardware is provided in figure 28. In the lower left corner, the LCD-screen is connected to the Raspberry Pi, which is centred in in the left-middle. A power-bank is connected to charge the device and is situated left of the Raspberry Pi. From the Raspberry pi, an USB-cable connects the Arduino, situated in the right middle. From the Arduino there is a connection through jumper wires to the speaker, situated in the lower right. The SD-card reader is also connected through jumper wires, situated in the right and connected to the Arduino. Lastly the breadboard, the upper device, is connected through jumper wires to the Arduino.

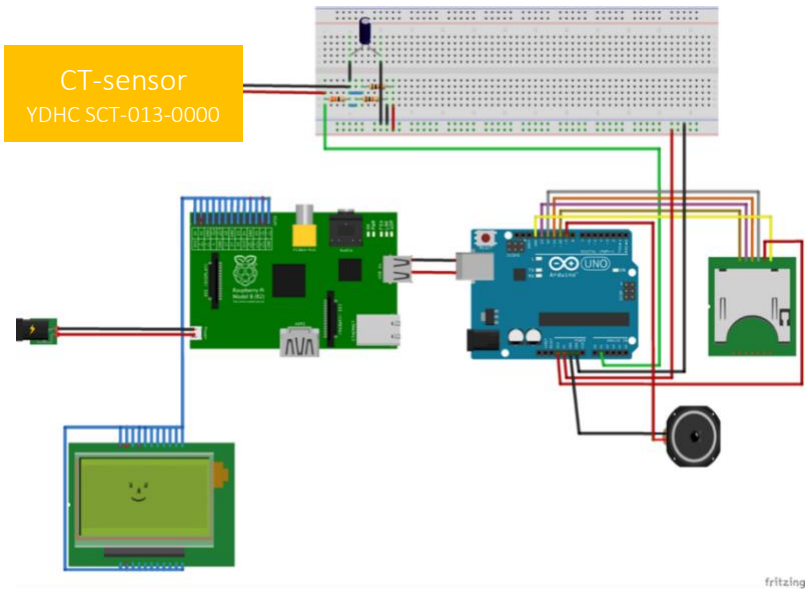


Figure 29 Overview hardware

The CT-sensor is attached to the breadboard and not directly into the Arduino because there needs to be a 10uF capacitor, 2 x 10k Ohm resistors and a resistor of 33 Ohms to regulate the measured values. The 10k Ohm resistors will act as voltage dividers while the resistor of 33Ohms will act as burden resistor. The capacitor has a low reactance and provides a path for the alternating current to bypass the resistor. A list of the used components can be found in appendix D.

6.4 Final prototype

The final prototype of the EB is a box with the LCD screen visible on the front. The used devices are placed inside the box. The EB is visualized in figure 30. In this figure the EB is in the aware state and the mac-book is powered through the power strip. The final prototype is working as expected, it shows the correct sign with textural messages, gesture and slides through the different emotional states. When the user plugs a computer into the EB, the emotion starts glowing and a negative sound is played, where after it slowly decades to the appropriate state. When a laptop is removed from the EB, the positive emotion is shown with a positive sound, where after the emotion fluently decays to the appropriate state.

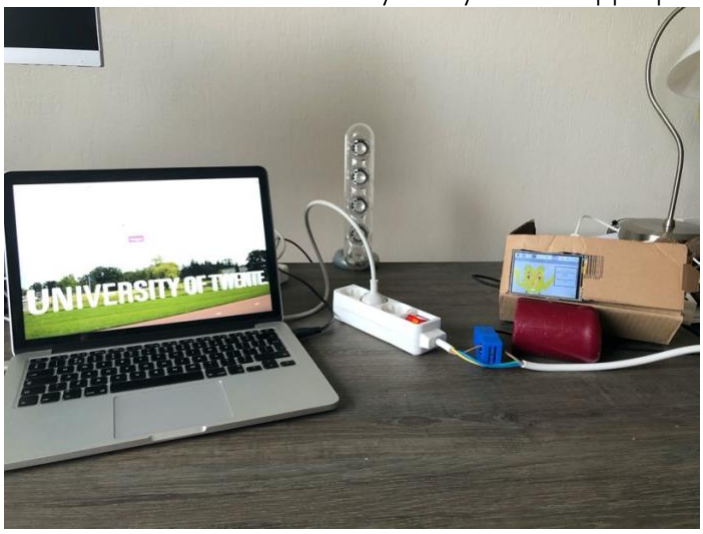


Figure 30 Final prototype

Before a sound is played, the measured power is correct. When the electricity consumption is increased, the Arduino plays a sound. After the sound is played, the received values from the CT-sensor get distorted and remains distorted. The sound-playing function is integrated, however turned off to let the other functions work properly. There has been chosen to continue the research without the sound because of the limited amount of time

6.5 Functional requirements evaluation

In this section the functional requirements are being evaluated. The functional requirements are summarised in table 6.1, together whether these requirements are met, partially met or not met.

Category	Met √ Partially met ~ Not met x
Must have	
The EB must be able to provide text messages to the user	√
The EB must communicate the user's electricity consumption to the user	√
The EB must show the average electricity consumption of the Horst	√
The EB must show the consequence of electricity consumption on climate change	√
The EB must show the gain of a reduced electricity consumption	√
The EB must ask the user to perform electricity saving actions	√
The measured electricity consumption must be live.	√
The EB must be able to play sounds	x
The EB must notify the user when there is an increase or decrease in electricity consumption	√
The EB must emphasize increases or decreases of electricity consumption with the aid of sound	~
The EB must have different emotions which the user can relate with	√
The EB's emotions must be in conjunction with the electricity consumption	√
The EB must notify the user when the emotion of the EB changes	√
The information shown must be correct	√
The EB must visually emphasize a decrease or increase in electricity consumption	√
Should have	
The EB should consist of one artefact	√
Could have	
The EB could be portable to be used in different settings	√
Won't have	
-	

Table 6.1 Functional requirements evaluation

In the table, it is visible that almost every requirement is met. The requirements regarding sound aren't met or partially met. This has also the additional effect that the EB is partially meeting the requirement: the EB must emphasize patterns or progresses with the aid of sound. This requirement is partially met because the function is integrated, it is able to emphasize patterns or progresses when there is an increase or decrease. However, the combination of measuring the electricity consumption and playing sounds is not working. The final prototype is finished and ready to be evaluated by the client and users.

7 Evaluation

In this chapter the realized product will be evaluated. In the first section the performed usability test will be evaluated. Hereafter the product will be evaluated by the client, these results can be found in section 7.2. Concluding, from both the survey as the interview with the client, the final-requirements will be evaluated.

7.1 Usability evaluation

In this section, firstly the participants demographic data will be discussed. Where after the observational results will be treated, from the observational results, suggestions for improvement will be derived. In section 7.1.4, as part of the non-functional requirements will be evaluated. Finally, the requirements regarding the different components will be discussed. The results of the usability test can be found in appendix F.1.

7.1.1 Demographic results

Nine participants agreed to participate in the usability test. In figure 31, the age, study and gender of each participant is visualised. Males are slightly more present than females, which is representable for the community of the UT. The variation in the different studies is large, ranging from, Advanced Technology to Psychology, this is representable for the UT-community. The age ranges between 18 and 23. All with all the, participants are representable for the UT-community.

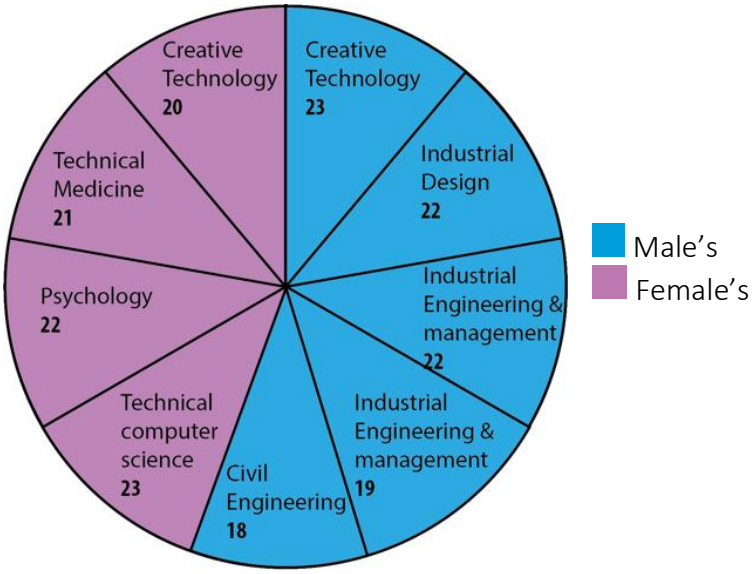


Figure 31 Overview participants age, study and gender

7.1.2 Observational results

Requirement evaluation

The participants generally reacted positive about the product, their first reaction was "wow" or "funny how it reacts to you" and "really nice how it plays with you". While the users interacted with the device it was clearly noticeable that people got a higher energy level, they started to move more, spoke more and got excited; the product energized the user. From this, a positive attitude towards the EB can be deduced. This might result that requirement 5, whether the product is appealing, is met.

Overall the users were positive about the translation of meaningless abstract figures to tangible relevant aspects. From this, it is likely that requirement 2 is met.

In addition, requirement 1 is also likely to be met. This can be deduced because the emotions of the EB were liked, especially the fluent change of emotions was liked. According to the participant this enabled them to sympathize with the EB.

Furthermore, they stated that the product gave insight in their consumption and that it draws your attention at the applicable moment. One user said: “Sharp! It directly notices what you are doing and acts proportionally, you directly get feedback”. The instant reaction between the EB and the participant is stated to be a strong element for personalized interaction. This states that the requirement 10 is met.

Negative feedback

During the evaluation the sound wasn’t present, to some participants the sounds was simulated, however wasn’t much liked. In general, the users had the opinion that the sound would draw too much attention. The sounds, were according to the participants, not in ratio with the task they were performing. For example, the sound would disrupt the user from their work or studying activity, which is found more important than the electricity consumption. The integration of the sounds therefor might not be preferred.

Furthermore, for some students the set consumption of 100 watts appeared to be too low. One participant reacted with the sentence: “wow, it gets angry really fast”. In addition, some participants didn’t like the angry emotion, they suggested to include a sad emotion.

Lastly, the majority of the users were less fond of the carton box around the EB itself.

7.1.3 Suggestions for improvement

From the observational results evaluation suggestions for improvement can be derived. These are, in arbitrary order:

- An option to turn on/off the sound
- Dynamical electricity settings, depending on individual’s electricity consumption
- Make the face sad instead of angry
- A more appealing box around the EB

7.1.4 Survey results

To evaluate the requirements, the survey results will be researched. The results of the survey questions regarding the interaction of the EB can be found in figure 32. The

From the observational results the assumption already has been made that the EB is appealing. In addition, 45% of the participants had a neutral opinion whether the EB is appealing while 55% agreed that the EB is appealing. From this, combined with the observational results, requirement 5 is met.

Requirement 2 is also likely to be met, referring to the fact that the electricity consumption must be showed in the context of the user. This can be derived from the question whether the users feel personally addressed, which was agreed by 89% of the participants. Furthermore, this is assisted in section 7.1.2.

In section 7.1.2, it is already suggested that requirement 1 is met. In addition, 100% of the participants agreed that they understand the message of the EB, therefor it can be stated that requirement 1 is met.

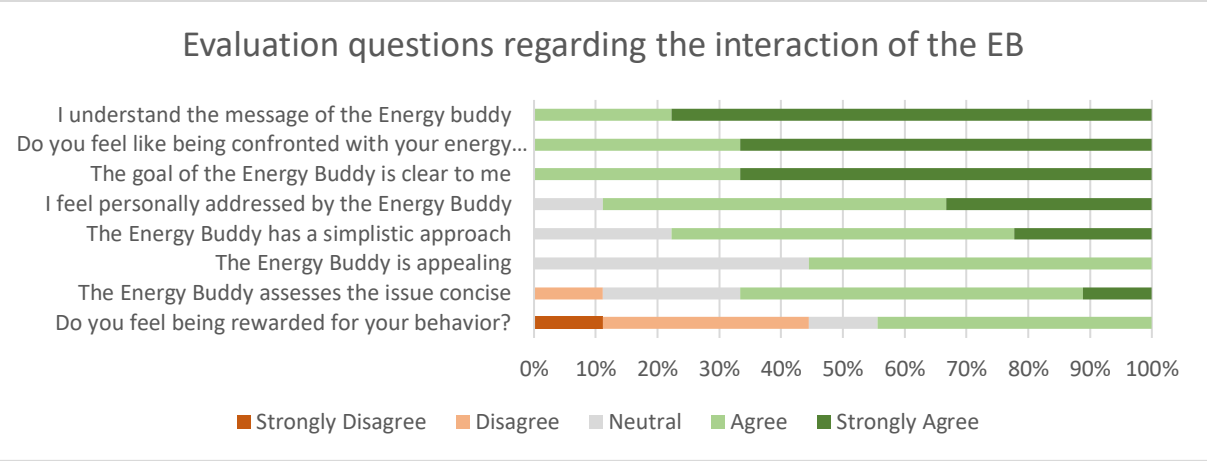


Figure 32 Results questions Energy Buddy's interaction

Requirement 3 is met because 44% of the participants stated that the EB assesses the issue concise, while only 11% disagreed.

Requirement 4 was set up to ensure that the functions of the EB are implemented efficient. The participants were asked whether the EB has a simplistic approach. 77% of the participants state that the EB has a simplistic approach. This requirement is therefor met.

100% of the participants agreed that the goal of the EB is clear, in fact 77% strongly agrees that the goal of the EB is clear. Requirement 7 is therefor met.

Requirement 9 was set-up to ensure that the EB rewards the user. In the observational results, the assumption was made that this requirement was likely to be met. The participants were asked whether they feel being rewarded for their behaviour. 45% agreed and 45% disagreed or strongly disagreed. Due to this division, requirement 9 is not met.

The evaluation results of the influence of the EB are visualized in appendix F.5. In the graph is visible that the participants still feel allowed to consume electricity. Requirement 14 is therefor met.

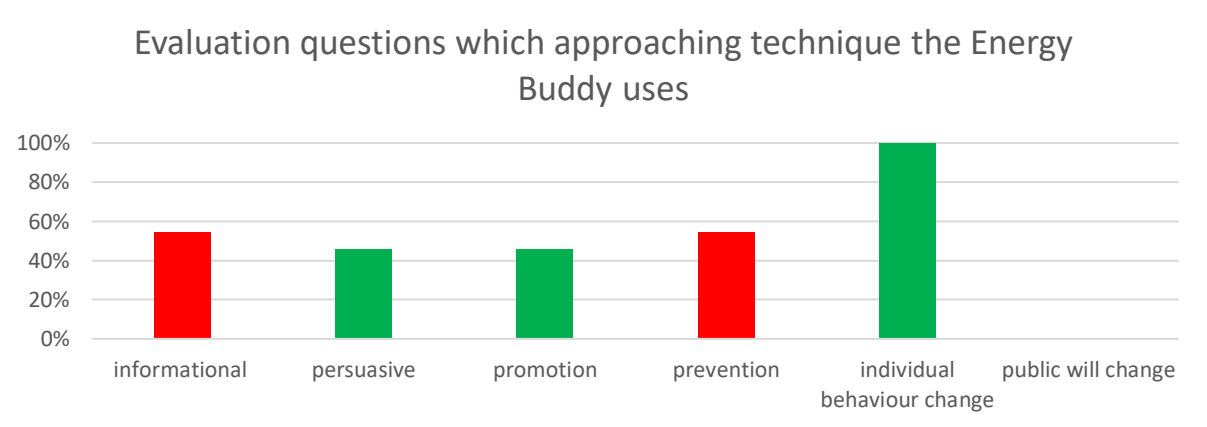


Figure 33 Results questions Energy Buddy's approaching technique

In figure 34 are the results of the questions regarding the approaching technique of the EB visualized. In which it the participants could choose between informational versus persuasive, promotion versus prevention and individual behaviour change versus public will change.

55% of the respondents stated that the EB approaches informational and 45% stated persuasive. These questions are similar to each other, therefore it is not possible to state that requirement 8 is met.

Secondly, the respondents were asked whether they think the EB is oriented on promotion or prevention. 55% of the respondents answered that they think the EB is oriented

on prevention, while 45% of the respondents answered that the EB is oriented on promotion. Therefor requirement 11, detecting whether the EB is convincing or descriptive, is not met.

Lastly, requirement 12 is met because 100% of the participants stated that the EB is oriented on individual behaviour change.

7.2 Interviews

Besides that, the usability test, the prototype was also evaluated by the client. Firstly, the interview with Henk Hobbelink will be discussed, where after the interview with Brechtje Marechal will be discussed. This section will end with suggestions for improvement derived from these interviews. The results of the interview can be found in appendix F.2.

7.2.1 Interview CFM: Henk Hobbelink

The first interview was held with Henk Hobbelink, contract manager of CFM and client of this project. Henk Hobbelink was very positive about the product. He even said: “this exceeds my expectations” [51].

He continued by another positive remarks which is the fact that the emotional states of the EB fluently changes along with your behaviour. According to Henk the facial expressions of the EB are strong, nicely expressed and have a simple thought, however he would have made the emotion sad instead of angry. Hobbelink states that the EB triggers the users concise and immediately expresses the EB’s opinion, he dedicates this to the emotional expressions. The emotions are strong elements according to Hobbelink. Hobbelink was surprised by the interaction methods of the EB, he explains this with: “Surprising, I think it’s surprising because you trigger people with actions that you perform, especially in combination with the facts and effects on climate change”. Hobbelink also said that he liked the fact that the product: “Focusses on the negative aspects, however it doesn’t bring it that way”. Another positive aspect according to Hobbelink is that the EB assesses a fraughted topic in a comical way.

Hobbelink also had some remarks about the product. Firstly, he indicated that the box in which the EB is situated isn’t beautiful. Secondly, the screen was too small and the text flickered sometimes. He added that another negative aspect of the product is that people get used to the product, this results in a bored product which won’t be used by the users. He furthermore suggested to place the EB as watermark on the screen. Also, Hobbelink would’ve added a feature which remembers the consumed electricity consumption and more sensing possibilities like the sun brightness or the electricity consumption of an entire building. Lastly, Hobbelink added that it would be nice to embed the power-strip into the box.

7.2.2 Interview CFM: Brechtje Marechal

Besides the interview with Henk Hobbelink, Brechtje Marechal was also interviewed [52].

She was amused by the fact that the product translates hard data towards a playful element like sea level rise. She sees potential in the product because the product assesses the issue of electricity consumption in a playful way.

However, she thinks that the product needs to be adjusted to be successful. According to Marechal this can be done by ensuring the product is adjusted to a laboratory, instead for normal computer devices. She furthermore assesses the issue of “boredom”, she is convinced that these products are new and interesting in the beginning, and therefor will raise awareness. However, people are getting used to the product and won’t listen after a while.

7.2.3 Suggestions for improvement

During the interview sessions the stakeholders provided suggestions for improvement. These are in arbitrary order:

- Make the EB sad instead of angry
- A bigger screen
- Ensure that the product keeps interesting for the user
- Communicate the average electricity consumption of that day
- Don't let the EB flicker
- Make the EB applicable for laboratory
- A more appealing box around the EB
- Embed the power strip into the box
- Embed the power strip into the box

7.3 Statistical evaluation

The aim for this project is to increase awareness among the UT-community regarding electricity consumption. To validate whether this goal has been achieved, a statistical evaluation is held. The obtained values, which are used in this test, can be found in appendix F.4. As explained in section 3.4.3, a t-test will be applied to validate the obtained results. Before and after the product was demonstrated the following questions were asked:

Q_1: I feel responsible of my contribution to the energy consumption of the UT-community
Q_2: I am aware of my energy consumption

For both questions, the h_0 hypotheses is: $\mu_1 = \mu_2$, thus that the means are equal. The h_a is that: $\mu_1 < \mu_2$, thus, the mean of the second question is larger than the mean of the first question. This implies that the mean, after the product was shown, is increased.

With the aid of the provided formulas in appendix C.1 and the obtained values, which can be found in appendix F.4. The t-test is executed, this resulted in a t-value of 1,36 for Q_1 and a t-value of 2,69 for Q_2. The calculation for Q_1 can be found in appendix C.4 and the calculation for Q_2 can be found in calculation C.5.

The rejection region is determined according to the number of participants There are 9 respondents, this substitutes to 16 degrees of freedom. 16 degrees of freedom, together with a confidence interval of 0,95, substitutes to a critical value of 1,746. Therefor any calculated t-value below 1,746 needs to be rejected.

For Q_1, the calculated t-value is 1,36 and doesn't exceed 1,76. Therefor the null hypotheses cannot be rejected. The hypotheses that $\mu_1 = \mu_2$ is assumed to be true. This shows that the participants do not feel more responsible for the energy consumption of the UT after the product was demonstrated than before.

For Q_2 the t-value of 2,69 exceeds the t-value of 1,746. Therefor the hypotheses that $\mu_1 = \mu_2$ has to be rejected and the alternative hypotheses: $\mu_1 < \mu_2$ has to be accepted. This shows that the participants are more aware after the product was demonstrated than on beforehand.

In conclusion, the EB raises awareness for energy consumption, the EB therefor fulfils requirement 6. The EB partially fulfils requirement 13 because it is not statistically proven that the EB increases the users sense of responsibility, however a higher average mean is visible.

7.4 Non-functional requirements evaluation

In table 7.1 the requirements are given in the table, ordered by the MoSCoW technique. Along with the requirement itself, it is indicated whether the requirement is met, partially met or not met. The requirements are derived from the final requirements set in chapter 5.

Number	Category	Met √ Partially met ~ Not met x
	Must have	
1	The visual communication of the EB must be recognized by the user	√
2	The EB must show electricity consumption in the context of the user	√
3	The functions of the EB must be implemented concise	√
4	The function of the EB must be Implemented efficient	√
5	The EB must be appealing	√
6	The EB must raise awareness for electricity consumption	√
7	The EB must have one goal	√
	Should have	
8	The EB should communicate in terms of gain rather than losses	X
9	The EB should reward the user for “good” electricity behaviour	x
10	The EB should indicate “bad” electricity behaviour towards the user	√
11	The EB should be convincing rather than descriptive	X
12	The EB should be focussed on individual behaviour change	√
13	The EB should raise the sense of responsibility regarding electricity consumption	~
	Could have	
	-	-
	Won’t have	
14	Evoke the impression that electricity consumption isn’t allowed	√

Table 7.1 Non-functional requirements evaluation

The majority of the requirements are met, there are three requirements which are not met or partially met, as can be seen in table 7.1. These requirements are regarding the influence the EB has on the user. Nevertheless, it is statistically proven that the EB raises awareness among the UT-community.

8 Conclusion

The world's climate is changing due to mankind, which is designated to the CO_2 emission. The UT feels responsible for this and set-up a task force which aims to decrease the CO_2 consumption by 49% in 2030. 60% of the UT's energy consumption is designated to buildings, this consumption has been decreased by facilitating durable buildings and automating climate control. The other 40%, is caused by the UT-community. Therefore, it is key that the UT-community consumes less energy. To realize awareness among the UT-community, the Trans Theoretical Model of behavioural change is applied. This model supplies a framework to shift unaware users to aware users. The stakeholders were identified and analysed, with the aid of interviews their ideas, opinions and issues were gathered. From the interviews, preliminary requirements were set-up which the product has to accomplish. With this information, possible campaigns were ideated, after which these were discussed with the stakeholders. The Energy Buddy (EB) was chosen to develop, the EB continuously monitors the user's electricity consumption and dependably acts in a personalized way. The clarified EB's functioning and the relation between the user, enabled a functioning EB. The EB was evaluated with a usability test. The users are fond of the EB, the expression which characterizes the EB is: "By triggering the user in a relatable manner, the Energy Buddy shifts a controversial topic to a discussable issue". The stakeholders were excited about the product, especially the relation between consumption and the EB's reaction. However, there arised remarks which have to be considered. The angry facial expression and casing of the EB could be improved. The functioning and personalized interaction were appreciated. The EB influences the user and is statistically proven to increase the awareness of the UT-community. The EB is a promising artefact to realize awareness among the UT-community.

9 Future work

The development of this thesis resulted in an EB which can be deployed across the UT to create awareness among the community. The requirements are met, the EB is liked and the results of the EB are promising. However, to realize a consistent amount of awareness which results in a lower CO_2 emission, further development, adjustments and research is needed.

CFM stated that the largest contributors of the CO_2 footprint are students and employees in laboratory. The EB has been made to be applicable in every setting, however is not specifically developed for usage in laboratory. To realize the wanted effects on the CO_2 footprint the EB should be adapted for usage inside laboratory. In addition, the implemented data of the Horst needs to be changed towards the consumption of each building.

Furthermore, CFM stated that people lose interest over time. To prevent this, the EB should be adapted that it continuously communicates new relevant data, another possibility is to deploy the system once in a while. CFM also stated that, because people lose interest over time, the EB should be made applicable for places which students visit once in a while, for instance the University Library.

Secondly, the prototype has some flaws or designing issues, for this purpose this was sufficient because the main elements are integrated and worked together flawless. However, when the EB is being deployed across the University the EB will be discarded due to its appearance. For instance, the angry face could be made sad and the box around the EB can easily be improved. To ensure a higher result, each element should be designed specifically and in the end these systems have to work together smoothly.

Also, future work is needed for the sounds, these have to be made work well with the system.

Besides the appearance, the functionalities of the EB could also be improved. The EB at this stage has different static parameters, for instance the time mechanism and the turn-over points for the emotions. By adjusting these settings adaptively, according the users consumption, the EB interacts more the belongings of the user.

The EB might be deployed across other universities, institutions or companies. The goal of the EB is to create awareness, this seems promising but has a limited scale on the UT. To fully extract the possibilities and opportunities of the EB, the EB should be deployed into other settings.

Lastly, to fully realize a lower CO_2 emission, behavioural change is necessary. However, this project only aims to realize awareness, which is the third stage of the TTM model. For behavioural change it is necessary to enter the 5^{th} stage, to realize this the EB must be adapted. Future research is necessary to implement components which ensure behavioural change. Nevertheless, due to the interaction, personal approach and triggering of the EB, the EB is a well-grounded starting point for behavioural change.

Appendices

A Interview questions

A.1 Semi-structured interview with Henk Hobbelink

1. Who are you?
    a. What is your position at CFM?
2. Why do you want to reduce energy consumption?
3. What do you think is the problem surrounding energy consumption?
4. What kind of energy is contributing the most to the CO_2 footprint?
5. Who consumes energy?
    a. Who wastes energy?
    b. Why is this energy being wasted?
    c. Where is this energy begin wasted?
6. Are there other projects executed to reduce energy consumption?
7. What does the UT do to prevent energy consumption?
8. Are there other wishes that needs to be integrated into the campaign?

https://www.youtube.com/watch?v=1-g73ty9v04&ab_channel=EuropeanCommission

9. What are positive aspects in this campaign according to you?
10. What are negative aspects in this campaign according to you?
11. What needs to be changed according to you?
12. What do you think of the style?
13. What is your general opinion about the video?
14. What do you think of the length of the video?
    a. How long should the length of the campaign be?

A.2 Semi-structured interview with Brechtje Marechal

1. Who are you?
    a. What is your position at CFM?
2. Why do you want to reduce energy consumption?
3. What do you think is the problem surrounding energy consumption?
4. What kind of energy is contributing the most to the CO_2 footprint?
5. Who consumes energy?
    a. Who wastes energy?
    b. Why is this energy being wasted?
    c. Where is this energy begin wasted?
6. In terms of feasibility, appearance, context applicability, personalized data and understandability, what do you think of the following ideas?
    a. Saving and collect the plants contest
    b. Talking tree on O&O square
    c. Interactive Billboard
    d. Energy Buddy
    e. Game
    f. Changing University of Twente letters
    g. Interactive installation
    h. Animation video
7. Are there other projects executed to reduce energy consumption?
8. What does the UT do to prevent energy consumption?
9. Are there other wishes that needs to be integrated into the campaign?

A.3 Semi-structured interview with students

1. Who are you?
2. What is your general opinion about energy consumption?
3. Did you ever think of this?
4. Did you ever think of energy consumption at the UT?
5. Are you aware of the UT consuming energy consumption?
6. Are you personally concerned about energy consumption at:
7. Worldwide?
8. Home?
9. UT?
10. Did you ever turn on lights?
11. Did you ever turn off lights?
12. What kind of flush do you use?
13. Did you ever lower the thermostat?
14. Did you ever raise the thermostat?
15. Is your computer/screen on power saving mode?
16. Is there any personal motivation to change your behaviour?
17. https://www.youtube.com/watch?v=1-g73ty9v04&ab_channel=EuropeanCommission
18. What are positive aspects in this campaign according to you?
19. What are negative aspects in this campaign according to you?
20. What needs to be changed according to you?
21. What do you think of the style?
22. What is your general opinion about the video?
23. What do you think of the length of the video?
24. How long should the length of the campaign be?

A.4 Semi-structured interview users interview for evaluation users

1. What is your age
2. What is your gender?
3. What do you study?

4. I am aware of my energy consumption
5. I feel responsible of my contribution to the energy consumption of the UT-community

6. What is your first impression of the EB?
7. What do you think of the sounds?
8. What do you think of the vibration?
9. What do you think of the glowing?
10. What do you think of the emotions of the EB?
11. What do you think of the texts which the EB is displaying?
12. What aspects of the design do you like?
13. What aspects of the design do you dislike?
14. The EB is appealing
15. Do you feel being rewarded for your behaviour?
16. Do you feel like being confronted with your energy behaviour?
17. The EB assesses the issue concise
18. The EB has a simplistic approach
19. The EB has a simplistic approach
20. The interactions of the EB are in line with my electricity consumption
21. I feel personally addressed by the EB
22. I understand the message of the EB
23. The goal of the EB is clear to me
24. I feel responsible of my contribution to the energy consumption of the UT-community
25. I am more aware of my energy consumption

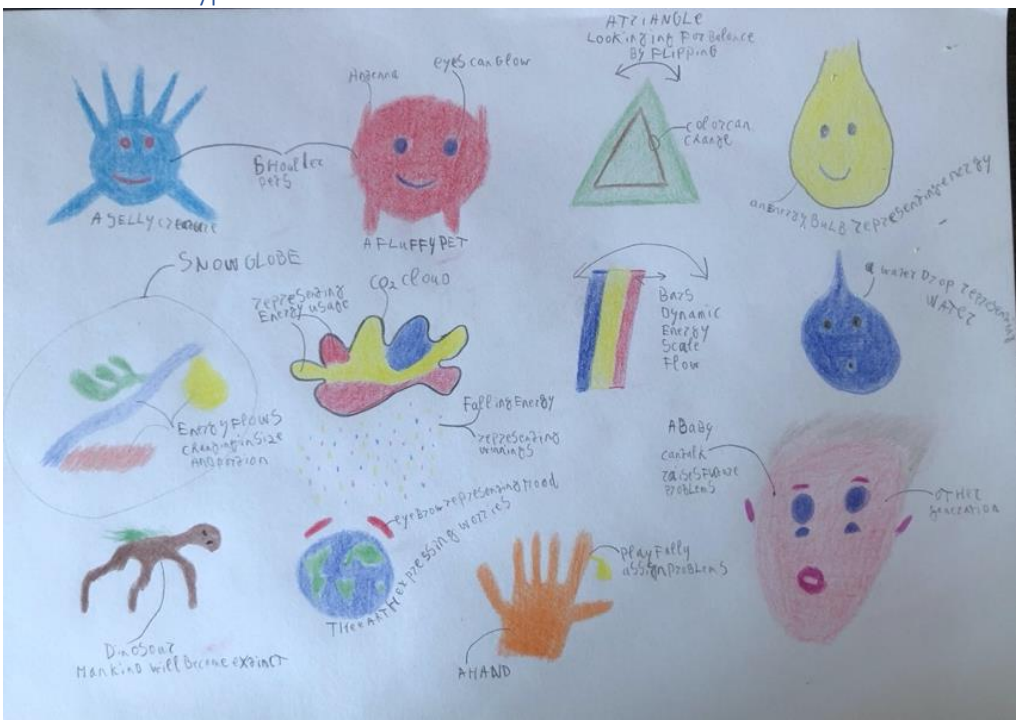
26. Do you think that the is EB oriented on prevention of energy usage or the promotion of less energy usage?
27. Do you think that the is EB informational or persuasive?
28. Do you think that the is EB oriented on change of the public will or individual behaviour change?
29. Does the product increase your confidence about actions which you can perform to decrease the energy consumption?
30. The products assigns barriers for behavioural change?
31. The product gives examples about actions which you can perform to decrease the energy consumption?
32. The product increased my sense of responsibility about my contribution to the energy consumption?
33. I still feel allowed to consume energy
34. The product increases my concerns about energy consumption
35. The product assigns the fact that I am part of the energy consumption
36. The product assigns the consequences of my personal behaviour?

A.5 Semi-structured interview for evaluation Client

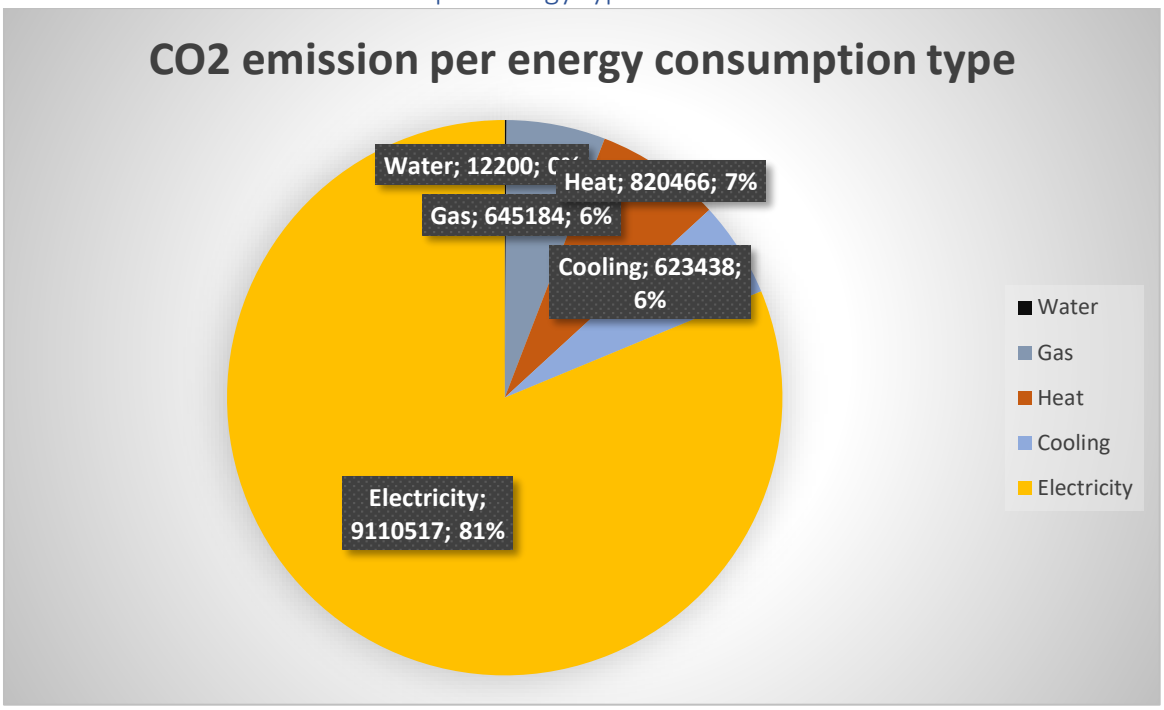
1. What is your first impression of the product?
2. Do you think people at the UT would use it?
3. What aspects do you like?
4. What aspects do you dislike?
5. Are there aspects which you would change to make the product more applicable for the UT-community?
6. Are there aspects which you would change to make the product more effective?
7. What would you like to be integrated?
8. Do you think this product will create awareness among the UT-community
9. Does this approach fits for the UT-community
10. The goal of the EB is clear
11. Do you think that the is EB oriented on prevention of energy usage or the promotion of less energy usage?
12. Do you think that the is EB informational or persuasive?
13. Do you think that the is EB oriented on change of the public will or individual behaviour change?
14. Does the product increase your confidence about actions which you can perform to decrease the energy consumption?
15. The products assigns barriers for behavioural change?
16. The product gives examples about actions which you can perform to decrease the energy consumption?
17. The product increased my sense of responsibility about my contribution to the energy consumption?
18. I still feel allowed to consume energy
19. The product increases my concerns about energy consumption
20. The product assigns the consequences of my personal behaviour

B Data

B.1 Character types



B.2 Data about the CO2 emission per energy type



B.3 Data of household appliances

Appliance	Wattage per hour	Current energy consumption For example: 100
Freezer	47,5 watt [53]	2 freezers
Phone charger	8,5 watt [53]	12 phone chargers
Lighting	20 watt [54]	5 lighting bulbs

C Applied Formulas

C.1 Formula t-test

$$t = \frac{\mu_1 - \mu_2}{\sqrt{\frac{{s_1}^2}{n_1} + \frac{{s_2}^2}{n_2}}}$$

$$s = \sqrt{\frac{(n_1 - 1)\sigma_1^2 + (n_2 - 1)\sigma_2^2}{n_1 + n_2 - 2}}$$

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}$$

C.2 Formula personal consumption

$$user\ consumption = average\ consumption - minimal\ consumption$$

$$personal\ consumption = \frac{user\ consumption}{users}$$

C.3 Calculation personal consumption

$$649{,}212 - 422{,}9 = 226{,}312\ kWh$$

$$\frac{226{,}312}{653} = 0{,}346\ kWh = 346\ W$$

C.4 Calculation t-test Q_1

$$\sqrt{\frac{8 * 0{,}69^2 + 8 * 1{,}13^2}{16}} = 0{,}936$$

$$0{,}936 * \sqrt{\frac{1}{9} + \frac{1}{9}} = 0{,}441$$

$$\frac{2{,}2 - 1{,}6}{0{,}441} = 1{,}36$$

C.5 Calculation t-test Q_2

$$\sqrt{\frac{8 * 1{,}26^2 + 8 * 1{,}11^2}{16}} = 1{,}183$$

$$1{,}183 * \sqrt{\frac{1}{9} + \frac{1}{9}} = 0{,}558$$

$$\frac{3{,}9 - 2{,}4}{0{,}558} = 2{,}69$$

D List of components

CT-sensor: YDHC SCT-013-0000
Raspeberry Pi 3: model B
2X SD card
LCD module Pi TFT 3,5 inch (320*480) touchscreen
Speaker HiBox 3070-k
Power bank: Xoopar xp61031
Arduino compatible SD card reader
Arduino Uno
Breadboard
2X 10k Ohm resistors
33 Ohm resistor
10uF capacitor
Appropriate wiring

Power strip
Housing

E Code

E.1 Arduino

```
#include <SD.h>
#include "SD.h"
#define SD_ChipSelectPin 10
#include "TMRpcm.h"
#include "SPI.h"
#include "EmonLib.h"
int numBlinks; // variable to store the number of blinks

// Include Emon Library
EnergyMonitor emon1;
TMRpcm tmrpcm;
int data;
// Create an instance
void setup()
{
Serial.begin(9600);
pinMode(LED_BUILTIN, OUTPUT);
tmrpcm.speakerPin=9;
tmrpcm.setVolume(3);
emon1.current(1, 30);           // Current: input pin, calibration.
pinMode(13,OUTPUT);
if(!SD.begin(SD_ChipSelectPin)){
  return;
  }
}
```

E.2 Python

```
import serial
import time
from datetime import datetime, timedelta
from tkinter import *
from tkinter import Tk, PhotoImage, Label
import tkinter as tk

global average
import pyfirmata
#from playsound import playsound
import random
from tkinter import Tk, Frame, Canvas
count1 = 0
count2 = 0
count5 = 0
count6 = 0
window = tk.Tk()
width = 475
height = 250
fontsize = 9
xpos = width / 20 * 13.8
ypos = height / 20 * 3
board = pyfirmata.Arduino('/dev/ttyACM0')
serial_object = serial.Serial('/dev/ttyACM0', 9600)  #
'/dev/cu.usbmodem14201''/dev/ttyACM0'
start_photo = PhotoImage(file='startphoto.png')

label_photo = Label(window, image=start_photo, width=width, height=height)
label_photo.pack()
window.geometry("%dx%d+0+0" % (width, height))
window.update()
lengtharray = 40


##### DEFINING TEXT LABELS FOR SIGNS
def load_img(filename):
    return PhotoImage(file=filename)

def img_seq(values):
    return [load_img(f'[35].png') for x in values]

def render_img(img, text=None, anchor=CENTER):
    global label_photo, window
    label_photo.configure(image=img, anchor=anchor)
    label_photo.image = img
```

```
    if text is not None:
        my_label = tk.Label(window, text=text, justify="center", font=('helvetica', fontsize))
        my_label.place(x=xpos, y=ypos)
        window.update()
        my_label.destroy()

def animate_seq(sequence, text=None, interval=2, shake=False):
    for img in sequence:
        if shake:
            anchors = [N, NE, E, SE, S, SW, W, NW]
            started = datetime.now()
            i = 0
            while started + timedelta(seconds=interval) >= datetime.now():
                anchor = anchors[i % len(anchors)]
                render_img(img, text, anchor=anchor)
                time.sleep(.01)
                i += 1
        else:
            render_img(img, text)
            time.sleep(interval)

def animate_seq_short(sequence, text=None):
    for img in sequence:
            render_img(img, text)
```

```
def get_data():
    global reference
    while True:
        if (serial_object.in_waiting > 0):
            serial_object.iread_until(1)
            serial_data = serial_object.readline()
            serial_data = serial_data.decode().strip('ascii')
            readSensorLine = float(serial_data)-reference
            #values = []
            #for o in range(lengtharray):
              #values.append(readSensorLine)
            average = readSensorLine#sum(values) / len(values)
            print (average)
            return int(average)

low = 3  # 15
med = 100  # 25
min_pulse_diff = 6
max_pulse_diff = 300
reference = 0

states = ['neutral', 'aware', 'annoyed', 'frustrated_1', 'frustrated_2', 'frustrated_3']
def target_state(state, since, val):
    if val < low:
        return 0
    elif low <= val < med:
        return 1
    else:
        if state <= 1:
            return 2
        else:
            if datetime.now() - timedelta(seconds=20) > since:
                return state + 1
            else:
                return state

animations = {
    ('neutral', 'aware'): img_seq([2, 3, 4]),
    ('aware', 'neutral'): img_seq([3, 2, 1]),
    ('aware', 'annoyed'): img_seq([5, 6, 7]),
    ('annoyed', 'aware'): img_seq([6, 5, 4]),
    ('annoyed', 'frustrated_1'): img_seq([8]),
    ('frustrated_1', 'annoyed'): img_seq([7]),
    ('frustrated_1', 'frustrated_2'): img_seq([9]),
    ('frustrated_2', 'frustrated_1'): img_seq([8]),
    ('frustrated_2', 'frustrated_3'): img_seq([10]),
    ('frustrated_3', 'frustrated_2'): img_seq([9]),
```

```
    ('neutral', 'neutral'): img_seq([1]),
    ('aware', 'aware'): img_seq([4]),
    ('annoyed', 'annoyed'): img_seq([7]),
    ('frustrated_1', 'frustrated_1'): img_seq([8]),
    ('frustrated_2', 'frustrated_2'): img_seq([9]),
    ('frustrated_3', 'frustrated_3'): img_seq([10]),
}

animation_text = {
    'neutral': "       You're\n doing great!",
    'aware': '      Each person\n   contributes to\nhis/her own electricity\n consumption',
    'annoyed': "       Each person\n contributes to\n the electricity\n consumption\n of the UT",
    'frustrated_1': "      Your consumption\nof electricity has\n climate change\n effects",
    'frustrated_2': "      Your consumption\nof electricity has\n climate change\n effects",
    'frustrated_3': "      Your consumption\nof electricity has\n climate change\n effects",
}

pulses_positive = {
    'neutral': img_seq([23, 22, 21, 1]),
    'aware': img_seq([33, 32, 31, 4]),
    'annoyed': img_seq([43, 42, 41, 7]),
    'frustrated_1': img_seq([53, 52, 51, 8]),
    'frustrated_2': img_seq([53, 52, 51, 9]),
    'frustrated_3': img_seq([53, 52, 51, 10])
}

pulses_negative = {
    'neutral': img_seq([63, 62, 61, 1]),
    'aware': img_seq([73, 72, 71, 4]),
    'annoyed': img_seq([83, 82, 81, 7]),
    'frustrated_1': img_seq([93, 92, 91, 8]),
    'frustrated_2': img_seq([103, 102, 101, 9]),
    'frustrated_3': img_seq([113, 112, 111, 10])
}


def main(init_state, seconds_per_loop, count1, count2):
    global my_label, count5, count6
    print("Entering main loop")
    bard = load_img('sign.png')
    label1 = Label(window, image=bard, border=-200, padx=0)
    label1.image = bard
    label1.place(x=310, y=17)
    state = init_state
    since = datetime.now()
    val = get_data()
```

```
   while True:
      time.sleep(seconds_per_loop)
      prev_val = val
      val = get_data()

      print(f'The new value is: {val} ({prev_val})')
      ###                                          if there is a decrease
      if prev_val > 1.8 * val and abs(prev_val - val) > min_pulse_diff and abs(prev_val - val) <
max_pulse_diff and count6==0:
         count6=1
         if prev_val > 0:
            x = random.randint(1, 3)
            if x == 1:
               print("a")
               cmd = ('A')
               serial_object.write(cmd.encode())
            if x == 2:
               print("b")
               cmd = ('B')
               serial_object.write(cmd.encode())
            if x == 3:
               print("c")
               cmd = ('C')
               serial_object.write(cmd.encode())

            ts = target_state(state, since, val)
            if ts != state:
               state = ts
               since = datetime.now()
            text = f'You decreased your\nenergy consumption with\n{int(prev_val - val)}\n watts
per hour\n and saving:\n{int((prev_val - val) * .56)} g\nCO2 per year'
            animate_seq(pulses_positive[states[min(ts, 5)]], text=text)
      ###                                          if there is an increase

      elif prev_val * 1.8 < val and abs(prev_val - val) > min_pulse_diff and abs(prev_val - val) <
max_pulse_diff and count6==0:
         count6=1

         x = random.randint(4, 6)
         if x == 4:
            print("d")
            cmd=('D')
            serial_object.write(cmd.encode())
         if x == 5:
            print("e")
            cmd=('E')
            serial_object.write(cmd.encode())
```

```
            if x == 6:
                print("f")
                cmd=('F')
                serial_object.write(cmd.encode())

            ts = target_state(state, since, val)
            if ts != state:
                state = ts
                since = datetime.now()
            text = f'You increased your\n electricity consumption with\n{int(val - prev_val)} W\nper
hour\n and contributing:\n{int((val - prev_val) * .56)} g\nCO2 per year'
            animate_seq(pulses_negative[states[min(ts, 5)]], text=text)

        else:
            prev_state = state
            ts = target_state(state, since, val)
            if ts == state:
                count1 = 0
                count2 = 0
                count6 = 0
                print(count6)

                #### make another loop for a transition to refresh the text but only show 1 new
image instead of 3

            # decrease of consumption
            if ts < state:
                count2 += 1
                if count2 > 2:
                    count1 = 0
                    state = max(0, state - 1)

            # increase of consumption
            if ts > state:
                count1 += 1
                count2 = 0
                if count1 > 2:
                    state = min(5, state + 1)
            print(f'Update with vals ({prev_val}, {val}) and states ({prev_state}, {state})')
            if state != prev_state:
                since = datetime.now()
                count1 = 0
                count2 = 0
                count5=0
                count6=0
                transition = (states[prev_state], states[state])
                animate_seq(animations[transition], shake=True,text=animation_text[states[state]])
```

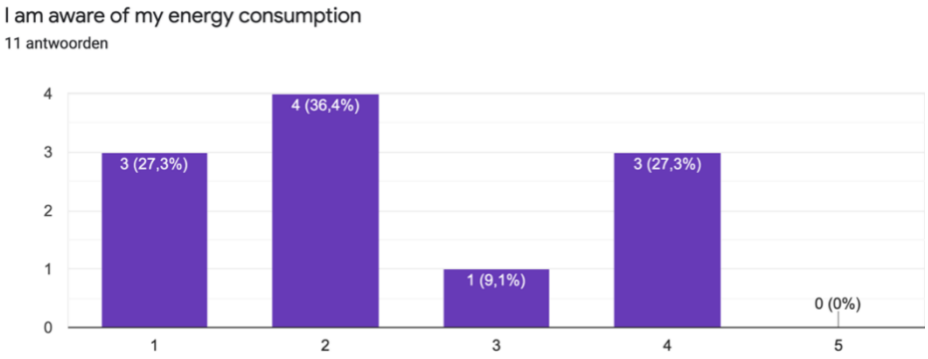
```
        if ts == 0 and state == 0:
            if val < 0:
                val = 0
            text = f'Your current electricity\n consumption is\ncontributing to\n{int(val)} g\n CO2
per year'
            transition = (states[prev_state], states[state])
            animate_seq_short(animations[transition], text=text)

        if ts == 1 and state == 1:
            text = f'Your current\nelectricity consumption is\n{int(val)} W\nper hour\n
\nAverage consumption is\n 270 W'
            transition = (states[prev_state], states[state])
            animate_seq_short(animations[transition], text=text)

        if ts == 2 and state == 2:
            text = f'Is it possible\nto switch of a device?\n \nCurrent consumption is:\n{int(val)}
W\nper hour'
            transition = (states[prev_state], states[state])
            animate_seq_short(animations[transition], text=text)

        if ts == 3 and state == 3:
            text = f"Your current consumption\nis equivalent to\n{int(val / 6)}\nphone's
charging"
            transition = (states[prev_state], states[state])
            animate_seq_short(animations[transition], text=text)

        if ts == 4 and state == 4:
            text = f'Ice caps are melting\ndue to your contribution of\n{int(val)} W\nper hour'
            transition = (states[prev_state], states[state])
            animate_seq_short(animations[transition], text=text)

        if ts == 5 and state == 5:
            text = f'The Dutch sea level will\n raise with 5-7 centimeters\ndue to your
contribution of\n{int(val * 0.56)} g\nCO2 per year'
            transition = (states[prev_state], states[state])
            animate_seq_short(animations[transition], text=text)

def take_out():
    for _ in range(5, 0, -1):
        serial_object.readline()
if __name__ == '__main__':
    take_out()
    reference = get_data()
    start_state = target_state(0, datetime.now(), get_data())
    main(start_state, 1, count1, count2)
```

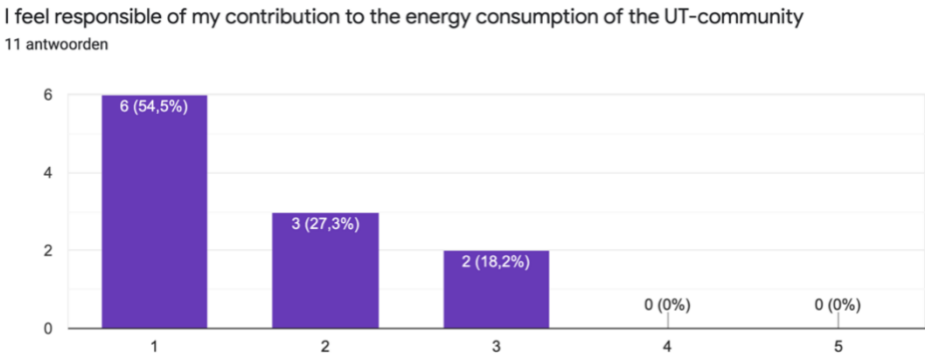
```
void loop()
{
if (Serial.available()>0){
numBlinks = Serial.read(); //Read the data the user has input
if (numBlinks=='2'){
//Serial.println("the led is turned on");
//digitalWrite(5,HIGH);
//delay(2000);
//digitalWrite(5,LOW);
Serial.println("the sound is played");
tmrpcm.play("1.wav");
  }
}
double Irms = emon1.calcIrms(1480);  // Calculate Irms only
Serial.print("Watt:");
Serial.println((Irms*230));          // Apparent power
}

//}
//else if (data='Z'){
  //tmrpcm.play("5.wav");
    //  digitalWrite(LED_BUILTIN, HIGH);   // turn the LED on
//}
//else if (data='Z'){
//  tmrpcm.play("6.wav");
//      digitalWrite(LED_BUILTIN, HIGH);   // turn the LED on
//}
//else if (data='Z'){
  //tmrpcm.play("1.wav");
    //digitalWrite(LED_BUILTIN, HIGH);   // turn the LED on
//}
//else if (data='Z'){
  //tmrpcm.play("2.wav");
    //digitalWrite(LED_BUILTIN, HIGH);   // turn the LED on
//}
//else if (data='Z'){
  //tmrpcm.play("3.wav");
    //digitalWrite(LED_BUILTIN, HIGH);   // turn the LED on
    //}
//  }
//}
```

F Evaluation results

F.1 Usability testing

User 1	Advanced Technology	23	Male
User 2	Industrial Design	22	Male
User 3	Industrial Engineering & Management	22	Male
User 4	Creative Technology	20	Female
User 5	Industrial Engineering & Management	19	Male
User 6	Civil Engineering	18	Male
User 7	Technical Medicine	21	Female
User 8	Psychology	22	Female
User 9	Technical computer science	23	Female





What is your first impression of the EB?

a bit overdreven cool in insight in my consumption
Very nice concept
Funny and effective
it works that is nice, it is funny to see how much you electricity you use. especially in relation with other devices.
Impressive
funny little device, get your attention.
interessant vooral it fastly looks angry het gaat een beetje leven ipv enkel cijfers
it is quickly angry it is confronting that when you use something it changes its state nice creative product it makes people aware je wordt tot verantwoording geroepen it is quickly angry
scherp, hij heeft gelijk door wat je doet, hij is streng want ik wil meer gebruiken it is funny the levels of usage and that it related with your usage nice the relation with phones

What do you think of the sounds?

not present
Amazing
No sounds
Not present
Extremely clear
non exsistent

What do you think of the vibration?

good, to alert the user
Could be a little bit more
Didnt notice
It alerts you, it attracts the focus towards the screen so you can see your consumption
Didn’t notice
helps with getting your attention
it triggers your attention which is key to keep attention to the user
nice to alert you, wouldve missed it otherwise
it is nice that you get alerted with a change nice since sounds I would switch off

What aspects of the design do you dislike?

randinformatie willen hebben om te weten of het verbruik normaal is of niet what is the average consumption, 270 w is not in perspective
Dat het in een doos zit
De doos? Haha
the box around the EB make it one device with the power strip
The small screen
the plain carton box could be worked out a little bit more to feel more astaetic.
to snell to angry, should swithc of sounds
ik zou meer spelen met hoofdletters, de belangrijke dingen zoals wattage sounds would be annoying during meetings
te snel te boos

What do you think of the emotions of the EB?

beetje fluctuerent not consistend, it gets angry, but i need to consume energy, so it is not applicable that i am destroying ice capas

Fine, maybe you can add a sad feeling

I think it would be more effective if the EB would be sad.

applicable to the things that you are using it is good that it shifts with your usage

Very compliant with the user's feelings

are very matching with the actual emotions that come with the energy consumption

it is good that is gets angry fast because a phone and a pc should be

it goes to fast to angry, passemistic

het is duidelijk wanhopig/boos maar hij gaat te snel te veel een beetje is neutral soieso een laptop anders zou ik hem niet aanzetten meer overgangsniveaus

What do you think of the texts which the EB is displaying?

overdreven

Pakkende teksten.

Good, effective with some facts

nice contfrinting and good ratio between the consumption and other devices

When the EB shows these texts it makes you think, because it gives clear examples of how much energy you consume on a day to day basis

are very witty and funny

goed, aan de ene kant dat je weet hoeveel wat je verbruikt en aan de andere kant dat je eenheden die je kent ziet

more for people who not know anything, express what is the goal and give handvaten

duidelijk en nice met vergelijken met andere devices

What aspects of the design do you like?

the different kinds of interaction that is in on a lcd screen, visual strong the relation with consumption and devices

De energiebuddy zelf.

Poppetje is duidelijk, effectiever dan een kleur bijv. Goed concept met pakkende teksten

the EB which moves along

Very smooth and clear

it is appealing to look at

het mannetje laat goed zien in welke staat je ziet en of je goed bezig bent of niet

dat het poppetje een emotie heeft, want het geeft direct weer wat het poppetje ervan vind

dat de verschillen in de mannetjes groot zijn, dit geeft de extra feature dat je meer getriggert wordt

What do you think of the glowing?

visual strong

Could be a little bit more

Didnt notice

it gives you the feeling that you do something wrong

It expresses the inner feelings of the elektro buddy

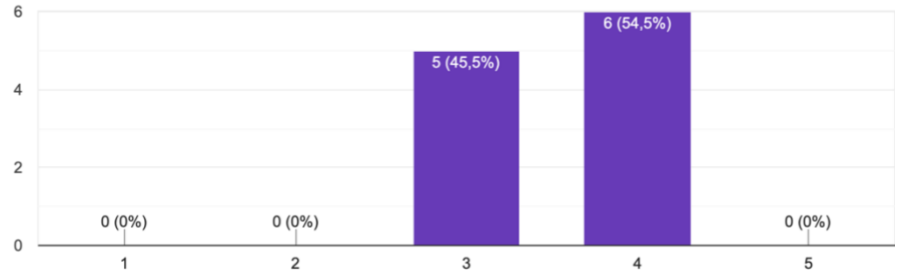
same answer

you know that you are using more, so it is nice that it triggers you

het benadrukt het nog een extra keer dat je er iets in gooit je komt er hierdoor wel achter dat het extra effect heeft

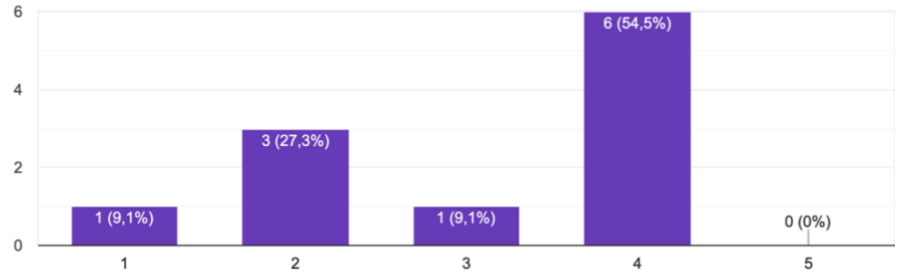
The Energy Buddy is appealing

11 antwoorden



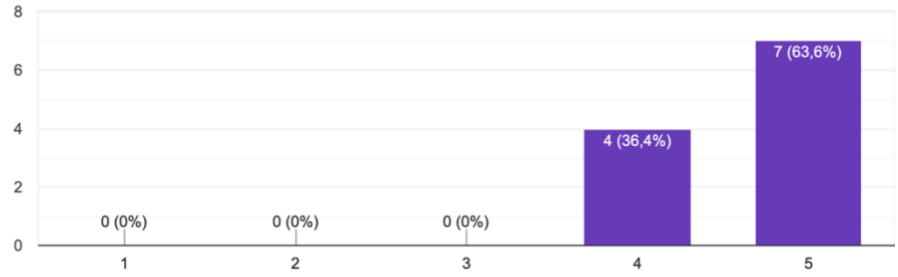
Do you feel being rewarded for your behavior?

11 antwoorden



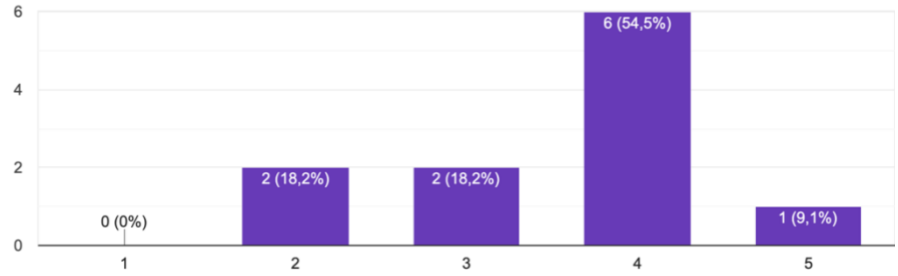
Do you feel like being confronted with your energy behviour?

11 antwoorden



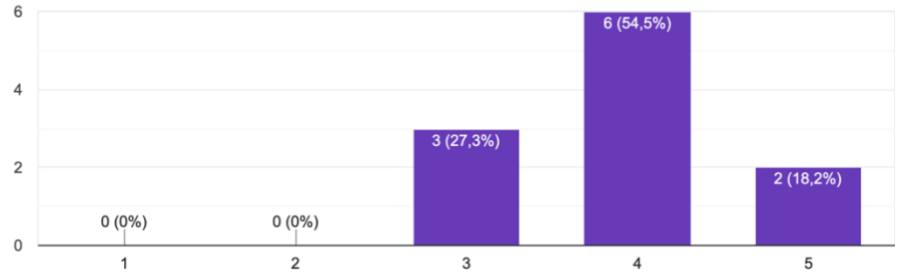
The Energy Buddy assesses the issue concise

11 antwoorden



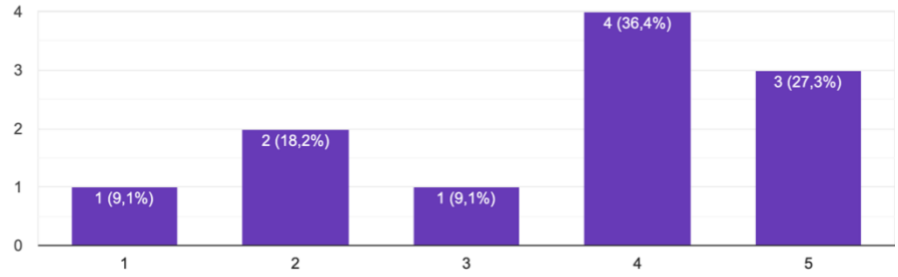
The Energy Buddy has a simplistic approach

11 antwoorden



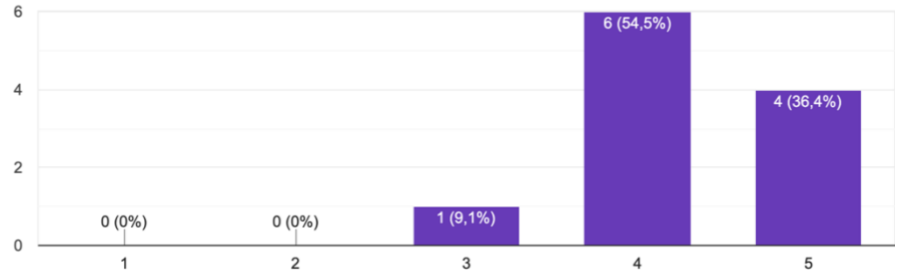
The interactions of the Energy Buddy are in line with my electricity consumption

11 antwoorden



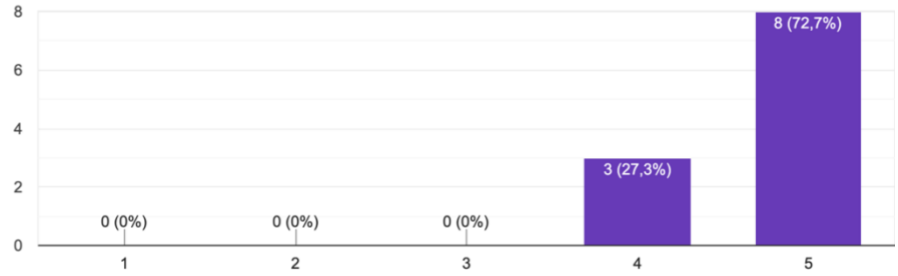
I feel personally addressed by the Energy Buddy

11 antwoorden



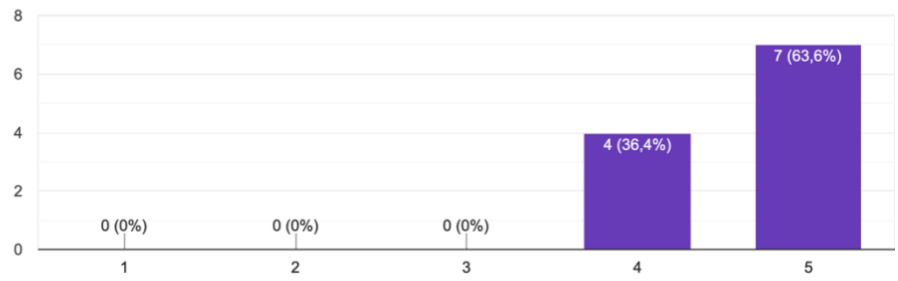
I understand the message of the Energy buddy

11 antwoorden



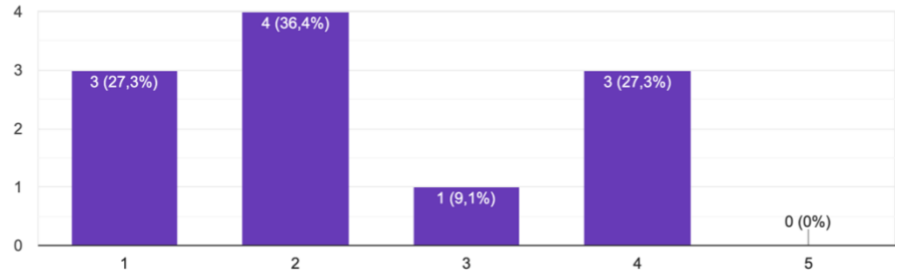
The goal of the Energy Buddy is clear to me

11 antwoorden



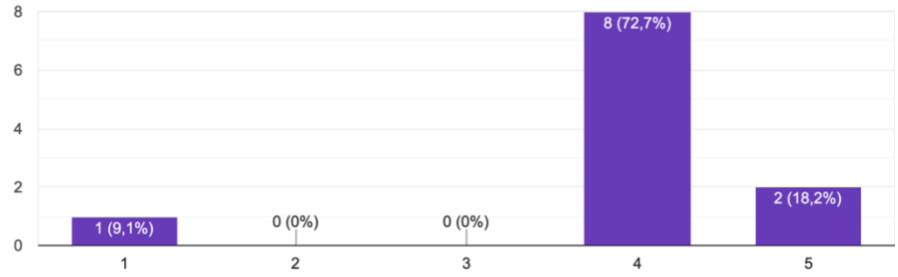
I feel responsible of my contribution to the energy consumption of the UT-community

11 antwoorden



I am more aware of my energy consumption

11 antwoorden



F.2 Client results

What is your first impression of the product?

hij doet het omgekeerde van stimulerren hij highltight het negatieve waarom invalshoek:

negatieve aspecten lijken it is something speelvol

verrassend, ik vind het verrassend, het triggeren van mensen op wat er gebeurd. mij zegt het iets, dat is handig, dat triggeren, facts icm gevolgen is levendig en nice extra dingetje, voor wat er normaal gedaan wordt, met stapjes, mooi geintegreerd

Do you think people at the UT would use it?

weet ik niet het is lastig om te blijven stimuleren in de bibliotheek zou het kunnen werken

incidenteel, verrassend

yeh, but it needs to be developed continuesly, it needs to be updated to be triggered for people, it gets bored, new aspects or new impulses

What aspects do you like?

de vertaling naar harde cijfers zoals zeespiegel het speelse is heel erg leuk
the colour with the trigger the texts the mymics of the EB the EB itself it is very simple thought, nice thing short and concise dynamical it triggers me, on good way de lading is eraf, gebracht met een komische manier

What aspects do you dislike?

dat het focust op negatieve, maar het brengt het niet negatief mensen moeten gewaardeerd worden, het wattage is te laag, meer gekoppeld aan een gemiddelde
het doosje it small screen the flickering of the text

Are there aspects which you would change to make the product more applicable for the UT-community?

watt aanpassen, aan locaties app gebruiken om meer mensen
on screen, as watermark with known information, like schermtijd wireless communication with computer

Are there aspects which you would change to make the product more effective?

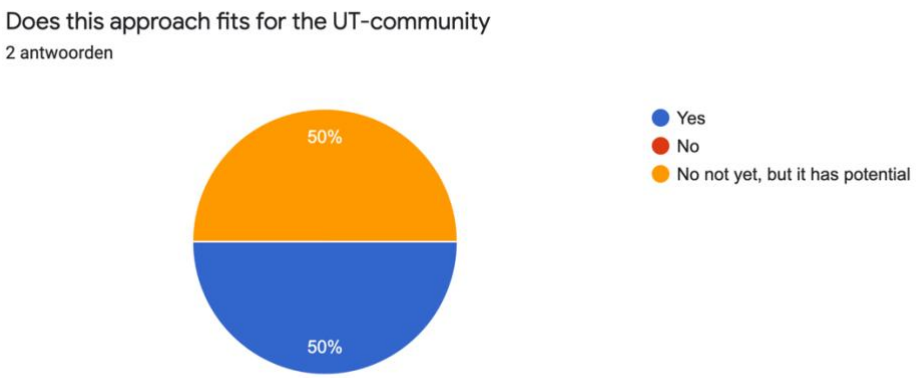
zorg dat het aangepast wordt voor een lab, bijvoorbeeld met de kasten en aanwezigheid, koppelen aan handelingen aan het einde van de dag
remembers how many times i uses today, and over a time limit like 8 hours

What would you like to be integrated?

doelgroepen, aanpassen biep en labs
rembember how much I consumed monitor the consumption of a whole building integratate sunny outside

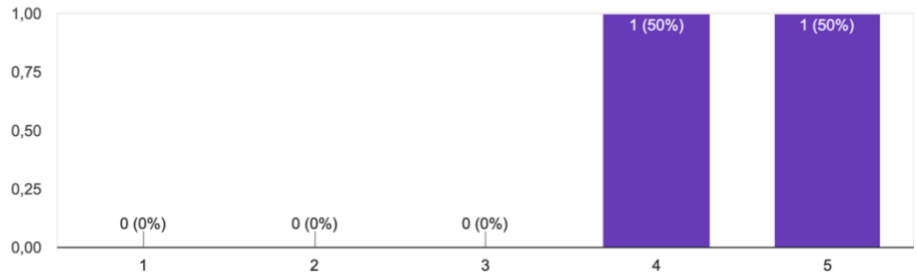
Do you think this product will create awareness among the UT-community

yes, it has potential, especially for the labs, make it applicable for them.
yes certainly, because it hits the people personnally



The goal of the Energy Buddy is clear

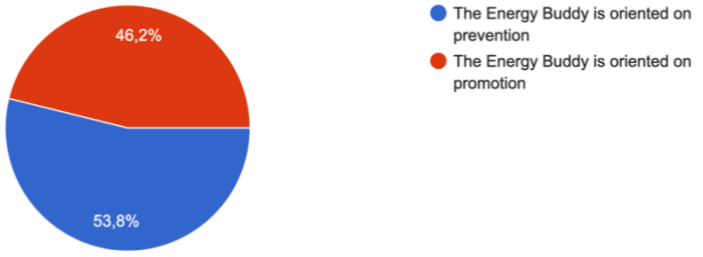
2 antwoorden



F.3 Generic questions

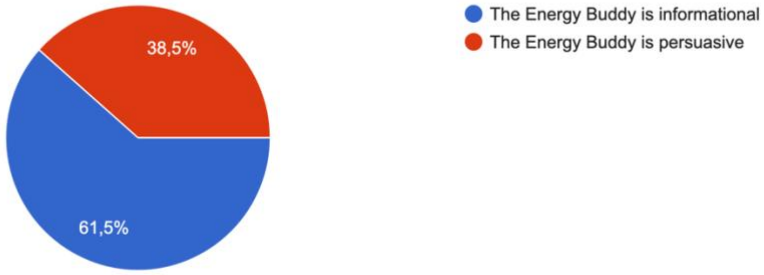
Do you think that the is Energy Buddy oriented on prevention of energy usage or the promotion of less energy usage?

13 antwoorden



Do you think that the is Energy Buddy informational or persuasive?

13 antwoorden

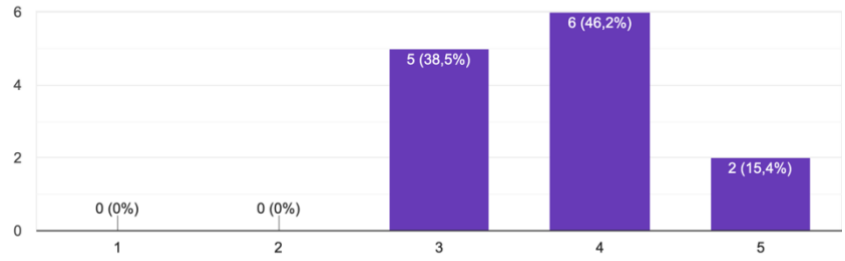


Do you think that the is Energy Buddy oriented on change of the public will or individual behavior change?

13 antwoorden

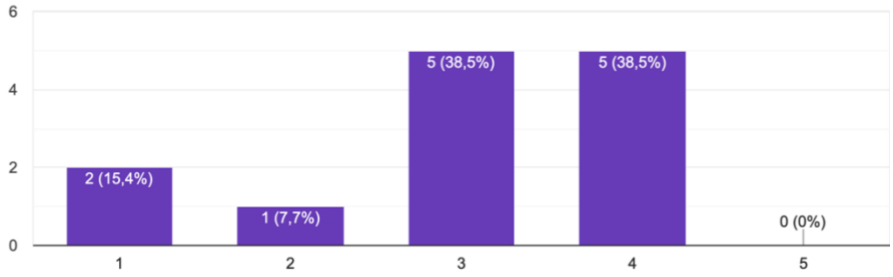
Does the product increase your confidence about actions which you can perform to decrease the energy consumption?

13 antwoorden



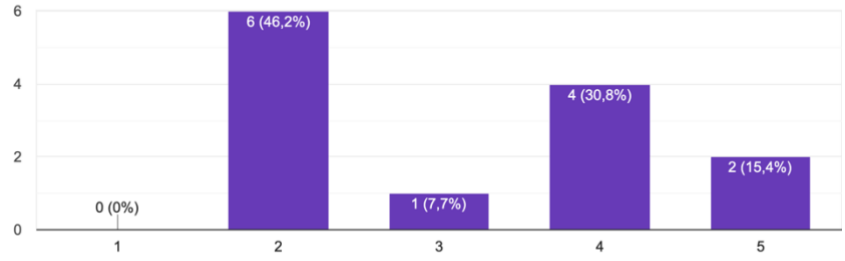
The products assigns barriers for behavioral change?

13 antwoorden



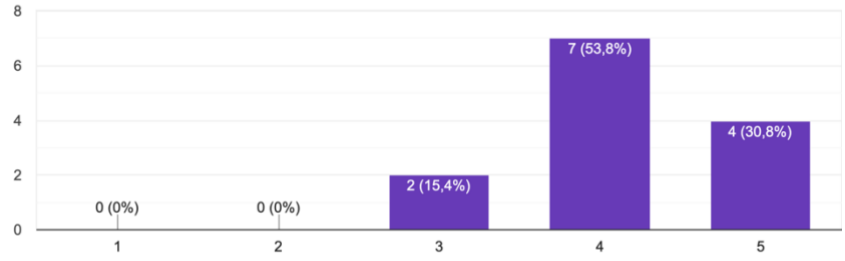
The product gives examples about actions which you can perform to decrease the energy consumption?

13 antwoorden



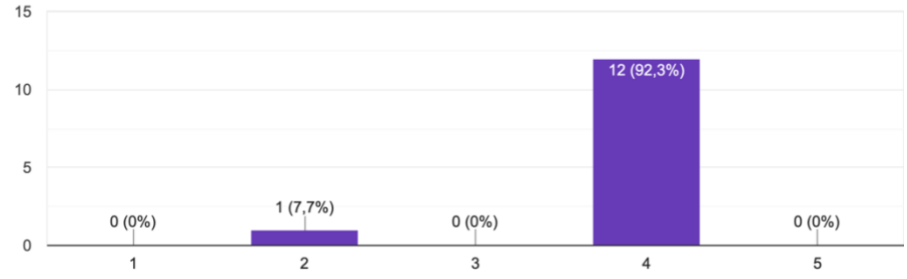
The product increased my sense of responsibility about my contribution to the energy consumption?

13 antwoorden



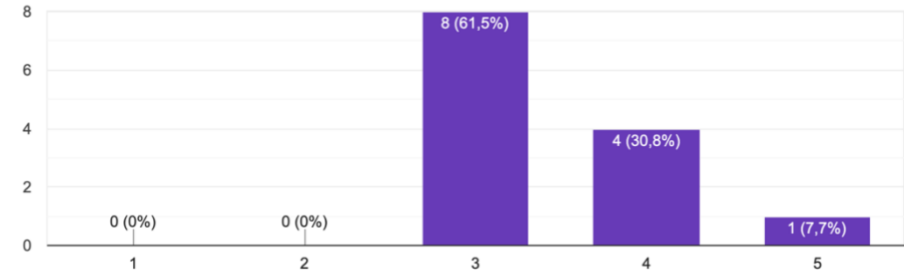
I still feel allowed to consume energy

13 antwoorden



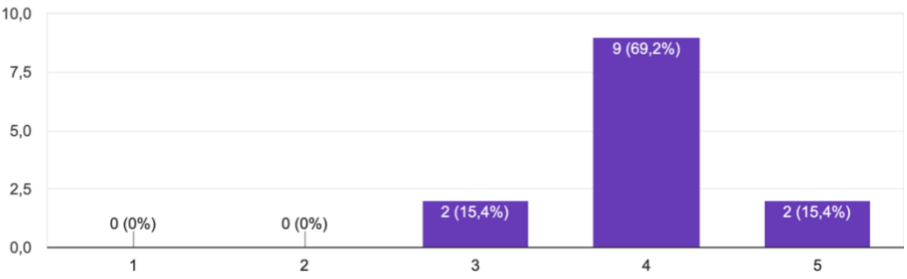
The product increases my concerns about energy consumption

13 antwoorden



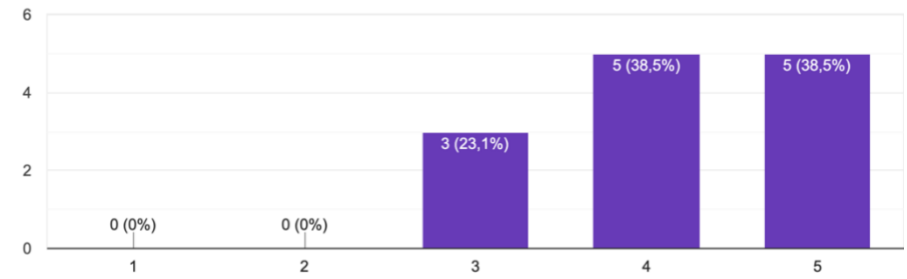
The product assigns the fact that I am part of the energy consumption

13 antwoorden



The product assigns the consequences of my personal behavior?

13 antwoorden



F.4 Obtained values

Q_1:

$h_0: \mu_1 = \mu_2$

$h_a: \mu_1 < \mu_2$

$\mu_1 = 1{,}6$

$\mu_2 = 2{,}2$

$\sigma_1 = 0{,}69$

$\sigma_2 = 1{,}13$

Q_2:

$h_0: \mu_1 = \mu_2$

$h_a: \mu_1 < \mu_2$

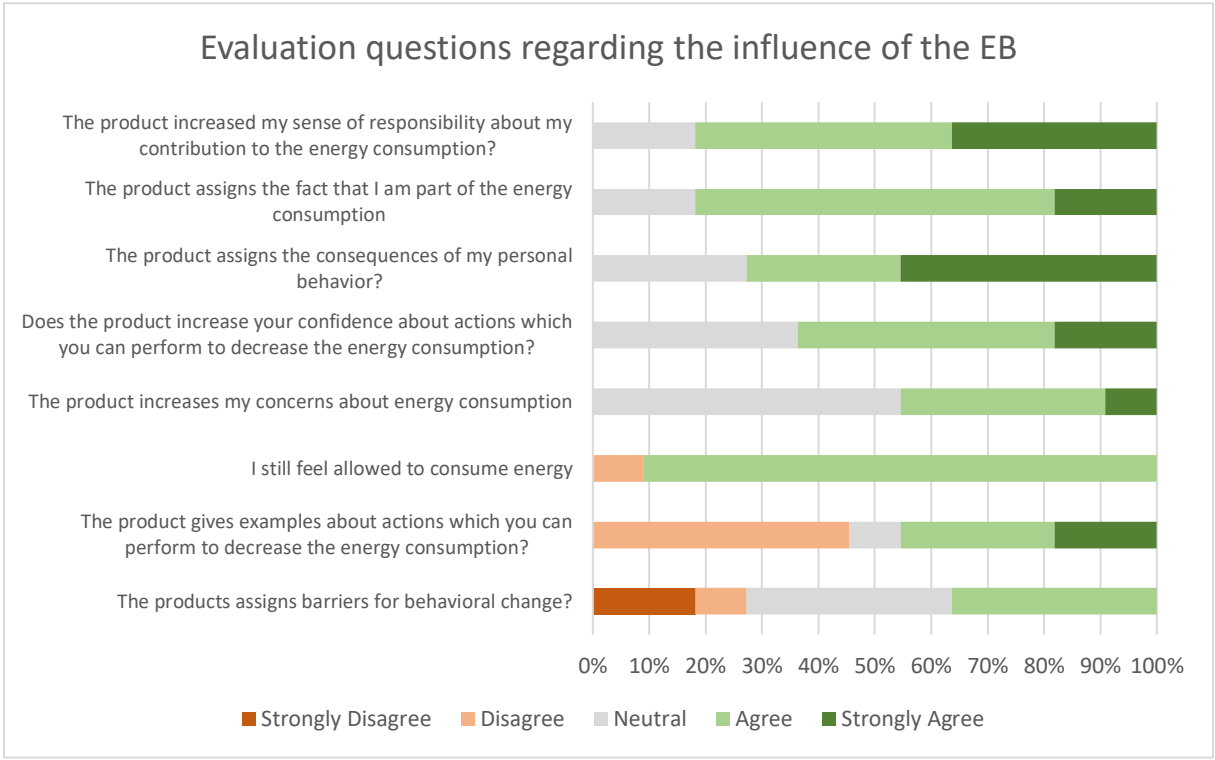
$\mu_1 = 2{,}4$

$\mu_2 = 3{,}9.$

$\sigma_1 = 1{,}26$

$\sigma_2 = 1{,}10$

F.5 evaluation questions regarding the influence of the EB



G Information brochure

Dear reader,

First of all, thank you for participating in this research, with this information brochure I would like to give you insights in the purpose of this research. This is part of the study Creative Technology at the University of Twente.

The goal of the thesis is to increase awareness among the UT-community. To realize this an Energy Buddy has been developed. To discover the possibilities and how users perceive the Energy Buddy this evaluation has been set-up. Please answer the questions honestly.

Besides that, the following sides nodes have to be made:

- You must be a member of the University of Twente and older than 18 to answer this questionnaire. To continue, the consent form has to be signed.
- The questionnaire is completely anonymous and will not asses personal information, neither answers will be judged
- The participation will take approximately 15 minutes
- You are free to withdraw at any moment without any consequences or refuse to answer questions

Lastly, I would like to thank you for the evaluation of the Energy Buddy, this will help to complete my Bachelor thesis successfully.

For any questions you can always contact me or my supervisors through:

Researcher
Thijn van Weert
T.vanweert@student.utwente.nl

Supervisor
Dr. Kazia Zalewska
k.zalewska-kurek@utwente.nl

If you have any complaints about this research or questions you are always free to approach the Ethics Committee of the Faculty of Electrical Engineering, Mathematics and Computer Sciences at the University of Twente at: ethics-commewi@utwente.nl

Consent form for evaluation Energy Buddy (EB)

You will be given a copy of this informed consent form

In this research you will be asked to evaluate an Energy Buddy (EB). The goal of this Energy Buddy is to increase awareness, therefor this question is asked twice. You are encouraged to answer the questions honestly and extensively, the developer won't assess you personally. The questionnaire should not take longer than 15 minutes and consists of 2 parts. By signing this document I agree with the following statements.

- I have read and understood the study information [DD/MM/YYYY], or it has been read to me. I have been able to ask any questions about the study and goal and these have ben answered to my satisfaction.
- I consent voluntary to this evaluation and am aware that I can refuse to answer questions and can withdraw from the study at any time without any consequences.
- I am aware that the study also involved hand written notes.
- I understand that the information that I provide will be used to gain knowledge about awareness regarding energy consumption and the performance of the EB.
- I understand that the personal information will be anonymized and no personal data will be placed in the research.
- I give permission that my anonymized data will be archived and processed for future research and learning.
- I give the researcher permission to keep my contact information.

Signature

_____

Name of Participant

_____ _____

Signature Date

If there are any questions about the research you are at any time free to contact the researcher or supervisor at:

Researcher
Thijn van weert
T.vanweert@student.utwente.nl

Supervisor
Dr. Kazia Zalewska
k.zalewska-kurek@utwente.nl

If you have any complaints about this research or questions you are always free to approach the Ethics Committee of the Faculty of Electrical Engineering, Mathematics and Computer Sciences at the University of Twente at : ethics-commewi@utwente.nl

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