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Responsible energy consumption amongst university employees:

Designing a behaviour change intervention

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Abstract

Initiatives to reduce energy consumption on the campus of the University of Twente have been mostly focused on increasing building efficiency like applying insultation to buildings. However, no research has been done on their long term plan to engage students and employees within their energy consumption initiatives. Knowing how to design responsible behaviour change interventions for electricity usage among university employees in the future could significantly enhance future energy-saving efforts on campus. In this study a design process for a responsible behaviour change intervention amongst university employees for their electricity consumption is described. Within this process a Behavioural Habits Model (BHM) was developed through a literature review. This model can guide designers to create similar effective responsible behaviour change interventions. With this model and relevant state of the art findings an intervention was developed and evaluated with a series of user tests. The design was generally positively reviewed and participants stated that they would intent to use the intervention and intent to change their behaviour when the intervention got implemented. These results support that a versatile design approach through the BHM with the implementation of multiple intervention types facilitates the intention to behaviour change and use of a responsible energy consumption intervention amongst university employees. Future work should focus on assessing whether the intervention or a design through the BHM facilitates a positive change in responsible energy consumption behaviour, as this aspect was not evaluated in the current study.

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Chapter 1 – Introduction

The Campus & Facility Management (CFM) at the University of Twente is a university department responsible for overseeing the campus and its facilities. The University of Twente is actively striving to evolve into a sustainable organization. Their sustainability mission involves addressing societal needs through the formulation of proactive and sustainable measures to support both the planet and its inhabitants.

The University of Twente has already fulfilled its long-term agreements with the government to reduce energy demand by 30% from 2005 to 2020, achieving this goal in 2014 [1]. This was primarily accomplished through energy-saving measures that focused on enhancing building efficiency. Think about insulation, natural lighting and ventilation, energy efficient appliances etc. There is however recognition that there are limits to building efficiency improvements.

Hence, the Campus & Facility Management (CFM) is looking for alternative measures sustain the downward trend in energy consumption. Apart from building efficiency users themselves also play a vital role in energy savings. A study by Azar and Menassa [2, Art. mentioned in Azar and Al Ansari] estimate potential energy saving in US office spaces at 21% if employees adopt simple actions. Examples are adjusting room temperatures and reducing the use of equipment and lights during unoccupied building periods. Similarly, the European Environment Agency [3] shows that up to 20% of the current consumed energy can be saved through changing behaviour. The CFM recognizes this role of users in influencing energy consumption and sees engaging students and employees as the next phase for energy reduction.

Research questions

Nevertheless, the CFM is still unsure on how students and staff can be involved in reducing energy consumption. This project aims to serve as an example or pilot project to the CFM of how to engage employees in responsible energy usage to reduce energy consumption. There are many forms of energy consumption: water, gas, electricity etc. This project strictly limits the scope to electricity consumption. Additionally, it specifically pursues to make pro-environmental behavioural (PEB) change regarding energy consumption among university employees possible as this user group generally has more control over their electricity consumption than students. Common PEB include, but are not confined to, controlling equipment, lighting usage, ventilation, air conditioning etc. The intent is to influence university employees to turn off devices when they are unnecessarily on. For this project a PEB change intervention will be designed. With this in mind the following research question is defined:

RQ: *How can an effective behavior intervention be designed to facilitate pro-environmental behavior among university employees, specifically targeting the responsible energy usage?*

Sub questions- behaviour

One of the reasons why engaging users in reducing energy consumption is a difficult topic is because of the complexity of behaviour change. The driving force of changing behaviours and habits remains a subject of ongoing discussion in the literature till this date. Before an intervention for pro environmental behaviour (PEB) change to reduce energy consumption can be created, it is necessary to conduct a research about these driving forces behind habits and behaviour change and how to effectively apply strategies to guide these forces to the desired PEB outcomes.

SQ1: *What are effective supporting behaviour change models for pro environmental behaviour intervention designs regarding responsible energy usage?*

SQ2: *Which techniques can be applied to change behaviour to pro-environmental behaviour regarding the responsible usage of energy?*

Sub question – data collection

A second component of the intervention which requires research is the requirement of data collection amongst university employees:

SQ3: *What are ways to collect electricity consumption data of university employees?*

Chapter 2 – Background Research

To create effective interventions, it is crucial to consider both academic literature and the practical implementation of existing products. By analysing both literature research and real-world applications, it is possible to gather valuable insights that will inform the design decisions for the intervention. This can ensure that it is both theoretically sound and practically effective. Therefore, this chapter is split up into a literature review subsection and a state of the art subsection.

Literature review

The literature review first examines the single determinant attitude. To gain a deeper understanding of behaviour change mechanisms, behaviour change models are also explored. This exploration aims to assist designers in creating interventions for promoting pro-environmental behaviour (PEB). Additionally, behaviour change techniques (BCTs) and their application in these interventions are discussed.

What are the relations of attitude and pro environmental behaviour?

Attitudes is a determinant that is frequently cited in the literature and behaviour models presumably because they reflect individuals' evaluations, beliefs, and feelings toward a behaviour. Understanding the relation between attitudes and PEB could potentially aid in identifying the underlying motivations and barriers that influence whether someone engages in a particular behaviour or not.

Attitude, is in itself not a good predictor for PEB. The theory of planned behaviour by Ajzen and Fishbein [4] states that attitudes not per se lead to actions, but help develop behavioural intentions (i.e., planned behaviour) which could eventually lead to actions. See next subsection “What are effective supporting behaviour change models for PEB interventions?” Wyss et al [5] and Kollmuss and Agyeman [6] both support the statement that attitudes do not necessarily lead to action by mentioning that there is indeed a discrepancy between attitudes and behaviours. However Murtagh et al [7] presents contradicting findings. Murtagh et al’s study focussed on plug load feedback in university offices. They found that positive attitudes towards reducing energy correlated with actual energy usage in the baseline month before introducing the intervention. Nevertheless it had no correlation with the feedback or reduction of energy after the intervention (MyEcoFootprint) was placed. This might suggest that attitudes have less impact on driving changes towards PEB than it has on current PEB. The contradicting findings in the studies might be present because of flaws in research methodologies. Lehmann [6, Art. in Kollmuss and Agyman], suggests that more narrowly focused attitude measurements results in stronger correlations, but that this comes at the cost of losing significant information. The attitude in Murtagh et al’s study are measured with three items. For example, the item "My opinion is positive about using MyEcoFootprint" only capture one aspect of attitudes towards technology use. This could potentially overlook other dimensions such as perceived usefulness, ease of use, ethical considerations etc. Similarly, the item "I believe it is a sensible idea to try to use less electricity at work" might not cover the full spectrum of beliefs and attitudes that individuals hold regarding energy conservation. Therefore, Murtagh et al might have found a higher correlation between attitude and energy usage than actually exists. Results of Wyss et al's study expands on the direct relation between attitudes and PEB. The study showed that attitudes become more predictive of PEB when personal costs are low or environmental benefits are high. Additionally, he concluded two things about self-control; an additional mediating determinant that could influence PEB. Firstly, he concluded that people with high levels of self-control raised the probability of their pro-environmental behaviour aligning with their attitudes by 38.23%. Secondly he showed that the relationship between attitudes and PEB is greater for participants with higher self-control. Kollmuss and Agyeman [6] analyse many different PEB models, but indicate that PEB is so complex that the causal variables of PEB cannot be visualized in one single framework. This suggests that while attitude might be an important determinant of PEB it can be influenced by mediating factors and requires alignment with other crucial determinants of PEB to translate into actual behaviour.

What are effective supporting behaviour change models for PEB intervention designs?

This section aims to determine what behaviour change models are effective to aid designers to create working PEB interventions. To reach this goal first existing behaviour models are analysed. These models are compared, and their limitations are addressed with insights from the other analysed models to develop a comprehensive framework that effectively aids designers in creating PEB interventions.

Analysing existing behaviour models

There are three effective models to encourage PEB change related to introducing interventions. This might however be a bold claim since Kollmuss and Agyeman [6] indicated that PEB is too complex to visualize the causal variables of PEB in one single framework. Nevertheless It is still useful to get a simplistic and limited overview and understanding of the factors contributing to PEB change. This can serve as a foundation for linking behaviour change techniques (BCTs) in the intervention later in the project. The theory of planned behaviour, Geller's behaviour change model [8, Art. discussed by Yun et al] and the model of Stern [2, Art. discussed in Azar and Al Ansari] and Kollmuss and Agyeman [6] are all closely tied to BCT's needed for an intervention. This creates a more simplistic overview for the purposes of this study than other complex models that are solely focused on integrating various specific attributes related to PEB change to construct a causal chain (e.g. models discussed by Kollmuss and Agyeman [6]). Therefore, these two models were selected to be analysed.

Firstly, the theory of planned behaviour (TPB) is a more effective representation than the theory of reasoned action (TRA). The model of TPB can be seen in Figure 1. Ajzen and Fishbein's [4] TPB is an expansion on the TRA, which is according to Kollmuss and Agyeman [6] of one of the most influential theories on behaviour change in social psychology. The TRA states that intentions (influenced by attitudes and subjective norms toward a behaviour) alone should be sufficient to predict behaviour. The TPB expands on the theory of reasoned action by introducing a third causal variable, perceived control, which influences intentions and behaviour directly. The perceived control over people's behaviour is according to TPB dependent on nonmotivational factors like the availability of resources and opportunities. It states that behavioural intention has a greater probability to be translated into behavioural expression when the person has control over the ability to engage in a specific behaviour. This is in line with the findings from Azar and Al Ansari [2] who found that a lack of control can hinder the intentions or motivations of behavioural actions and with Wyss et al [5] who suggested that situational constraints like lack of control and cultural factors (e.g. subjective norms) could hinder attitudes to translate into PEB. Although it should be taken into consideration that Wyss et al talks about attitudes instead of intentions here, it should be noted that all three causal variables of intention in TPB (attitude, subjective norms and control) are mentioned. However, Wyss et al [5] also states that whenever the situational factors are not a problem the attitudes still do not result in PEB. So, even though the importance of the extension of perceived control in TPB in regard to TRA seems viable, the TPB might still miss some vital factors that play a role in PEB.

The first weak point of the TPB is the assumption that people act rationally. Kollmuss and Agyeman [6] pointed out might not always be the case. Habits and emotions often influence PEB in some way or another. As Stern [9] pointed out many PEBs are part of habits or routines. (e.g. setting of thermostats, turning off devices etc.) Many sources [2], [6], [9] have emphasized on the importance of habits on behaviour. However, Ajzen [4] suggests that habits can normally only be added as explanatory variables instead of causal ones. He suggests that habits are the results of repeated behaviours instead of the direct causes of behaviour. For habits to be incorporated into the model the factors that have established the habit should be considered rather than the past behaviour itself. These are factors based on past experiences like attitudes, subjective norms and perceived self-efficacy. Nevertheless, this view on habits might overlook their automatic nature. Unconscious automatic behaviours seem to suggest that it can have direct influence on behaviour and thus be a viable causal variable of behaviour. To summarise, possible missing factors to consider in TPB are the lack of habitual and emotional influences in the theory. More research might be needed in weather habits can be broken when the factors that have established the habit fail to support current behaviour.

There are also two other factors that could discredit the effectiveness of the model. Firstly, findings from a study by Wyss et al [5] concluded that people with high levels of self-control raised the probability of their pro-environmental behaviour aligning with their attitudes by 38.23%. Additionally, the study showed that the relationship between attitudes and PEB is greater for participants with higher self-control. These findings might suggest that personal skills can also play a vital role in PEB; not only perceived external control, but also (perceived) internal control might play a role. Apart from this it is important to note that the TPB is used to predict behaviour instead of changing it. In conclusion, another additional factor that could influence behaviour are personal skills like (perceived) internal control. Additionally, the true intent of the model should be kept in mind when applying the model as a base for a PEB change intervention.

Apart from the weak points of the model, an additional interesting determinant to have a closer look at is attitude. This determinant is frequently cited in the literature and behaviour models. Attitude, is in itself not a good predictor for PEB. The TPB by Ajzen and Fishbein [4] states that attitudes not per se lead to actions, but help develop behavioural intentions (i.e., planned behaviour) which could eventually lead to actions. Wyss et al [5] and Kollmuss and Agyeman [6] both support the statement that attitudes do not necessarily lead to action by mentioning that there is indeed a discrepancy between attitudes and behaviours. However Murtagh et al [7] presents contradicting findings. Murtagh et al's study focussed on plug load feedback in university offices. They found that positive attitudes towards reducing energy correlated with actual energy usage in the baseline month before introducing the intervention. Nevertheless it had no correlation with the feedback or reduction of energy after the intervention (MyEcoFootprint) was placed. This might suggest that attitudes have less impact on driving changes towards PEB than it has on current PEB. The contradicting findings in the studies might be present because of flaws in research methodologies. Lehmann [6, Art. in Kollmuss and Agyman], suggests that more narrowly focused attitude measurements results in stronger correlations, but that this comes at the cost of losing significant information. The attitude in Murtagh et al's study are measured with three items. For example, the item "My opinion is positive about using MyEcoFootprint" only capture one aspect of attitudes towards technology use. This could potentially overlook other dimensions such as perceived usefulness, ease of use, ethical considerations etc. Similarly, the item "I believe it is a sensible idea to try to use less electricity at work" might not cover the full spectrum of beliefs and attitudes that individuals hold regarding energy conservation. Therefore, Murtagh et al might have found a higher correlation between attitude and energy usage than actually exists. However, results of Wyss et al's study expands on the direct relation between attitudes and PEB. The study showed that attitudes become more predictive of PEB when personal costs are low or environmental benefits are high. This might be an interesting finding to take into account during the ideation of the intervention. Kollmuss and Agyeman [6] analyse many different PEB models, but indicate that PEB is so complex that the causal variables of PEB cannot be visualized in one single framework. This suggests that while attitude might be an important determinant of PEB it can be influenced by mediating factors and requires alignment with other crucial determinants of PEB to translate into actual behaviour.

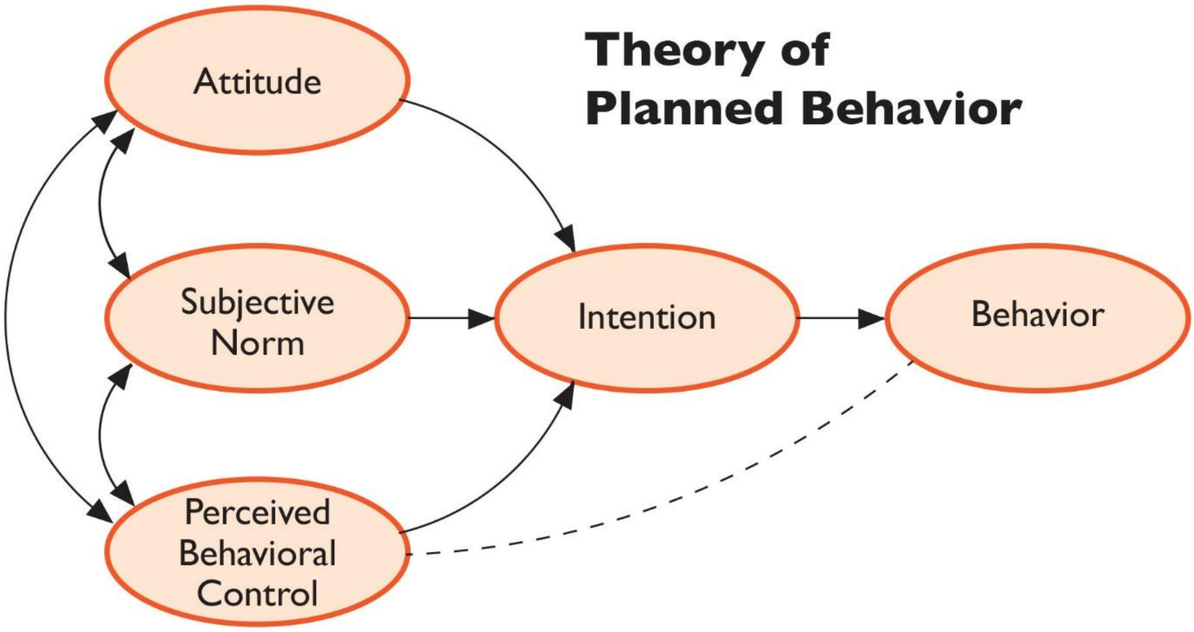


Figure 1: Model of the TPB.

Secondly, Geller's behavioural change model is a model to show transitions between stages of behaviour change when designing a BCT intervention. Geller's behaviour change model was suggested in Yun et al [8] and can be seen in Figure 2. It consists of four performer's stages. First, unconscious incompetence is the stage in which people do not behave sustainably, because they do not know how to. In this stage they should learn what they could do and why it is important. Second, conscious incompetence is the stage in which people are not showing PEB, because they lack the motivation to do so. Third, conscious competence is the stage where the person has already acquired the environmental knowledge and performed the PEB. The person however has not yet made this behaviour change a habitual behaviour. Lastly, when the behaviour change has become a habit the desirable behaviour of unconscious competence has been reached.

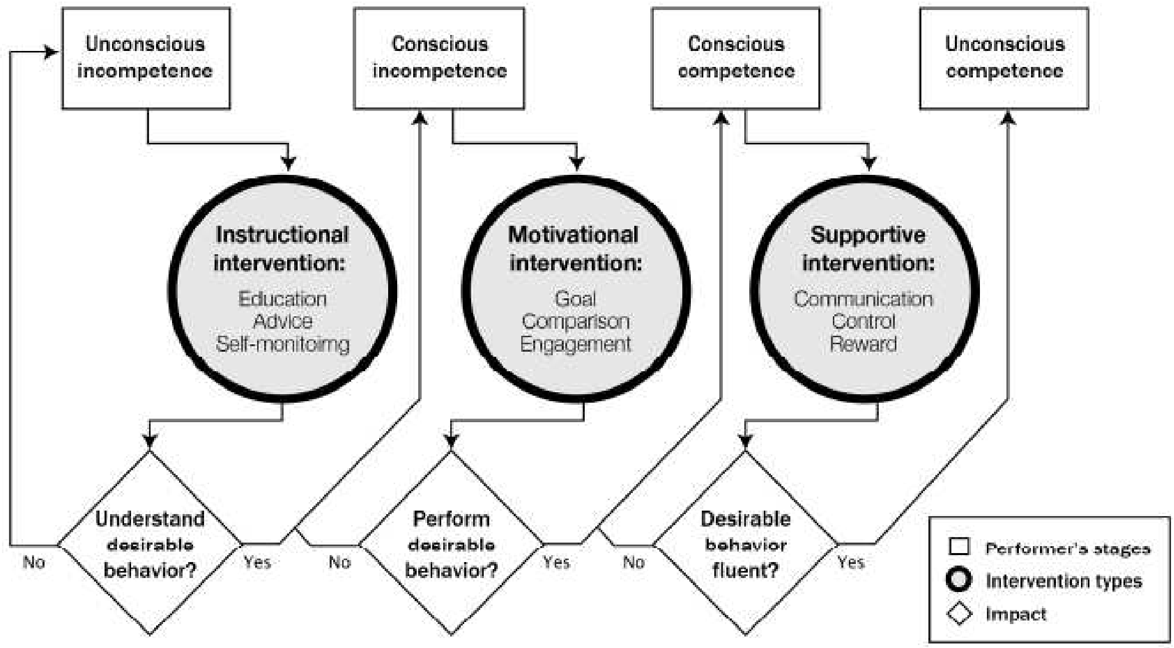


Figure 2: Geller's behaviour change model for sustainability adapted from Yun et al [8]. It shows four performer's stages and three types of interventions which support the performer move to the next stage.

Geller's model is based on a few assumptions which have a few flaws. Firstly, that individuals progress linearly from stage one to four. Secondly, that they do not experience relapses. Lastly, is that people completely understand desirable behaviour as a binary state, either yes or no. These can be some dangerous assumptions. For example, people can understand desirable behaviour in different levels (e.g. surface or in depth). These limitations should be taken into account when using Geller's model to design PEB change interventions. On its own Geller's model has quite a few shortcomings. A more concrete overview of PEB change can be found when Geller's model is expanded with additional theories.

Geller's model and the TPB complement each other. TPB assumes people are already in the conscious incompetence stage (e.g. they are already aware on how to behave sustainably). Geller's model expands on the TPB by introducing the unconscious incompetence stage to account for this assumption. People might not be aware about certain types of energy saving behaviours due to for instance lack of knowledge about equipment or the impact certain behaviours can have on the energy consumption. According to TPB the three determinants attitude, subjective norms, perceived behavioural control are the key factors that pose obstacles for the individual's progression from the conscious incompetence stage to the conscious competence stage. The Conscious competence stage resembles the intention to change behaviour in TPB. The second expansion that Geller's model introduces is the inclusion of the conscious competence stage by including habits in the model. To summarize, Geller's model expands on the TPB by introducing habits and a stage of non-awareness about how to save energy. Additionally TPB explains that attitude, subjective norms, perceived behavioural control are the key factors that pose obstacles for the individual's progression from the conscious incompetence stage to the conscious competence stage.

Lastly, Stern's theory contains four causal variables which relate to PEB. According to Stern's theory [2, Art. in Azar and Al Ansari] these variables include personal capabilities, attitudinal factors, contextual factors and habits and routines. Although, it is stated in the previous section by Kollmuss and Agyeman [6] and Wyss et al [5] that there is a discrepancy between attitude and PEB stern's theory discusses three additional factors. These factors could potentially help explain the discrepancy between attitudes and PEB. Stern's also talks about contextual factors like the difficulty of specific actions, institutional factors, physical environment constraints, policy or monetary incentives. According to Rajecki [6, Art. in Kollmuss and Agyeman] a possible explanation for the discrepancy between attitudes and PEB are normative influences. These could also include the institutional factors, physical environment constraints and policy Stern mentions. Although, these additional factors (e.g. personal capabilities, contextual factors and habits and routines) might help us explain the discrepancies between attitudes and PEB other factors still remain unaccounted for. For example Yun et al [8] mentions the additional importance of the leadership role in the workplace. It is important that the leadership give permission to focus on PEB, because the office workers primary duty is not saving energy, but doing their job. The importance of the leadership role is supported by the findings by foster et al [10]. Kollmuss and Agyeman [6] and Azar and Al Ansari [2] talk about many more models regarding behaviour change which incorporate other additional factors influencing PEB (e.g. factors like feelings, fear and emotional involvement). In conclusion, Stern's theory contains the causal variables include personal capabilities, attitudinal factors, contextual factors and habits and routines, but might be missing additional key factors like leadership roles and emotional factors to completely explain the discrepancy between attitude and PEB.

Stern's theory complements Geller's model. Stern's theory expands on the need to acquire knowledge in Geller's model by introducing the needed skills to perform an action and the sociodemographic variables. The second intervention type, motivational intervention, relates to Stern's variable of attitudinal factors like norms, values and beliefs. According to the TPB attitudes are a mediating factor for intentions which are very closely related to motivation. Stern's variable of habits and routine to break existing behaviours refers to the supportive intervention needed to go to the last stage. Stern also talks about contextual factors like the difficulty of specific actions, institutional factors, physical environment constraints, policy or monetary incentives. These are not included in Geller's model. To summarize, Stern's theory is indeed very similar to Geller's model, but it additionally includes skills, sociodemographic variables and contextual factors.

In conclusion, Geller's model expands on the TPB by introducing habits and a stage of non-awareness about how to save energy. Additionally TPB explains that attitude, subjective norms, perceived behavioural control are the key factors that pose obstacles for the individual's progression from the conscious incompetence stage to the conscious competence stage. Considerations like nonlinear progression, possibilities relapses and partial understanding of behaviours are aspects that Geller's model does not address. Therefore this should be taken into account when using this model to design PEB change interventions. Additionally, Stern adds on the need to acquire knowledge in Geller's model by also incorporating the skills to perform an action, sociodemographic variables and contextual factors (e.g. the difficulty of specific actions, institutional factors, physical environment constraints, policy or monetary incentives). All the models on their own consist of quite a few shortcomings. A more concrete overview of PEB change can be found when all models are compared to each other. Using all three models, a relevant overview can be created to design PEB change interventions.

Creating an overarching model

Three models were analysed to find behaviour change models that effectively support PEB interventions. The discussed models the theory of planned behaviour (TPB), Geller's model and Stern's theory on their own consist of a few shortcomings. A more concrete overview of PEB change can be found when all models are compared to each other. Through the integration all three models, a more comprehensive framework can be developed to aid designers to create effective PEB change interventions. This is the Behavioural Habits Model (BHM) and it can be found in Figure 3.

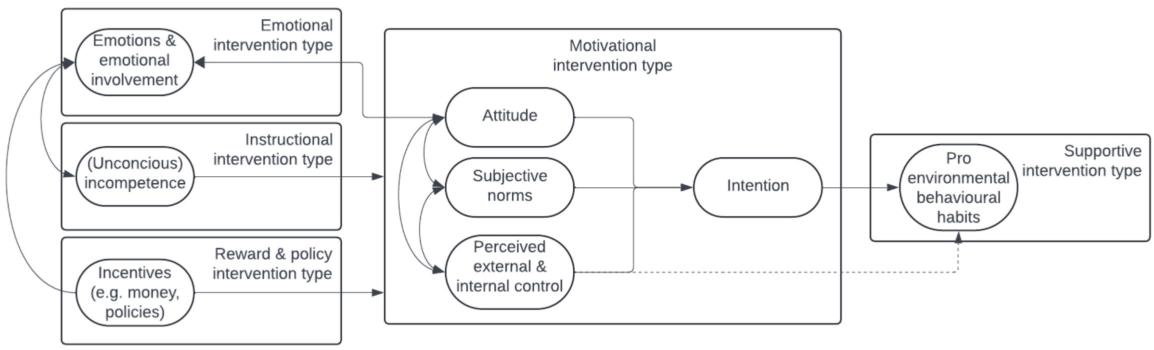


Figure 3: A behavioural habits model (BHM) or behavioural change model for pro environmental behavioural habits to gather insights on how to create an intervention that can effectively promote PEB. This model is created by comparing the TPB, Geller's model and Stern's theory.

In Figure 3 of the pro environmental behavioural habits model (BHM), the ovals showcase the determinants of PEB, with “pro environmental behavioural habits” depicted as the desired result. The boxes indicate the type of intervention needed to alter the determinants within the box. Arrows show the relations between determinants. TPB can be recognized in the “motivational intervention type” box. Expanding on Geller’s model two additional intervention types have been added: the “emotional” and “reward & polity intervention types”. Firstly, the “emotional intervention type” introduces general emotions and emotional involvement into the model. According to Kollmuss and Agyeman [6] these factors have a direct mutual influence on the attitude and knowledge determinants. Knowledge is in this model indicated as “(unconscious) incompetence”. The factors have an indirect effect on subjective norms and perceived external or internal control since attitude influences these determinants as well. However, additional research could be carried out to check whether these relations between the emotional factors and subjective norms or perceived external control may also be direct. Secondly, the “reward & policy intervention type” has been added. These were mentioned within Stern’s model. However, it is unclear how exactly they influence other determinants. It is speculated that the incentives like money and policies play a role in influencing the emotional factors. Additionally, it is believed to have an influence on the attitude, subjective norms and perceived external & internal control and thus also intention. It is expected that policies will impact subjective norms and perceived external & internal control and monetary incentives attitudes. More additional research might be needed to verify these claims made in the BHM.

There are also three main differences in definitions and scopes of the factors influencing PEB in the BHM. The first being “(unconscious) incompetence”. Unlike Geller’s model it does not only focus on learning what can be done to behave sustainably (e.g. reduce energy consumption) and why this is important, but also how to do it. (Unconscious) incompetence expands on Geller’s model by recognizing the importance of skills as well. Secondly, “perceived external & internal control” differs from TPB by not only taking the external perceived control into account, but also the internal control. This was difference was added since Wyss et al [5] showed that participants high in self-control increased the probability to show PEB in accordance to their attitudes. However, only a limited number of literature sources were consulted Therefore it might necessary to analyse additional literature to check it’s validity. Lastly, “pro environmental behavioural habits” is not simply behaviour, but corresponds to Geller’s unconscious competence stage where the behavioural change in question has become a habit. However, the model should not be misinterpreted. Intention does not always lead to pro environmental behavioural habits. Old habits may form obstacles. Supportive interventions might help address the challenges posed by these inconvenient habits.

This study will specifically focus on the emotional, instructional and supportive intervention types. The reward & policy intervention type is left out due to the following two reasons. Firstly, altering policies is considered to be out of the scope of the project. Secondly, because rewards could also be seen as an emotional intervention type and will be treated as such for this project. The motivational intervention type is left out of the project since the emotional, instructional and rewards & policy intervention types can influence the determinants within the motivational intervention type box. This means that these three intervention types together could be regarded as a motivational intervention type on itself. Apart from this a mixture of the different intervention types is required to reach pro environmental behavioural habits. In summary, this study will only focus on providing a mixture of the emotional, instructional, and supportive intervention types, as the motivational intervention is already addressed by combining the three intervention types. Policy changes are out of scope and thus disregarded.

How to effectively apply education, goal setting and social comparison techniques in interventions for energy consumption?

Three intervention types from the BHM model are considered for this project; emotional, instructional and supportive. To make these interventions effective they need to apply BCT's. There are many BCT's that support PEB change. Examples of these BCT's mentioned in the literature [8], [11], [12] are: education, advice, self-monitoring, goal setting, social comparison, engagement, rewards and penalties, feedback and commitment. This section examines one BCT for each intervention type that is being considered, specifically the effectiveness of education (instructional) , goal setting (supportive), and social comparison (emotional) techniques in reducing energy consumption, along with the optimal timing and resolution of the feedback.

Firstly, education techniques is an important BCT for university employees. For instance, not all employees might fully understand the extent of their impact on energy consumption. To illustrate, when a person books a room on campus the rooms environment is adapted in advance. Heating, cooling and ventilation systems are activated to make sure that when you booked the room you enter a pleasant environment. A reoccurring problem is when people show up late or not at all which waste energy. Not all university employees are well informed about these kinds of topics. Therefore education techniques might help in increasing awareness among university employees. Additionally it could correct for misconceptions like that devices don't consume energy when turned off or that drastically turning up or down thermostats heat or cool rooms faster. Apart from this education can help serve as a reminder for people which could potentially renew their sense of motivation and teach them the skills needed to perform energy saving behaviours.

Education techniques can teach why users should aim to reduce their energy consumption and learn skills on how to do so. The education technique targets unconscious incompetent people within Geller's model [8, Art. in Yun et al] and relates to Stern's [2, Art. Azar and Al Ansari] causal variable of personal capabilities. It is an instructional intervention and can help people move from the unconscious incompetent performers stage in Geller's model to the conscious incompetent performers stage instead of leading to direct PEB change. This is supported by Kollmuss and Agyeman [6] who pointed out that research indicated in most cases that knowledge and awareness did not lead to PEB. Or that, according to Froehlich [12], it only has a marginal effect. Additionally, Siero et al's [11] states that education is necessary, but almost never sufficient for behaviour change to occur. The effect of the instructional intervention can however be improved by applying strategies on how the education technique is presented. Firstly, Bandura et al [8, Art. in Yun et al] stated that demonstrating desired behaviour yields better results than simply describing behaviours. Secondly, Fogg in Yun et al [8] also argued in his book that when systems guide users through a process, it can enhance the persuasive power. Lastly, Froehlich et al [12] suggested the following strategies to maximize the information's transformative potential towards PEB: it must be easy to understand, trusted, presented in a way that captures attention and is remembered, and delivered as closely as possible—in time and place—to the relevant decision-making context. Examples of education techniques are campaigns, websites that provide online training, information sharing and pamphlets. In conclusion, education techniques are instructional interventions, but information itself only has a marginal effect on PEB. The effect that information has on PEB can be improved by applying strategies in how the information is presented.

Secondly, goal setting is an effective strategy to motivate university employees by challenging them to achieve the aim. Goal setting can be related to rewards and punishments. It is classified as an motivational intervention according to Geller's model [8, Art. in Yun et al] and relates to Stern's [2, Art. Azar and Al Ansari] attitude factors. A number of studies [10], [11], [12] mention that goal setting is most effective when it is executed in conjunction with regular feedback. Van Houwelingen and van Raaij [8, Art. in Yun et al] and Froelich et al [12] found that assigning 10% reduction goals with daily feedback about consumption reduced natural gas usage by 12.3%. Additionally, a study by Becker in Froehlich et al [12] about electricity usage showed that households who received a difficult goal and feedback about their performance conserved the most energy (15.1%) in comparison to the control group. The difficulty and formulation of the goals also have shown to have an effect. Siero et al [11] mentions in that a number of studies have shown higher and more precise formulated goals increase performance in energy reduction. On the other hand, Shiraishi et al [8, Art. in Yun et al] argues that when a goal is too difficult it makes people unmotivated. Additionally, Siero et al [11] and Foster et al [10] mention that effective goals should be accepted as achievable by the individuals targeted. Failure to meet this criteria may increase the risk of potential disengagement. Therefore, goals should be carefully selected. More additional research might be needed to find the line between difficult goals which result in higher energy reductions and too challenging goals that cause disengagement with the intervention. Apart from this Shiraishi et al identified a second factor that could lead to potential disengagement of the users; long-term goals. Lastly, Foster et al [10] additionally suggested the use of targets with small incremental steps to increase the uptake and adherence in the intervention. To sum up, goal setting is an effective strategy when it is paired with regular feedback and high, precise formulated, short-term goals with small incremental steps. However, too challenging and long-term goals might cause disengagement with the intervention.

While literature generally agrees with the effectiveness of goal setting, it has varying opinions on who should design targets and whether they should be common or individual goals. For example, Yun et al [8] suggested companies to quantify and visualize each employee's performance and assign short-term personal goals to individuals. In contrast, Foster et al [10] concluded in a sequence of workshops, similar to focus groups, that employees should be involved in setting energy consumption targets. This way of involving employees in goals setting would according to them increase the engagement, uptake and adherence in the intervention. Another contradictive suggestion came from one of the participants in the workshops who recommended to have a separate target per department within the company. This contradicts Yun et al’s suggestion to assign personal goals to individuals. Siero et al [11] also contradicts this suggestion. They mentioned that for changing behaviours in organizations contexts it is typically necessary to refer to collective interests rather than individual ones. When applying goals in non-organizational contexts, it's possible that individual-oriented goals could be more effective. So, although there are some varying opinions it can be assumed that involving employees in goal setting can improve the engagement with the intervention. Additionally, goal setting in organizational context typically involves a common goal. Hard evidence on the effectiveness of personal goals versus common goals is lacking and might require further research.

Having examined the different perspectives on the effectiveness of goal setting, potential challenges that may arise during the implementation of targets within interventions remain unclear. One should pay specifically attention to the implementation of performance indicators to measure the extent to which goals are achieved and to determine who needs to be held accountable for failing to meet the target. An example in Foster et al [10] shows that the introduction of waiting time targets in the UK Accident and Emergency wards initially seemed to speed up the queues. However, closer investigation discovered that people were being kept in ambulances, discharged early or redirected to wrong department so administrators could meet their targets. Introducing performance indicators can result in managers and employees gaming the system. Additionally, Foster et al [10] mentioned his concern for accountability and the blame management when targets where failed to be met. What happens if the targets are not met and who needs to be held accountable? They stressed the importance of the organizational culture and politics for the implementation of energy reduction interventions. In summary, one should be carefully design performance indicators to prevent users from gaming the system. Additionally, organizational culture and politics need to considered to ensure fair and effective accountability mechanisms which support an effective energy reduction intervention.

Thirdly, social comparison is an effective tool to reduce energy consumption. Siero et al [11] did a study to increase energy savings with help of education and feedback. They found that when additional feedback was given the energy savings increased. Noteworthy to mention is that even savings on behaviours about which no education was given were realised within the social comparison group. Siero et al provides several reasons for the effectiveness of social comparison: it is a straightforward feedback manipulation, it was encouraging, it incited curiosity towards the performance of the other group and the fact that they were well informed about the performance of the other group. (The other group is in this case the participants group without comparative feedback). Mukai et al [13] supports the finding of Siero et al that social comparison is effective in increasing energy savings. They found that social comparison based home energy reports were more effective in reducing energy consumption in households then reports that were based on historical comparisons. Peschiera and Taylor [14] also support Siero et al's finding by stating that researchers have shown that energy conservation practices are more likely to be realised when comparisons or norms are more socially closely related to the individual. The study shows that sharing electricity usage of individual rooms with peers as a form of social comparison is more effective to reduce energy consumption than comparing it with a general average. Moreover, it showed that participants with an below-average or average energy consumption are more likely to increase energy savings when social comparison is applied. Therefore, social comparison is an effective way to increase energy consumption savings and can be made more effective by making the comparisons or norms more socially relevant to the user.

Not only the proximity of the comparisons and norms to the individual him- or herself influence the effectiveness of the social comparison BCT. Peschiera and Talor [14] found that the network degree of the participants and the Eigenvector centrality also play an important role in influencing the effect of social comparisons that are made. They found that participants showed a more likely significant decrease in energy consumption when they had a high network degree and eigenvector centrality.

Eigenvector centrality is a score that is determined by your amount of network connections and the network connections of your connections. The higher the eigenvector centrality, the more connected and influential you are in the network. In contrast, the network degree only looks at your connections and not that of your friends. So, this suggests that social comparison BCT is more effective for people who have a large network.

Additionally, social comparison could help with the engagement of the intervention. Competition elements like sharing performance data with others were frequently mentioned in Foster et al [10] who researched how technological interventions could be designed to motivate reductions in energy consumption through behaviour change with the help of focus groups. The competition elements were mentioned by the focus group participants to prevent disengagement and lower participation barriers. Therefore, social comparison could potentially maintain engagement and reduce participation barriers.

However, there are also a few concerns with the use of social comparison as a BCT. Foster et al [10] mentions that participants believed precautions should be taken regarding the granularity and disclosure of the performance data. Additionally, Siero et al [11] raises the concern that when a group has a continuing bad performance with regards to others this can cause demoralization and a decreased performance in energy savings. In conclusion, performance data should be handled with respect for personal boundaries and privacy and it should be taken into account that continuous bad performance can have negative consequences on energy savings.

All the mentioned techniques, education, goal setting and social comparison, require some sort of feedback to the user. However, the timing that this feedback is provided to people also influences the effects of these techniques on the energy saving behaviours. Thornock [15] found that providing feedback directly after an action is executed keeps the learning costs low. Which in turn improves the learning process and future performances. Darby [16] and Tiefenbeck et al [17] also stress the value of immediate feedback. Tiefenbeck et al finds a 11.4% reduction in energy use when giving the user real time feedback on their resource consumption during showering, despite participants being unaware of the study and not bearing the financial responsibility for the energy costs. In contrast Thornock [15] states that receiving feedback after extended delays increases learning costs which results in less improvement in learning and future performances when compared to providing real time feedback. Opitz et al [18] supports this statement as they found that the gain in performance regarding a grammar learning task was significantly higher for participants that received immediate feedback relative to participants receiving the same feedback with a short delay of 1 second. This might suggest that feedback with any noticeable delay might already effect learning behaviour negatively. Furthermore, Thornock [15] found that receiving feedback before an action is undertaken increases the learning costs which in turn discourages learning and future performances. However, it is good to note that the studies of Thornock [15] and Opitz et al [18] don't focus on energy consumption behaviours, but instead respectively on multi-step task setting where learning can improve task performance and grammar learning tasks. Therefore, it is questionable if the findings in the studies also apply to the energy consumption behaviour contexts. In conclusion, providing real time feedback directly after an action has been executed is the most effective option for feedback timing to alter energy consumption behaviours.

Furthermore, when giving feedback on energy consumption it is not only important to know what the timing of this feedback should be but also in which resolution this should be provided. Anvari et al states that load profiles with a 15 minute resolution which showcase how the electrical demand of a group of people varies over time ignore energy consumption spikes at short time scales. Therefore, a 15 minute resolution does not accurately represent users' energy consumption. Anvari et al states that this highlights the importance of the temporal resolution to accurately capture and manage the varying energy consumption spikes in short periods of time ranging from seconds to minutes. In summary, averaging energy consumption data over a span of 15 minutes fails to correctly represent users energy consumption data. However, averaging the energy consumption data over a time span from seconds to minutes might suffice. Apart from Anvari et al no sources were found on the resolution of energy consumption feedback. In summary, averaging energy consumption data over 15 minutes fails to accurately represent users' energy consumption. Instead, averaging over shorter time spans from seconds to minutes may provide a more accurate depiction. However, thorough research in this area is lacking, with Anvari et al [19] being one of the few sources addressing the importance of temporal resolution in energy consumption feedback.

Conclusion

The aim of this study is to gather insights in how to create an intervention that can effectively promote PEB change in university employees to reduce energy consumption. By examining the determinant attitude, behaviour change models and behavioural change techniques (BCTs) as education goal setting and social comparison insights are gathered to create an effective intervention for university employees. There are many determinants that have a relation with pro environmental behaviour (PEB). The determinant analysed in this review was attitude. Findings suggest that while attitude might be an important determinant of PEB it can be influenced by mediating factors and requires alignment with other crucial determinants of PEB to translate into actual behaviour. It often does not directly translate into PEB. A single determinants did not provide an accurate image of how behaviour should be changed.

To get a better understanding of other factors influencing PEB, attention was turned to behavioural models. Three models the theory of planned behaviour (TPB), Geller's model and Stern's theory were analysed to find behaviour change models that effectively support PEB interventions. However, each of these models on their own had a few shortcomings. The Behaviour Habits Model in Figure 3 was developed to aid designers to create effective PEB change interventions with a more comprehensive framework. This study only focusses on three of the five intervention types described by the BHM model; emotional, instructional and supportive.

To effectively apply the intervention types BCT's have to be employed. Three types of BCT's were considered within this literature review. Firstly, education techniques can be classified as instructional interventions. Therefore, it often does not impact pro environmental behavioural habits directly. Education itself only has a marginal effect on PEB. The effect that information has on PEB can however be improved by applying strategies in how the information is presented.

Secondly, goal setting can be classified as a supportive intervention as it provides individuals with structured objectives and milestones to guide their behaviour change journey and thus their habits. However, on the short term it could also be seen as an motivational intervention type as you set an intention. Although there are some varying opinions it can be assumed that involving employees in goal setting can improve the engagement with the intervention. For goal setting to be effective performance indicators should be carefully designed to prevent users from gaming the system. Additionally, organizational culture and politics need to considered to ensure fair and effective accountability mechanisms which support an effective energy reduction intervention.

Lastly, social comparison is considered to be part of the emotional intervention type. It is an effective way to increase energy consumption savings and is an more effective BCT when the comparisons or norms are more socially relevant to the user or the user has a large network. It could potentially maintain engagement and reduce participation barriers. However, performance data should be handled with respect for personal boundaries and privacy and it should be taken into account that continuous bad performance can have negative consequences on energy savings.

Apart from this, all BCT's mentioned require some sort of feedback to the user. The timing and resolution of this feedback also influences the effectiveness of the different BCT's. Real time feedback directly after an action has been executed was found to be most effective in altering energy consumption behaviours. Besides that, a 15-minute resolution of energy consumption data was found to inadequately represent users' actual energy usage. Instead, averaging over shorter time spans from seconds to minutes would possibly provide a more accurate depiction. However, thorough research in this area is lacking so no indefinite conclusions can be drawn.

Thus, the BHM in can be used as a simplistic overview for support in the creation of PEB interventions for university employees. I do not claim that this model is more inclusive or ‘better’ than other models out there. It is specifically designed as a support for interventions and is meant to be serve as a guideline. BCTs can be chosen to tackle certain intervention types. A intervention ideally consists of multiple intervention types to increase its probability to transform a non-sustainable behaviour into a PEB habit.

Behaviour is a complex subject and is still a much debated topic within the literature. Therefore, it is currently impossible to grasp the full scope of how behaviour change manifests. More research about the causal variables of PEB change is required. The uncompleted picture of the relation between the causal variables and PEB change might also reflect on a possible PEB intervention. It is very likely that the BHM still lacks some key causal variables that are linked to each other or linked to PEB. This uncomplete picture could potentially explain unsuccessful interventions for PEB change. The literature covers many more behavioural models then the three discussed in this review. Comparing more models might also help fill in more parts of the picture. Additionally, only the determinant attitude was covered within this review. It might help to analyse and discuss other key determinants as well to get a deeper understanding of how they work and can effect PEB or act as a mediating factor. Lastly, this review only covered three BCT’s. However, intervention design for PEB might benefit from a comparative review to determine which BCTs have the most impact on PEB habits.

A shortcoming of this review is that most of the reviewed literature is in the context of work environments. It was assumed that these were similar to university work environments since literature specifically targeting university environments were lacking.

There are three additional topics for further research. Firstly, it is important to know in which stages the university employees are within the determinants. For example, for (unconscious) incompetence it is important to know when designing an educational intervention type what skills the employees poses and what they already know. With this information the interventions could be tailored specifically to the target group’s needs. Additionally, knowing in which stages the employees are within the determinants could potentially provide insights into which BCTs might be most effective for this specific target group. Therefore a survey on this topic would be suggested. Secondly, for the goal setting BCT it remained unclear whether common goals or individual goals have a greater influence on university employees. Therefore, this also requires more additional research. Lastly, more research might be needed in weather habits can be broken (easier) when the factors that have established the habit fail to support current behaviour. When this is the case new angles to tackle PEB change might open up.

State of the art

This subsection provides a comprehensive review of current state-of-the-art techniques and designs about the following topics:

1. Data gathering
2. Indicating energy consumption performance through methods like colour, brightness and patterns.
3. Energy consumption feedback applications
4. Smartwatch functions
5. Interface design for a bar or gauge

Data gathering

To create an effective behaviour change intervention, it is essential to first gather data about the users behaviour. Here five existing products are analysed that collect energy consumption data to get an overview of the available data gathering possibilities regarding energy consumption.

Curb

The Curb energy monitor mentioned in [20] measures energy for homes. It specifically measures the homes main energy supply and the circuits within a home. It does this through using CT clamps, Figure 4 left picture. The current transformer (CT) clamp can measure the currents flowing through electrical conductors and thus electrical wires. It does this without making contact with the wire. The main energy supply and the circuits are measured from within the electrical panel in the home. The main energy supply enters the home from this electric panel and is the connection between the homes energy supply and the grid. A CT clamp is put around the incoming electricity wire from the grid which is the main energy supply. Other CT clamps are put around the wire connected to the breaker in the electric panel that controls a specific group of outlets. A large hub and transmitter are located in the electrical panel. The hub is connected to the ethernet. The ethernet connection allows for the data to be transmitted for a real-time data monitoring and processing. The processed data can be visualized in an app.

Figure 4: An illustration of curb can be seen in the left picture. The blue box is the hub and transmitter. On the phone the processed data is visualized. In the middle an electrical panel can be found. On the left an example of what a CT clamp looks like is shown.

Sense

Other than the Curb the Sense [21] energy monitoring system only uses 2 clamps. Sense only monitors the energy of the main energy supply to the house. The clamps are then only applied to the hot wires of the energy supply and potentially also the neutral ones. It is connected to the Wi-Fi network in the house and does therefore not require an ethernet connection. The sense has a developed an AI to be able to tell different types of devices apart. Every device has a different signature in their energy consumption patterns, see Figure 6. However, some signatures are very similar. Reviews show that it sometimes has difficulty telling these devices apart. Noise within the overall energy consumption of the home can also lead to confusion within the system. The system samples the data 1 million times per second.

Figure 5: An illustration of what the Sense app on the phone looks like.

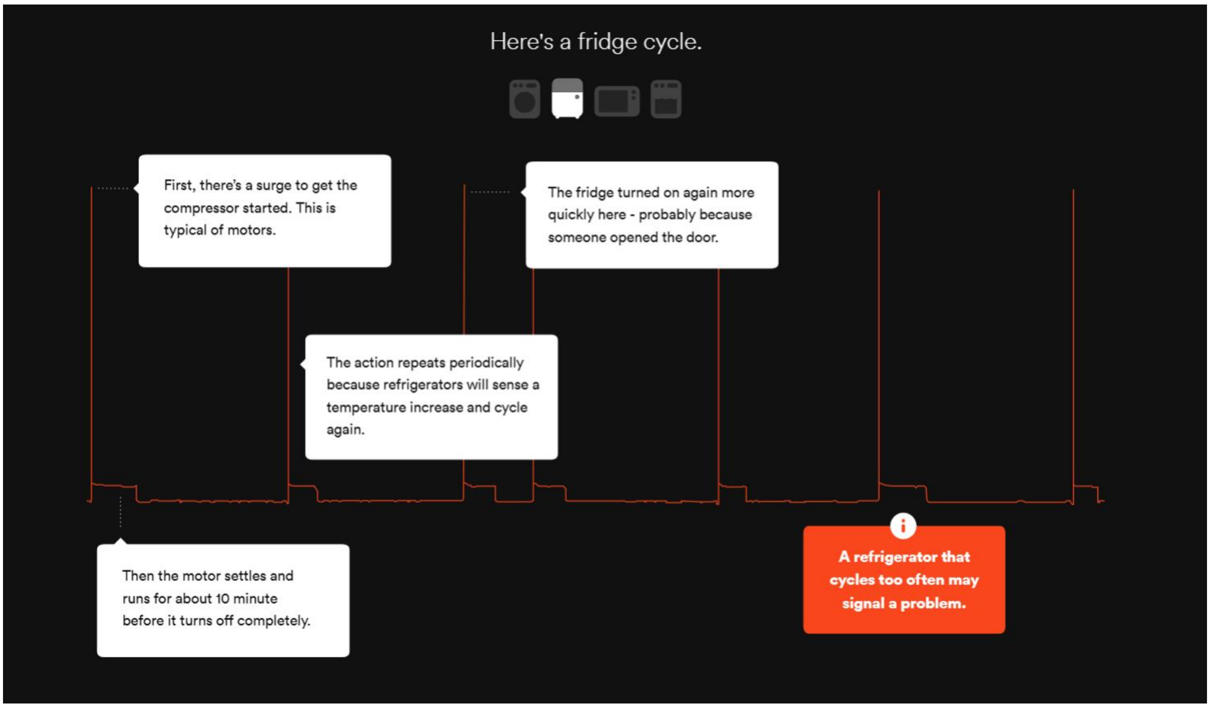


Figure 6: An example of the energy consumption signature of a fridge from Sense [22].

Smappee Infinity

The Smappee Infinity [23] energy monitor are customizable for every user. The customer can buy different parts depending on their needs which they can connect. It allows for three possible ways to submeter appliances [24]. The first option is to put CT clamps at the around the wires of the different circuits in the electricity panel. This allows for to measure the circuits of groups of devices, but not the individual devices. The second option is to use a smart plug connections between the devices and the power outlets. With this it is possible to measure the energy consumption of individual devices. The last option is to submeter from the main energy supply like with Sense. This is done with the NILM feature. It also uses machine learning and databases to identify the appliance specific energy signatures. However, it can only identify up to five devices with an accuracy of 70%.

Figure 7: Illustration of the product Smappee Infinity.

Emporia Vue

Emporia Vue can measure up to 16 different circuits and can be combined with emporia's smart plugs to measure the energy consumption of specific devices. It is connected via Wi-Fi and streams continues real-time 1 second data to the app.

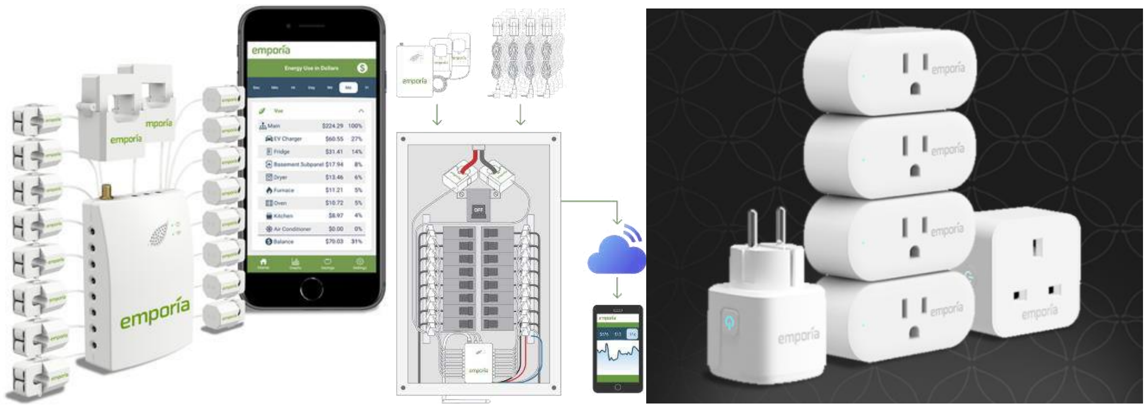


Figure 8: On the left an overview of Gen 2 Emporia Vue. In the middle an overview of how to connect the CT clamps onto the electrical panel. On the right an illustration of the emporia smart plugs.

Conclusion

There are two main ways in which energy consumption data can be collected. The first option is to measure the electricity consumption via CT clamps in the electric panel. The CT clamps can either measure the individual groups or they can measure the incoming electricity from the grid. In order to measure the electricity consumption per device an AI can be applied that can identify individual devices by their unique power signatures. However, this technology is still in its infancy stage.

The second option is to measure the electricity consumption at the devices outlets through smart plugs. However, this option would require a lot more physical infrastructure and materials which costs energy. This is a disadvantage as the intervention should save more energy than it uses. Table 1 shows an overview of the possible electricity data gathering techniques per product that is analyzed.

Application	Sense different devices	How does it measure?	Amount of infrastructure required	Connection
Curb	Only circuit groups	though CT clamps in the electrical panel (groups and main)	Hub with transmitter and multiple CT clamps	Ethernet
Sense	Individual devices	though CT clamps in the electrical panel (only main) and an AI	Only 2 CT clamps	Wi-Fi
Smappee	Group and individual devices	Through CT clamps in the electrical panel (main and groups), through smart plugs or NILM (machine learning and databases)	Minimum of two clamps, but can use more. Can also use smart plugs.	Wi-fi
Emporia Vue	Group and individual devices	CT clamps in the electrical panel (main and groups) and optionally through smart plugs	Multiple CT clamps and smart plugs per individual device	Wi-Fi

Table 1: Overview of possible electricity data gathering techniques for the intervention.

Indicating energy consumption performance through light with colours, brightness and patterns

In order to make design decisions on how the intervention will indicate the energy consumption performance of its users, different existing products and studies are analysed on how they present the energy consumption performance of their users with colours, brightness and patterns.

Visualizing buildings occupants energy performance

In a study by Peschiera and Taylor [14] participants were able to see their energy consumption performance with colour coded bar graphs. For participants in participants groups A, the bar showcasing their room's per capita average daily usage over the past 7 days is red if it was more than 20% above the building-wide average, green if more than 20% below and yellow if within 20% of this generic descriptive norm. The colour of the graph for participants group B followed the same colour coding except the point of comparison was the 7-day daily average of peers, see Figure 9.

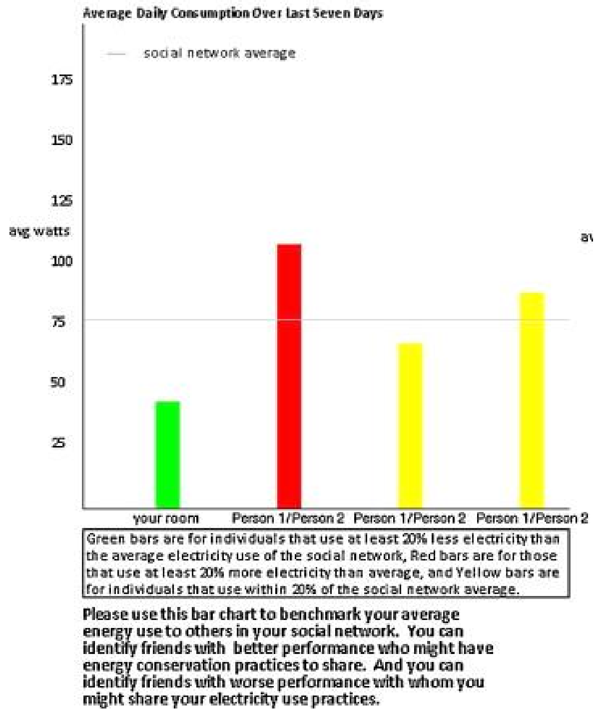


Figure 9: Visualization of energy consumption performance by Peschiera and Taylor [14] in order to compare your energy consumption to others and help participants share energy saving practices.

Energy labels

The European commission [25] has implemented the EU energy label since 1994 to support the consumption decisions of consumers. Specifically, supporting the consumers in the search to find more energy efficient products. Apart from this it also serves as a motivator to manufacturers to develop energy efficient technologies. Not only the EU has implemented energy labels. Other countries all over the world as well, see Figure 10. However, each country has a different label design and efficiency rating. Nevertheless, an aspect of the energy labels that stays the same is the colour gradient from green to red that is used. Green indicates very energy efficient products and red nonefficient energy products.

Figure 10: Energy labels from all over the world. The energy label on the left is the EU energy label.

BIM-integrated energy visualization approach

A eco-feedback system by Truonga et al [26] was developed which combined a building information model (BIM) with energy information, see Figure 12. This would enhance the visual representation of energy consumption. The data collection focussed on gathering energy consumption data for each individual room inside a building. The energy information was visualized through colours and was split into nine categories. Each category of energy consumption is associated with a colour gradient between green and red, see Figure 11. The energy use levels are determined with Equation 1.

$$E_i = E_{min} + i(\frac{E_{max} - E_{min}}{8})$$

Equation 1: Calculation of the energy use levels. E_i is the energy use intensity for level i (ranging from 0 to 8). E_i is determined by dividing each room's daily energy use by the room's area. E_{min} represents the minimum energy intensity observed in the collected energy data. E_{max} represents the maximum energy use intensity observed in the collected energy data.

Energy use Levels	E_0	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8
Color Spectrum									

Figure 11: Overview of the associated energy use levels with the colour gradient.

Figure 12: Illustration of the BIM-integrated visualization approach.

CoSSMic

Vilarinho et al [27, Art. mentioned in Chalal et al] created a CoSSMic, a software with user interfaces, to increasing awareness of residents of smart houses and supporting PEB change to more responsible consumption habits. The energy consumption of the smart home was visualized through a 2D tree fill gauge which was combined with a traffic light colour coding system (red, orange, yellow, green). The colour coding represented the overall performance of the household regarding their energy efficiency and behaviour change. The colour coding is based on a certain user score that can increase when certain milestones or PEB are achieved. Red indicates a low performance level and green indicates a high performance level. The user interface can be seen in

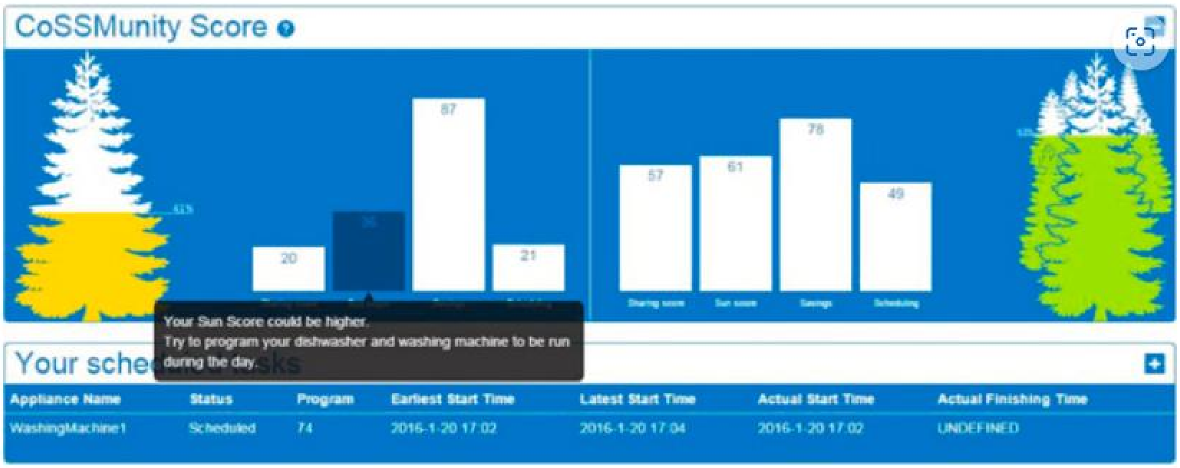


Figure 13: Illustration of the UI of the CoSSMic software to increase awareness and support PEB habits among smart home residents.

Power-Aware Cord system

The Power-Aware Cord system developed by Gustafsson and Gyllenswärd [27, Art. mentioned in Chalal et al] aimed to investigate how ambient displays can be utilized to increase energy consumption awareness. The watt-Lite system attempted to achieve this through feedback to the end users. The prototype of the Watt-Lite system can be seen in Figure 14. It is a power cable is overlayed with three phosphor threads that starts glowing when an AC-current is introduced within the power cable. These threads can be set at any intensity and be lit one for one creating a flowing motion. The light pattern changes its state of being static, pulsing and flowing intensity blue light depending on the users electricity consumption or load. A user study was conducted (this study was not representative for the target group) which came to the following conclusions:

- Blue light represents electrical current well
- Majority stated that the constant light glow with varying intensities is calming and visually pleasing
- Flow and pulse animations were the most informative of all states
- Pulsing and flowing light patters perceived irritating when consumption high

Overall the initial user test points out that the Power-Aware Cord is very accessible and intuitive in order for the user to get a better comprehension of their energy consumption.

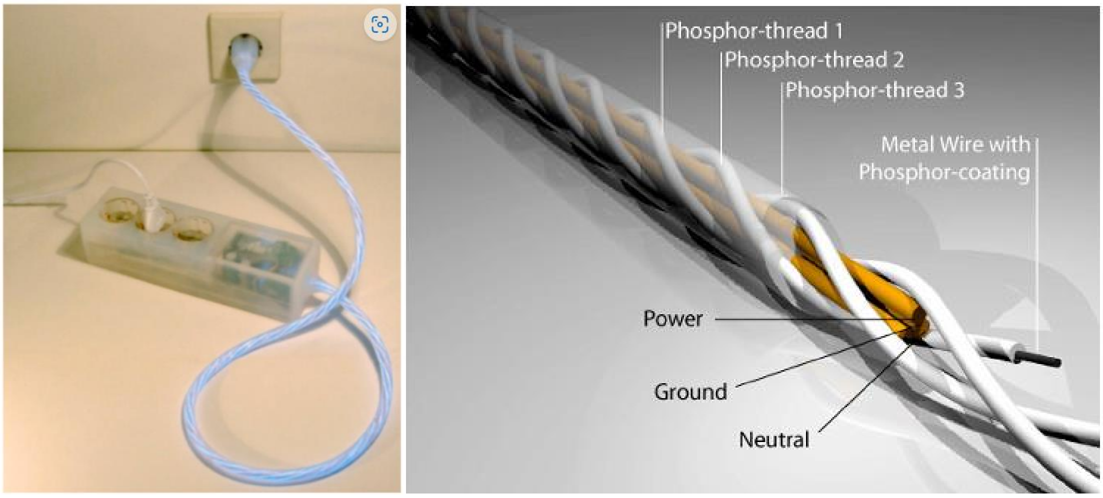


Figure 14: On the left the finished prototype of the Power-Aware Cord can be found. Here it can be seen that the power cord is blue whenever energy is used. On the right side an overview of the different layers that make up the product.

Conclusion

Existing products or studies utilize colours from green to red to indicate energy consumption performances. With green indicating a low energy consumption and red a high energy consumption. Only one product was found that did not indicate energy performance through colours. Instead it utilized the colour blue to represent the electricity current. The intensity of the lights was used to showcase the current energy consumption and fluctuations or spikes in energy consumption were visualized though light patterns. However, no other products or studies were found that utilized light intensity or patterns to visualize the energy consumption performance. A overview of the findings can be found in Table 2. Therefore, it is recommended to use gradients from green to red to indicate energy consumption performance.

Project	Colour	Intensity	patterns
Visualizing buildings occupants energy performance	Green, yellow and red to indicate energy consumption relative to a last 7 day average energy consumption	**-**	**-**
Energy labels	Gradients from green to red to indicate a products energy efficiency	-	-
BIM-integrated energy visualization approach	Colour gradient from green to red divided in 8 categories. Colours represent the energy use intensity for level: room's daily energy use divided by the room's area	-	-
CoSSMic	Traffic light colour coding system: red, orange, yellow, green. Red indicates worst performance of energy efficiency and PEB habits and green the best.	-	-
Power-Aware Cord	Blue to represent electricity current	To indicate current electricity usage	Pulsations indicate fluctuations or spikes in energy consumption

Table 2: Overview of the state of the art findings regarding the indication of energy performance with colours, intensity and patterns in existing products or studies.

Energy consumption feedback applications

Indicators such as colour, brightness and patterns only provide a general sense of energy consumption, but they are lacking in precise detail. To offer users a clearer understanding of their energy usage and which behavioural techniques are utilized, four different feedback applications are analysed.

My Green Butler

My Green Butler [28] claim to be the world's first proven solution which utilizes behaviours to reduce unnecessary consumption. They sell their product to owners and managers of tourist accommodations. It is an app which reports the ESGs and targets guests to alter their behaviour, see Figure 15 and Figure 16. They noticed that the energy consumption could vary highly per guest. So, to change behaviour they motivated the guests by comparing their energy usage with respect to the lowest measured energy consumptions among the guests to show them how low the energy consumption of the accommodation could be. [29] Their website [28] states that research has shown that the guest don't mind to reduce their footprint while staying in the accommodation. The research even state that My Green Butler increases guest satisfaction.

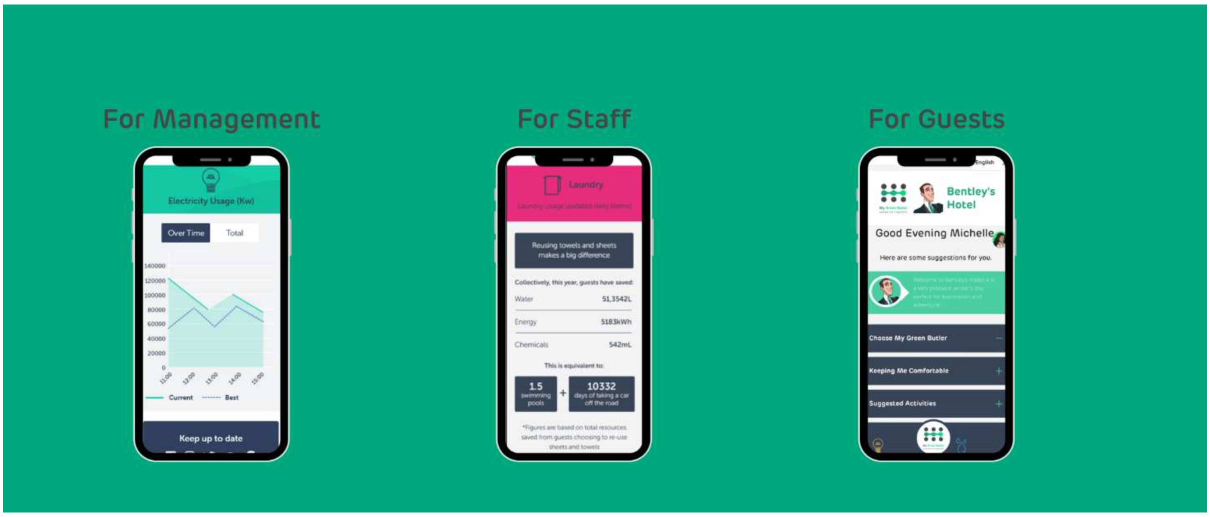
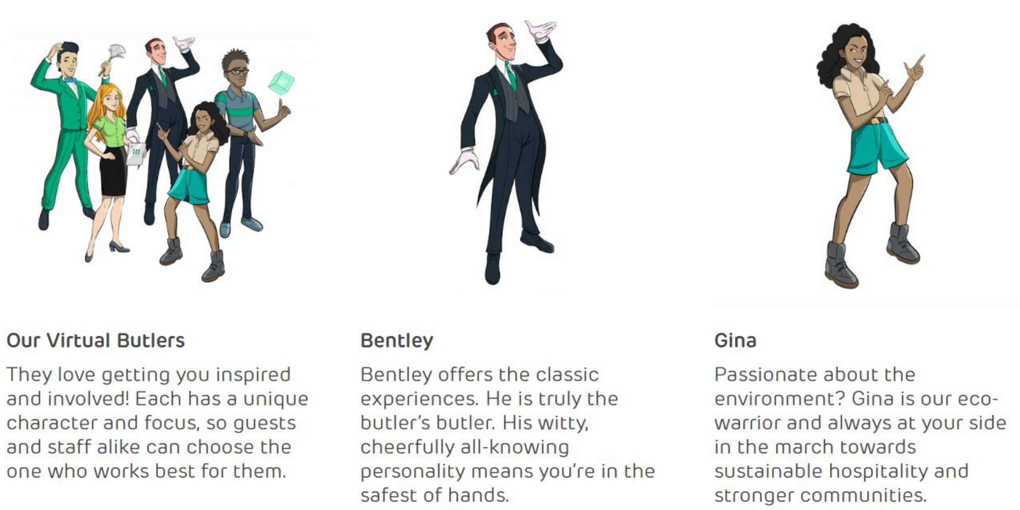


Figure 15: My Green Butler is personalized dependent on the roles of the user: manager, staff or guest.



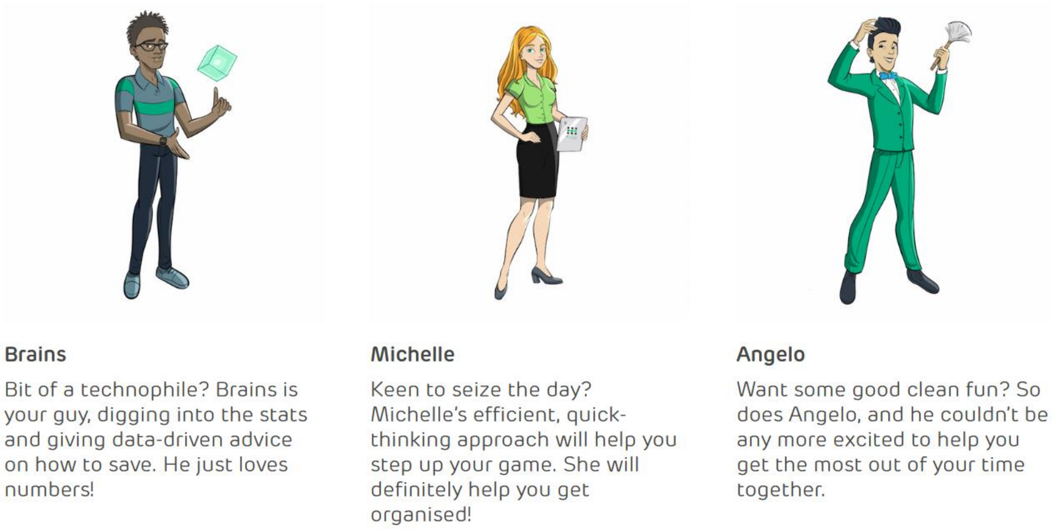


Figure 16: My Green Butler utilizes different characters to communicate different types of information in a fun way.

Buddy Ohm

Buddy Ohm is an IOT device as in Figure 17 that measures electricity, gas, water and steam consumption and the solar power generation. A visualization can be seen in Figure 18. It measures these things for entire buildings or public infrastructures. Therefore it is not able to provide individual feedback, but is rather designed to provide real-time insights to help determine resource flows by connecting actions with energy consumptions. The company focusses on small or medium-sized companies.

Figure 17: The buddy ohm IOT device created by the buddy platform.

Figure 18: Buddy Ohm overview of measurements in graphs.

Energy Buddy – Energiemanager

The Energy Buddy is an app on google play in which you can track your electricity consumption and costs. The app provides data about the users CO_2 footprint. Additionally, it can suggest personal goals to reduce emissions. A visual representation of the app is shown in Figure 19.

Figure 19: visual representation of the Energy Buddy app.

Pure Energie

On the website or app of the energy supplier Pure Energie clients can see their energy usage in graphs over different time frames. On the top right of the graph in Figure 20 it is possible to change the time frame displayed on the x-axis in the graph to a day, month, year or total. The actual energy usage is compared to the estimated energy usage. Pure Energie tries to estimate the monthly payment with the estimated energy usage, however you can also set or alter it yourself. Apart from electricity usage it is also possible to look at the gas consumption or at the costs instead of the energy usage in kWh or m^3.

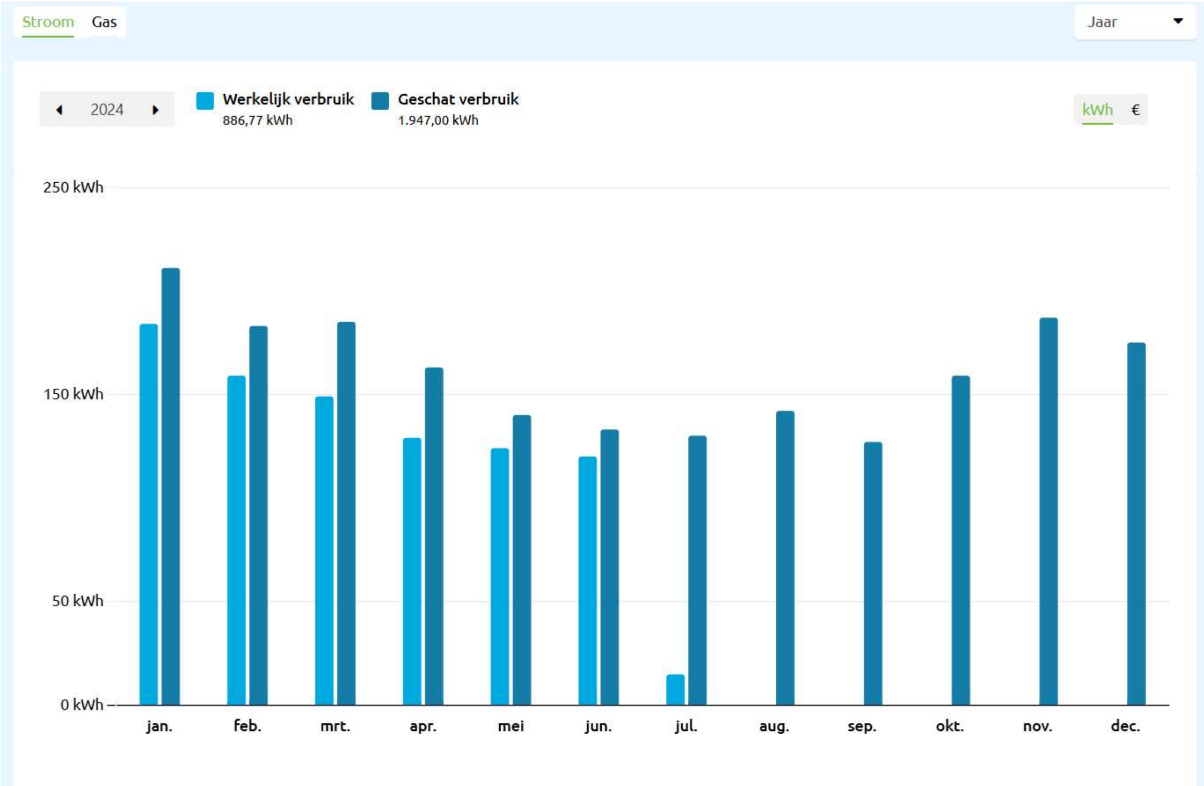


Figure 20: Energy consumption overview provided by the Energy supplier Pure Energie.

Conclusion

The different energy consumption feedback applications can be linked to different behavioural changing techniques. Although not all applications are aimed at changing behaviours they do support it. A reoccurring technique that is present in all analysed applications are graphs that give you an insight into your energy consumption. It is also important to note that My Green Butler, which is a application that has proven to reduce the energy consumption and behaviours of its users uses most different intervention type techniques. This corresponds to the findings provided in the BHM model. Therefore, multiple intervention types should be combined into one solution. Graphs are a familiar tool for users to get an insight into their energy consumption. Furthermore, social comparison and goal setting could be an interesting combination to indirectly prompt the user to set goals.

	Social comparison	Education/ instructional	Suggestions for actions	Analogies	Goal setting
My Green Butler	Compare to lowest energy consumption with graphs	Shows how low can your energy consumption be with graphs	Yes	Energy saved is equal to x amount of days taking a car off the road	Potentially indirect by comparing yourself to others
Buddy Ohm		Provides real-time insights into the energy flows using graphs			
Energy Buddy – Energiemanager		Graphs with energy consumption and costs		(Costs)	Yes
Pure Energie		Graphs with energy consumption			Staying below your set monthly payment or the estimated energy usage

Table 3: Overview of the different behavioural changing techniques per energy consumption feedback application. The colour green is used for emotional intervention types techniques, yellow for instructional intervention techniques and blue for supportive intervention techniques.

Smartwatch functions

In the specification chapter it is decided to create an intervention in the form of a smartwatch. In order to make an intuitive user interface for a smartwatch it is important to include already familiar aspects of similar existing products. The functions of the Apple watchOS 10 are analysed for this reason.

The Apple watchOS 10 [30] has the function to wake (turn on from sleep mode) when you raise your wrist and to go to sleep when you lower your wrist again. This is interaction via gestures. It has an always-on display option, but for a project regarding responsible energy usage this might not be desirable. It contains virtual assistants and voice commands (Siri). Additionally to this it also is equipped with health and fitness tracking sensors, GPS and an NFC for contactless payments. It also has a lot of settings options which allows for a personalization. Lastly, it also is water resistant. There are many more features, but they are way too much to cover. These examples display the wide range of usages.

Interesting functions that could be added for an intuitive smartwatch interface are familiar symbols like in Figure 22 and familiar interactions like in Figure 21. Additionally, the smartwatch should have a sleep and wake function to save energy.

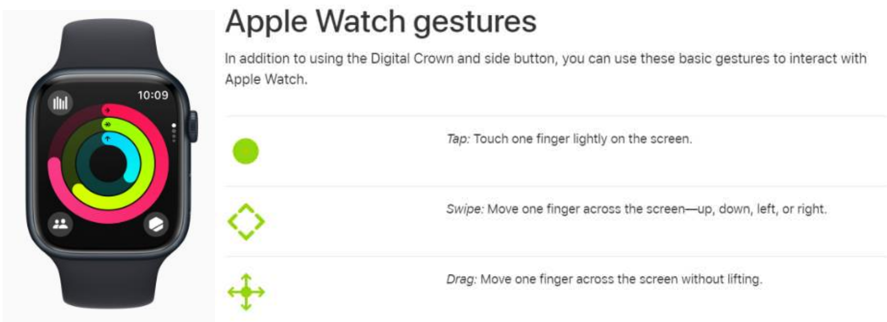


Figure 21: Apple watchOS 10 on the left and some common apple watch gestures from Apple [31] on the right.

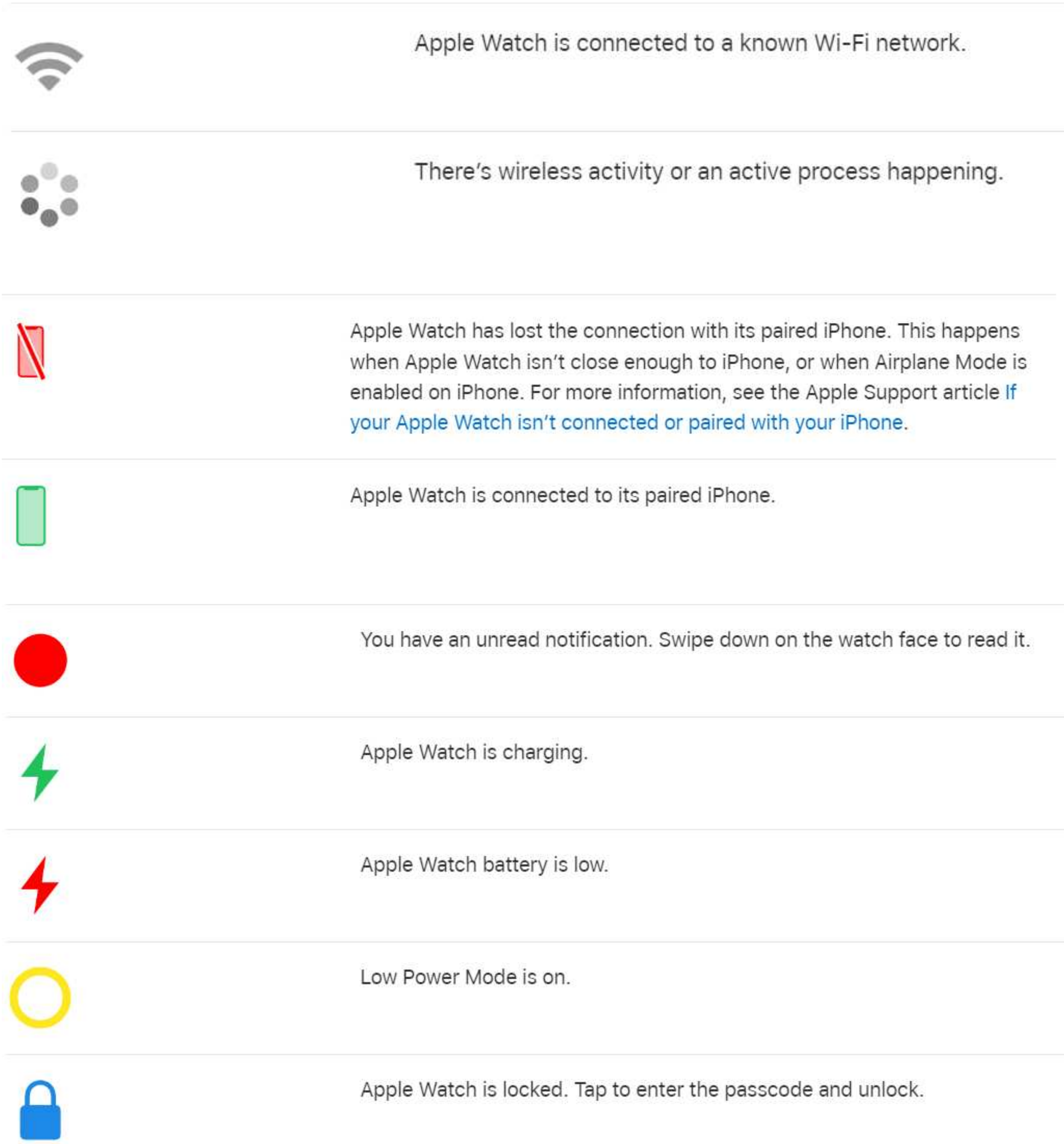


Figure 22: Some interesting Apple [32] status icons.

Interface design for a bar or gauge

In the specification chapter a design decision has been made to implement lights into the wristband of the smartwatch to give an indication of the users cumulative energy consumption of the current day relative to his personal average or that of similar employee types depending on which state the smartwatch is in. See "*Energy bar light*

. These lights are supposed to represent a bar with a scale of percentages with the end of the bar representing 100% and the beginning 0%. To find out what a intuitive way is to visualize the energy bar lights, specifically when representing a percentage over 100%, different experience bars from different games are analysed.

Minecraft

The experience bar in the Minecraft game is divided into 18 subsections. When a player receives experience the bar slowly fills up. With each higher level the subsection requires more XP to be filled. The animation to fill subsections based on the gained experience is seemingly instant. When an experience orb is picked up the player gets auditory feedback through a *ping* sound. If the player reaches a new level the bar is reset. In Figure 23 an illustration of the experience bar can be found.

Figure 23: Illustrations of Minecraft's experience bar.

Fortnite

Fortnite's experience bar only pops up whenever the player gains experience and disappears again when it updated the players level. It first shows your previous experience and then shows an animation where it adds the newly gained experience to your previous experience, as can be seen in Figure 24. Whenever a player reaches a new level the pop up in Figure 25 is displayed. The experience bar is split up into subsections which require more experience to fill when on a higher level.

Figure 24: Fortnite's pop up of the experience bar.

Figure 25: Fortnite's pop up for a level up.

Conclusion

Both analysed experience bars were split into subsections. Therefore, it could be intuitive to split up the energy light into subsections as well. This might also make easier for the user to determine the percentage that is being displayed by the user. Whenever the experience bars of the analysed games were filled the bar resets and is being filled up again. Thus, this might also be a intuitive thing to do for the energy bar lights. However, there is a difference in information that is being shown between the analysed games who showcase levels and the bar light which showcases percentage. Therefore, it could be that is not the same for the energy bar lights. To find out whether this is the case it would require testing. Furthermore, incorporating sound effects when filling a subsection or reaching 100% and displaying a visual cue or popup upon reaching 100% could enhance user engagement.

Chapter 3 – Methods and Techniques

The design method selected in this study is the Creative Technology Design Process as described by Mader and Eggink [22]. It is inspired from the Divergence and Convergence Models and the spiral models. The Creative Technology Design Process consists of the four phases ideation, specification, realisation and evaluation. This model, as can be seen in Figure 9, serves as a guideline for an iterative design process.

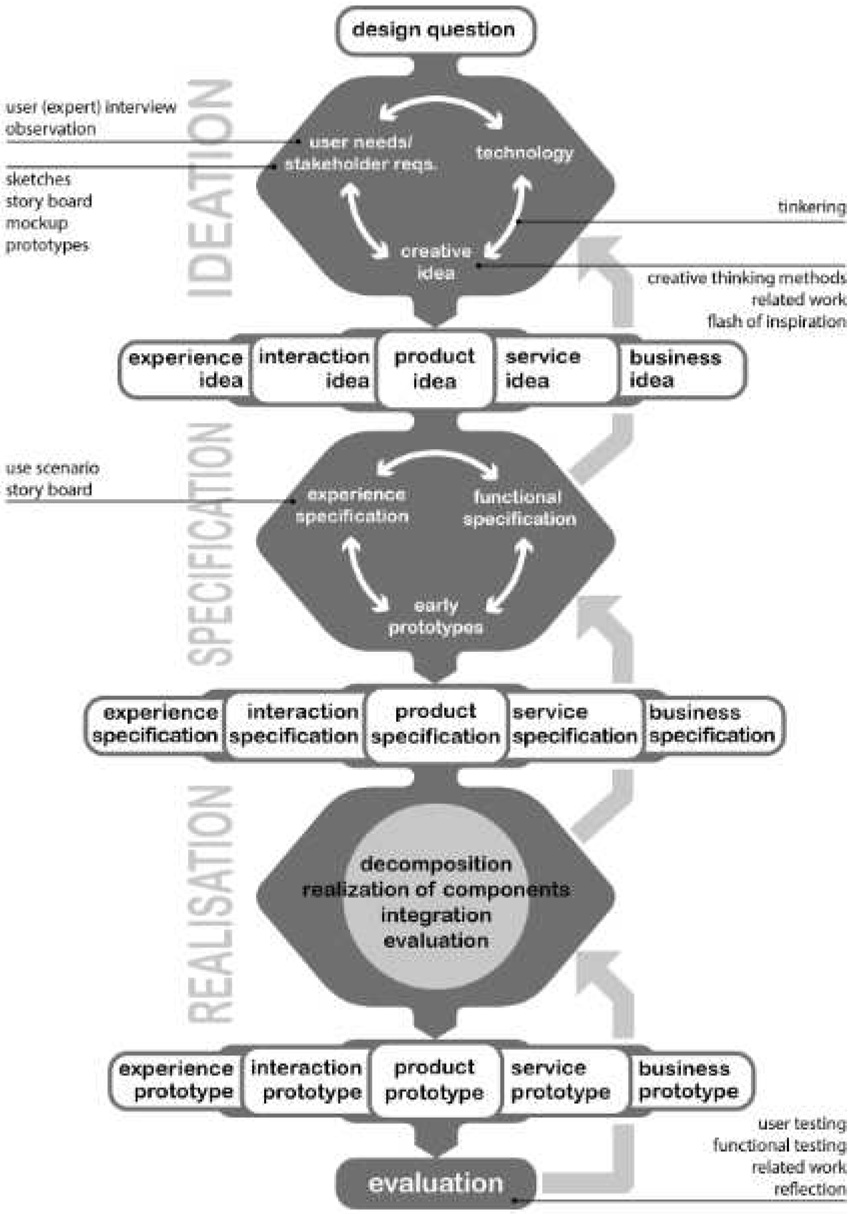


Figure 26: Creative Technology design process. [33]

Ideation

In the ideation phase creative ideas are generated to solve the design question which is in this case also the research question. Here different brainstorming techniques can be applied. The ideation process as described in Mader and Eggink [33] and Figure 26 incorporates a stakeholder analysis and user needs, problem definition, and early idea evaluation to develop a refined project idea, along with requirements for the solution.

For this project, brainstorming was chosen as the initial step. Given the broad scope of energy conservation, starting with exploration allowed for a clearer understanding before narrowing down specific areas. Initial efforts focused on identifying scenarios where energy savings could be achieved. This groundwork provided a foundation for brainstorming sessions aimed at devising strategies to realize these scenarios.

During brainstorming, the Behaviour Change Model (BHM) served as a tool to generate ideas on applying different intervention types; emotional, instructional and supportive. Additionally, brainstorming sessions were conducted to explore wearable technologies, which enable users to receive feedback continuously regardless of location. Another session explored sensory feedback types to investigate effective ways of engaging users through the intervention.

Following the brainstorming phase, the project progressed by combining concept ideas into an initial design, thereby narrowing down the broad topic of energy conservation even further. This approach, focusing on emotional, instructional, and supportive interventions, was aimed at enhancing the effectiveness of behaviour change interventions, as indicated by analysis using the BHM.

Subsequently, attention turned to data gathering methods specific to the intervention's needs, building upon propositions outlined in the state of the art. This previous section already discussed which techniques could be used to gather energy consumption data. However, discussion surrounding the operational environment of the infrastructure in which the data would be collected has yet to be addressed. This brainstorming session will focus on how data gathering methods can be integrated into the intervention.

After all brainstorming aspects have been completed and the initial concept design has been created it is time to incorporate stakeholders in the design process. To do this first a stakeholder analysis is introduced. Here the stakeholders are identified and analysed according to the Stakeholder Salience Model (SSM) by Mitchell et al [34]. The stakeholders are categorized according to the three attributes described in the SSM. These attributes are power, urgency and legitimacy. What these attributes exactly express are explained in the “*Stakeholder identification and analysis*

” section. Based on whether the stakeholder possess or lack the corresponding attributes they are categorized into one of eight different stakeholder groups as can be seen in Figure 27. Four different stakeholders are analysed for this project.

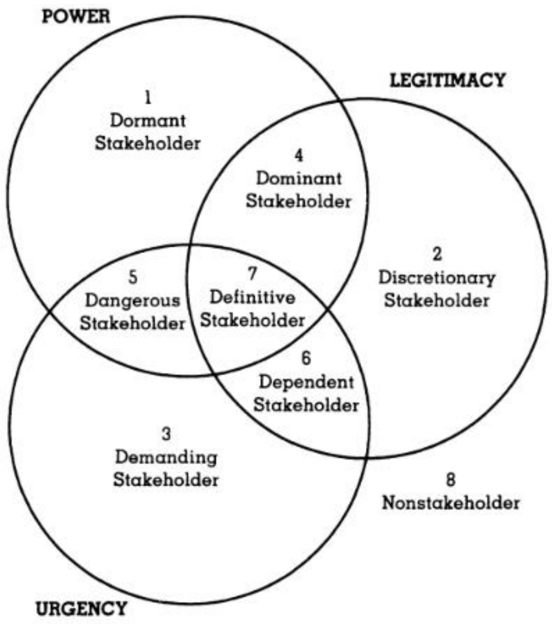


Figure 27: An overview of the Stakeholder Salient Model (SSM) from Mitchell et al [34] and their respective stakeholder classifications.

Then, after all stakeholders have been analysed and identified an unstructured interview is performed amongst three university employees. This interview aims to get a general understanding of the university employees in order to validate previous design decisions and assumptions and to get insights into possible variables that could influence the effectiveness of the intervention results. Furthermore, it aimed to let the university employees revise the initial design in order to create an effective design and thus take into account the opinions of the university employees. The informed consent form used can be found in “*Appendix A*: Informed consent form

” and the interview questions are detailed in “*Appendix B*: Stakeholder interview questionsAppendix B: Stakeholder interview questions”.

The findings from the unstructured interviews that influenced revisions to the initial idea were utilized to develop a refined concept. This revised concept, along with additional detailed interview findings, are further elaborated upon in Chapter 5.

Specification

The specification initially focuses on refining stakeholder analysis through the creation of three personas, each representing one intervention type from the BHM used in this project. This step is crucial to gain a deeper understanding of various user profiles (university employees) who may potentially use the product. It aims to ensure that the design meets diverse user needs and preferences effectively.

Following the creation of personas, user needs were identified. A comprehensive list of stakeholder requirements were generated with help of the results of the questions asked stakeholder interviews in "*Appendix B*: Stakeholder interview questions" and categorized into functional and non-functional requirements. These requirements were then prioritized using the MoSCoW method [35]. This prioritization is essential for optimizing time and resources throughout the project.

Lastly, the intervention concept is further specified with help of the new personas and stakeholder requirements. This section is divided into two main parts: the prototype design specifications and the data gathering specifications. Following the discussion of the intervention concept specifications, examples of its use will be visualized in user scenarios, and an overview of the intervention concept will be provided through a specification diagram.

Realization

The realization phase focussed on creating the actual prototype. However, since the concept explained in the specification was too large to realize some aspects of this idea, mainly the data gathering aspect of the intervention, were left out. Therefore, the prototype was dependent on the simulation of data (Wizard of oz) instead of actual energy consumption data.

For the realization, the necessary materials were gathered first. The instructions from the specification diagrams and graphical representations of user interactions in Chapter Five were then used as examples and instruction guides to realize the concept of the intervention.

Evaluation

Lastly, in the evaluation phase user testing along with an assessment of the findings and the met requirements will take place. The explanation of the evaluation method is split up into two subsections. The first subsection arguments on why intention is used as the variable to evaluate the behaviour change intervention. The second subsection explains the method of the gathering and showcasing of the results and their respective assessments.

Measuring intention

This project aims on creating a possibility for PEB change by introducing the smartwatch. This PEB change is defined as a responsible energy behaviour change. As can be seen in the research question:

RQ: *How can an effective behavior intervention be designed to facilitate pro-environmental behavior among university employees, specifically targeting the responsible energy usage?*

However, PEB change will take a long time to occur and due to boundaries and limitations of the project PEB change won't be able to be measured. Therefore, an alternative measure needs to be determined to evaluate if the created prototype facilitates PEB among university employees, specifically to promote the responsible energy usage.

The *BHM* model in Figure 3 and the *TPB* in Figure 1 could help justify an alternative measure instead of behavioural change. Although TPB might miss some vital factors that play a role in PEB and is from origin a predictive model instead of a model focused on behavioural change, it still offers a good simplistic overview. Alternatively, the BHM model which is created in this project is a model specifically designed for behavioural change. However, this model has never been tested, but is based on different theories about behaviour in the literature.

The alternative measure selected to assess the possibility for PEB change is intention. Both the BHM and TPB state that not only intentions, but also perceived (external and internal) control have a direct influence on PEB. Even though there is a secondary direct variable present that influences the PEB change besides intention, intention is still seen as a valid measurement to see if the designed intervention would to facilitate pro-environmental behaviour among university employees. The reason being that it can still measure the possibilities for PEB change for whenever the perceived control of the user would be moderate or high. Since perceived control usually only involves external factors like automated or manual control systems for devices as lighting, temperature etc. it is outside of the scope of the intervention. This is considered outside the scope of the intervention, because these things can't be changed through the altering of behaviours. This is also the reason that the control of the user on the targeted behaviours is seen as moderate or high within the intervention. Furthermore the aim of the project is not to change the systems at the UT that would allow them to gain more control. The other factors like habits should be taken into account in the discussion since the measurement of intention only measures the motivation of the users. It fails to measure if the users pick up these PEBs as habits.

In conclusion, the BHM and TPB both offer a simplistic overview which can help justify using the measure intention instead of behavioural change when testing the intervention.

Results & assessment

Intention will be used to evaluate the realized prototype with user testing. For this an unstructured interview was used. First the method as described in "*Appendix F1*: Initial method

" was used, but later this method was revised to the method detailed in "*Appendix F2*: Improved method

" due to the learning curve of the intervention affecting results and time constraints.

The results of the user testing are put in an overview to provide a comprehensive understanding of the intervention's effectiveness. The results consist of: statements from the interview questions and an indication of usefulness per aspect of the intervention. The results are analysed for noticeable outcomes through the BHM to assess the effectiveness of the selected BCTs in the intervention and through the stakeholder requirements. Additionally, general noticeable outcomes where no analysis with the BHM is made are also highlighted. This all provides a detailed evaluation of how well the intervention meets its intended goals and user needs.

Chapter 4 – Ideation

Introduction

This chapter delves into the ideation phase of designing a behaviour change intervention aimed at promoting energy conservation among university employees. We start with the brainstorming phase to explore various energy-saving scenarios, intervention types, wearables, and sensory feedback. As energy conservation is a broad topic, this initial exploration helps narrow down and target specific areas for effective stakeholder feedback in a later phase of the ideation process. The initial concept further refines these ideas, focusing on developing tangible strategies that are in correspondence with the findings from the literature. With the initial idea created an brainstorm about the operational environment is executed to provide options of how to communicate the data that is required for this idea. After this a stakeholder analysis is introduced to gain a deeper understanding of the people that are influenced by the intervention or can influence the process of the project. A stakeholder interview is conducted to review the initial concept and design decisions. After stakeholder feedback and concerns have been taken into consideration a revised initial concept will be discussed. This concept will be further specified in chapter five.

Brainstorming

In Figure 28 a high level overview of the intervention can be found. This overview is used as starting point for the whole brainstorming process. First, before brainstorming the scenarios in which energy could be saved are determined. This provides more specific insights in the non-responsible habitual patterns that need to be targeted within the solutions. The energy saving scenarios are followed up with three brainstorming sessions: Brainstorming though the BHM

Brainstorm wearable types

Brainstorm sensory feedback types

After these brainstorm sessions an initial idea is generated. Lasty, the possible operational environments are discussed and explored to gather the required data necessary for the initial idea.

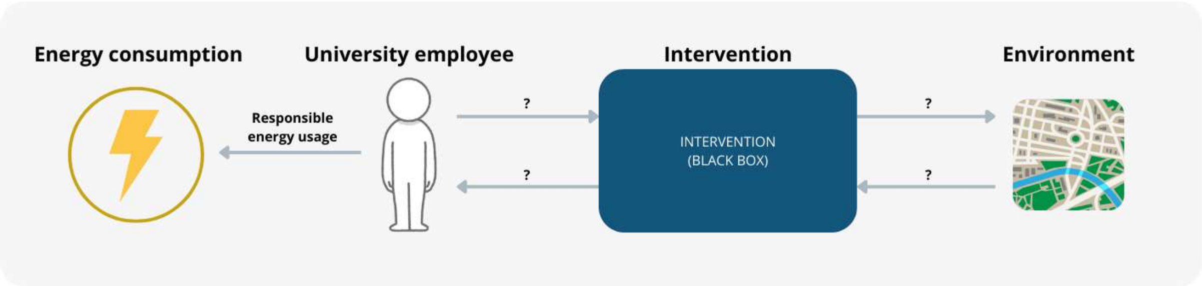


Figure 28: General overview of the implementation/ effects of a still undetermined intervention.

Energy saving scenarios

Reducing energy consumption is a very broad topic which can be tackled from many angles. To get a clearer picture about where energy savings could be realized a set of scenarios were created. In Figure 29 scenarios of non-responsible energy usages can be seen. These provide opportunities for behaviour change to reduce energy consumption during the brainstorming phase. Alternative scenarios not illustrated in Figure 29 are setting room temperature too much in advance, not having devices set in sustainable mode, the unnecessary use of multiple screens at the same time, having more lamps on than is necessary, not loading the washing machine till full weight, difference between standby mode and off, excessive heating due to lack of clothing layers, putting heating or cooling at their maximum level, cleaning or hoovering when it is not yet necessary, wasting energy through inefficient cooking methods e.g. not using lids, using large pans for small portions, warming up the oven for too long, leaving the extractor hood on after cooking etc. There are still many more scenarios, however using even more scenarios for the brainstorm session would be inefficient. Therefore only the currently named scenarios are taken into account during the brainstorm sessions.

Additionally, it is good to note that during this phase of the design process, it was not yet determined that this project would only focus on electricity consumption. This means that during the process energy consumption might also point towards other forms of energy consumption than electricity usage.

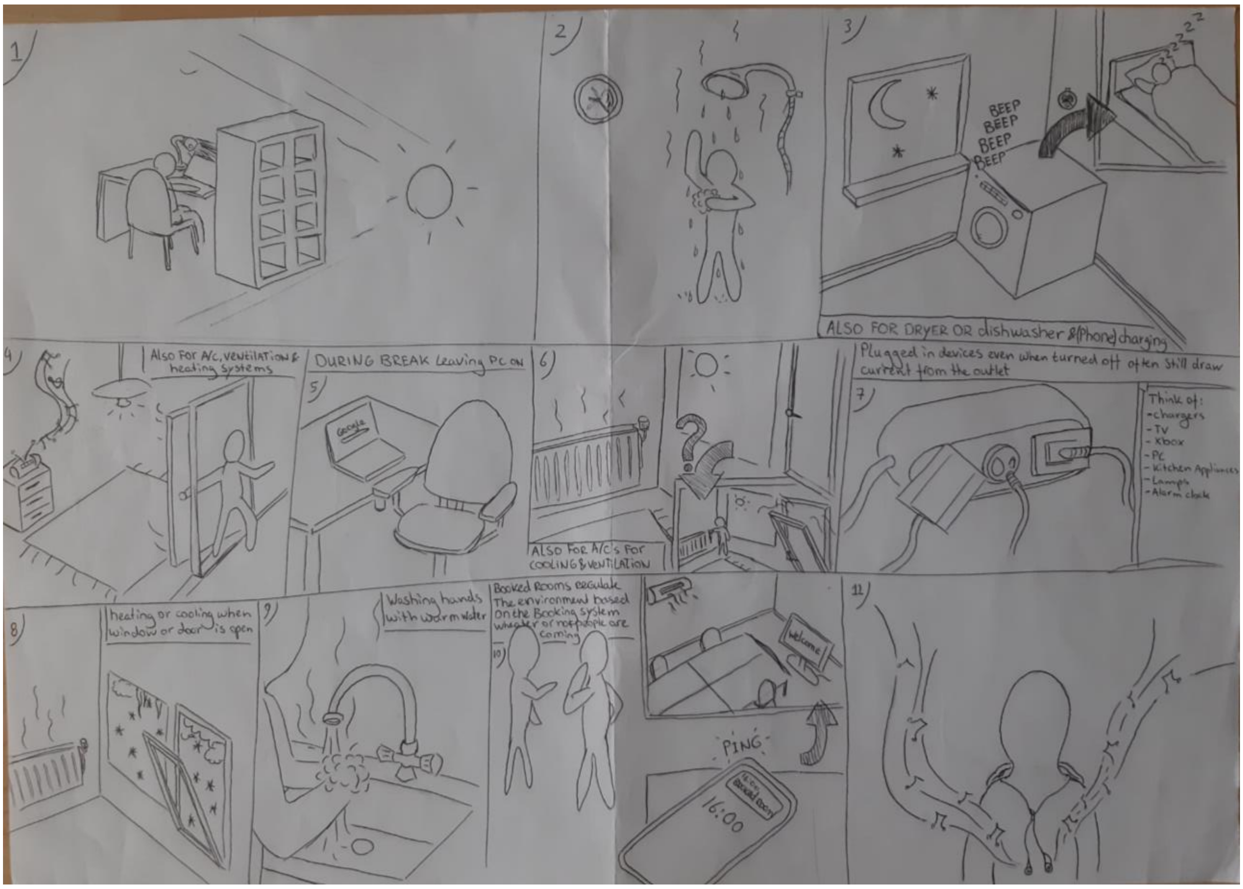


Figure 29: Illustrations of scenarios of non-responsible energy usages which could provide opportunities for behaviour change to reduce energy consumption. Utilizing lights because of obstructions while sunlight is available (1), taking unnecessary long hot showers (2), not turning off devices like washing machines, dryers, dishwashers or chargers when they completed their task (3), leaving devices on when exiting a room or building (4), not turning off devices when taking a break (5), heating or cooling a room when alternative measures like opening or closing windows, curtains etc. are available (6), have a unnecessary high plug load which draws currents for devices that are not in use (7), heating or cooling while working against competing systems or in opposition to environmental factors e.g. open doors, windows, having both heating and cooling systems on at the same time etc. (8), washing hands with warm water (9), booking a room at the University of Twente while arriving late or not at all which automatically starts to turn on room regulating devices e.g. heating, cooling and ventilation systems (10), put on music while not actively listening (11).

Brainstorming though the BHM

The BHM model in Figure 3 from the literature review is used as a tool to aid in an effective intervention design for this project as it is based on behavioural models which should incite behaviour change. This means it is important to involve this model into the brainstorming phase to increase chances of an effective result. This brainstorming phase is split into three categories: Supportive intervention types, emotional intervention types and instructional intervention types. Why it was determined that these three intervention types were used in this project can be found in the "*Creating an overarching model*

" section.

The brainstorm and concepts of the supportive intervention type can be seen in Figure 31 and Figure 32. The concept generation focusses on generating concepts for general solutions regarding the behaviour change for reduction in energy consumption and for specific scenarios mentioned in the previous section "*Energy saving scenarios*

An illustration of the scenarios 1, 2, 3, 4 and 6 can be found in Figure 30. The second brainstorm regarding the emotional intervention types can be found in Figure 33 and the third brainstorm about the instructional intervention types in Figure 34.

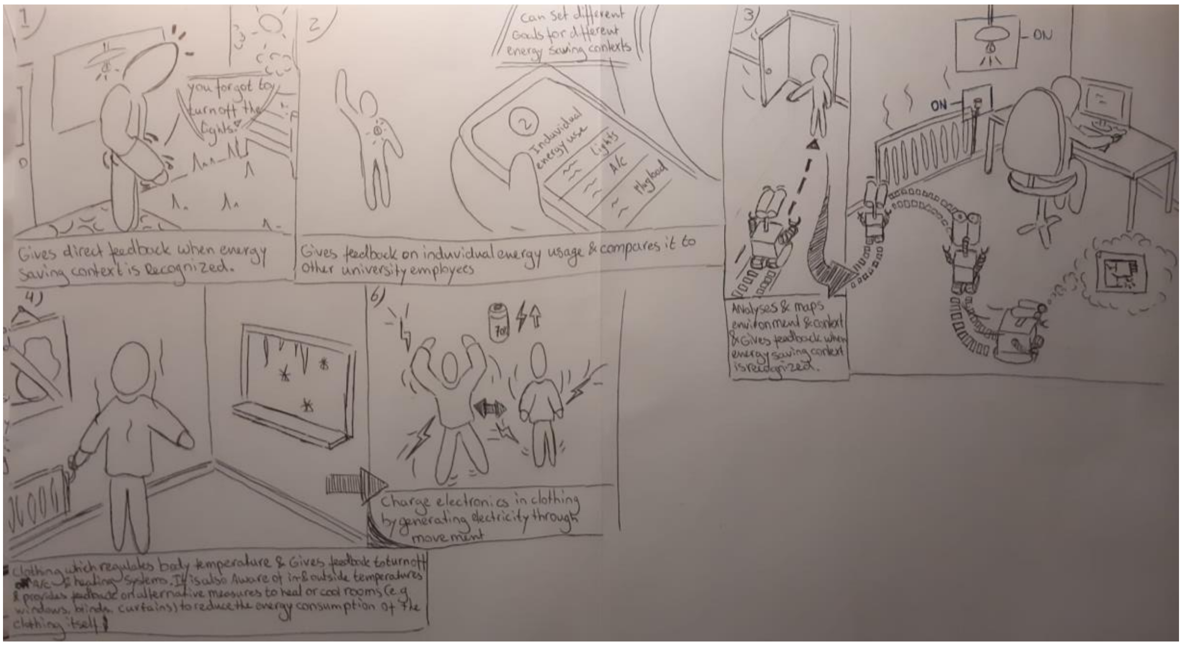


Figure 30: Illustrations of scenarios 1, 2, 3, 4 and 6 from the supportive intervention type brainstorm in Figure 32.

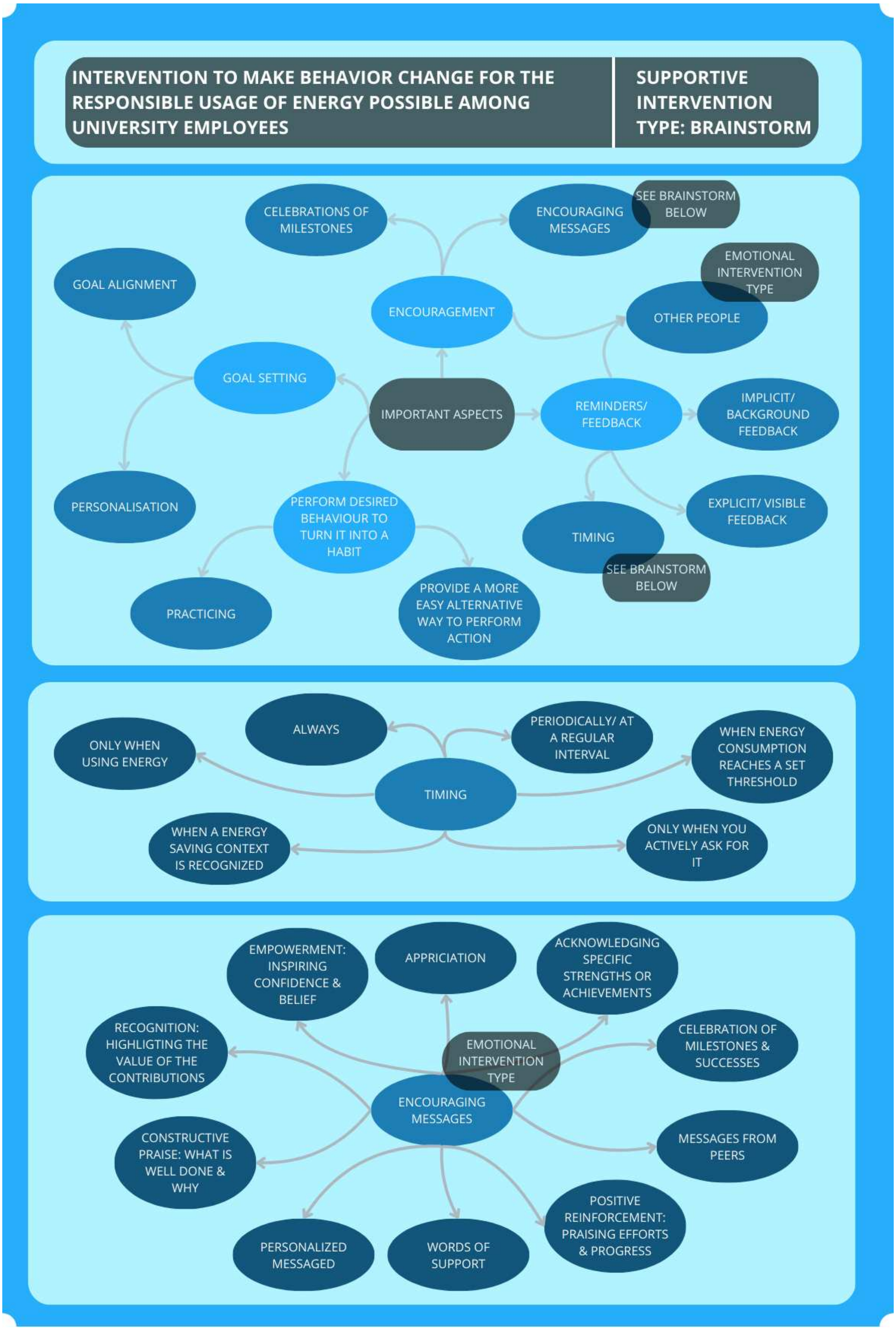


Figure 31: Brainstorm of the important aspects for supportive interventions to create more responsible energy consumption habits.

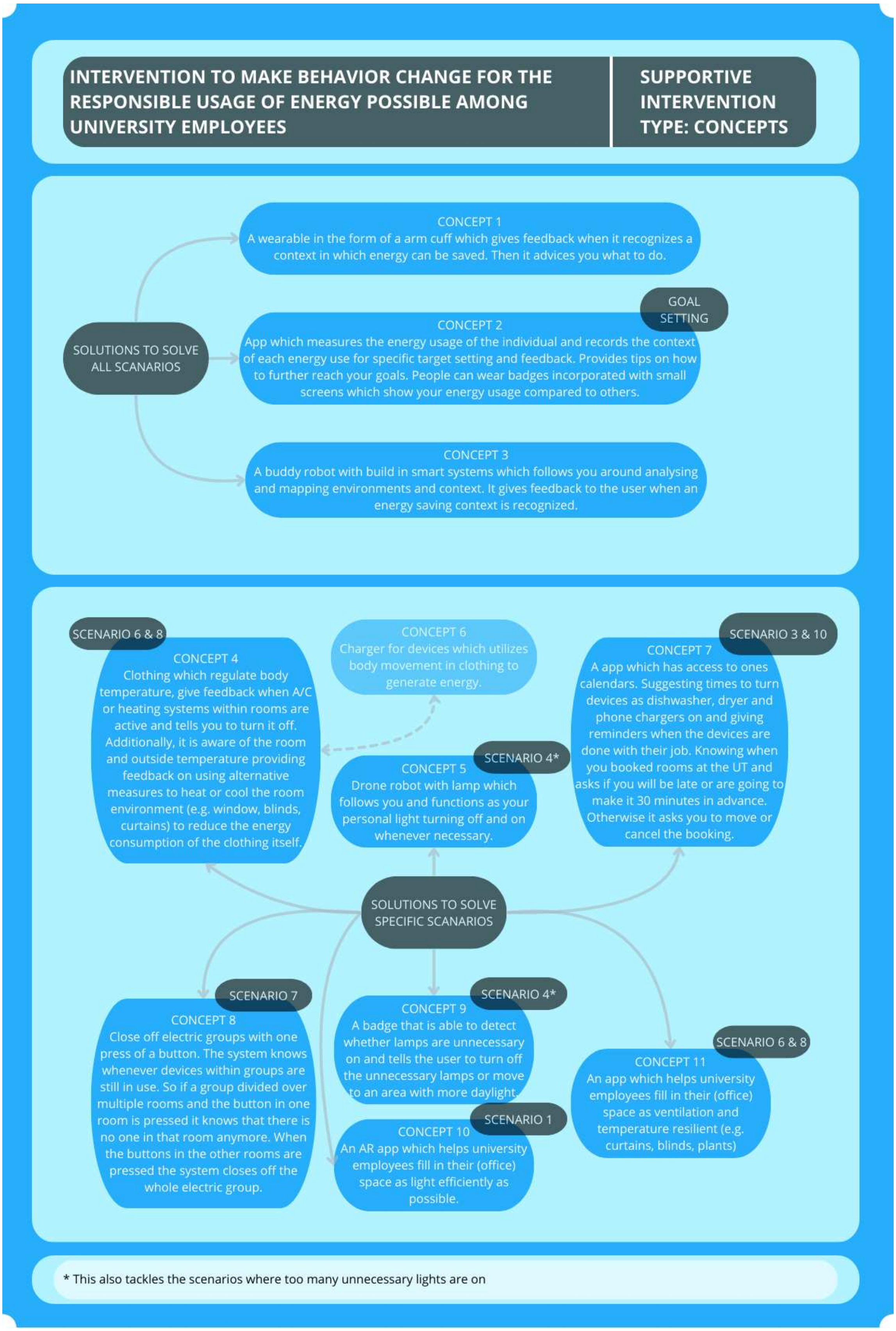


Figure 32: Concepts of supportive interventions split into general solutions and solutions for the specific scenarios mentioned in the previous section "Energy saving scenarios

". The scenarios in the black boxes refer to the scenarios in Figure 29.

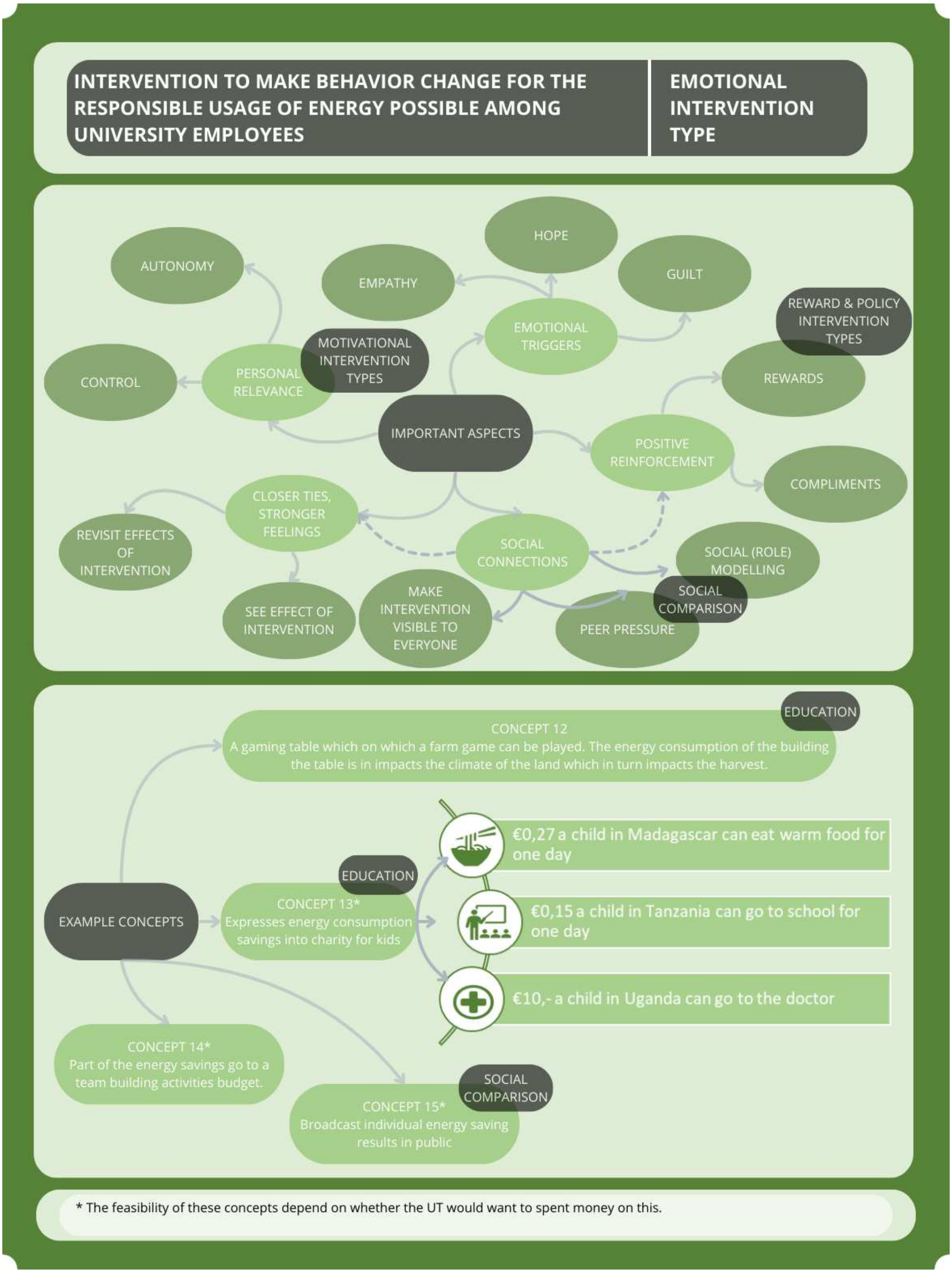


Figure 33: Brainstorm of emotional intervention type concepts and relevant aspects.

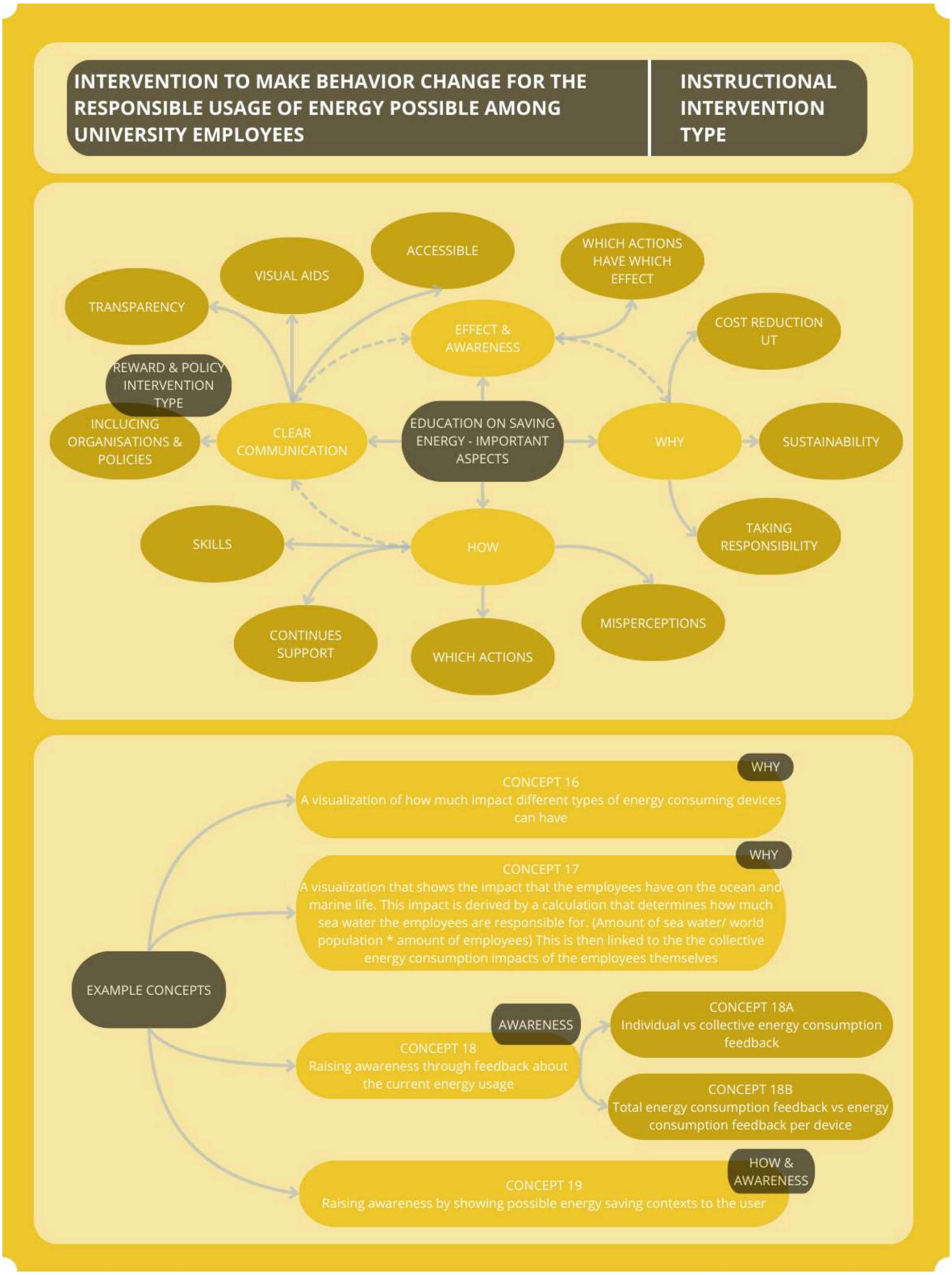


Figure 34: Brainstorm of instructional intervention type concepts and important aspects to take into account.

The chances of successfully altering behaviour improve greatly when the different intervention types are combined as can be derived from the BHM in Figure 3. Therefore, the best aspects of different ideas should be combined. First, the best aspects of the brainstorming and concepts will be defined.

Regarding the supportive intervention type brainstorm in Figure 31 all mentioned aspects could be important. Through reminders and feedback the intervention could prompt users to alter their behaviour. This has to go hand in hand with encouragement to be most effective. In this brainstorm "other people" link the aspects encouragement and reminders/ feedback together. This might therefore be an extra effective aspect to add into the intervention. The emotional intervention type brainstorm in Figure 33 describes more about the impact social connections can have. Goal setting is actually more of an aspect related to motivational intervention type rather than the supportive intervention type. However, no brainstorming has been done for this intervention type. Therefore it is put in the supportive intervention type instead. In summary the supportive intervention type aspects that could be important for the initial idea are reminders/ feedback, encouragement, goal setting and the performance of the desired behaviour to turn it into a habit.

Regarding the supportive intervention type concept generation some refining can already be done. The concept generation of this intervention type in Figure 32 is split into two parts: solutions to solve all scenarios and specific scenarios mentioned in the section "*Energy saving scenarios*

". However, the solutions that offer the possibility to save energy for all scenarios will have significantly more impact than the concepts that focus on only saving energy in one specific scenario. Therefore, concepts 1, 2 and 3 seem to be most effective. In conclusion, the intervention will have the most impact when it aims to save energy in all scenarios instead of specific ones.

For the emotional intervention type the social role modelling seems to be most feasible and effective within this project and the generated ideas. Most example emotional intervention concepts (13 and 14 in Figure 33) are focused on interventions that distribute energy money savings in a way that would hypothetically emotionally motivate employees to reduce their energy consumption. However, this emotional driver is expected to not be very stable. This driver relies on the decisions made by the direct stakeholders identified in **Error! Reference source not found.**, which are external factors beyond the control of this project. The direct stakeholders have the power to decide whether to invest the saved money through the intervention in the proposed emotional motivators. Therefore this project itself has very little influence in whether money related emotional drivers would be feasible to apply within this target group. The direct stakeholders make that decision. Additionally, choosing money related emotional motivators as the main motivational driver can cause issues whenever the direct stakeholders change their funding plans. If direct stakeholders were to first support money related emotional motivators, but stopped this support later down the line, it can have negative consequences on end users behaviours. With the emotional intervention type lacking from the prototype it will cause demotivation among the users. Core users who were strongly motivated by this emotional driver will be extra effected and might not perform the desirable PEBs. An alternative provided concept (12 in Figure 33) focusses on the emotional attachment of games. Gaming might be a good option for an emotional driver. However, it is difficult to get every university employee to take part and invested in playing a game. Alternately, social (role) modelling could potentially merge multiple emotional motivators together through peer pressure and social comparison. With social connections it can initiate emotional triggers, create closer ties or attachment to the intervention goal and feedback (positive reinforcement or stimulation to improve). Furthermore, focussing on social connections helps to reach more people and broaden the network and through peer pressure and social comparison more university employees will be persuaded to take part in the intervention. Lastly, social (role) modelling or peer pressure can be a connection point between the supportive and emotional intervention type as social connections can also be a considered a form of feedback, see Figure 31. One way of creating an environment to where social (role) modelling can thrive is by making results of for instance energy saving publicly known or visible as mentioned in Figure 33 in concept 15. In summary, social (role) modelling through peer pressure and social comparison could merge the emotional and supportive intervention and many of the important emotional aspects together. Additionally it could support the network growth of the intervention.

The most important aspects of the instructional intervention type brainstorm are the how, effect & awareness and clear communication. It is assumed that all university employees know why they should participate in energy saving behaviours. Therefore, the why aspect and the concepts 16 and 17 in Figure 34 are not required for this intervention. Concepts 18 and 19 in Figure 34 could be promising instructional intervention concepts. However, these concepts should be realised through clear and transparent communication with the core users to reach their full potentials. Both these concepts could possibly be combined each other. They both overlap with the concepts 1, 2, 3 in Figure 32 from the supportive intervention types.

So, in short a combination of the different intervention types integrates the best aspects of the brainstorm into one concept idea. Aspects that could be considered for integration are reminders/ feedback, encouragement, goal setting, the performance of the desired behaviour to turn it into a habit, social connections (e.g. social (role) modelling, peer pressure, social comparison), how to save energy, the effects of actions, awareness and clear communication. One of the most promising aspects that combines the emotional and supportive intervention with one another are the social connections. Another very promising aspect is feedback since during an attempt at behaviour change it is important for the users to know how well they are performing. Lastly, for the intervention to have most impact in the reduction of energy consumption it would have to focus on this reduction within multiple scenarios at once. Therefore, an product idea that aims to alter behaviour to reduce energy consumption in every context is considered. This means that the intervention functions within every environment e.g. at home, the university, public spaces etc. However, not every environment has the appropriate existing infrastructure to be able to support the behavioural change towards responsible energy usage. Therefore, the intervention has to be brought with the user to every different environment to manage this behavioural change.

Brainstorm wearable types

An effective way for the intervention to be carried around with the user in their day to day lives are wearables. A brainstorm about possible wearable type options for the product idea can be seen in Figure 35.

The most promising wearable types mentioned in the brainstorm are artifacts, clothing and accessories. The skin categorized wearable types is a whole new and mostly still undiscovered wearable type. These wearable types require an extra amount of innovation. The development of new skin based wearable types are not the goal of this project. Therefore, this type might not be suitable for this project as all the effort should be focused on supporting responsible energy usage. A buddy could be a nice option for an wearable. A buddy is an object that could potentially function as a "friend" to the user. This would for instance work when the buddy is incorporated or combined with another wearable type. The incorporation of a buddy might create a more emotional bond between the user and the intervention. However, if the buddy system is a wearable itself it might be impractical for a large amount of the scenarios mentioned in "*Energy saving scenarios*

For example, a stuffed animal is not an object what you would like to carry around all day. On the other hand, artifacts that are already present in the environment, clothing and accessories are very promising. These are objects that users already are used to carry around which lowers the threshold of utilization. A condition for these artifacts is that they have to allow for the functionality of the intervention. In summary, promising wearables that should be considered for the wearables are artifacts, clothing and accessories which could potentially be integrated/ combined with a buddy.

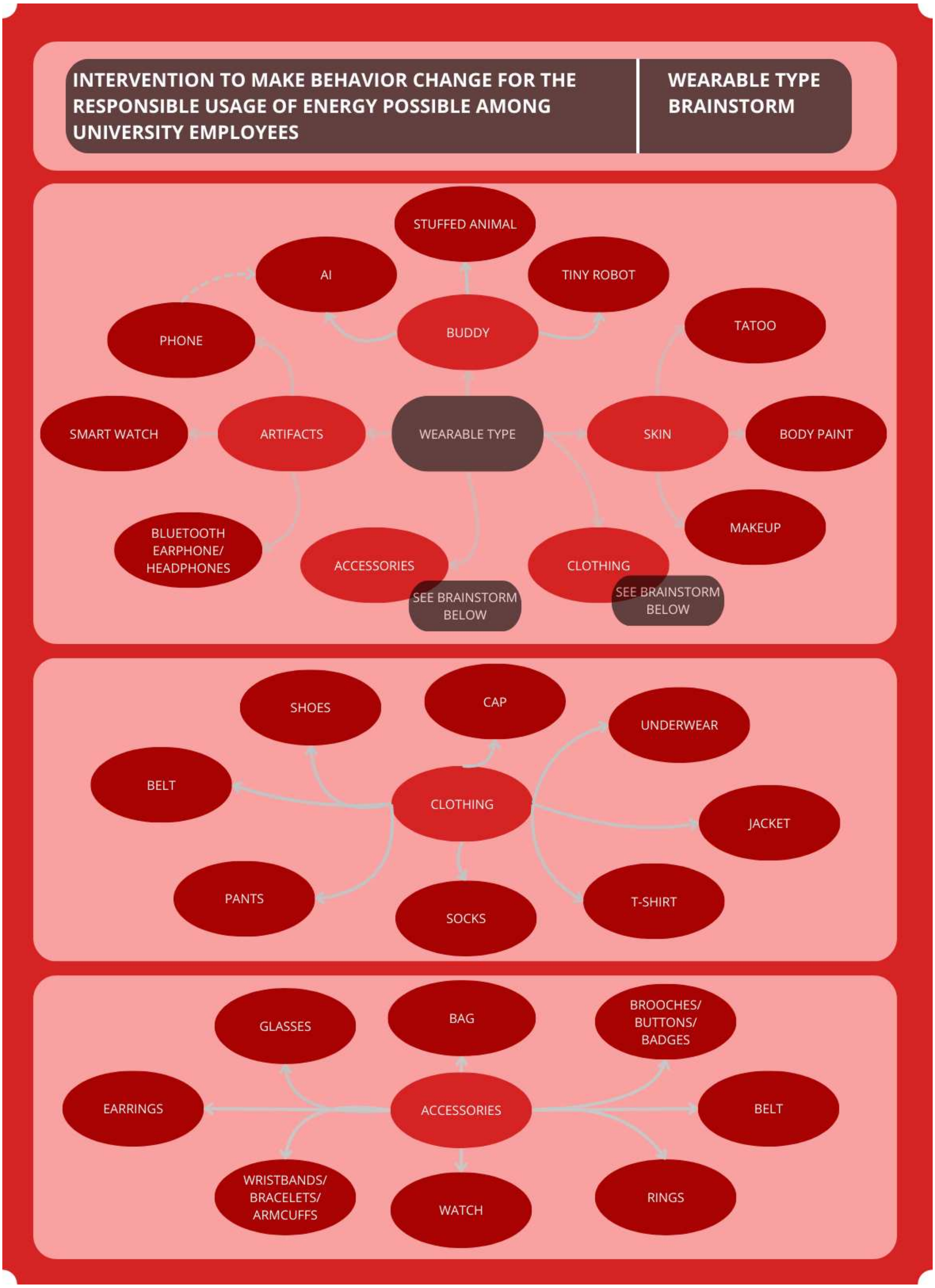


Figure 35: Brainstorm regarding wearable type options for the intervention.

Brainstorm sensory feedback types

Most of the key features that are necessary for the intervention are discussed. However, it is still unclear how the intervention will interact with the user. Therefore, a brainstorm regarding the possible sensory feedback types is undertaken. This brainstorm can be seen in Figure 36. Feedback was already mentioned in the supportive intervention type brainstorm in Figure 31, however, this did not focus on the sensory aspects within the user interaction.

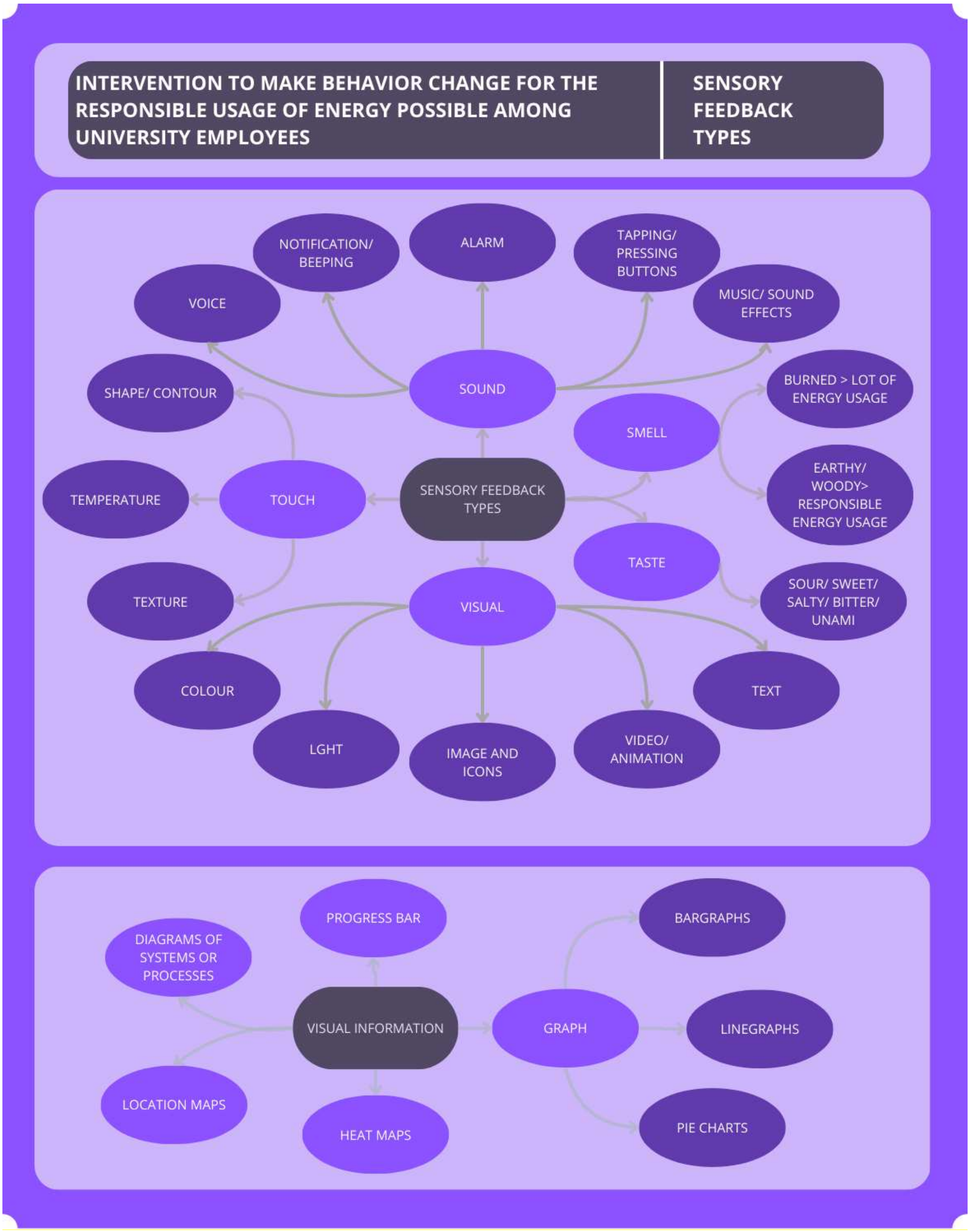


Figure 36: Brainstorm of sensory feedback types for the intervention.

Sound, visual and touch are promising sensory feedback types for the intervention. Smell and taste don't have much relation to the intervention. Sound can be a good way to support interaction experiences as conformation of interactions like the tapping/pressing/button sounds. Apart from this, it could function as a feedback for reminders. This is also the case for feedback aimed at human touch receptors. Feedback in the form of voice might be a form of too direct (or intrusive) feedback. Meaning that it can disturb or disrupt the activities the users are performing. Possibly resulting in annoyance or dissatisfaction. Visual feedback like text or graphs can contain more explicit informational feedback containing more information. Icons, images, lights and colours can be applied to create a more intuitive design.

Initial idea

Feedback mechanisms in the initial design

A general overview of the initial idea for the intervention can be seen in Figure 37. All features are inspired by aspects from the different intervention types discussed in the "*Brainstorming though the BHM*

" section. The features as reminders, feedback, encouragement, goal setting and the performance of behaviours are incorporated from the supportive intervention type brainstorm in Figure 31. Hypothetically, the intervention should bring about the performance of behaviours that save energy. When this is repeated, it should create new responsible habits towards energy conservation. The reminders and encouragements are included within the feedback. Feedback points 1, 2 and 3 in Figure 37 are always visible to the user and function as reminders. Additionally, feedback point 4 also functions as a reminder and are notifications that are only visible to the user whenever the specific situation occurs. Point 6 function as encouragement through celebrations of milestones and successes. It gives you a notification when you have reached your goal and the streak of the user reaching the goal. Whenever you set and reach more difficult goals you get extra bonus streak points. However, users might not always want to receive feedback. In this case the users can turn the wristband off.

Features of the emotional intervention type are included through social connections. Users of the intervention will interact with each other in their day to day lives. By displaying feedback points 1 and 2 publicly users can receive feedback—whether positive or negative—about their energy performance. This can motivate them to either improve or maintain their current level of performance. Social (role) modelling, peer pressure and social comparison are the main drivers for this type of feedback and motivation.

The instructional intervention type features focus on showing the user on how to save energy through educating them on how much energy they are using in real-time. This influences the mentioned awareness aspect. Furthermore it shows the current individual energy consumption per device as a percentage of the total current energy usage. This educates the users on how to save energy and the effects their actions have on their overall energy consumption.

In Table 4 an overview can be found of the different feedback types and their corresponding intervention types. It is expected that a feedback type which can be applied to multiple intervention types will be most effective in altering behaviours.

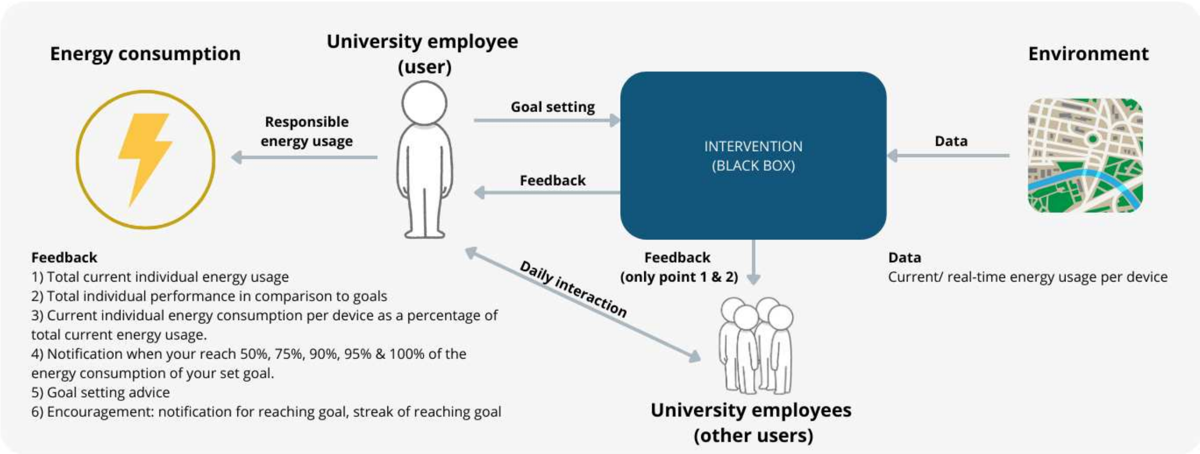


Figure 37: Overview of the general initial idea.

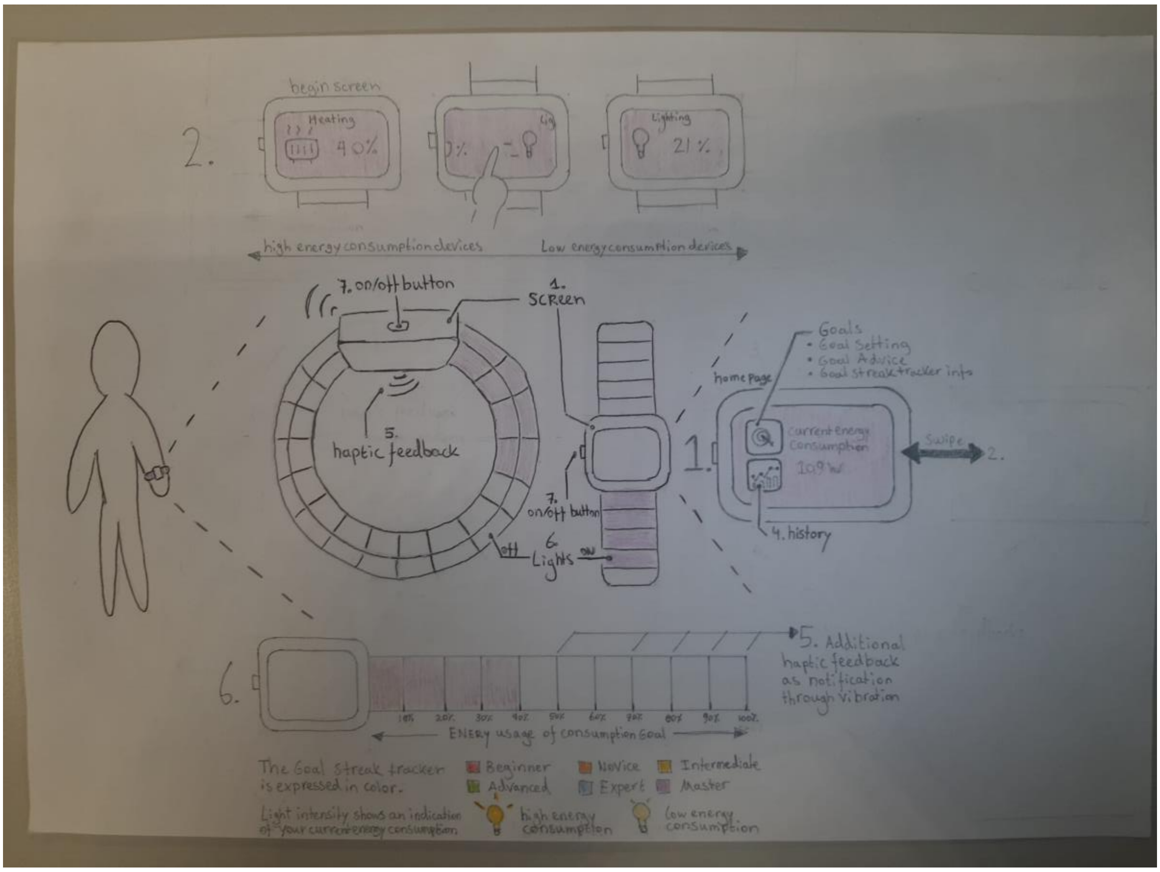
Feedback points in Figure 37 / intervention types	Emotional	Instructional	Supportive
1) Total current individual energy usage	X	X	
2) Total individual performance in comparison to goals	X	X	X
3) Current individual energy consumption per device as a percentage of total current energy usage		X	
4) Notification when you reach 50%, 75%, 90%, 95% and 100% of the energy consumption of your set goal			X
5) Goal setting advice			X
6) Encouragement: notification for reaching goal, streak of amount of days the goal is reached	X		

Table 4: Overview of the different feedback points and their corresponding intervention types.

Initial concept design (specified)

To enhance the concepts generated in the brainstorming phase, the best aspects of different ideas can be combined. Furthermore, the feedback mechanisms mentioned in Table 4, which focus on multiple intervention types, greatly improve the chances of successfully altering behaviour when these intervention types are combined, as derived from the BHM in Figure 3. This approach leads to the development of the initial concept.

An overview of the initial concept can be found in Figure 38. The initial concept is a wristband which measures personal energy consumption. In an additional app you can set the your daily energy consumption goals, see your exact energy consumption, history and rank. The wristband contains lights. How much of these are on determines what percentage of your consumption goal you have used. The lights intensity shows your current energy consumption. The brighter the more energy you are consuming. Additionally the colour of the lights says something about the streak you have in reaching your energy goals. Setting more difficult goals gets you bonus streak points. Warnings for when you are over your daily target or reach 50%, 75%, 90% or 95% of your target utilize organic haptic feedback in the form of pressure on the skin.



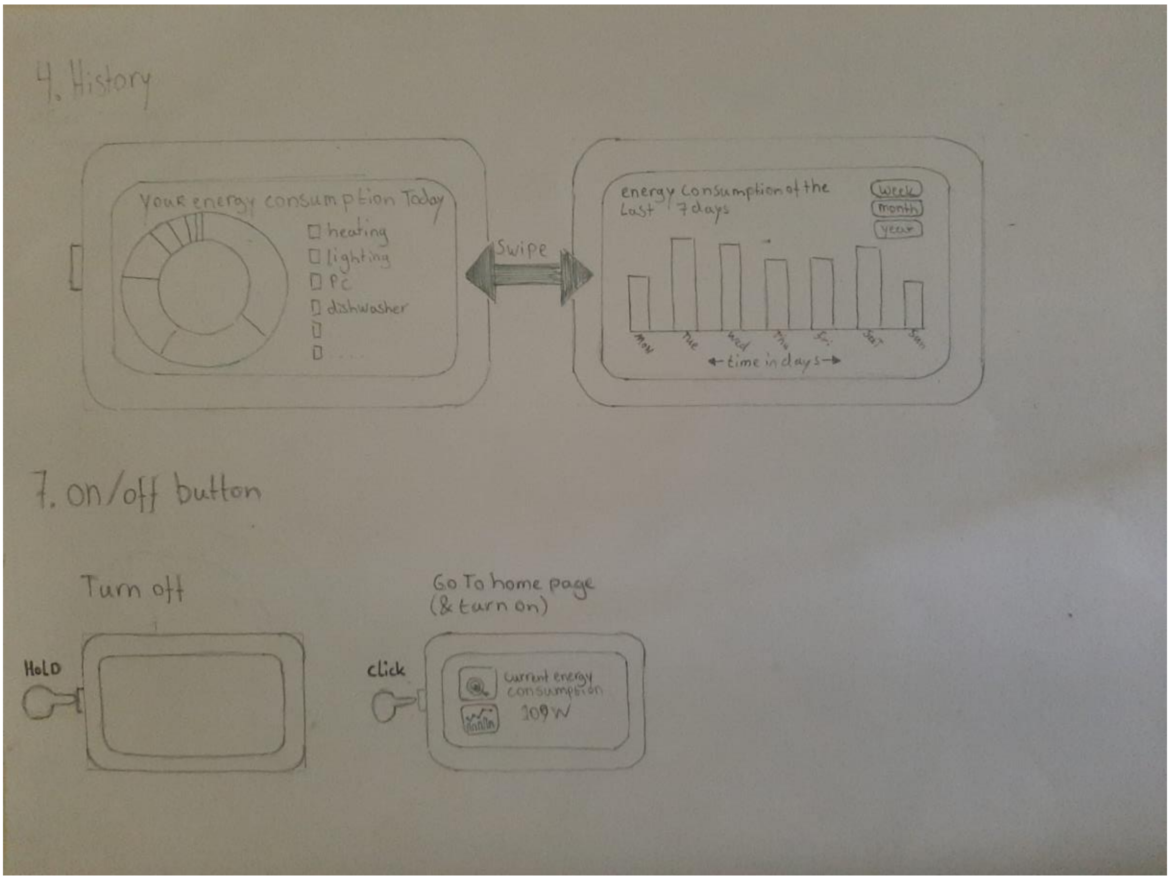


Figure 38: Overview of the specification of the initial idea.

It measures:

- Amount of energy used by A/C and heating systems in personal rooms
- Amount of energy used by ventilation in personal rooms
- If you are in a personal room
- Amount of energy used by lights
- Amount of energy used by personal pc and phone

Feedback:

- Organic haptic feedback in the form of pressure on the skin
- Light intensity
- Amount of lights
- Colour of lights

Other activities:

- Can add personal rooms to the system?
- Can set personal daily energy consumption goals

Intervention types:

- **Supportive:** it aims to motivate people to change their habits through goal setting, engagement, peer pressure and modelling.
- **Emotional:** The performance of the user towards their energy consumption goals is clearly visible towards other potential users. Being shown the accomplishments of others while walking by or in conversation can positively influence peer pressure and social modelling. Additionally, users can get feedback (positive or negative) about their energy performance. Which might stimulate them to improve or keep up their good work.
- **Instructional:** It educates users on their current energy consumption. Making them more aware of their actions.
- **Reward & policy:** The reward is a social status of being sustainable.

Operational environment brainstorm

However, the concept of the initial idea did not yet focus on how the intervention should gather its energy consumption data to function properly. This was not yet possible before as it was yet unclear what type of data needed to be measured. With the initial idea determined it is now known that the intervention should gather real time energy consumption data per device of each individual user. To gather this information and data for the intervention three environments/ scenarios for data gathering are sketched to make this possible. These scenarios can be found in Figure 39, Figure 40 and Figure 41. In all of these scenarios the hub, smartphone or intervention could also interact with other smart systems to gather more (specific) information. This section is an brainstorm of the operational environment and how the data is communicated. The state of the art section already gave examples on how to measure energy consumption data.

Instrumentation

The first scenario to gather the data needed for the intervention is to instrument the rooms in which the measurements need to take place. An overview of this scenario can be seen in Figure 39. The intervention then communicates with a hub located in a room. This hub is in contact with all the energy consuming devices within that room. These devices give the hub the right data that it then forwards to the intervention. A hub could potentially also cover a bigger area then one room and connect multiple rooms together. In the case of scenario 1 the CFM would have to provide all the instrumentation needed in order for this to function.

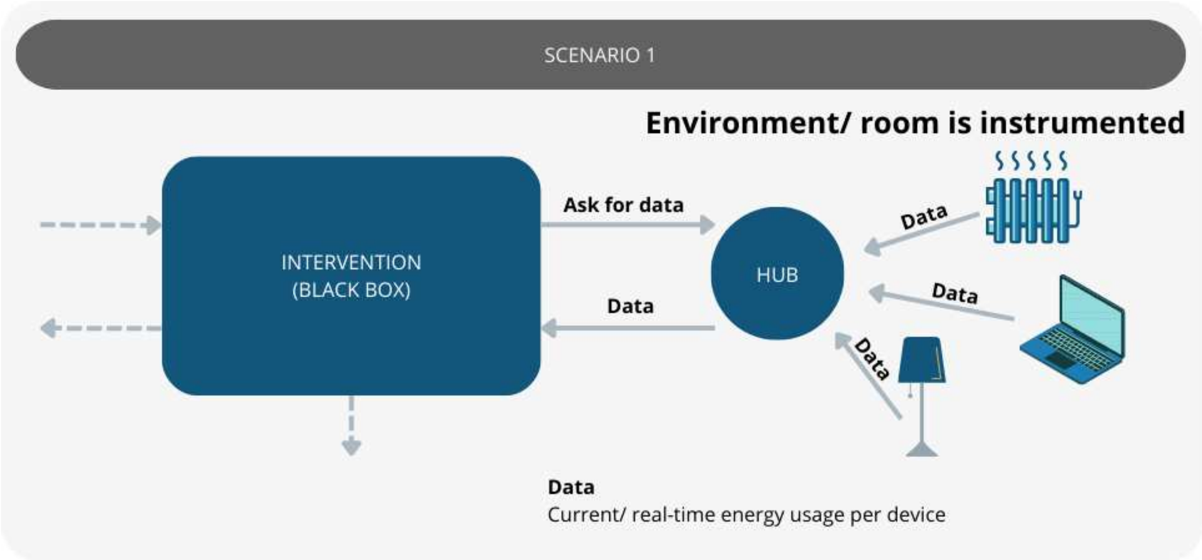


Figure 39: The first option to gather the data required for the intervention utilizes instrumentation and a general hub.

Smart phone

The second option is to create context awareness through the utilization of existing artifacts like a smartphone. This is illustrated in Figure 40. Smartphones contain many sensors which can help determine specific context in which energy conservation is required. The smartphone then gives contextual information to the intervention. This information can contain information on whether the user is inside or outside, whether the lighting conditions change etc. With this knowledge the intervention can make estimations on which energy consuming devices are currently in use. However, the intervention would then be based on estimations which leaves room for the possibility to give inaccurate feedback to the users. Additionally it might be hard to determine which type of device they are using (there are multiple types of lights) and its energy consumption. Therefore it might be necessary to add an average energy consumption per device type or give the possibility to let the user personalize the energy consumption settings per device type.

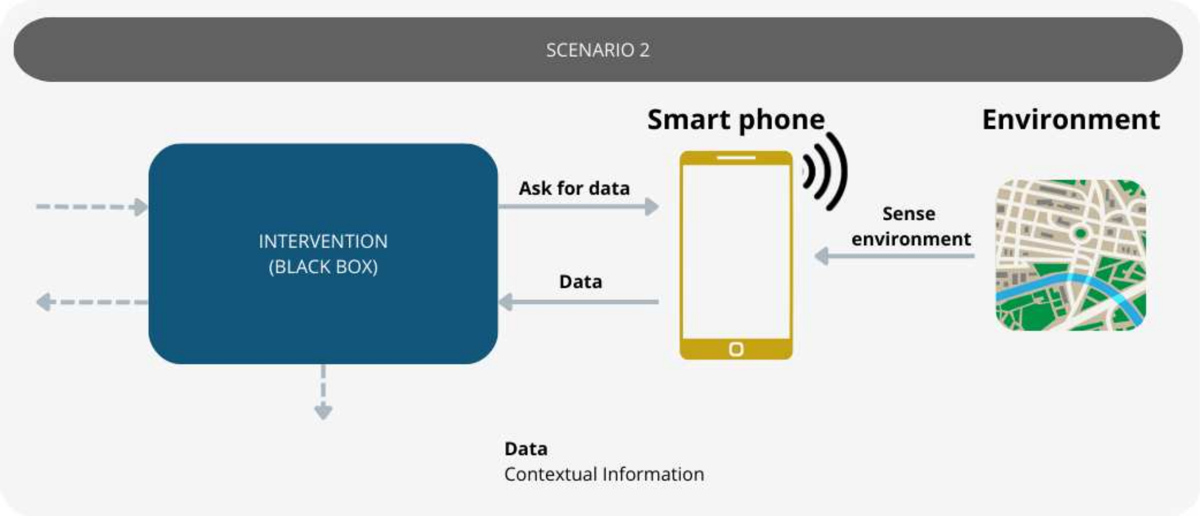


Figure 40: The second option to gather data for the intervention is by measuring context with the smartphone. These context then form a basis for the estimation regarding the current energy consumption per device.

Additionally to measurements the smartphone could also gather contextual insights through access to personal apps like the calendar.

Smart system

The last option to measure the data needed for the intervention to function is the situation in which everything is integrated within the intervention itself. This means that all the communication with the external devices is executed by the intervention without any use of a device functioning as a mediator. This scenario is illustrated in Figure 41.

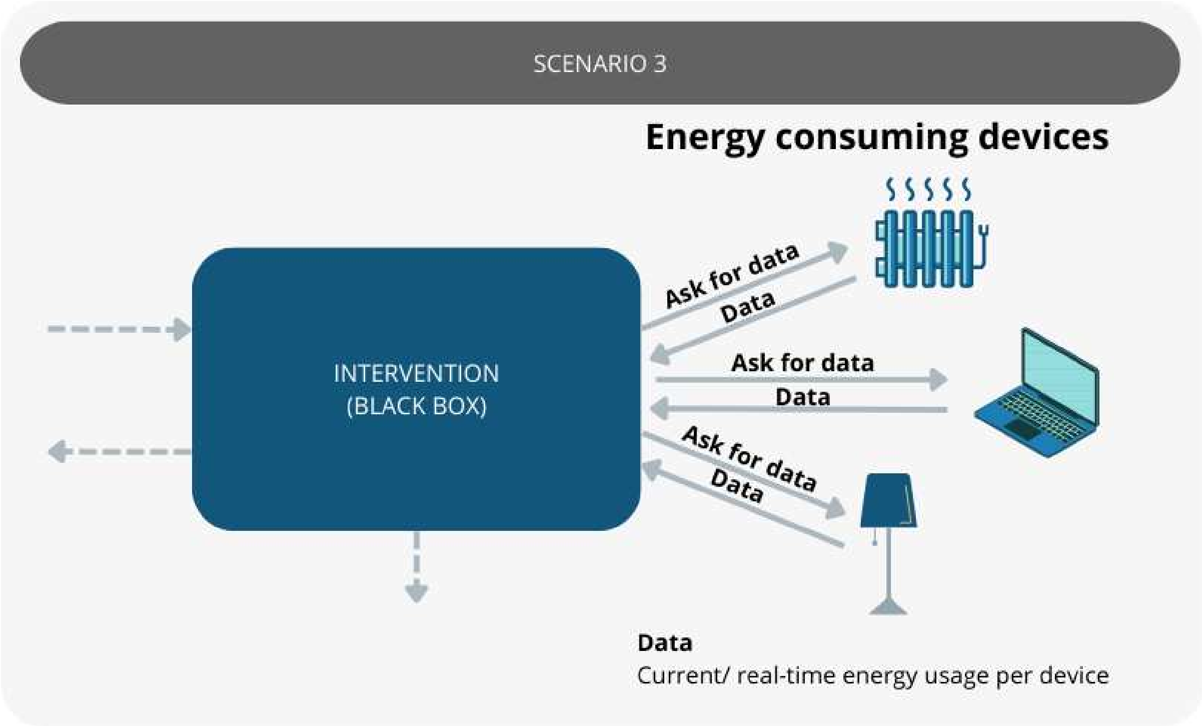


Figure 41: The last scenario to gather the data needed for the intervention. All the communication with the external energy consuming devices is done by the intervention itself. There is no device functioning as a mediator.

Stakeholder analysis

Stakeholder analysis is a crucial step in the process of designing effective interventions. This phase involves identification, analysation and the understanding of the various stakeholders who are impacted by or have influence over the project. By examining their interests, roles, and potential impact, we can prioritize the most important stakeholders whose engagement and support are essential for the success of the intervention. This analysis ensures that the strategies are tailored to meet stakeholder needs and effectively address their concerns. This will enhance the likelihood of achieving a sustainable behaviour change intervention.

Stakeholder identification and analysis

When designing behaviour change interventions it is important to take into account the perspectives and needs of the different stakeholders. This can be achieved through a stakeholder analysis with the Stakeholder Salience Model (SSM) proposed by Mitchell et al [34]. In this model the stakeholders are distributed among three attributes. The first one is legitimacy which indicates the “right” or claim a stakeholder has to make requests related to the project. The second attribute is power which shows the influence of the stakeholder over the projects actions and outcomes. The last attribute is urgency which reflects the degree of immediacy or priority that stakeholders attach to their interests or concerns related to the project. The presence or lack of these attributes for each stakeholder determines the stakeholder groups, as can be seen in Figure 42. The stakeholders involved in this study will be analysed through the SSM.

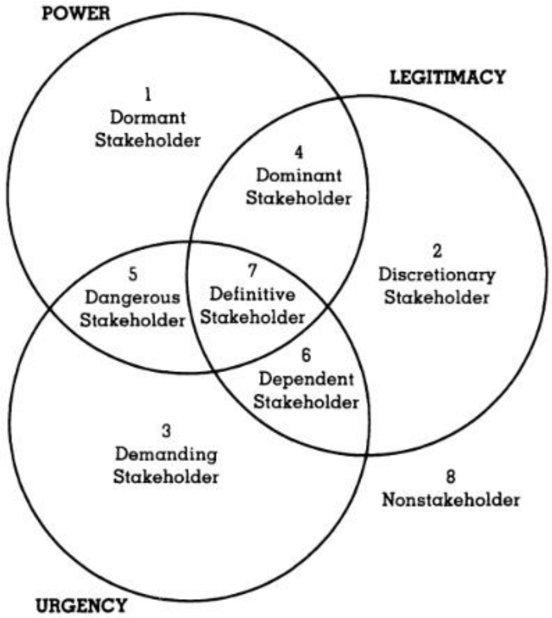


Figure 42: An overview of the Stakeholder Salient Model (SSM) from Mitchell et al [34] and their respective stakeholder classifications.

University employees

The university employees are the core users of the intervention. Therefore, they definitely have legitimacy as they have a claim to make requests to the project. Furthermore, because they are the end users of the intervention they have a lot of influence in the design decisions in the intervention. This means that they have the power over the projects actions and outcomes. Additionally, their concerns about design are critical for intervention effectiveness in promoting behaviour change. Therefore the university employees interests are considered to be urgent. University employees are categorised as the most important stakeholder group since they have a high legitimacy, power and urgency. Therefore, they are considered to be a definitive stakeholder group.

Campus & Facility Management

The CFM is the client of this project. However, the CFM is considered to be an indirect stakeholder as they are mostly interested in the study results on how to design these types of interventions instead of the prototype that will be created. Therefore, they do own the legitimacy to make requests for the study, but don’t hold any specific power or urgency along with these interests. Hence, the CFM is considered to be a discretionary stakeholder.

Designer

The designer creates the project. Therefore, the designer definitely has legitimacy and power as they can alter the intervention to how they see fit. Moreover, the urgency of designers interests are considered to be high due to academic timelines and project milestones that need to be reached. Consequently, the designers of the project are considered to be a definitive stakeholder group.

Supervisors

The supervisors support the designers of the project with their process. Therefore, they definitely have legitimacy and power as they have a claim and influence to make requests to the project and to alter the design decisions in the intervention. Additionally, the urgency of their interests with respect to project deadlines and opinions about the process and intervention are considered to be important for a smooth project implementation and alignment with academic standards. Consequently, the supervisors are considered to be a definitive stakeholder group.

Conclusion

The university employees were found to be the most important stakeholders within this project since their interests have most influence on the effectiveness of the design. Other important stakeholders within this project are the designers and the supervisors who play a big role in the design process and making final design decisions. All three of these stakeholder groups are considered to be definitive stakeholders. The CFM is considered to be a discretionary stakeholder since this stakeholder is the client of the project, but is more interested in the project results than the actual prototype. An overview of the categorization of the stakeholders with the SSM can be found in Figure 43.

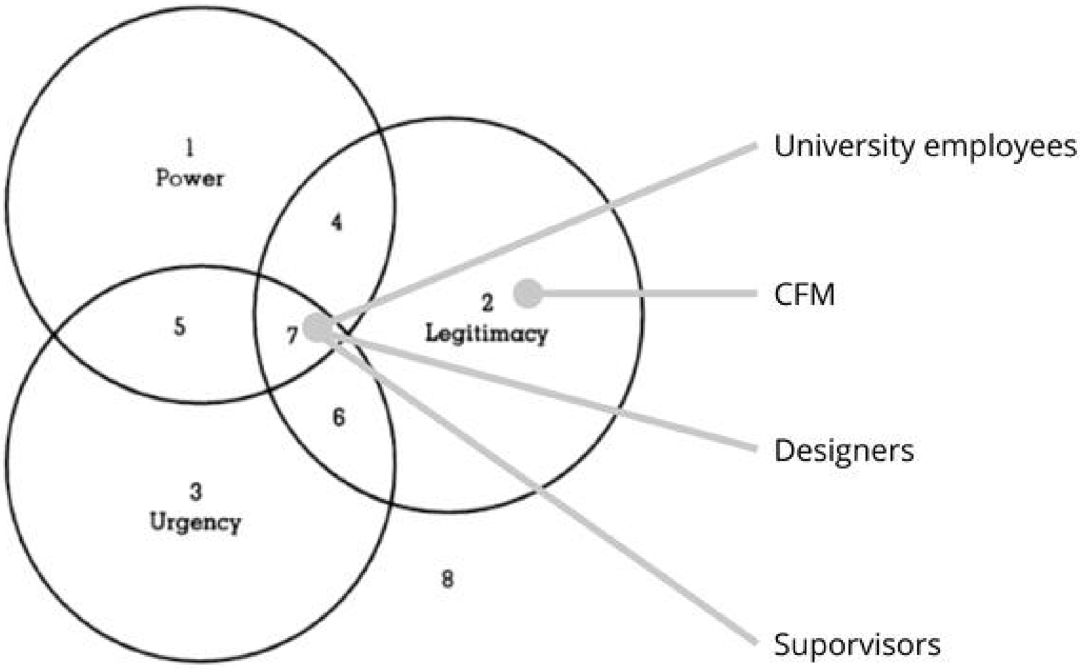


Figure 43: Categorization of the stakeholders with the SSM.

Understanding the stakeholders

To design an effective behaviour change intervention for university employees, this stakeholder group needs closer examination. Stakeholder interviews were conducted with university employees to investigate their energy consumption behaviours and tailor effective interventions. The interviews focused on their control over energy use, opinions on sustainability, understanding of the importance of energy conservation, preferred intervention types, and perspectives on key aspects of energy-saving initiatives. These questions were asked to validate previous design decisions and to get insights into possible variables that could influence the effectiveness of the intervention results.

Other findings from these stakeholder interviews are explored further in the sections titled "*Revising concept design*

" and "*Stakeholder requirements (MoSCoW)*

". More detailed information about the interview itself can be found in the "*Appendix A*: Informed consent form

" and "*Appendix B*: Stakeholder interview questions" and the method chapter.

The results of these stakeholder interviews can be seen in Table 5. Two out of the three participants mentioned to have a low control over their personal energy consumption. The pc was mentioned by participant 1 as a device that the employees do have control over. However, this was often left on standby mode for convenience as the information then does not disappear when opening the screen again. This might suggest that energy savings for this participant are hard to realise. However, participant 2 who works in the same building and hallway as participant 1 does state to have a high control over her energy consumption. Stating that if you know about things you can have a lot of control. Meaning university employees who experience a low control over their energy consumption might lack knowledge about the actions they can perform to reduce their energy consumption. Participant three, who works in a different building on campus, attributes her low control over energy consumption to the control systems, which do not allow for specific control and personalization. In summary, participants low control over their energy consumption might indicate that they lack knowledge about the actions they can perform to reduce their energy consumption. An instructional intervention could solve this problem. However, a low control could possibly also justify future findings for not realized potential with respect to energy savings.

University employees generally have a positive attitude towards sustainability and energy conservation. However, two out of the three participants state that there must be a balance between energy reduction and comfort or convenience.

Additionally, it seems that university employees generally have a good idea on why they should participate in energy saving initiatives. All naming costs and sustainability related topics. This validates the assumption made earlier that university employees don't need education on why they should participate in energy saving initiatives.

Lastly, it was found that there is not one specific intervention type that university employees seem to find most effective. This supports the design decision to use a mixture of intervention types as mentioned before.

	Participant 1	Participant 2	Participant 3
Control over personal energy consumption	Low	High	Low
Opinion on sustainability or energy conservation	Positive	Positive	Positive
Have a good understanding of why it is important to save energy	Yes	Yes	Yes
Type of intervention of the BHM that would benefit you the most?	Reward and motivational (specially subjective norms)	Mixture of different intervention types and highlights emotion	policy

Table 5: Results of the stakeholder interviews before revealing the initial idea.

University employees mentioned the following things to be important in order to save energy:

- Insights into energy conservation savings, expressed in energy and money.

- Kilowatt is not a sufficient unit for expressing energy savings as it does not provide meaningful information or a basis for comparison.
- The intervention must alter habits.
- Show the best ways to save energy as sometimes employees are unsure of the best ways to save energy.
- Feedback on results is crucial for evaluation.
- Encouragement is important.
- Balance between reduction in energy and comfort and convenience. The intervention should not be too extreme or limiting that it takes away all comfort or convenience.
- Information on the energy-saving goals of the University of Twente (UT), the amount of green energy produced, and how much of it is used.
- Energy savings information at the group or office level is seen to be useful.
- Interventions that facilitate group discussions on sustainability topics, such as sustainability dialogues and think tanks, could be very useful for gathering input from others.

In conclusion, the stakeholder interviews provided key insights into university employees' energy consumption behaviours and their views on effective interventions. Participants with low control over their energy consumption may lack knowledge on energy saving actions, suggesting a need for instructional interventions. Apart from this, university employees generally have a positive attitude towards sustainability and energy conservation, but they emphasize the need to balance energy reduction with comfort and convenience. Furthermore, employees already understand the importance of participating in energy-saving initiatives, so educational interventions on this aspect are unnecessary. Lastly, the findings support the decision to use a combination of intervention types to effectively promote energy-saving behaviours.

Additional to the stakeholder interviews with the university employees, a meeting is conducted with the CFM, who serves as the client for this project. However, the CFM is considered to be an indirect stakeholder as this meeting cleared up they that were not convinced about the project's implementation effectiveness without proof of results and associated costs. However, they do see potential in the future if the study results on how to design such interventions prove effective, viewing it possibly as a crucial first step. The CFM was originally thought to be a more important stakeholder in the project. Therefore, the stakeholder analysis in "*Campus & Facility Management* section was revised and altered after this meeting to its current classification.

Revising concept design

In order to create an effective design it is important to take into account the opinions of the university employees. Therefore, the initial design was revised by the university employees. This revision of the initial design was executed during the same interviews mentioned in the "*Understanding the stakeholders*

” section. Findings relevant to revise the concept design are the following:

1. Comparisons between employees are appreciated, but there should be a contingency against setting goals too easily.
2. An option to not set goals is desired.
3. The brightness should reflect average energy consumption over the month, allowing it to indicate whether more energy is being used than normal, functioning as a reminder.

Additionally, two out of three participants stated they would be willing to wear a wearable device, at least for a short period of time. The participant who initially mentioned that kilowatt is not a sufficient unit for expressing energy savings stated that kilowatt would be easier to understand than she initially thought after seeing the initial design in Figure 38, because it would be easier to grasp over a period of time. However, she still mentioned that costs would have more personal meaning. Furthermore, one participant mentioned that the idea of setting a goal is nice, but she would first need to understand what the energy consumption really entails before setting the goal.

The other findings of the stakeholder interviews that go more into detail are discussed in the specification chapter and will be used to specify the concept into desired directions. These findings can be found in the MoSCoW Table 7 stakeholder requirements.

So, when taking these things into account there seem to be a few concerns about the current concept of the goal setting. One participant's notable point underscored the importance of understanding energy consumption before setting goals. This was exactly the issue the designer faced when trying to implement the goal setting in practice. Literature stated that goal setting should be paired with regular feedback and high, precise formulated, short-term goals with small incremental steps and that it should not be too challenging or aimed at the long-term as this might cause disengagement. However, this does not say anything about what a reachable goal is and how to guide users to set a reachable goal. (It is good to note that the reachable goals are dependent on the control the employees experience over their electrical appliances.) To make educated decisions about what a reachable goal would be data gathering and testing is required. However, this would be a whole study in itself. Therefore, goal setting was decided to be too complex to effectively implement for this current study.

Another argument which supports the decision to scrap the goal setting BCT from the intervention has to do with the data uncertainties. The energy data is too uncertain due to temperatures, holidays etc. The goal setting was supposed to add an element of comparison to the intervention. Comparison in combination with fluctuating and uncertain data is very complex. Due to these additional implementation complexities, the decision was made to scrap the goal setting BCT from the intervention.

Future studies could focus on the implementation of goal setting by gathering energy consumption data of university employees and testing the possible energy savings. However, they should also take findings 1 and 2 mentioned above into consideration and find a workaround for the complexities with regard to data uncertainties when designing goal setting based interventions.

Instead the feedback points were changed. This can be seen in Figure 44 and Table 6. Feedback points 1, 2 and 3 in Table 4 were reformulated to points 1, 2, 3 and 4 in Table 6. With point 3, the comparison of personal and similar employees performances inspired by finding 3 mentioned above which suggests that brightness should reflect average energy consumption over the month, allowing it to indicate whether more energy is being used than normal. Feedback point 5, 7.1 and 7.3 were additionally added in Table 6 to increase the users insight in their energy consumption. Point 5 was specifically added after analysing how existing energy consumption feedback applications visualize their users energy consumption via instructional intervention types, see the conclusion about this "*Conclusion*

". 7.1 was added since it was expected that users maybe did not know their final performance of yesterday if they did not check their smartwatch at the end of the day since it measures the cumulative energy consumption. 7.3 was added to encourage users on the short term by providing an indication on their current performance relative to the last hour. Point 5 from Table 4 is removed as the goal setting itself is removed from the intervention. Furthermore, point 4 and 7 from Table 4 is revised to point 6 and 7.2 as the goal setting is no longer part of the intervention. Instead of comparing energy consumption to set goals this revised intervention will focus on comparing it with previous performance data. This way users can set their own goals for themselves in their head. Which type of operational environment is be used is specified in chapter 5.

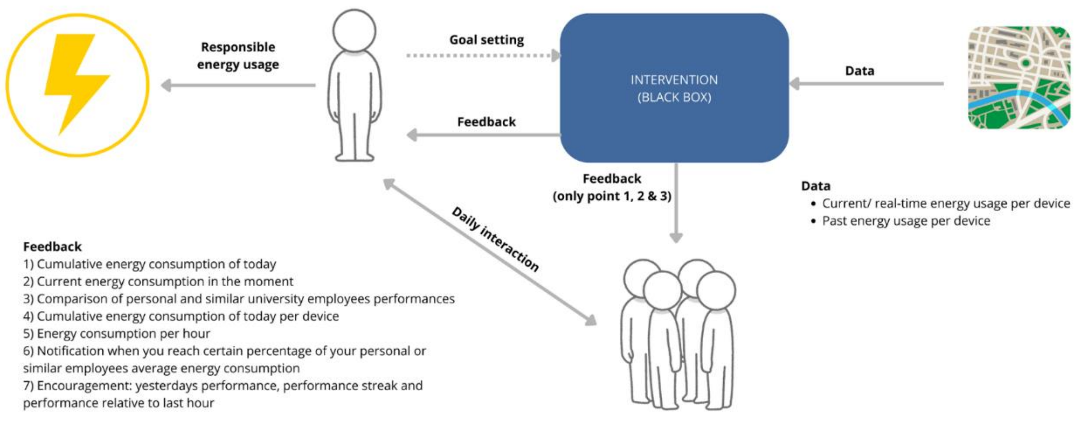


Figure 44: Revised overview of the general initial idea.

Feedback points in Figure 37 / intervention types		Emotional	Instructional	Supportive
1) Cumulative energy consumption of today		X	X	X
2) Current energy consumption in the moment		X	X	X
3) Comparison of personal and similar employees performances		X	X	
4) Cumulative energy consumption of today per device			X	
5) Energy consumption per hour (or over a different time unit: week, month, year, total)			X	
6) Notification when you reach certain percentage of your personal or similar employees average energy consumption				X
7) Encouragement	7.1) Yesterday's performance		X	
	7.2) Performance streak	X		
	7.3) Current performance relative to last hour		X	

Table 6: Revised overview of the different feedback points and their corresponding intervention types. Feedback points 1-3 are an emotional intervention type because this data is visible to other users. Meaning the performance data can be compared though the BCT social comparison. The performance streak can be seen as an emotional (or motivational) intervention type as this prompts emotional involvement within the intervention. All instructional feedback types show insights into the energy consumption of the user. Point 1, 2 and 6 can be considered supportive intervention types as they can function as reminders to the user.

Chapter 5 – Specification

Personas

Before continuing with the concept specification a better understanding of the core users is needed. The intervention should be designed with the users context in mind. Personas can function as a tool for a user centred design process. User centred design supports the satisfaction of the users and reduces the costs and risks of the project. The personas can be seen in Figure 45. To read the personas please go to the "*Appendix C: Personas*

". The personas are based on answers from university employees on the stakeholder interview questions in "*Appendix B*: Stakeholder interview questions**Error! Reference source not found.**". The personas are classified into three different intervention types for ease of classification. However, most users will benefit from a mixture of the different intervention types.

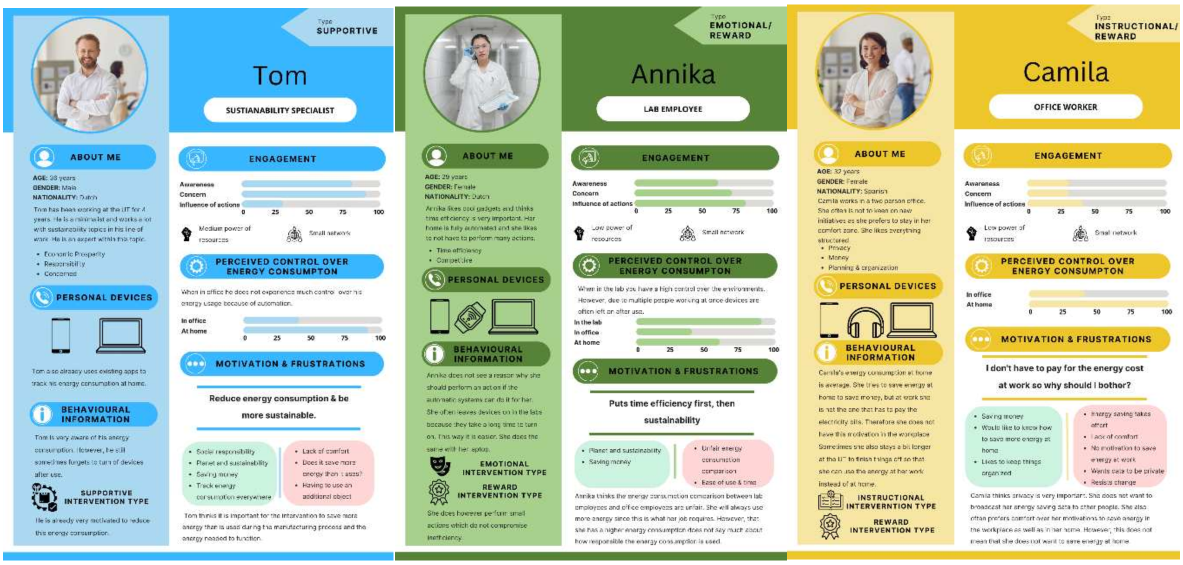


Figure 45: An overview of the different personas. The persona on the left is for the supportive intervention type. The persona in the middle is for the emotional intervention type. This persona also additionally takes into account the rewards intervention type. The persona on the right is for the instructional intervention type. This persona also additionally takes into account the rewards intervention type. To read the persona's please look in the "Appendix C: Personas

"

Stakeholder requirements (MoSCoW)

With help of the user personas and the stakeholder interviews, questions can be found in "*Appendix B*: Stakeholder interview questions", the stakeholder requirements are determined. The stakeholder requirements of the core users can be seen in Table 7. They are prioritized according to the MoSCoW method [35] and colour coded as non-functional and functional requirements. Prioritization is necessary for better utilization in time and resources during the project.

In conclusion, the smartwatch must be able to be personalized and allow users to decide what to do with their data. In short, the user should have control over what information the smartwatch showcases and how it handles its data. Moreover, it should not be annoying in any way or consume more energy than it saves.

Must have	Should have	Could have	Won't have
Must not require more energy to be build and function than what can be saved	Should be as small as possible	Comparison of energy consumption in relation to other employees	An additional device (only use the existing infrastructure and artifacts)
Must not sacrifice comfort for a reduction in energy usage	History reports	Top down intention to sustainable transition	Won't have very "loud" notifications
Must secure privacy	Overview of what type of devices are currently in use	Comparison with the university energy usage	Something that causes a hassle
Option to turn smartwatch on and off	A lot information visible to the user	Comparison of users energy use of a specific type of device and the average energy usage of that device	Won't be something that you have to actively think about
Option to turn lights off and on to provide option to share information instead of obligation	A clear unit to express energy savings	Compatible with other devices (e.g. smart watches)	Won't be something that you can forget
The option to not receive feedback	An intuitive interface/ easy to use	Own energy source	Won't be annoying.
Option to take the smartwatch off	A big enough screen for people to read	Precautions for colour blind people.	
Option to delete information on a certain time frame (e.g. once per month)	Should be able to monitor all of your energy consumption as a precaution against a skewed representation of the users energy consumption	Option to form social bubble to share performance information. Also the additional option to choose who to share your bubble with.	
The option to personalized feedback settings	Precautions for unfair energy consumption comparisons (e.g. office employee vs. lab employee	Contextual data shown alongside energy usage for a more complete picture when doing social comparisons	
	Subtle feedback	Notifications when having an extreme high energy consumption for a period of time.	
	Provide feedback when reducing energy consumption		

Table 7: Requirements of the core users (university employees) prioritized with the MoSCoW method. Both the non-functional and the functional requirements are shown in different colours

Non-functional requirements

Functional requirements.

Intervention concept

The intervention concept consists of two main parts, the prototype design specifications and the data gathering. After the intervention concept specifications have been discussed, examples of its use will be visualized in user scenarios and an overview of the intervention concept will be given through a specification diagram.

Prototype design and specifications

The intervention will feature a wearable. This is in contradiction with a non-functional requirement mentioned in the MoSCoW method in Table 7. This requirements describes that the intervention won't have an additional device and that it will only use existing infrastructures and artifacts. Nevertheless, a distinct design choice contradicting this non-functional requirement was made. This design choice is that the intervention will feature a wearable. This decision was made to be able to give the user constant, indirect and undisruptive feedback. Indirect and undisruptive feedback support in achieving other requirements set in Table 7 (e.g. won't have "loud" notifications, won't be annoying and won't be a hassle). The constant feedback is part of the supportive intervention type and serves as a reminder to the user. Existing infrastructure like the smartphone could not support these requirements. This is because constant, indirect and nondisruptive feedback requires something that is always there, but does not require too much attention. Users are for example not always on their phone. Therefore, the user is not able to receive constant feedback. Additionally, when a phone gives feedback like notifications it is often performed through sounds or vibrations which is neither indirect as nondisruptive. Lastly, when using vibrations as feedback it might be hard to tell different types of notifications apart. Is the notification from the intervention or did I get a WhatsApp message? In summary, the intervention will feature a wearable as existing infrastructure do not support constant, indirect and nondisruptive feedback.

The type of wearable that has been selected for the specification phase is an smart watch. This type of wearable was selected for the visual feedback it could show to the user. The system requires many personalized settings, see Table 7. This means the user requires a lot of interaction options. This can only intuitively be realized through visual and possibly audio based representation. However, as mentioned the feedback is required to be indirect and undisruptive. This requirement takes the audio representation out of the equation as many users would classify a for example talking intervention as annoying and disruptive. A visual representation via an interactive screen for system settings is generally non disruptive as the user can simply turn the screen off and on. Audio feedback like interaction sounds are added to increase the user experience, but not used as the main representation. Another benefit of incorporating an interactive screen within the intervention is that it is a very compact solution to show the user a lot of information. For example a smart watch enables the possibility of visualizing (comparison) energy usage graphs in a familiar and intuitive way. So, the smart watch is selected as the wearable for the intervention, because of the need to have a lot of user interaction options and to show the user a lot of information via indirect and undisruptive interaction.

Figure 46: Illustration of the smartwatch. It has a wristband that contains lights and that can be adjusted in length by the holes.

The smartwatch also allows for constant feedback to the users though lights that are incorporated within the wristband of the watch. These lights are used as reminders to the user and show their performance data. The smartwatch can be seen in Figure 46. Originally, as described in Figure 37. A detailed explanation about the lights in the wristband can be found in the "*Wristband lights*

" section.

These lights are also a feedback point which incorporates personal comparison and social comparison. With social comparison the performance of similar employee types are considered. The information of the comparisons are also directly visible though the lights. By including both direct personal and social comparison feedback, the intervention aims to provide a more comprehensive feedback mechanism. Initially, social comparison was avoided due to the risks highlighted in the background literature, such as potential disengagement from continuous poor performance. However, it is expected that these risks will be significantly reduced when users can also draw motivation from personal comparison. To further mitigate the risks associated with social comparison, an option to turn off the direct feedback of comparisons is available. This feature has been extended to include other feedback options as well. How the comparisons are integrated within the performance feedback is also detailed in the "*Wristband lights*

" section.

The similar employee types are determined in the "*Settings*

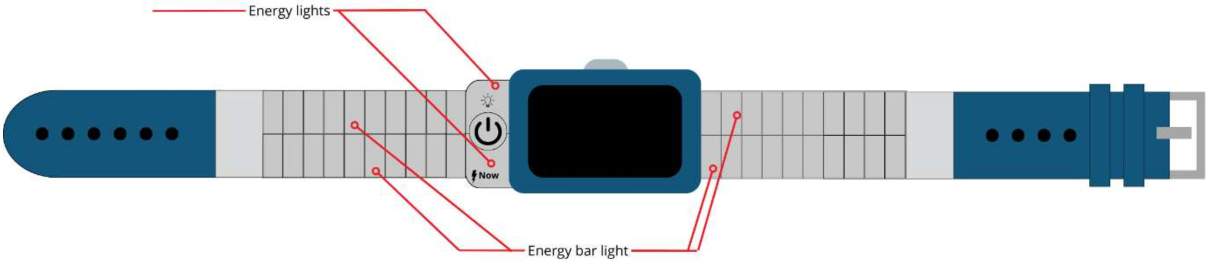
" section under the personal account. Has the personal account not yet been completed then instead of utilizing the average energy consumption of similar employee types the average energy consumption over the last seven days of all university employees using the intervention is used.

Wristband lights

The wristband lights in Figure 47 show the user feedback points 1 to 3 from the revised initial idea in Figure 44:

1. Cumulative energy consumption of today
2. Current energy consumption in the moment

3. Comparison of personal and similar employees performance



4. *Figure 47: An overview of the whole smartwatch. The positioning of the lights are highlighted.*

With the toggle button, highlighted in Figure 48, the user can determine to what the cumulative energy consumption of today (point 1) and the current energy consumption in the moment (point 2) are compared. Either your personal performance or the performance of similar employee types or both (point 3). More on the toggle button in the "*Toggle button*

" section.

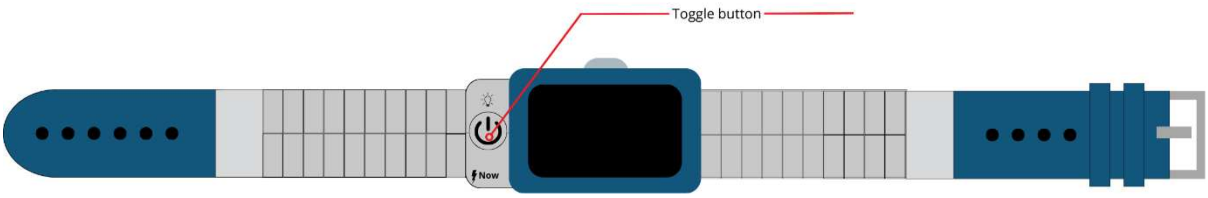


Figure 48: Overview of the smartwatch. The toggle button is highlighted.

The feedback in the energy bar light, detailed in Figure 47, is visualized through the filling the bar through turning on the lights and by altering the colour of the lights in the wristband of the smartwatch. Each light used in the filling of the light bar represents a certain percentage of the cumulative energy consumption of today relative to one of the performances determined by the toggle button. More on this in section about the "*Energy bar light*

" itself.

The feedback in the energy lights, also detailed in Figure 47, are visualized though colour change. The colours are an indication for the current energy consumption in the moment or the current performance in the moment. More on this in the section about the "*Energy*" itself.

Toggle button

Depending on the state of the lights the smartwatch provides different feedback to the user. This state can be altered with the toggle button. The positioning of the toggle button can be found in Figure 47. By clicking on the button the user can toggle between the following four states:

1. No feedback is shown (all lights are off)
2. Only a bar for personal comparison is shown
3. Only a bar for social comparison is shown

4. Both personal comparison and social comparison are shown

A representation of toggling between the different states regarding the light bar can be seen in Figure 49. To what the information in the "*Energy*" or "*Energy bar light*

" is compared depends on the state determined by the toggle button. In state 1 the both lights are off and no information about the current or cumulative energy consumption is shown. In state two the current and cumulative energy consumption are compared to the personal average energy consumption and for state three to the personal average energy consumption of similar employee types. Lastly, in state four it is compared to both personal and similar employees energy consumption. In this last case the energy light may have two different colours. One light colour for each comparison. For the light bar the same comparisons are made.

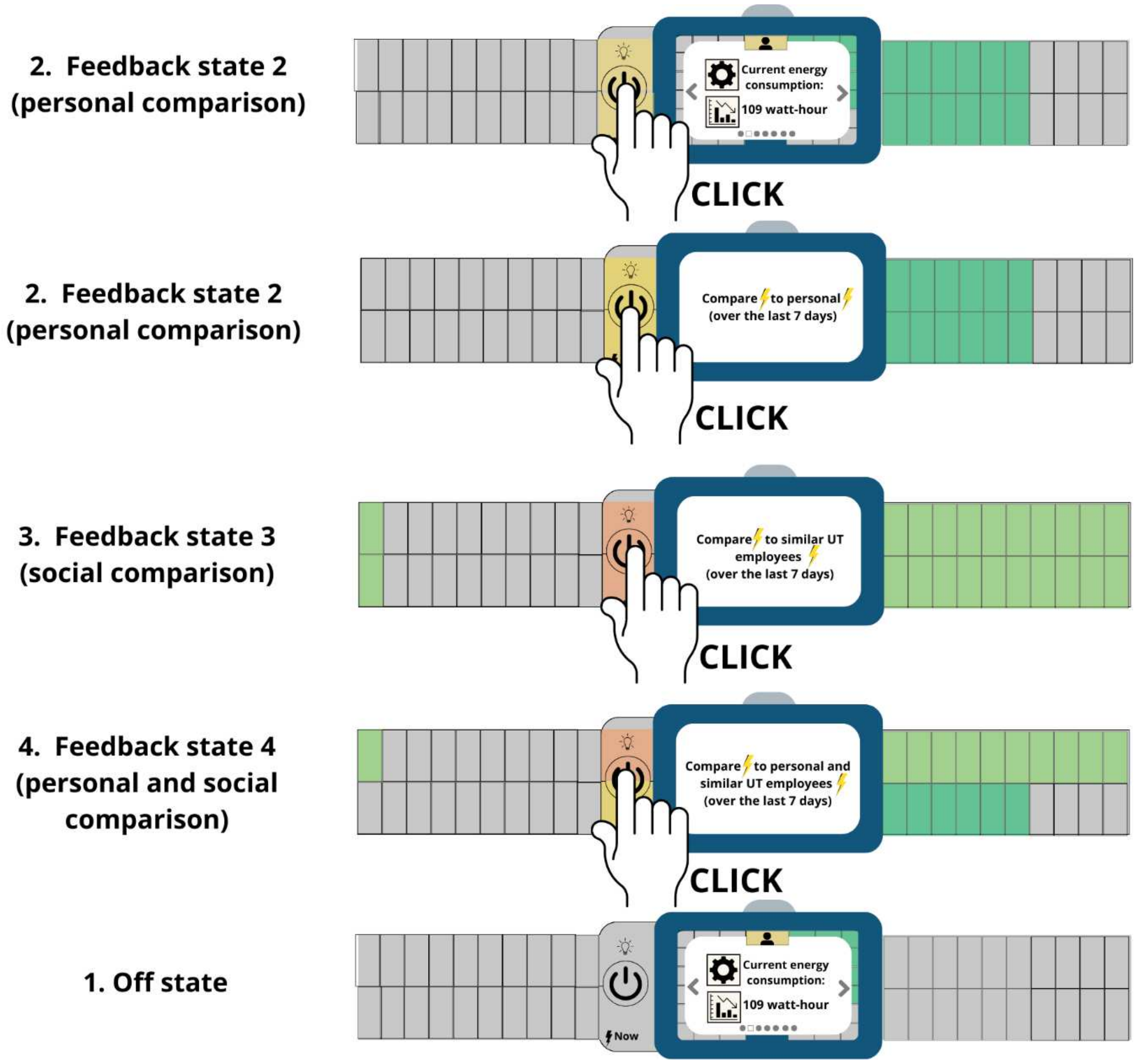


Figure 49: Illustration of user toggling though the four states. In state one the lights on the wristband are off. However the screen is not necessarily off. This is determined by other factors. See the "Screen button

" section. In state two the user receives only feedback with personal comparison. In state 3 this is only in regard to social comparison. In state four the user receives both feedback regarding personal and social comparison.

A deliberate decision was made to include the feedback types of both personal and social comparison simultaneously on the lights bar. This was added so users can easily compare both performance states.

As illustrated in Figure 49 the smartwatch lights don't always start in the off state (state 1) when the toggle button is pressed. The user starts toggling from the current state of the smartwatch. The first time the button is pressed and no pop up is shown on the screen, the smartwatch first reminds the user of the current state. This is done via a pop up. This design choice was made to ensure that the user is aware of the smartwatch's current status before making any changes. More on this in the "*Informing the user about the feedback*

" section. When the screen was initially in sleep mode it wakes. Only while a pop up of the current state is shown on the screen the user can toggle to other states.

The lights in the wristband automatically go in a sleep mode when for 30 seconds no interaction with the smartwatch is detected. When they go in the sleep mode the lights are temporarily turned off. When a new interaction with the smartwatch occurs they turn on again. Therefore, this is different than state 1 where all the lights are standardly off. Instead, the sleep mode of the lights can only occur in states 2 to 4.

The fact that the lights can be turned off was added because this was also a stakeholder requirement mentioned in the section "*Stakeholder requirements (MoSCoW)*

. The toggle button was selected as interaction interface for the stakeholder requirement rather than having a the option be incorporated in the settings on the screen. This decision was made since it is expected that this option will be used a lot more than other settings that can be operated through the screen.

Informing the user about the feedback

In order to inform the user about where to find what information more interactions and interfaces where added. In "*Appendix* D: Toggle button pop ups*D*" the pop up interfaces related to the states altered by the toggle button can be found. Figure 90 and Figure 91 in this appendix show a detailed overview regarding the added interactions and interfaces of state two (personal comparison). In Figure 92 and Figure 93 in the appendix this overview can be found for state three (social comparison). Lastly, in Figure 94 and Figure 95 in the appendix the overview for these interactions can be found for state 4. These interactions and interfaces mostly serves as a tutorial for users that are new to the system. More information on the interactions and interfaces can be found in the description of the figures in the appendix. More information regarding the feedback of the energy light can be found "**Error! Reference source not found.**" and for the light bar "*Energy* bar light

".

Energy bar light

Feedback of the energy bar light:	"Today's energy usage relative to the average energy consumption over the last seven days displayed in percentage."

Feedback that the energy bar light provides is a way to assess how the current energy consumption compares to the historical average over a specific period of time. In this case this is the last 7 days. This period was chosen as it incorporates all the different days within a weeks' time. It is assumed that people often have the same energy usage habits over one week. Choosing a the average energy usage of the last 7 days instead of a month also takes the temperature alterations of different seasons in mind. The feedback of the energy bar light is calculated through the Equation 2 below:

$$RECT = \frac{The\ cumulative\ energy\ consumption\ of\ today\ (till\ now)}{The\ average\ energy\ consumption\ over\ the\ last\ 7\ days} * 100\%$$

Equation 2: Calculating the Relative Energy Consumption of Today (RECT). This is the percentage of the energy consumption of today relative to the energy consumption over the last 7 days.

Depending whether the user is in the personal or social comparison state (or both) the average energy consumption over the last seven days is based on the users data or on the data of similar UT employees. The feedback of the energy bar light is visualized via a bar of lights on the wristbands of the smartwatch as can be seen in Figure 50. The energy light and the light bar are also visible on the screen. The two light bars (top and bottom) or energy lights (top and bottom) on the wristband are combined when the wristband only has to provide personal or social feedback. When it has to display both there are two bars and two energy lights as illustrated in the picture in Figure 50 or Figure 49.

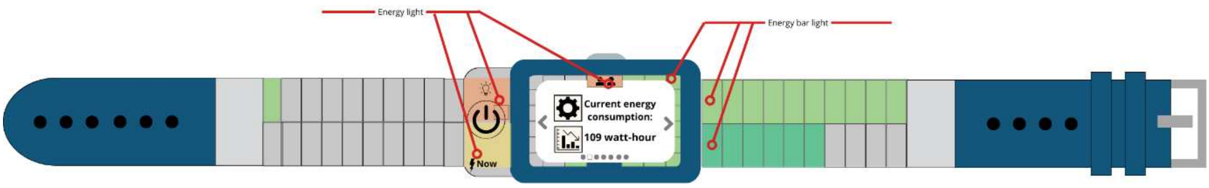


Figure 50: Overview of where to find the light bar and the energy light.

Each light that is on is equal to 5% of the average energy consumption of the last seven days. This feedback will provide insights into how well the user is doing in comparison to her- or himself or other similar employee types. The goal is to reduce the energy consumption or to keep the energy consumption around the same value as the average energy consumption over the last seven days. The scale of the bar of lights can be seen in

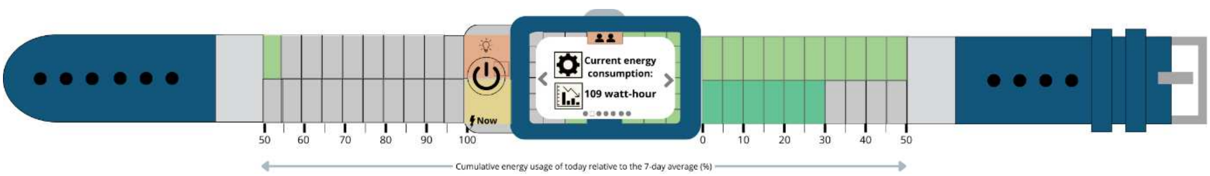


Figure 51: Today's energy usage relative to the average energy consumption of similar UT employees over the last seven days is 55% (top bar). Today's energy consumption relative to the personal average energy consumption over the last seven days is 30% (bottom bar).

The energy light as shown in Figure 50 is not part of the lights bar. The colour of the lights on the lightbar help give the user an extra indication of their energy consumption. Traffic light colour coding was deemed effective in the "*State of the art*

" section and is therefore applied. The colour of the light bar is based on the following classifications:

- Dark green: $RECT \leq 50\%$
- Light green: $50 < RECT \leq 100\%$
- Green-yellow: $100\% < RECT \leq 105\%$
- Yellow: $105\% < RECT \leq 130\%$
- Orange: $130\% < RECT \leq 160\%$
- Red: $RECT > 160\%$

These categories differ with the colour categories of the energy light. This is because energy usage over for instance a day as visualized in Figure 54 usually contains peaks. Energy consumption fluctuates over a period of time. Therefore it is not per se bad to have a current energy consumption that is higher than the average as long as the energy consumption at a later moment is lower than the average. Therefore, the classification for the yellow, orange and red colours are linked to lower RECT percentages for the cumulative energy consumption of today. While the current energy consumption is linked to lower RECC percentages, see the "*Energy*" section. Regarding the energy consumption of today it usually is bad if the users go over the average. Therefore the RECT percentages of yellow, orange and red stay closer to the 100%. Apart from the percentage difference another colour category has been added as well. This is due to another classification in the "*Encouragement*

section which classifies $100\% < RECT\%\ of\ previous\ day \leq 105\%$ as stable. In this section it is still argued that a stable energy consumption is something positive as users can't always reduce their energy consumption. Therefore, is was seen as important to give users feedback on when their energy consumption was considered stable as well. That is why the extra category is added.

The last four colour categories are additionally also an indication that the user has used more energy than the average of the last seven days. This means that the lights on the wristband have already done one "lab" or "round". The "State of the art

" section showed that experience bars in games and progress bars for loading screens usually reset. However, that during the resetting another indication in the form of text or numbers is offered. This is kind of similar to the light bar. In order to mimic the general designs regarding the experience and progress bars to gain an intuitive design the light bar will also be reset upon completion. However, in order to still be able to show the green-yellow RECT category the bar is only reset when the 105% RECT is reached. Therefore, when the RECT will be in between 100% and 105% all the lights of the bar will still be on. This is extended to 205%, 305%, 405% etc. as well for consistency reasons.

Another indication that the scale is changed is that whenever 100%, 200% etc is reached a pop up appears. This pop up provides the user with the information that it reached for instance 100% of the seven day average. A visualization can be seen in Figure 53. The scale of the light bar is always visible in a short pop up on the sides of the screen when the screen is turned on or touched without clicking on a button. This is illustrated in Figure 52. The pop ups slide into vison from the sides of the screen and slide the same way back. This is done to illustrate that the pop ups are actually coming from the begin and end point of the light bar. The last indication that the scale changed is the haptic feedback. This haptic feedback happens simultaneously with the pop up that provides information. More about this is mentioned in the "*Haptic feedback*

” section.

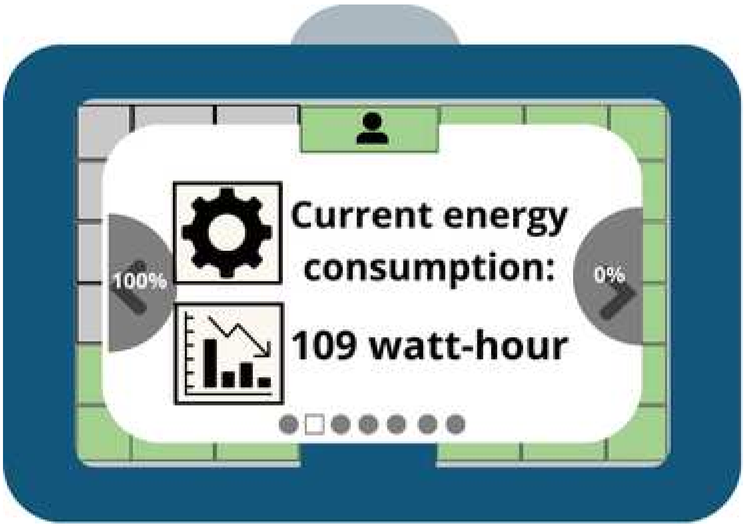


Figure 52: Pop up of the begin and end percentage of the light bar. This is always visible for 2 seconds whenever the screen is turned on or when the user tabs the screen without selecting a button. Whenever there are two bars showcased on the wristband two percentages are shown on either side. One above the other.

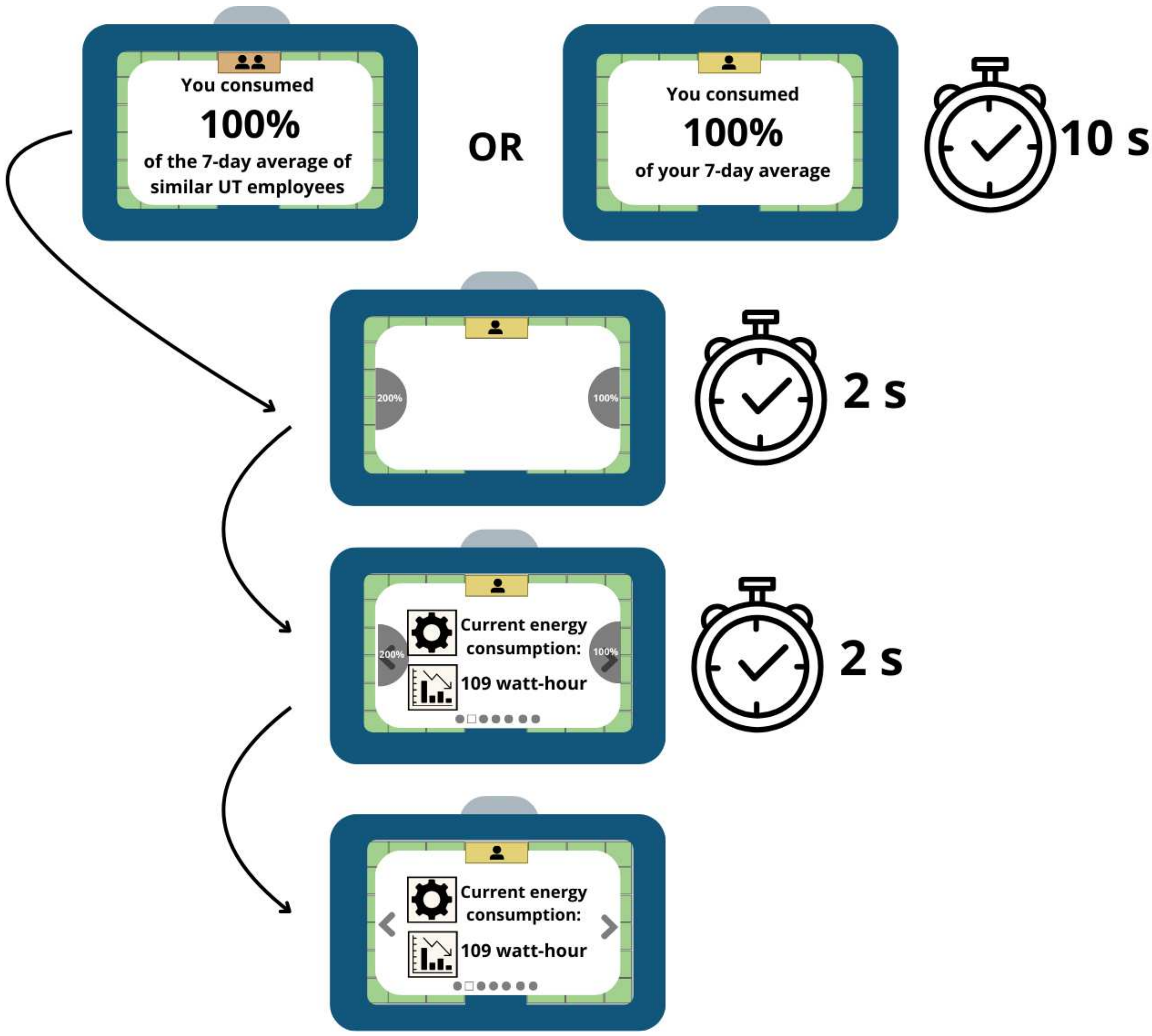


Figure 53: Pop up of user when 100% is reached. Similar pop ups show up when 200%, 300% etc. is reached. The first two delays in the pop up can be skipped through tapping on the screen.

Energy light

Feedback of the energy light:	"The current energy consumption per second and relative to the average energy consumption per second over the last 7 days"

The feedback that is provided through the energy lights **Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.**is a way to assess how much energy is used in the moment according to a standard set over the last seven days. This period was chosen as it incorporates all the different days within a weeks' time. It is assumed that people often have the same energy usage habits over one week. Choosing a the average energy usage of the last 7 days instead of a month also takes the temperature alterations of different seasons in mind. The feedback is displayed through altering the colour of the energy light. The energy light is on whenever the wristbands lights are on. (So, only in "*state*" the energy light is off.)

The feedback of the energy light is displayed through the use of colours. In the initial idea brightness was used instead. However, this change in the design decision was made since no background research could be found on the effectiveness of utilizing brightness for energy performance. Therefore, it was decided to use colours instead was deemed effective in the "*State of the art*

" section.

This also meant that this feedback point could not be displayed through the energy bar lights, as these lights were already used to show information about the cumulative energy consumption of the day using colours, which was the original design idea in the initial concept. Therefore, this initial concept had to be changed. A separate set of lights were introduced; the energy lights. These lights could display their own separate colours for feedback.

These energy lights are positioned to the left of the screen as Buschman et al [36] states that humans can remember objects better when objects are divided over the left and right side of the human vison. Consequently, the energy light is positioned on the left side on the screen and the start of the light bar on the right of the screen. The light bar does however also end on the left side of the screen, because when wearing the wristband is a circle. Nevertheless, this way the two aspects are at least somewhat separated. Therefore, this is seen as acceptable. Additionally, having the energy light on the left side of the screen is expected to be more intuitive to the users. Since they don't have to go with their hand over the screen to turn the lights on and off when they have the smartwatch around their wrist. The positioning of the energy light can be found in Figure 47 or Figure 50.

The colours for displaying the feedback of the energy light are determined through the relative energy consumption change (RECC) percentage. The calculation for this percentage is the following:

$$RECC\ percentage = \frac{Current\ energy\ consumption\ per\ sec}{Average\ energy\ consumption\ over\ last\ 7\ days\ per\ sec} * 100\%$$

Equation 3: The calculation of the relative energy consumption change (RECC) percentage used to categorize the current energy consumption in multiple colour categories for feedback point one.

The current energy consumption per sec in Equation 3 is expressed in watt-hour instead of watt. Meaning that the measured energy consumption in the moment is multiplied by 3600 go from the unit watt to watt-hour. This is a deliberate decision as energy is measured in watt-hours and power in watts, as stated by Endolith [37]. Energy indicates an amount while power indicates a rate of consumption. The energy consumption on labels of electrical appliances is also expressed in watt-hours even though the label might only indicate watt. This might be confusing since the definition of watt is 1 joule per second. To clarify this please, consider a 60-watt lamp:

- If it is on for 1 hour, it consumes 60 watt-hours.
- If it is on for 1 minute, it consumes 1 watt-minute.
- If it is on for 2 hours, it consumes 120 watt-hours.

Depending whether the user is in the personal or social comparison state (or both) the average energy consumption over the last seven days per sec is based on the users data or on the data of similar UT employees.

The colours serve as an indication of your current energy usage with respect to your average usage. It is a tool to determine if the user is more energy than normal. Traffic light colour coding was deemed effective in the "*State of the art*

" section and is therefore applied. The RECC percentage is categorized in five possible colour codes:

- Dark green: $RECC\ \% \leq 50\%$
- Light green: $50\% > RECC\ \% \leq 100\%$
- Yellow: $100\% > RECC\ \% \leq 200\%$
- Orange: $200\% > RECC\ \% \leq 400\%$
- Red: $RECC\ \% > 400\%$

Now that this is clarified, let's examine the origin of the percentages for the colour codes. These percentages were derived from personal energy data for a single-person household. The data can be seen in Figure 54. Here the average energy consumption over a period of 7 days was 3,365 kWh per day which is an average energy consumption of 140.2 watt-hour, as detailed in Equation 4.

$$Average\ energy\ consumption\ over\ the\ last\ 7\ days\ per\ hour = \frac{3{,}365}{24} * 1000 = 140{,}2\ watt$$

Equation 4: Calculation of the average energy consumption of the last seven days per hour using the personal data in Figure 54.

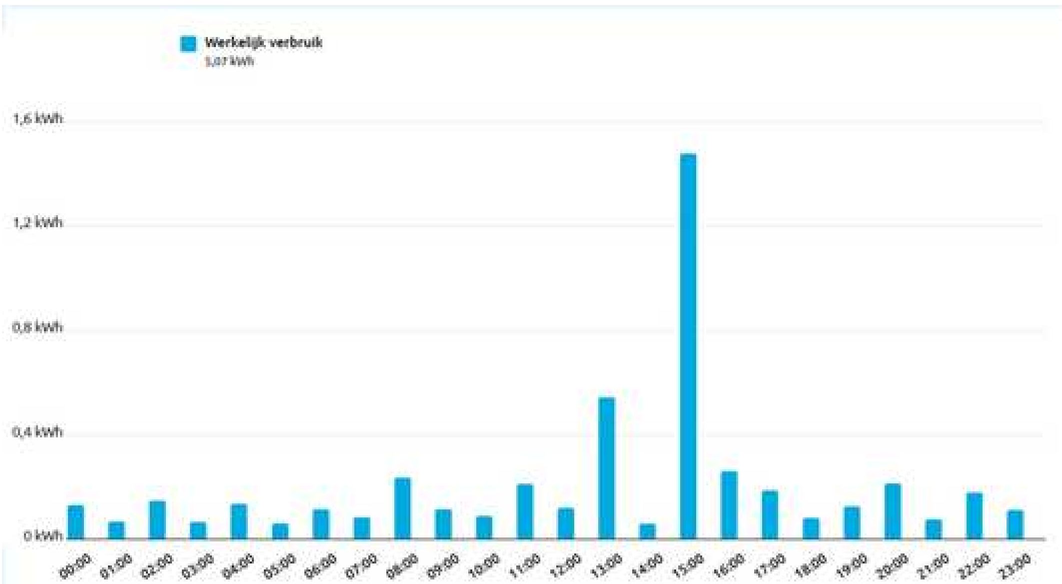


Figure 54: Energy consumption of a one person household during a random day.

Using the personal data showcased in Figure 54 an example of the relative colour codes per hourly energy consumption is generated in Table 8. During the actual implementation of the product the energy consumption would be measured per second and expressed in watt-hour. However, the data of Figure 54 only provides insights into the total energy consumption per hour. So, for this example the average of the hour is expressed as watt-hour instead of the energy consumption data per second. Nevertheless, Table 8 shows an useful indication of how the lights colour would function as feedback to the user.

hours	Energy consumption in kWh	Energy consumption in watt-hour	RECC %	Colour code
00:00	0,138	138	98%	Green
01:00	0,075	75	53%	Green
02:00	0,155	155	111%	Yellow
03:00	0,073	73	52%	Green
04:00	0,142	142	101%	Yellow
05:00	0,068	68	49%	Dark green
06:00	0,122	122	87%	Green
07:00	0,091	91	65%	Green
08:00	0,243	243	173%	Yellow
09:00	0,112	122	87%	Green
10:00	0,096	96	68%	Green
11:00	0,219	219	156%	Yellow
12:00	0,127	127	91%	Green
13:00	0,551	551	393%	Orange
14:00	0,067	67	48%	Dark green
15:00	1,485	1485	1059%	Red
16:00	0,268	268	191%	Yellow
17:00	0,194	194	138%	Yellow
18:00	0,088	88	63%	Green
19:00	0,133	133	95%	Green
20:00	0,221	221	158%	Yellow
21:00	0,083	83	59%	Green
22:00	0,186	186	133%	Yellow
23:00	0,119	119	85%	Green

Table 8: Energy consumption per hour categorized into one of the five light colour categories. The data is gathered from the personal data from Figure 54.

There are four important things to note. Firstly the energy consumption classified as red is way over its classification as "bigger than 400%" of the RECC%. Here, the RECC% is 1059%. However, this is not seen as an issue as the red colour should function as a warning to the user. How high the energy consumption is in that moment is than not of great intermediate importance. The user could still find this information elsewhere on the screen of the smartwatch. More on this in the "*Home screen*" section. Secondly, the personal data that is used is from a household. The intervention will gather data in every context. So, also from the work environment, public spaces etc. Nevertheless, it is still assumed to be a good enough representation of energy usage to categorize the energy consumption into colours. This is due to the expectation that the energy fluctuations remain still largely the same when incorporating other context besides energy usages at home. Apart from this, the personal data that was used was not collected from the target group university employees. However, it is expected that university employees will have the same types of fluctuations in their offices. Lastly, the data that was used is from a one person household that consumes way less energy than the average household in the same category. This means that fluctuations could possibly be higher and the categories would need to be adjusted after testing.

In contradiction with the energy bar lights the energy lights are always on whenever the smartwatch or lights are not in the off or sleep state. The energy bar lights can be off in the in state 2, 3 or 4 and since the users cumulative energy consumption of today relative to the average of the previous seven days will be at some points lower than 5%. Since the lights of the light bar only turn on after the relative 5% is reached no lights would be turned on when the relative energy consumption would be lower than 5%.

Screen button

The screen button can be clicked to set the whole smartwatch (screen and lights) in sleep mode, wake mode, off mode, on mode or as a shortcut to the home page. This is illustrated in Figure 96, Figure 97 and Figure 98. These figures can be found in "*Appendix* E: Screen button interactions

E". The light button could theoretically also be used to wake the smartwatch as each interaction with the smartwatch when in the sleep mode activates the wake mode. The screen button has three functionalities:

(1) Clicking the screen button (Figure 96)
    a. Turning the whole smartwatch into sleep mode. This will turn off the screen and the lights within the wristband. Energy measurements will still take place.
    b. Wake the whole smartwatch up. It will turn the screen on and display feedback through the lights on the wristband.
(2) Hold the screen button down (Figure 97)
    a. Shut off the whole smartwatch. The screen and lights are turned off. No energy consumption measurements will take place.
    b. Turning on the whole smartwatch. The screen and lights are turned on. Energy consumption measurements will take place.
(3) Click button twice (Figure 98)
    a. Go to the home page screen.

The device also goes automatically into sleep mode after thirty seconds when no interaction with the smartwatch is detected. (So, the screen and the lights will go into a sleep mode). This design decion was made to save energy. As this is the end goal of the intervention. The smartwatch is easily waked up again after a second interaction through a click on the button. The lights will also be put in sleep mode when the screen is put in sleep mode. The second functionality of the button is to hold it in order to shut off the whole device. The device will than no longer measure the energy consumption and the communication with the smartphone is interrupted. This interaction can be found in Figure 97. Lastly, the button also provides an immediate shortcut to go back to the home page. This happens if the button is pressed twice.

An illustration of this interaction can be found in Figure 98. More on the home screen can be found in the section "Home screenHome screen

Using gestures for control

When you lift your wrist you wake the smartwatch. Both the screen and the lights on the wristband wake. Whenever, you lower your wrist again you turn your smartwatch into sleep mode again. Then both the screen and the lights on the wristband go into sleep mode. This interaction is also part of the Apple watchOS 10 [30]. It was decided to incorporate it into the design as it is a very intuitive interaction. More about the apple watchOS 10 can be found "*State of the art*

" section.

Screen

Additional to the feedback through the lights the smartwatch also provides information via the screen of the smartwatch. The screen can display the following pages:

- Home screen
- Settings
- Encouragement
  - Yesterday's performance
  - Performance streak
  - Current performance in relation to last hour
- History
  - Circle diagram of today's energy consumption per device
  - Graph of energy consumption over certain time periods.

All these pages also have a lights bar and energy light visualized on the screen. An illustration of this can be found in Figure 55. The lights on the screen and on the wristband demonstrate the exact same information in the same way. Both use the amount of lights and its colour to communicate information. Whenever the lights on the wristband are in the off state ("*state*") or in the personal and social comparison state ("*state* the light bar and energy light on the screen switches every ten seconds between personal ("*state*") and social comparison ("*state*"). Whenever the lights on the wristband are in only the personal or only the comparison state the light bar and energy light on the screen don't switch. Then they stay in the same state as the lights on the wristband. Now the user has the possibility to see in one instant in which state they find themselves in. They can see a symbol of one person in the energy lights on the screen. This indicates that they are in the personal comparison state. Alternatively, they can see a this symbol displayed twice. This indicates that they are in the social comparison state. An illustration of the screen lights bar and energy light can be found in Figure 56.

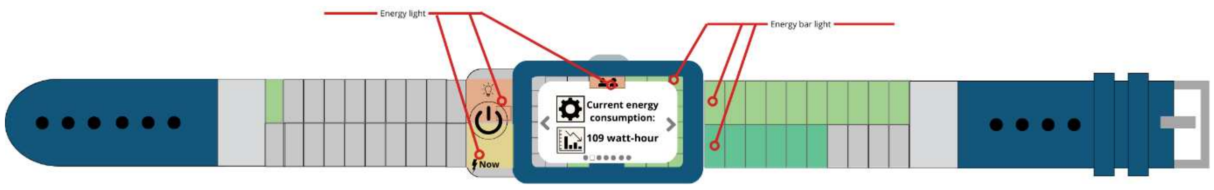


Figure 55: Overview of the home screen and comparison of the light bar and energy light in the screen and on the wristband.

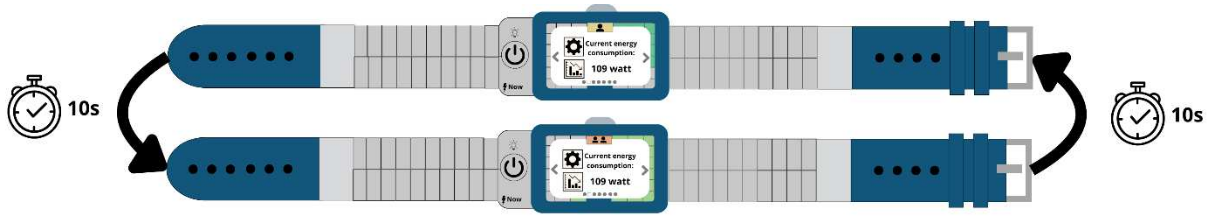


Figure 56: Illustration of the switching the states of personal and social comparison. Personal comparison is indicated through the symbol of a single person within the energy light. Social comparison is indicated though the symbol two persons within the energy light. Each ten second the state switches between the two. This happens when all of the wristband lights are turned off like in the picture (state 1). It also happens when two light bars are visible on the wristband. This happens when the wristband both provides personal and social comparison to the user. (state 4)

The dots on the bottom of the pages indicate the current page the screen is displaying. Currently, in for instance Figure 55 this is the home screen, which is visualized by a rectangle. An outline of the shape is visible for the current page, while filled-in shapes represent other pages. These dots at the bottom of the screen, along with arrows on the right, signal that users can swipe to navigate to another page. Additionally, users can tap the arrows on the side of the screen to switch pages. The navigation does not allow users to go directly from the first page to the last or vice versa.

Home screen

The home screen, detail in Figure 57, has a settings button in the form of a gear which directly redirects the user to the settings page. Additionally, a history button in the form of graph is displayed which when clicked redirects the users directly to the first history page (the circle diagram). Here the user can see its energy consumption data. These direct links were added as these pages are seen as the most important to the user due to the insights and support these pages can provide. Furthermore, the current energy consumption of the user is displayed in watt-hour on the home screen.

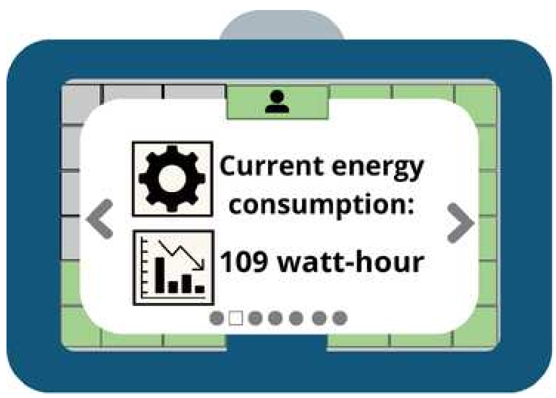


Figure 57: Overview of the home page on the screen of the smartwatch.

Settings

When the settings icon (The gear) is pressed the user goes to the settings menu. Another way of going to the settings menu is to swipe from the home page to the left or tab the left arrow on the home screen. The settings menu can be seen in Figure 58.

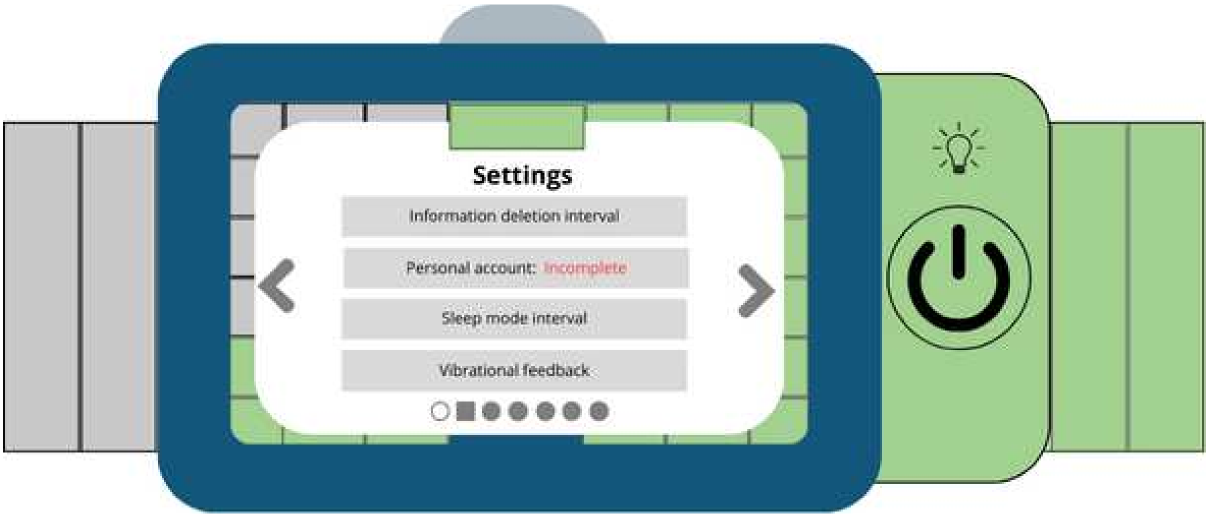


Figure 58: Illustration of the settings menu. It incorporates information about the deletion interval of the energy consumption data gathered by the intervention, a personal account used to categorize employees for comparison in the history page section of the intervention, a sleep mode interval and a setting to turn the haptic feedback on or off.

When clicking on one of the settings in the menu, a page pops up overlaying the setting menu page. On these pop ups the settings can be altered. To go back to the settings page the user simply slides her or his finger upwards. This is illustrated in Figure 59. The "Information deletion interval" pop up is illustrated in Figure 60. This interval determines how old the data has to be before it is thrown away. When changing this setting from the standard setting "Nothing" a warning pops up. Changing this setting will degrade the functionality of the intervention as data from the history page will be deleted. This might cause the user to be less informed about their energy consumption. The lowest interval the system allows is 8 days since the system has to compare the energy consumption of the current day to the average of the last seven days. This is also the reason that most of the options delete data that is older than a specific amount of time rather than from a specific point in time like every first day of the month. The possible options for the data deletion interval are:

- Nothing: never deletes data
- From a year ago: only deletes data that is older than a year
- From 31 days ago: only deletes data that is older than 31 days
- Form 8 days ago: only deletes data that is older than 8 days

The setting of data deletion was added as this was mentioned in the section "*Stakeholder requirements (MoSCoW)*

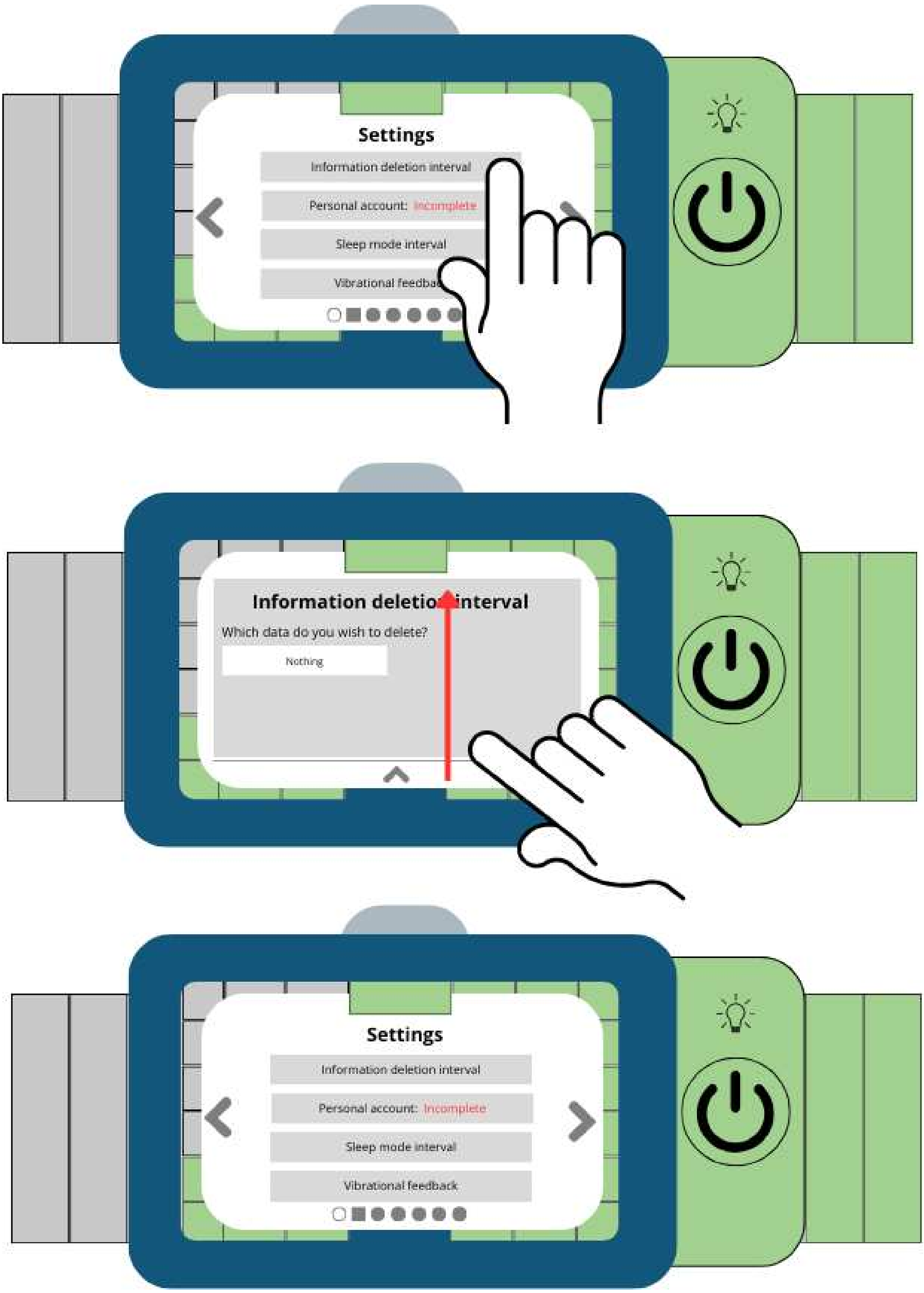
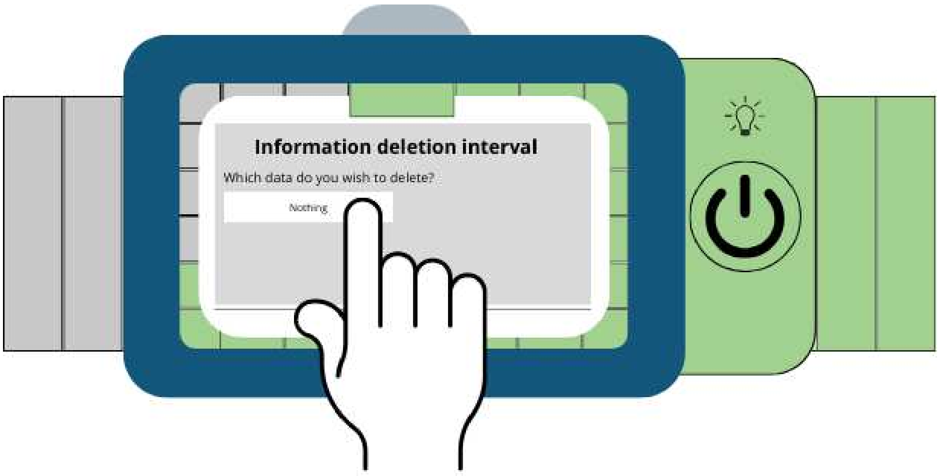
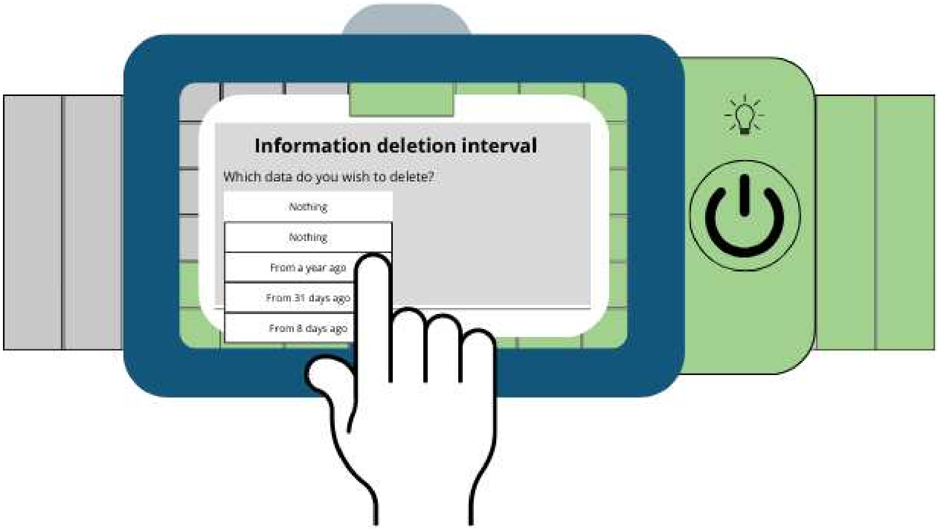
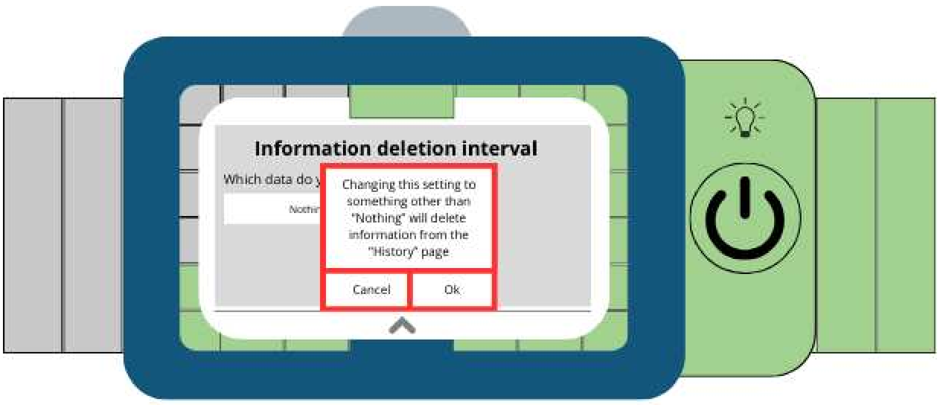


Figure 59: Illustration of how to close pop up settings. The user slides upwards.


Information deletion interval
Which data do you wish to delete?
Nothing


Information deletion interval
Which data do you wish to delete?
Nothing
Nothing
From a year ago
From 31 days ago
From 8 days ago


Information deletion interval
Changing this setting to something other than "Nothing" will delete information from the "History" page
Cancel
Ok

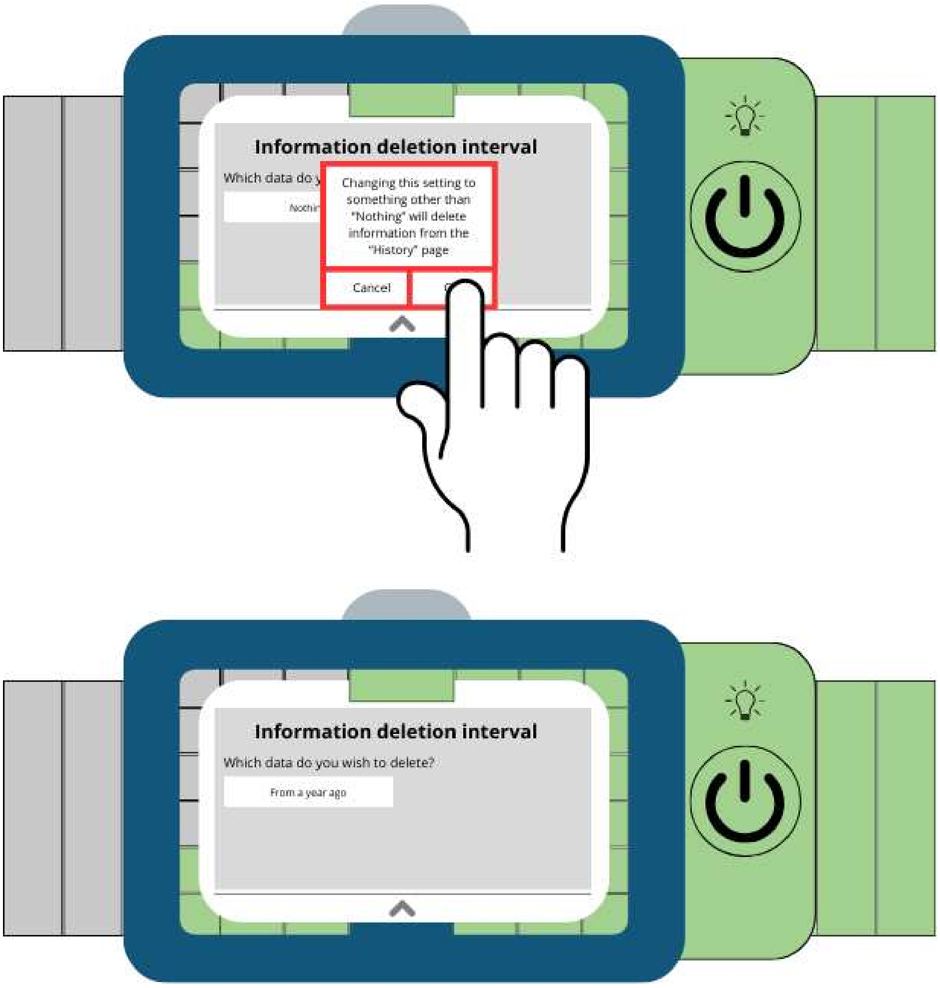


Figure 60: Information deletion interval in the settings. This interval determines how old the data has to be before it is thrown away.

The second setting in the menu is the personal account. This is used to classify UT employees in categories to be able to compare UT among themselves. This was implemented as a precautions for unfair energy consumption comparisons (e.g. office employee vs. lab employee) and this was one of the stakeholder requirements classified in with the MoSCoW method. This requirement states that it is not fair to simply compare all university employees with one another. Some will have a larger energy consumption, because of their environments like (shared or personal) offices, function at work etc. Therefore, the user has an option to create an personal account. When this account is completed the user can compare his or her energy consumption with other UT employees that live and work in the same types of environments. The UT employees are categorized by four things: their type of office space, the building their office is positioned, their type of function at work and their working hours. These three elements were selected as they generally have a great impact in one's energy consumption. The different functions of the university employees that are considered are:

- Lab employees

- Office employees
- Professors

Each function requires a different amount of energy to their job. The reason a professors are distinguished from office employees is, because professors have a very low control over their energy consumption when teaching in a classroom. Additionally, not all the energy consumption in the classroom is part of their energy usage. For instance, students also charge their pcs. However, they are less in their office than office employees. Therefore, this was considered to be an unfair comparison and thus these two functions are distinguished from each other. However, it is also good to note that sometimes these functions also overlap. Professors also have to make office hours for example. This is not incorporated into the current project as creating detailed comparisons is something that can be improved upon when it is concluded that the intervention has the desired effect, as mentioned Improving **comparisons among employees**".

The office type categories considered in this project are:

- Personal office
- Two person office: office is shared with one other employee.
- Three person office: office is shared with two other employees.
- Four person office: office is shared with three other employees.

The different office types also have a big impact on the employees control over their energy consumption. They will also share certain appliances like lights, heating and ventilation which need to be adjusted to the needs of the employees in the office in general. Additionally, only two buildings will be considered:

- Zilverling
- Horst

Buildings are considered because each building has its own control systems, which may vary and provide different levels of control to employees over their electrical appliances.

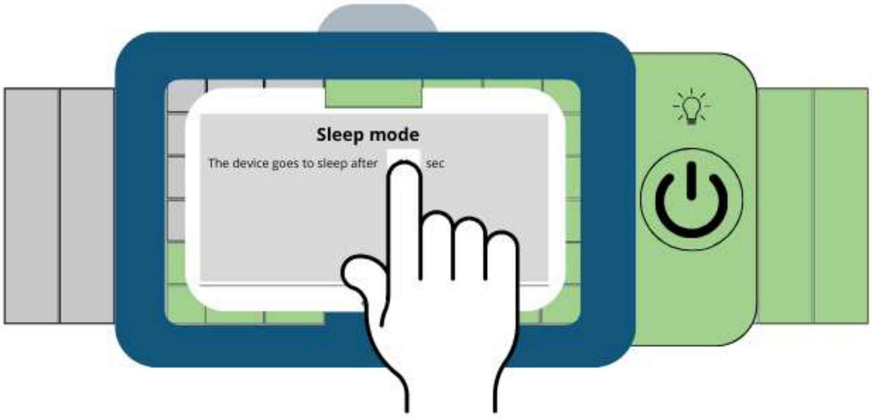
Lastly, it is also important for classification to know their working hours. This can also be filled in. An overview of the personal account pop up can be found in Figure 61.

It is good to know that there are more subcategories of functions, offices and buildings than the ones considered in this project. However, this project is mostly focused on presenting a proof of concept. Therefore, it is not required to go into the details. Moreover, this project does not focus on the energy consumption of university employees outside of office hours. Nevertheless, this expansion could be included in future iterations to provide a more detailed overview of the employees energy consumption on a whole.

Figure 61: A user scenario showcasing the interaction with the personal account to classify the UT employee.

The third setting in the menu is sleep mode. The device automatically goes into sleep mode after a specific amount of time. This time (in seconds) can be altered in the sleep mode setting. The standard setting is 30 seconds. A overview of the sleep mode pop up and its interactions can be seen in Figure 62.


Sleep mode
The device goes to sleep after
30
sec


Sleep mode
The device goes to sleep after
sec


Sleep mode
The device goes to sleep after
sec
1 2 3
4 5 6
7 8 9
0 Ok


Sleep mode
The device goes to sleep after
6
sec
1 2 3
4 5
7 8
0

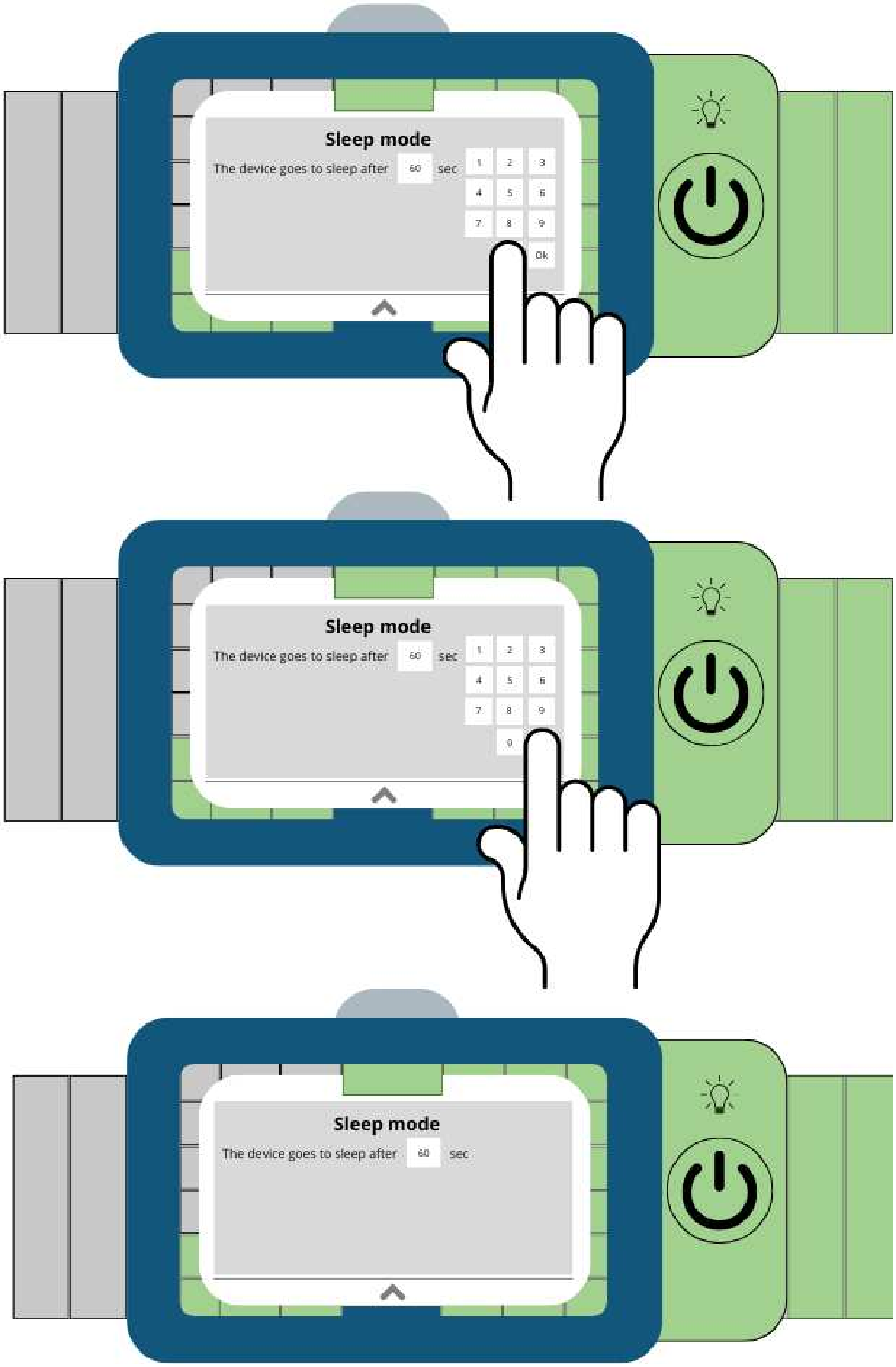


Figure 62: User scenario to alter the set time for the screen of the smartwatch to go to sleep mode. The sleep mode occurs when there has not been an interaction for a certain amount of time.

The last setting in the menu is the vibrational feedback. More information about this type of feedback can be found in the section "*Haptic feedback*

. The vibrational feedback settings as shown in Figure 63 provide the option to the user to turn the haptic feedback off or on.

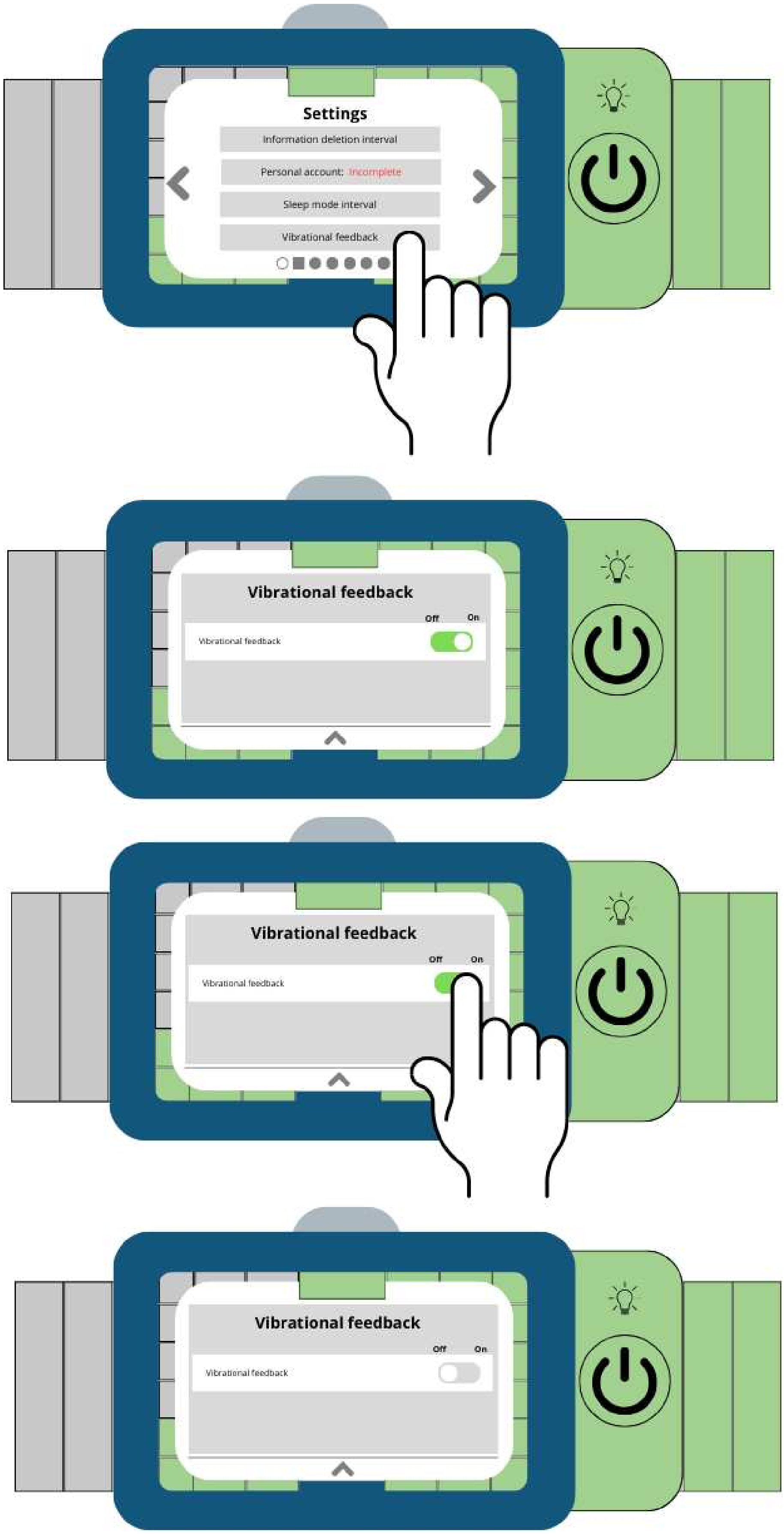


Figure 63: Overview of the vibrational feedback settings. The user can turn the haptic feedback on and off.

Encouragement

When you swipe right from the home screen or tab the right arrow you move on to the encouragement pages. These pages consist the three pages which show the following:

- The RECC percentage of yesterday (or yesterday's performance)
- Your positive RECC streak (or performance streak)
- The RECCH percentage (or the current energy consumption relative to last hours performance)

These pages were added to encourage users. Yesterday's performance is included as a reminder for those who might not have checked their performance at the end of the day, allowing them to review it the next day. The performance streak feature was introduced to foster emotional engagement with the system. Additionally, current energy consumption relative to the previous hour's performance was added to provide short-term motivation and insights into their energy consumption.

Yesterday's performance

Whenever the system shows the RECT percentage of the previous day (yesterday's performance) it supports it with positive reinforcement for positive encouragement. Table 9 shows multiple possible responses. The responses are categorized in the "User improved", "User remained stable" and "User struggled". The boundaries of these categories are as follows:

- $RECT\ of\ previous\ day \leq 100\%$
    - "User improved"
- $100\% < RECT\ of\ previous\ day \leq 105\%$
    - "User remained stable"
- $RECT\ of\ previous\ day > 105\%$
    - "User struggled"

The definition of that the user 'remains stable' actually allows for the user to consume more energy. However, it is infeasible for the user to continuously improve as he or she would than no longer have an energy consumption at some point. Therefore, the 'stable' state is still deemed as a positive component for the responsible energy consumption. The boundary of 105% is an educated guess and might be changed later on.

User improved	User remained stable	User struggled
"You're making progress with your energy consumption—let's keep moving forward."	"Your energy efficiency journey is underway—let's continue & strive for improvement!"	"We can amplify your energy-saving performance with ongoing improvements."
"Your efforts in energy conservation are making a difference—let's keep going!"	"You're on the right track with your energy-saving strategies— Keep up the good work and look in the	"There are amazing opportunities ahead to boost your energy efficiency—let's

	consumption overviews on how to improve."	have a look at the energy consumption overviews."
"Keep up the good work on energy conservation!"	“Good job! Your energy consumption is stable!”	“Let's build on your energy-saving efforts for even better results."
"You're already making positive strides in energy efficiency—let's keep up the good work!"	"Consistent energy usage—keep it up!"	"Struggled a bit with energy efficiency—let's find solutions to apply to today! Have a look at the energy consumption data for improvements.”
"Impressive improvement in energy usage!"	"Steady energy consumption is a positive sign!"	"Energy conservation was a bit tough yesterday—let's keep pushing forward."
"Your energy-saving efforts are paying off!"	"Well-maintained energy levels—great job!"	"Found it challenging to save energy yesterday—let's improve. Have a look at the energy consumption data."
"Fantastic job on reducing energy consumption!"	"Your energy consumption remains steady—good work!"	"Encountered some obstacles with energy conservation—let's address them. Look at the energy consumption data for possible improvements."
"Well done on boosting energy efficiency!"	"Stable energy usage reflects your commitment."	"Yesterday’s energy consumption was a bit of a struggle—let's work through it."
"Notable improvement in energy conservation!"	"Consistency in energy consumption is key—keep it going!"	"Energy-saving efforts encountered some challenges—let's overcome them today!"
"Great progress on saving energy!"	"Stable energy consumption shows your dedication to efficiency."	"Facing difficulties with energy conservation yesterday? Good news you have a new chance today!"
"You're making strides in energy efficiency—keep it up!"	"Your consistent energy usage is contributing to sustainability."	
"Way to go on enhancing energy-saving practices!"		
"Your improved energy usage is commendable!"		

Table 9: Overview of possible responses of the system on the RECC percentage of the previous day using positive reinforcement.

The RECT itself is not shown on the encouragement page, but rather the difference of the RECT percentage with the average. This is a bit more intuitive as the RECT itself has a long definition which might confuse the users. Therefore, the categories percentages that are shown are calculated as follows:

- “User improved”
    - Title: Remained below the average energy consumption yesterday by:
    - $Shown\ percentage = 100\% - RECT\%\ of\ previous\ day$
    - Positive reinforcement in left column of Table 9
- “User remained stable”
    - Title: Average energy consumption remained stable yesterday only a slight increase of:
    - $Shown\ percentage = RECT\%\ of\ previous\ day - 100\%$
    - Positive reinforcement in left column of Table 9
- “User struggled”
    - Title: Exceeded the average energy consumption by:
    - $Shown\ percentage = RECT\%\ of\ previous\ day - 100\%$
    - Positive reinforcement in left column of Table 9

Only the “User remained stable has some additional text in the same line where the percentage is shown. An overview of the element that showcases these elements in the encouragement page can be found in Figure 64.

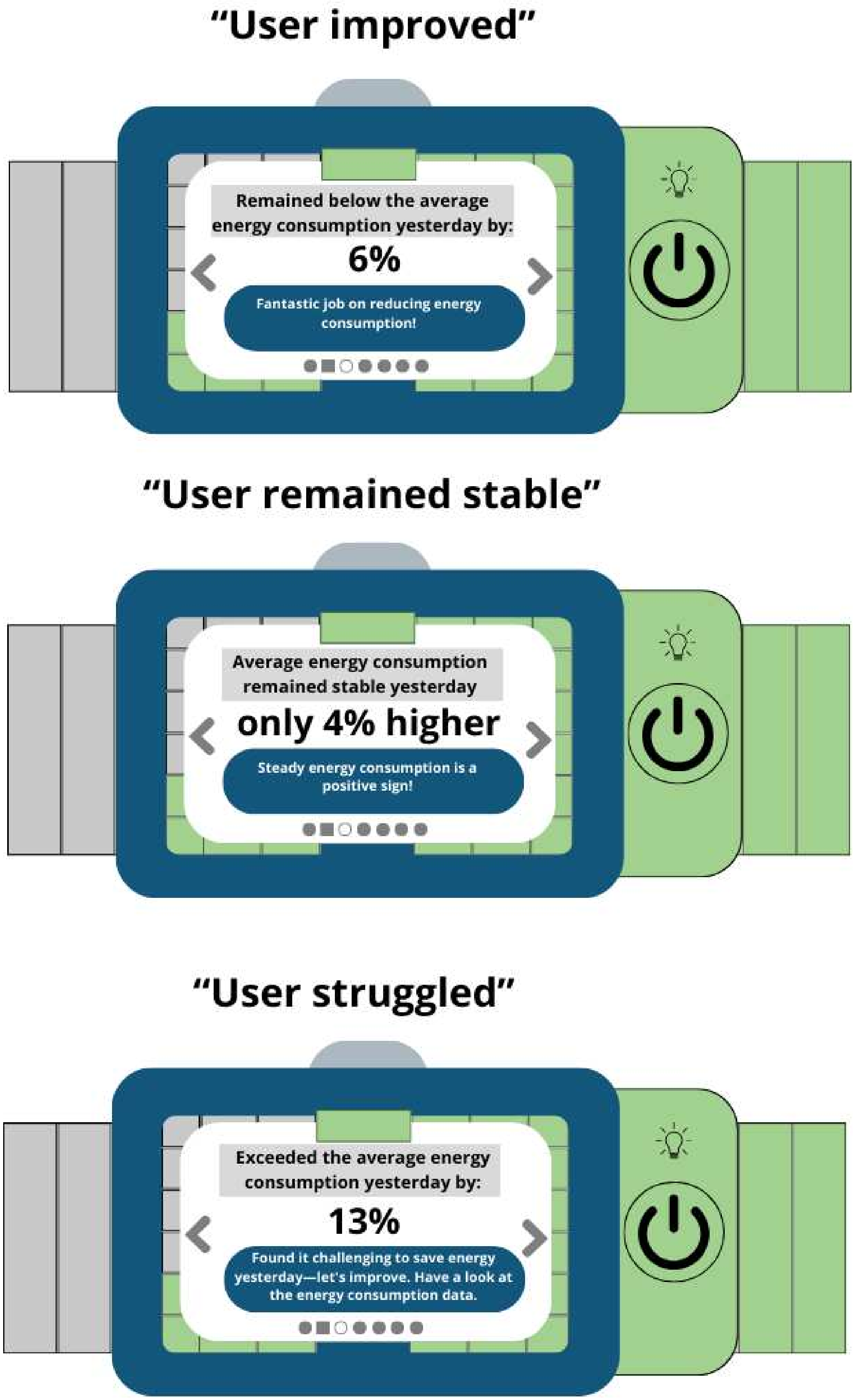


Figure 64: Illustration of the encouragement page in which the RECC percentage of yesterday is shown.

Performance streak

The second element the encouragement pages show is the RECT streak or performance streak. This is streak visualizes the amount of days the user got the “User improved” or “User remains stable” response on the RECT percentage of the previous day in a row. This element is added to motivate the user to engage in responsible energy usage. When the RECT streak is showed in days it also displays a message through positive reinforcement. These can be seen in Table 10. An example of how the RECT streak will be displayed can be found in Figure 65.

RECT streak in days	**Positive reinforcement**
0	"No energy-saving streak yesterday, but let's keep striving."
	"Missed the energy-saving streak yesterday, but let's rebound tomorrow."
	"Energy-saving streak didn't continue yesterday, but today is a new opportunity."
	"Yesterday didn't continue the energy-saving streak, but progress is still possible today!"
	"Didn't maintain the energy-saving streak yesterday, but we'll keep striving for improvement."
	"The energy-saving streak didn't continue yesterday, but stay positive. You can get one today!"
	"Energy-saving streak interrupted yesterday, but let's stay committed."
	"Yesterday didn't extend the energy-saving streak, but progress remains."
	"No energy-saving streak today, but let's get back on track."
1-2	"Great job on saving energy!"
	"Excellent work on conserving energy!"
	"Fantastic job on your energy-conscious choices!"
	"Well done on reducing energy usage!"
	"Keep shining bright with your energy-saving efforts!"
	"Keep up the good work on energy efficiency!"
	"Keep up the energy-saving efforts!"
3-6	"Congratulations on consistently reducing your energy usage! Keep up the great work!"
	"Excellent work on conserving energy!"
	"Well done on reducing energy usage!"
	"Your commitment to sustainability is making a difference!"
	"Your energy-saving habits are paying off! Keep making smart choices and inspiring others to do the same."
	"Your efforts in saving energy are paying off!"
	"Fantastic job on your energy-conscious choices!"
	"Keep up the energy-saving efforts!"
	"Way to go on reducing your carbon footprint!"
7-14	"Keep up the energy-saving efforts!"
	"Your energy-saving habits are fantastic!"
	"Excellent work on conserving energy!"
	"Your commitment to saving energy is commendable!"
	"Impressive energy conservation!"
	"You're making a real difference with your energy-saving actions!"
	"Kudos on being an energy-saving champion!"
	"Bravo on your eco-friendly practices!"
	"Your dedication to conserving energy is admirable!"

	"You're rocking the energy-saving game!"
> 14	"You're demonstrating fantastic energy-saving practices. Keep it up and continue to lead by example!"
	"You're rocking the energy-saving game!"
	"Your commitment to saving energy is out of this world!"
	"Keep up the energy-saving efforts!"
	"Your energy-saving initiatives are inspiring!"
	"You're a sustainability superstar!"
	"You're making a real difference with your energy-saving actions!"

Table 10: Overview of responses of positive reinforcement for the RECC streak in the engagement page.

Figure 65: An illustration of the RECC streak display in the engagement pages.

Current energy consumption relative to the performance of the last hour

The last element in the engagement pages is the RECCH percentage. This is the energy consumption change in relation to the average energy consumption of last hour in percentages. This is calculated through the formula in Equation 5. The RECCH percentage provides users with an overview of their performance compared to the previous hour. While the RECC does this in relation to the last seven days. Maintaining a RECCH percentage of 100% throughout the hour will result in the same energy consumption as the hour before.

$$RECCH\ percentage = \frac{Current\ energy\ consumption\ per\ sec}{Average\ energy\ consumption\ over\ last\ hour\ per\ sec} * 100\%$$

Equation 5: Equation of the calculation for the RECCH percentage. The RECCH percentage gives the user an overview of how well they are doing in comparison to the previous hour. If they remain the whole hour at exactly 100% of the RECCH they will have exactly the same energy consumption as the hour before. Again the 'Current energy consumption per sec' is expressed in watt-hour.

Along with the RECCH percentage a positive reinforcement will be shown. The specific responses can be seen in Table 11. Again this is categorized in the three categories “User improved”, “User remained stable” and “User struggled”. The boundaries of these categories are the same as with the first element that showcases the RECC percentage of the previous day. Only here the RECC percentage in the definition of the boundaries is exchanged for the RECCH percentage.

- $RECCH\% < 100\%$
  - "User improved"
- $100\% \leq RECCH\% \leq 105\%$
  - "User remained stable"
- $RECCH\% > 105\%$
  - "User struggled"

An example of how the RECCH percentage will be displayed can be found in Figure 66.

User improved	User remained stable	User struggled
"Currently on the right track to improve compared to last hour—well done!"	"Consistency is currently being maintained in comparison to the last hour—well done!"	"Challenging hour—let's regroup and make strategies for next hour. Look at your energy data for areas of improvements"
"Progress is being made compared to previous hour!"	"Stable energy usage—keep up the good work!"	"You are currently struggling a bit with your energy usage—let's keep pushing."
"Better energy usage than last hour—great job!"	"Energy consumption remained steady—great job!"	"Found it challenging to save energy this hour—let's improve in the next!"
"Improved energy consumption—keep it up!"	"Maintained stability compared to last hour!"	"Energy conservation was a bit tough this hour—let's push forward."
"Moving in the right direction from last hour!"	"Steady progress in energy efficiency—keep it up!"	"Had some trouble maintaining efficiency compared to last hour."
"This is a step forward in energy efficiency—good work!"	"Consistent energy usage observed—nice work!"	"Energy usage was a bit tougher this hour, but this only means that there is more room to improve."
"Notable improvement over the last hour!"	"Stability maintained in energy consumption—good job!"	"Facing some obstacles this hour—let's work through them in the next!"
"Energy-saving improvement observed—nice job!"	"Energy levels held steady—well done!"	"Found it tough compared to last hour, but you can still make strides next hour!"
"Heading in the right direction compared to last hour!"	"Stable performance in energy usage—keep going!"	"Struggled a bit compared to last hour. However, that is nothing we can't handle!"
"Positive change in energy usage—keep going!"	"No distinct change from last hour—keep the momentum!"	"Encountered difficulties this hour—let's overcome them in the next!"

Table 11: Positive feedback to back up the RECCH percentage in the engagement page.

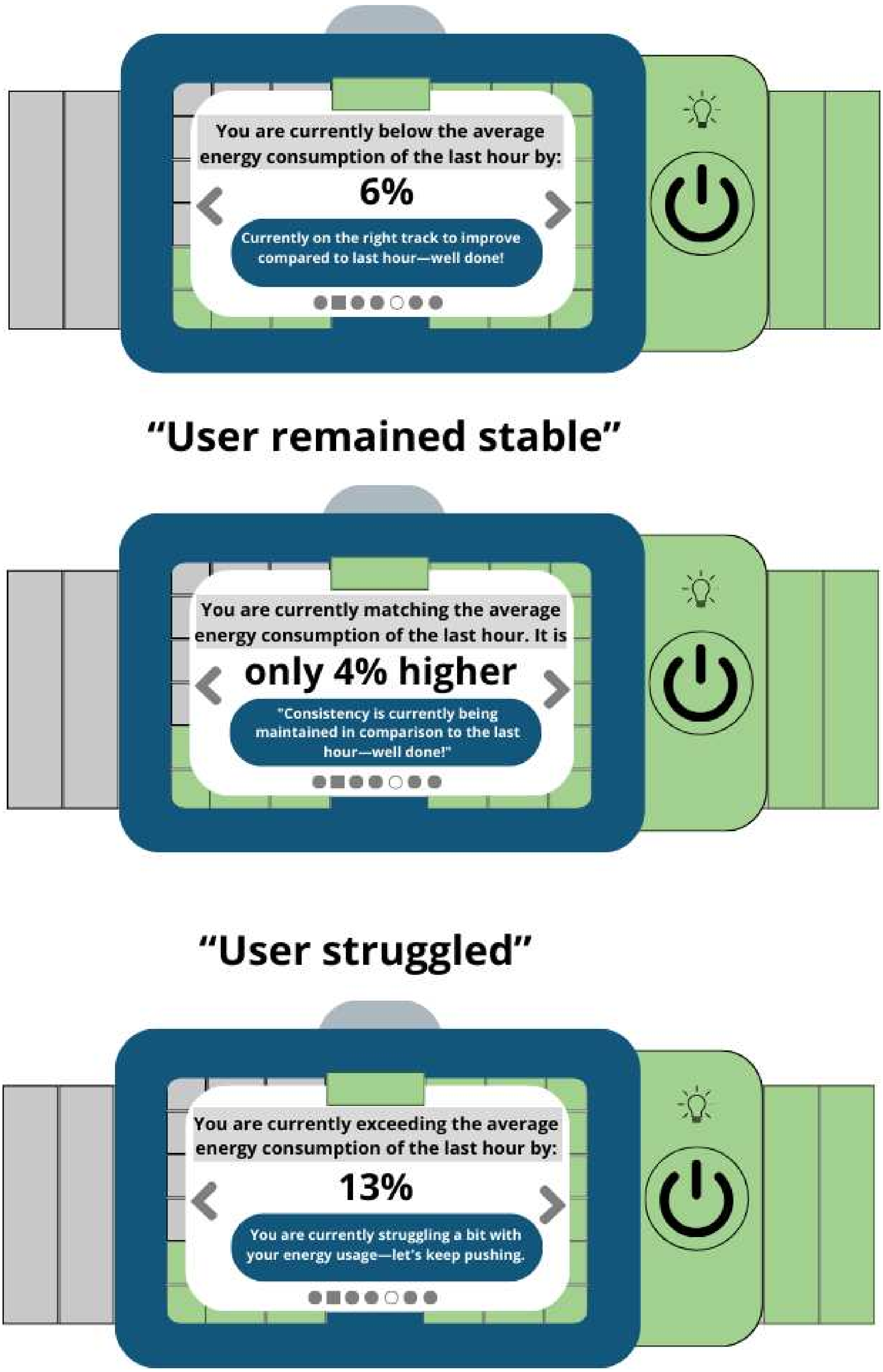


Figure 66: : Illustration of the encouragement page in which the RECCH percentage of yesterday is shown.

History

The history element consists of two pages. One showcasing the division of the percentage of the type of devices that contributed to the energy consumption of the current day. This can be seen in Figure 67. An illustration of the second page can be found in Figure 68. This showcases the energy usage of the user over a period of time. This period can be altered through interaction with the bar highlighted in the first element in Figure 68. This second page also contains an option to compare ones individual energy usage to the average energy consumption of UT employees or to the average energy consumption of similar UT employee. An example of this interaction can be found in Figure 69. When the option “compared to” is turned on an extra bar appears in the graph. The information about the contribution of specific types of devices is no longer available unless these comparisons are turned off. The scenario of when a user selects the “Average of similar UT employees” option to compare her- or himself with is illustrated in Figure 70. In this case a warning pops up and the user can choose to change the settings.

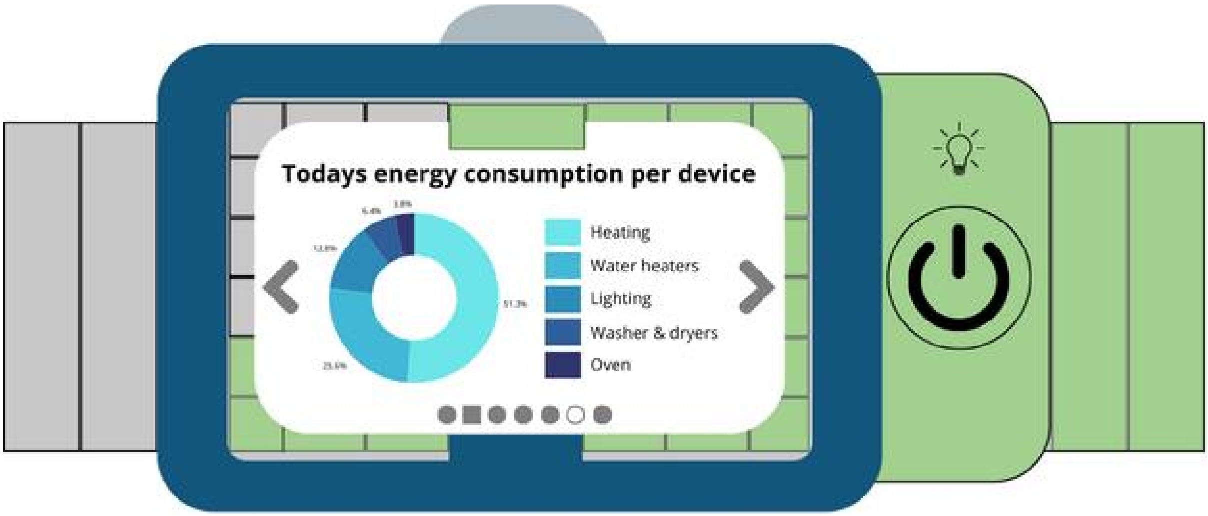


Figure 67: Circle diagram showcasing the division of the type of devices contribution to the energy consumption of the current day in percentage.

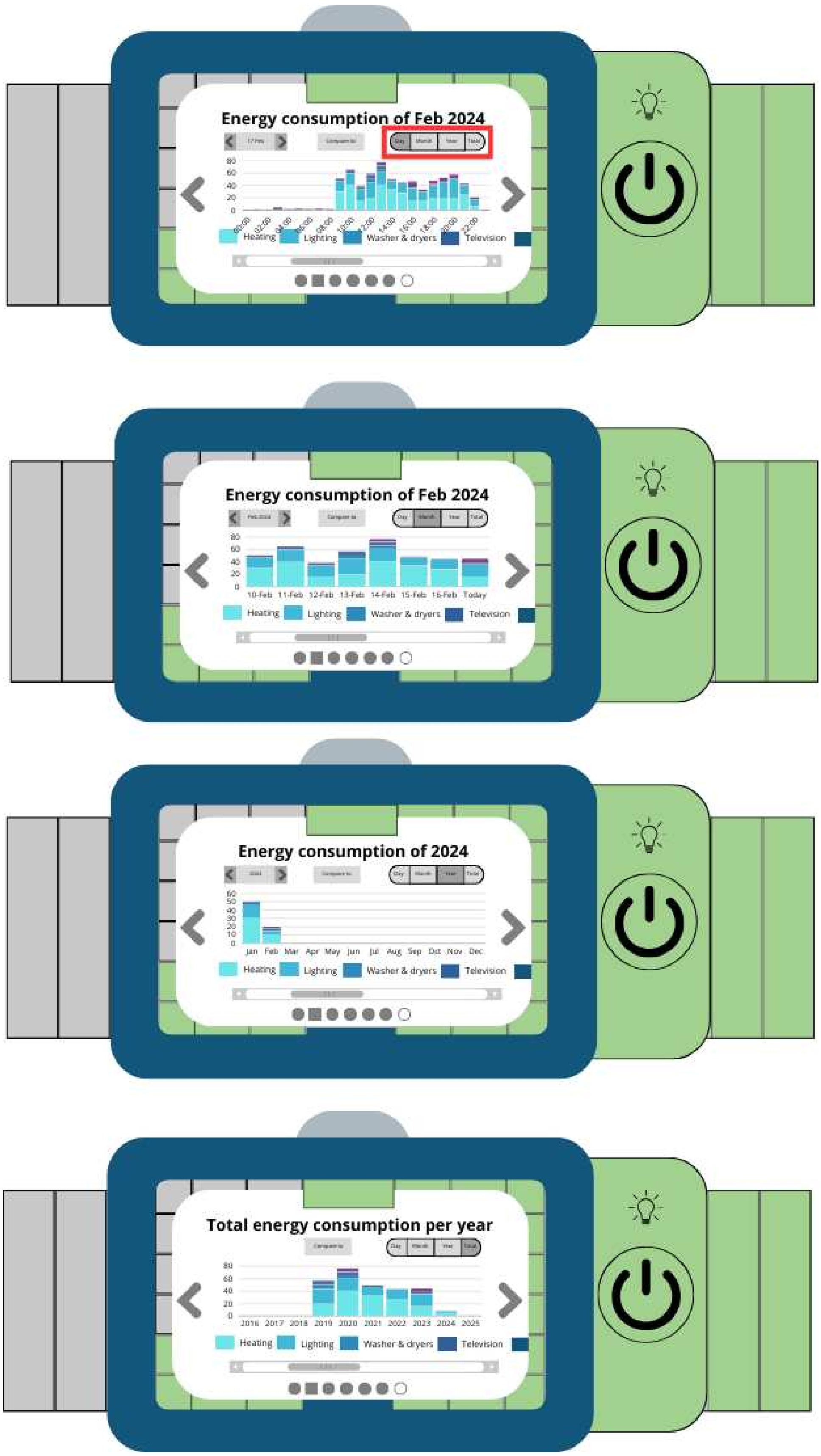
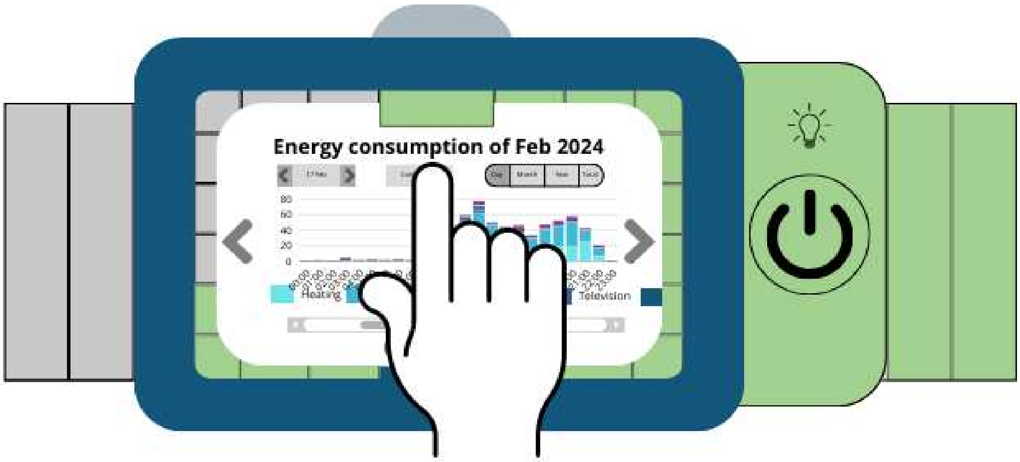
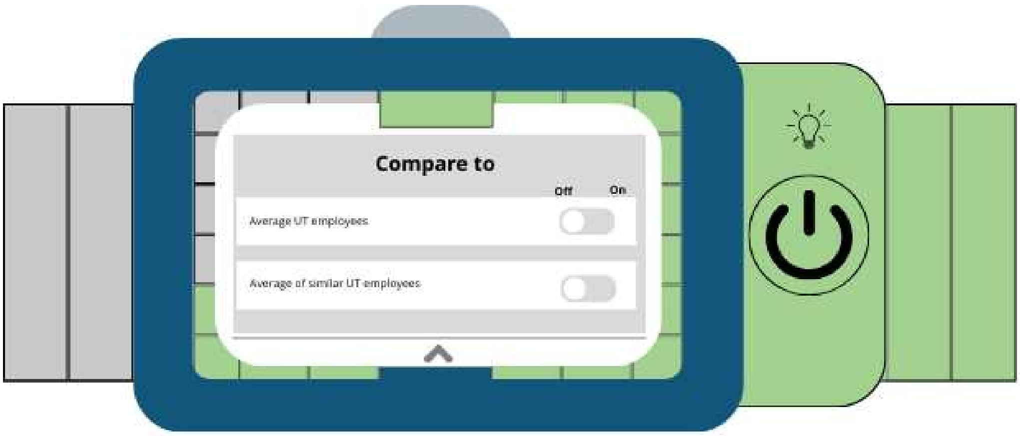


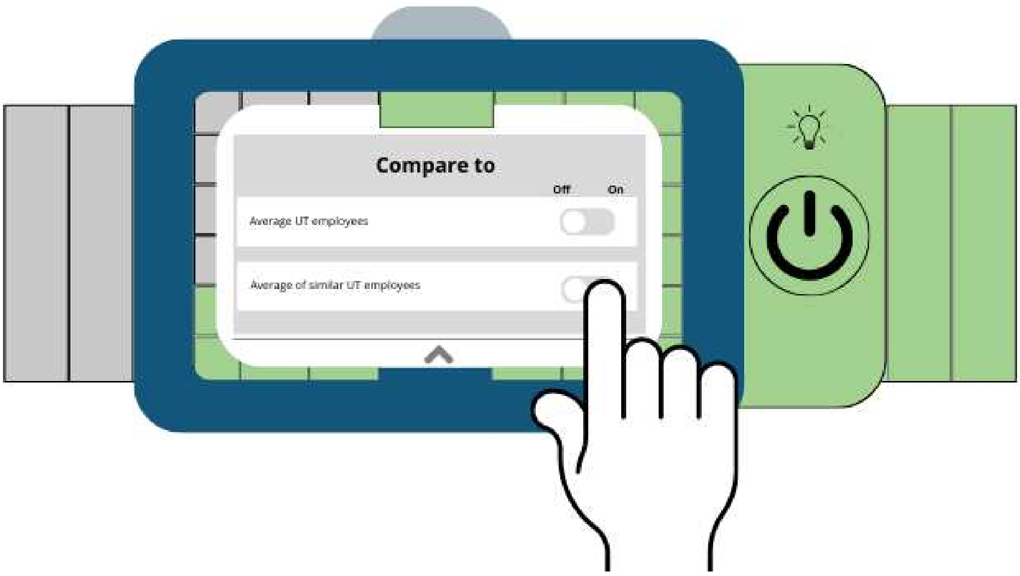
Figure 68: Illustration of the second page of the history section on the smartwatch. In the first element of the image a red box highlights the bar in which the user can tab “Day”, “Month”, “Year” and “Total” to go to the other elements of the figure.



Energy consumption of Feb 2024
80
60
40
20
0
Heating
Television



Compare to
Off
On
Average UT employees
Average of similar UT employees



Compare to
Off
On
Average UT employees
Average of similar UT employees

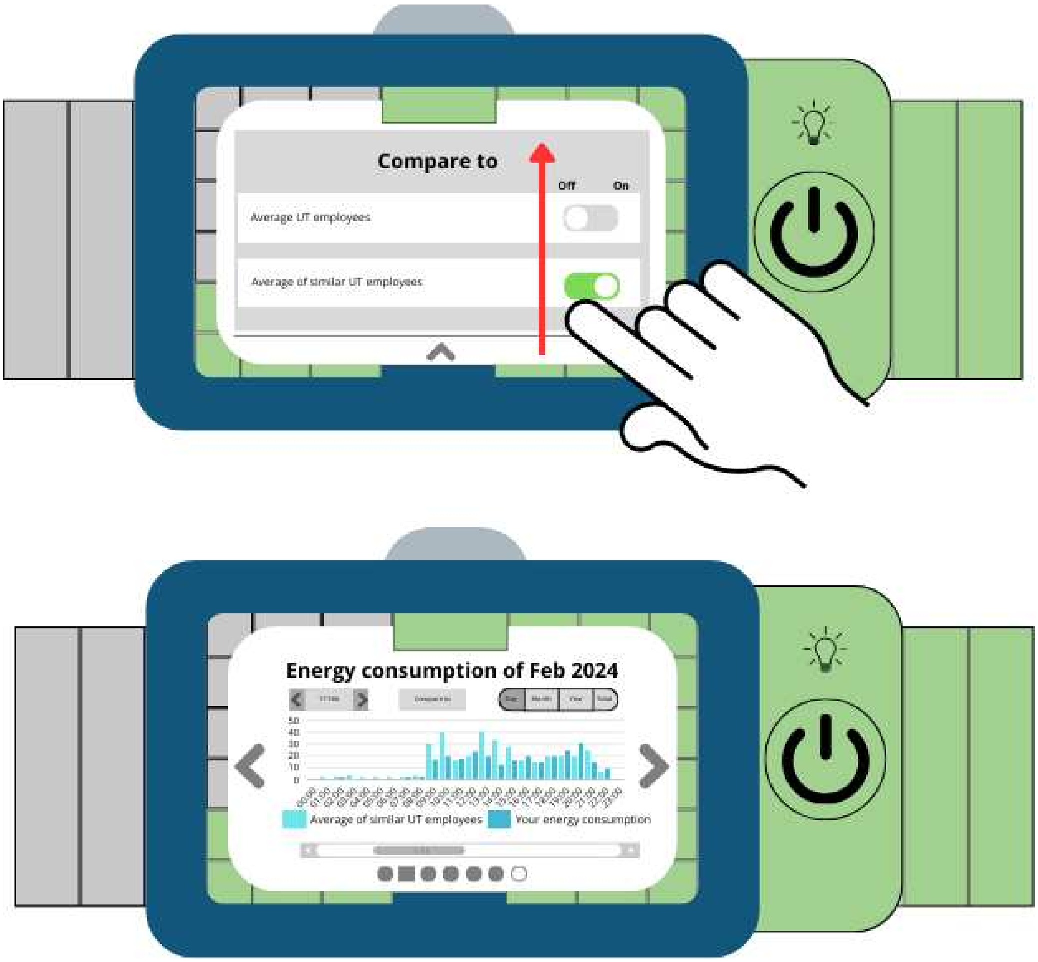


Figure 69: Illustration of the option to compare the users energy consumption with the energy consumption of the average UT employee or the average of similar UT employees. When the option to compared is turned on an extra bar appears in the graph. The information about the contribution of specific types of devices is no longer available unless these comparisons are turned off.

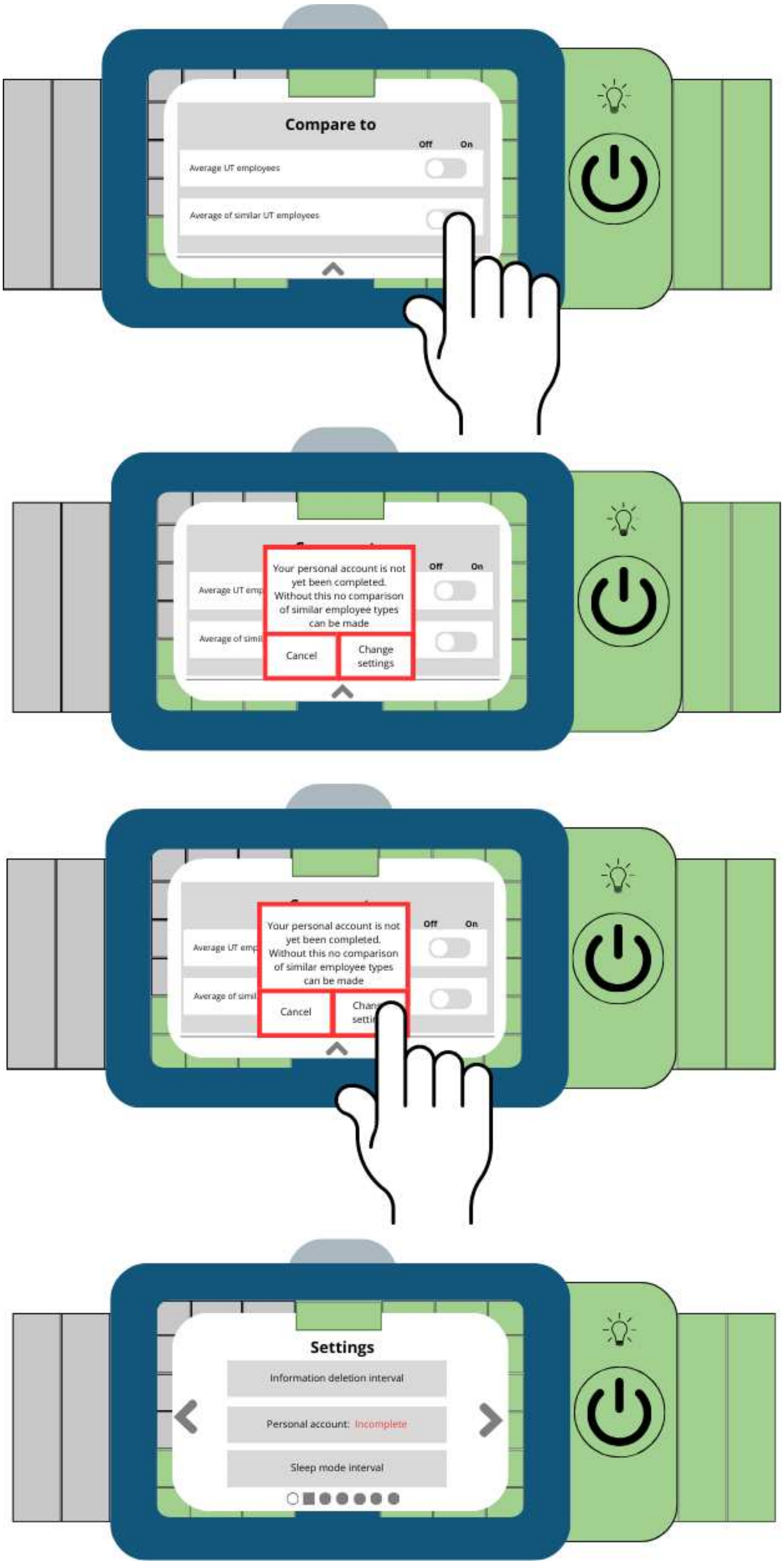


Figure 70: A warning pops up whenever the user tries to compare him- or herself with the average energy consumption of a similar UT employee and the personal account has not yet been completed. When the user tabs the "Change settings" option in the warning pop up it routes the user to the settings page. When the user tabs the "Cancel" button of the warning pop up the "Average of similar UT employees" remains turned off.

Haptic feedback

There are two instances for which haptic feedback is provided. Haptic feedback is given in the form of vibrations. For the first instance this is whenever the user reaches the following RECT percentages: 50%, 75%, 90%, 100%, 150%, 175%, 190%, 200%, 250%, 275%, 290%, 300% ect. Examples of when haptic feedback is initiated can be found in Figure 71. An illustration of the haptic feedback in the form of vibrations itself can be seen in Figure 73. The vibrations initiate from the position of the screen. For 100%, 200% and 300% there are two vibrations directly after each other. For the other percentages this is only one vibration. With each vibration a corresponding pop up is shown on the screen, as detailed in Figure 72.

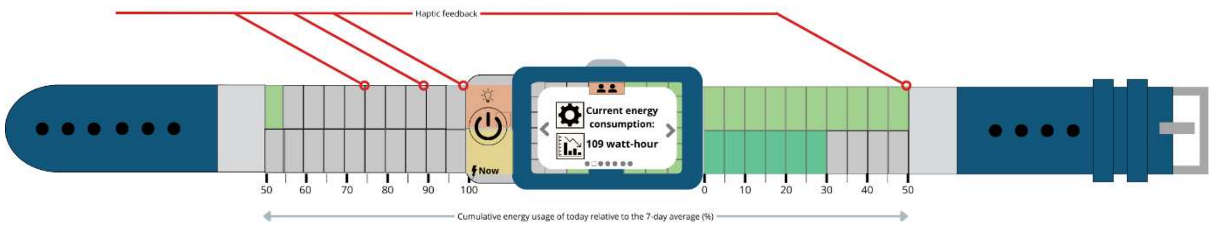


Figure 71: Examples of when the haptic feedback is initiated. The first element shows the haptic feedback getting initiated when the RECC percentage is at 50%. Additionally it shows the options for 75%, 90% and 100% RECC. The second element shows the haptic feedback getting initiated when the RECC percentage is at 110%. Additionally it shows the options for 150%, 175% and 200% RECC. The last element shows the haptic feedback getting initiated when the RECC percentage is at 250%. additionally it shows the options for 175% and 300% RECC.

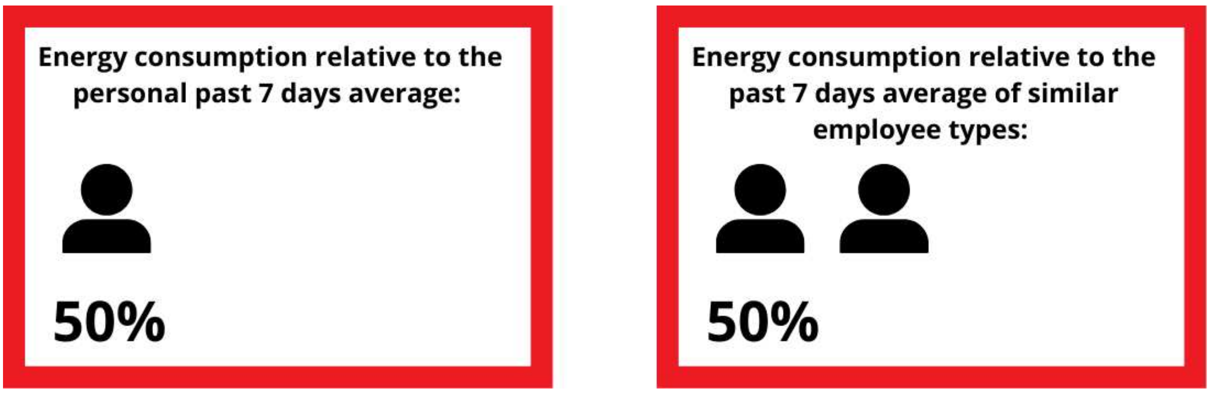


Figure 72: Examples of the buzz pop ups on the screen that is displayed alongside the vibrational feedback.

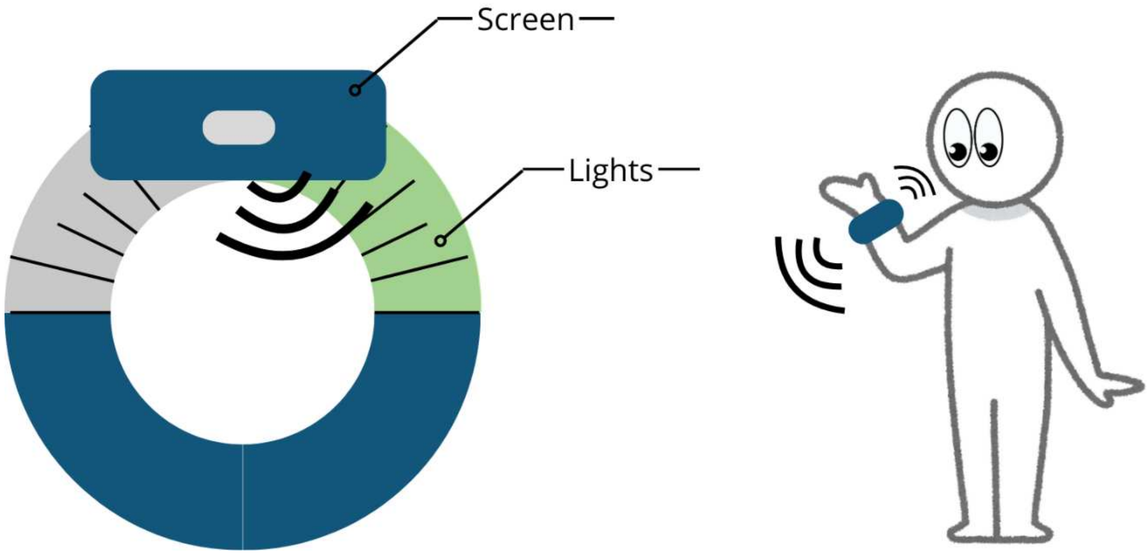


Figure 73: Illustration of the haptic feedback in the form of vibrations.

The other form of vibrational feedback happens when a user left on an electrical device while not being nearby. In this case the user receives one buzz notification alongside a pop up with additional information. An example of such a pop up is illustrated in

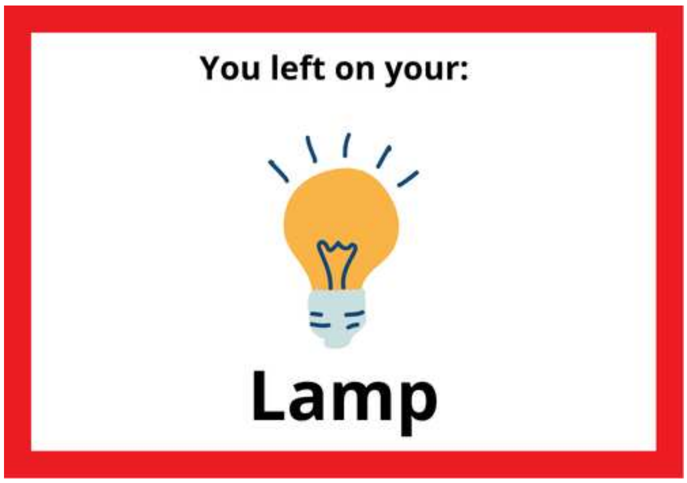


Figure 74: Example of a buzz pop up to warn users about electrical appliances that are left on when walking away.

Data gathering

Now that the prototype design has been determined it is known which type of data is required for the intervention to be able to function properly. The data has to follow the following requirements, it must be:

- Real-time
- Identify different devices
- Identify different users
- Be stored
- Be communicated to the smartwatch

- Be able to be deleted
- Be private and anonymous
- Adhere to privacy laws

In the state of the art different methods of data measurements were discussed. The data gathering method that will be used is through the use of smart plugs. Although, both smart plugs and CT clamps on the electric panel with an AI could both identify different devices and measure the real-time energy consumption of its users smart plugs are considered prominent for two different reasons. Firstly, the technology of utilizing an AI to identify different types of devices though their power signature is still in its infancy and is still very prone to errors. This would make the data of the intervention less reliable. Secondly, though measuring the energy consumption at the electric panel you either measure the main incoming electricity or that of the electric subgroups. However, this makes it very difficult to identify the energy consumption of different users utilizing the energy at the same moment in time. There is however also a downside in utilizing smart plugs instead of an AI. Every single device that would be measured would require a separate smart plug. This costs a lot of materials and thus energy, especially when expanding the intervention to more users since more smart plugs would be required by every expansion. This could have negative consequences as the goal is to reducing energy consumption. Nevertheless, smart plugs are considered to be significantly more effective in the data measuring than the AI in its current development stage. Therefore, smart plugs are chosen as the way to gather the energy consumption data of the users of the intervention.

The smartwatch allows the user to compare their energy consumption with similar employee types. As Dik [38] mentions the smartwatch would not only require access to their personal energy consumption data, but also that of similar employee types. This could potentially cause privacy issues when not carefully managed. To make sure no privacy is being compromised, Dik [38, p. 6] suggests that “each user has a personal database in which the data gets processed and stored. This database communicates with a server which keeps track of the average energy consumption per employee type. The communication is executed through an Anonymous Communication Protocol named HTTPS which ensures that the IP addresses of the communication devices remain hidden to the server.” This allows the data to be private and anonymous. This is exactly how this intervention will store and communicate information between the different databases.

The personal database of the intervention will be stored on the users personal phone via an application. This phone will then communicate to the smartwatch via Bluetooth Low Energy (BLE) with data encryption during transmission. This way of communication was selected because of the low power consumption, its secure communication abilities and the fact that it is widely adopted on phones as well as smartwatches. Similarly, Bluetooth can also be used as a communication protocol for the communication between the smart plugs for the same reasons. Long distance communication is not needed since both the phone, the smartwatch and the smart plugs are likely close by when in use. This means it is not an issue to use Bluetooth which is a short range communication method. One downside of utilizing the phone as mediator in the communication is that it is required to always be on. Meaning when the phone battery is dead the smartwatch will not be able to update. However, this is not seen as a big issue as most people have charged phones when working. The utilization of the phone as a mediator in communication utilizes existing infrastructure and therefore saves materials and energy. In Figure 75 the specified version of the operational environment can be found.

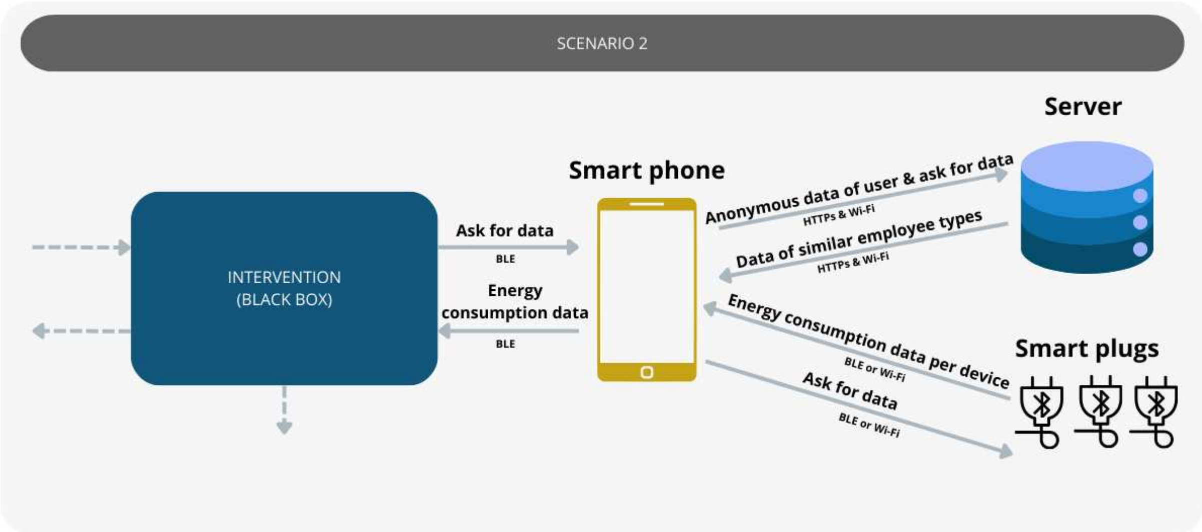


Figure 75: The second scenario of the "Operational environment brainstorm

is selected. This figure shows an overview of the communication protocols within the intervention and the method of data gathering and storing. It is a further specified scenario 2 then the one described in the "operational environments section".

Users can link their devices to the intervention by linking the respective smart plugs to their individual devices. This can be done in the application on the phone. However, sometimes users will share their devices with other users. Most university employees share rooms and will share usage of the lights while keeping personal devices like PCs for themselves. This could potentially cause for inaccurate energy consumption measurements. To measures are taken to avoid this.

Firstly, multiple users can link the to the same smart plug for energy usage. It is chosen not to divide the energy consumption amongst the different users that are linked to the same smart plug. Instead they will be compared to other employees who also share a room with the same amount of people and thus have a similar energy consumption.

Secondly, only users that are currently close to the smart plug which is measuring the energy are send the energy consumption data of the specific smart plug. Meaning that when for example three users share a room and have all linked the smartwatch to the smart plug for the lighting in the room only the people close to the lighting will 'consume' energy according to the intervention.

Bluetooth is a short range communication protocol. Whenever one of the three users leaves the room and exits the range of the Bluetooth communication, this person is considered to no longer be using the electricity for the lighting. This is an elegant solution, as this user is also not able to receive the data from the smart plug from the lighting anymore. However, is the smart plug only linked to one user, then this data is communicated over a Wi-Fi connection instead of Bluetooth. Whenever a user leaves his personal devices on (smart plug only linked to one user) or he is the last to break a Bluetooth connection with a shared device (smart plug linked to multiple users) the communication continues via Wi-fi and the smartwatch gives a buzz notification with a pop up on the screen which displays information about which device is left on.

Users should give consent via the intervention for if they would allow the university to utilize their energy consumption data to gain insights into the general in- and outflows of electricity on campus which they could utilize to create more effective future energy saving initiatives. This should be clearly and transparently communicated to the user.

User scenarios and story board

Figure 78 showcases an user scenario. It shows how the current energy consumption feedback through the energy light can help UT employees manage their energy consumption. It also shows how the energy consumption of today (using the lights bar) and the data overview can support the users.

Another user scenario can be found in Figure 76. The example showcases Camila getting visitors. Nevertheless, the same thing applies to meetings, general areas etc. In the example the user does not want to broadcast the energy feedback via the lights due to privacy reasons. However, there can also be other reasons. These include users being embarrassed by their energy consumption, it being perceived as distracting because of their current task etc. The design had incorporated the consequences of the option to turn off the lights in the wristband. Not being able to perceive this feedback would have been a major disadvantage for the intervention and drastically decrease its effectiveness. All comparisons, which function as motivators, would be gone. However, the light bar is also visualized on the screen, but all the information on the screen is more personal as other people don’t have access to the information. Therefore, the function to turn the lights of the wristband off is to give the users a sense of privacy while not sacrificing the effectiveness of the intervention itself.

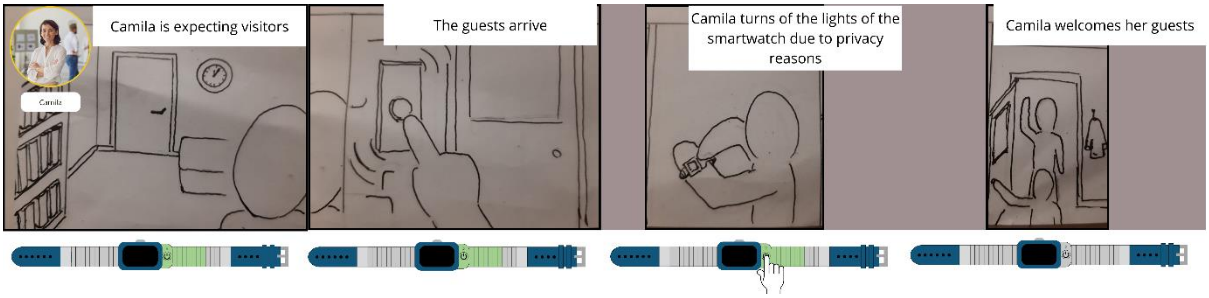


Figure 76: User scenario of a user turning off the lights of the smartwatch. This specific scenario features the situation in which the user receives guests, but does not want to broadcast the feedback during the visit due to privacy reasons.

The last user scenario can be seen in Figure 77. This shows how the vibrational feedback makes the user persona Henk more aware of his energy consumption over the day. Henk responds to the feedback by figuring out how well he is doing. How much electricity does he still need to consume today? And does that mean that he needs to change his energy consumption pattern now? Of course it users should always try to use their energy as responsible as possible. However, Henk is already someone who does this. His energy consumption is already very low. Therefore, he mostly uses it as a check-up tool. When he would have a higher energy consumption than desired he has a look at the data or history pages to get more information. With this additional information he can decide on further actions.

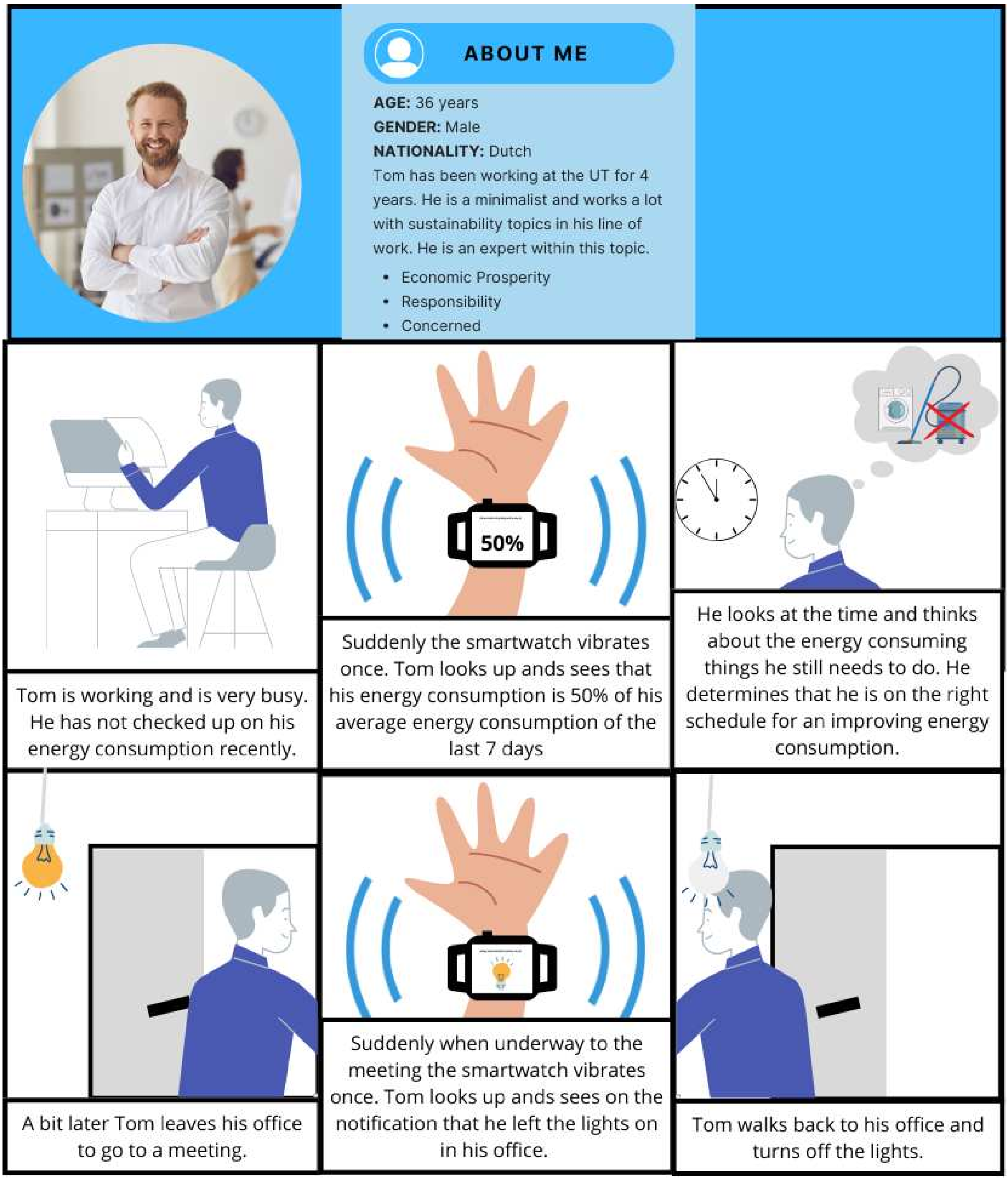


Figure 77: User scenario showcasing the effect of the haptic feedback on the user persona Tom.

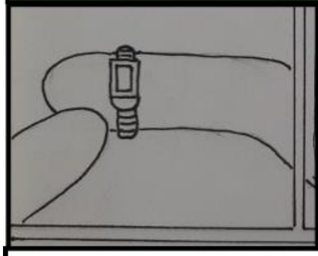
ABOUT ME

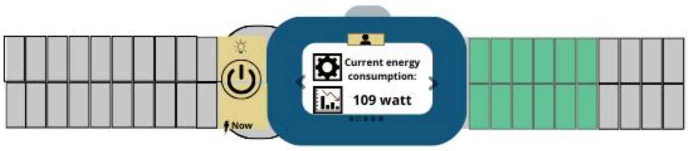
AGE: 29 years
GENDER: Female
NATIONALITY: Dutch

Annika likes cool gadgets and thinks time efficiency is very important. Her home is fully automated and she likes to not have to perform many actions.

- Time efficiency
- Competitive

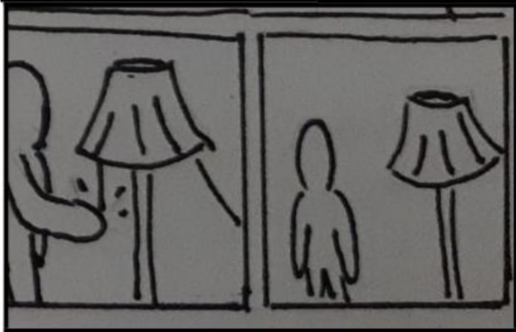
Annika has had the smartwatch for a week and the smartwatch is now able to calculate the average of the last weeks energy consumption. She thinks the smartwatch is cool and wants to try the function out in which she can compare her energy consumption with herself.

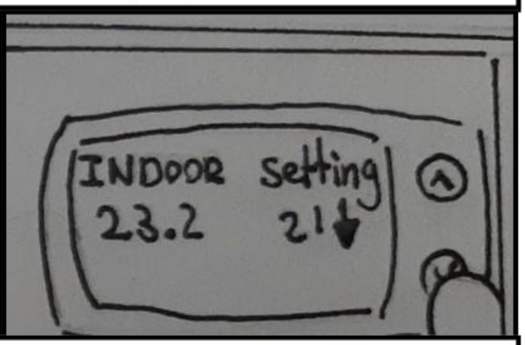




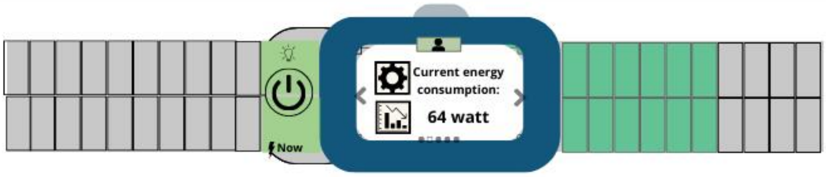
Annika puts her smartwatch in the personal comparison state

She sees that er current energy consumption is a bit higher than the average in comparison to that of the last seven days. (The initial light is yellow)

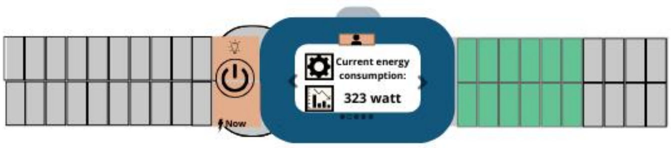




Wanting to do better than the previous week she performs a few energy saving actions: turning off the lights and altering the thermostat settings. After each device that she turns off she sees the current wattage on the homes screen go down. With this see sees its effect on the current energy consumption.



Annika turns her wrist to see the effects of her actions. Her current energy consumption is now lower than her average energy consumption of last week! Her actions worked!



When turning on the washing machine she checks on how she is doing. She realizes that the initial light on the smartwatch has turned orange. An indication that she is currently using a lot of energy with respect to her average energy consumption. Yet the only difference is that she turned on the washing machine. Therefore she concludes that next time she should be careful on when and how to use the washing machine. In order to save energy.

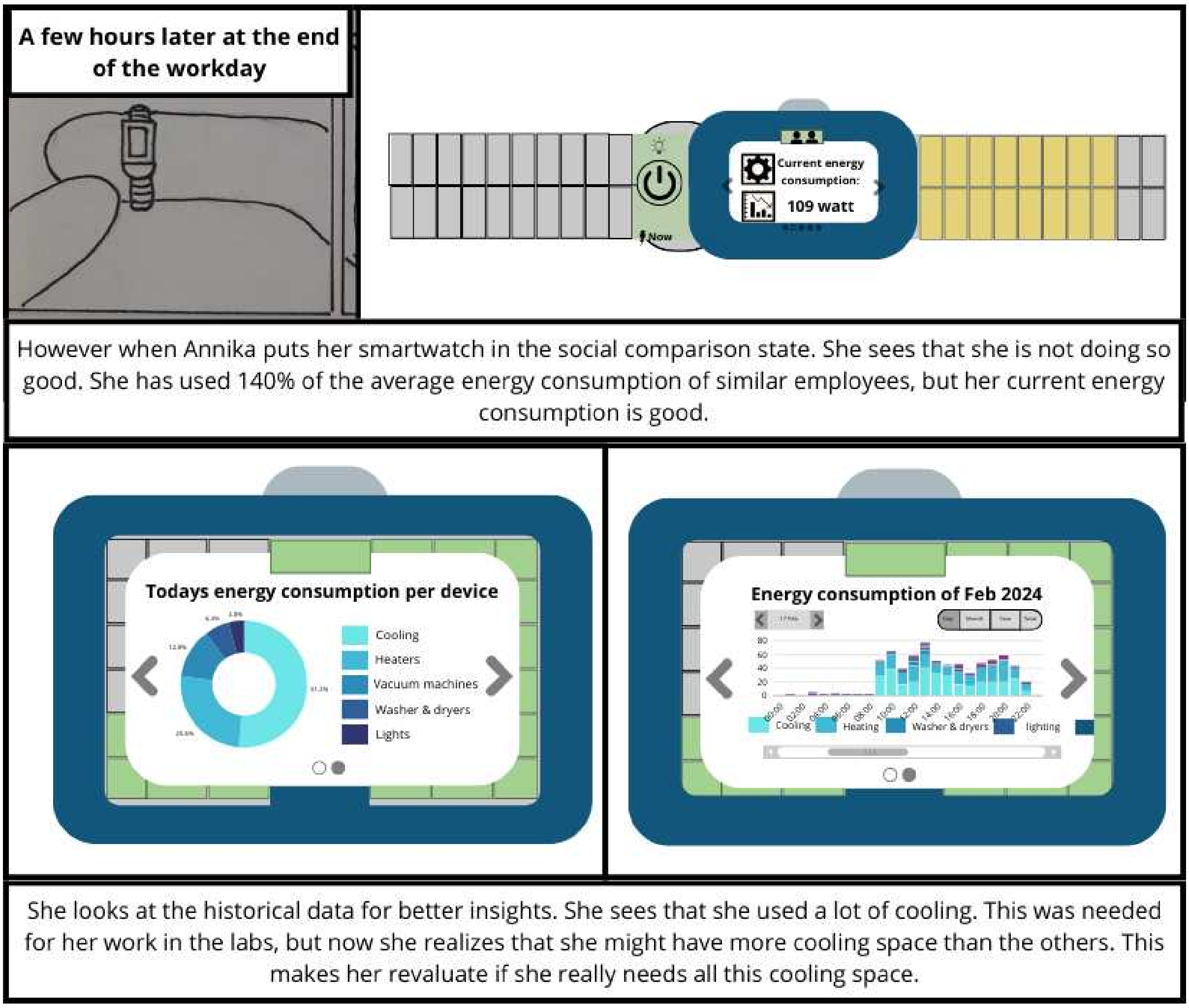


Figure 78: User scenario using the Annika persona. It shows how the current energy consumption feedback through the energy light can help UT employees manage their energy consumption. It also shows how the energy consumption of today (using the lights bar) and the data overview can support the users.

Specification diagram

To get an complete overview of the intervention, before it is realized in a prototype, some specification diagrams are made. Because the intervention itself is really big, as can be seen in level 1 provided in Figure 80, this project will only focus on realizing the part of the intervention which communicates with the user. This means that the data gathering part of the intervention will not be realized. With this decision in mind, no detailed descriptions (or specification diagrams) have been created for the data gathering aspect of the intervention, as can be seen in Figure 79.

As detailed in Figure 79, there are 4 types of interactions the user can have with the system. These are the interactions with the toggle button, screen button, rotation of the wrist and display interaction. The information from the data gathering aspect of the intervention are highlighted with the top two arrows. This information includes the current and saved energy consumption data. Then there are also four types of feedback that the system can give. These are feedback via the energy lights, the energy bar light, vibrations and via information on the screen.

Figure 80 illustrates how these in- and outflows of the system are connected. Two logical processes of the energy bar light and energy light are further worked out in Figure 81 and Figure 82 in a level 2 specification diagram.

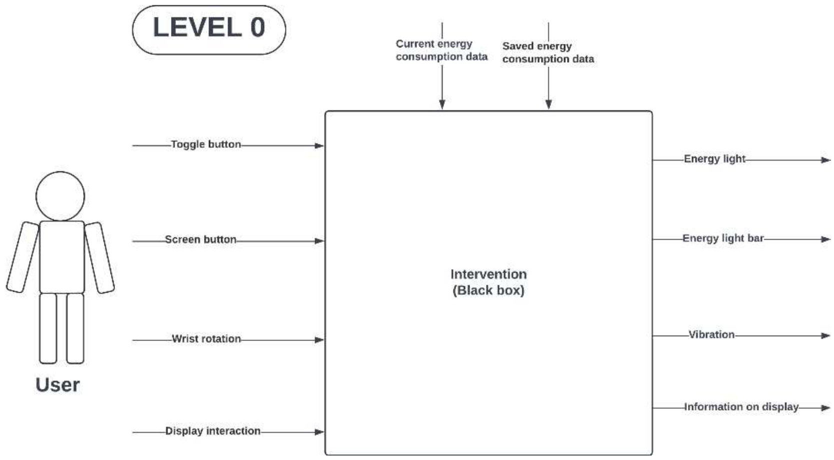


Figure 79: Illustration of the specification diagram of the intervention, level 0.

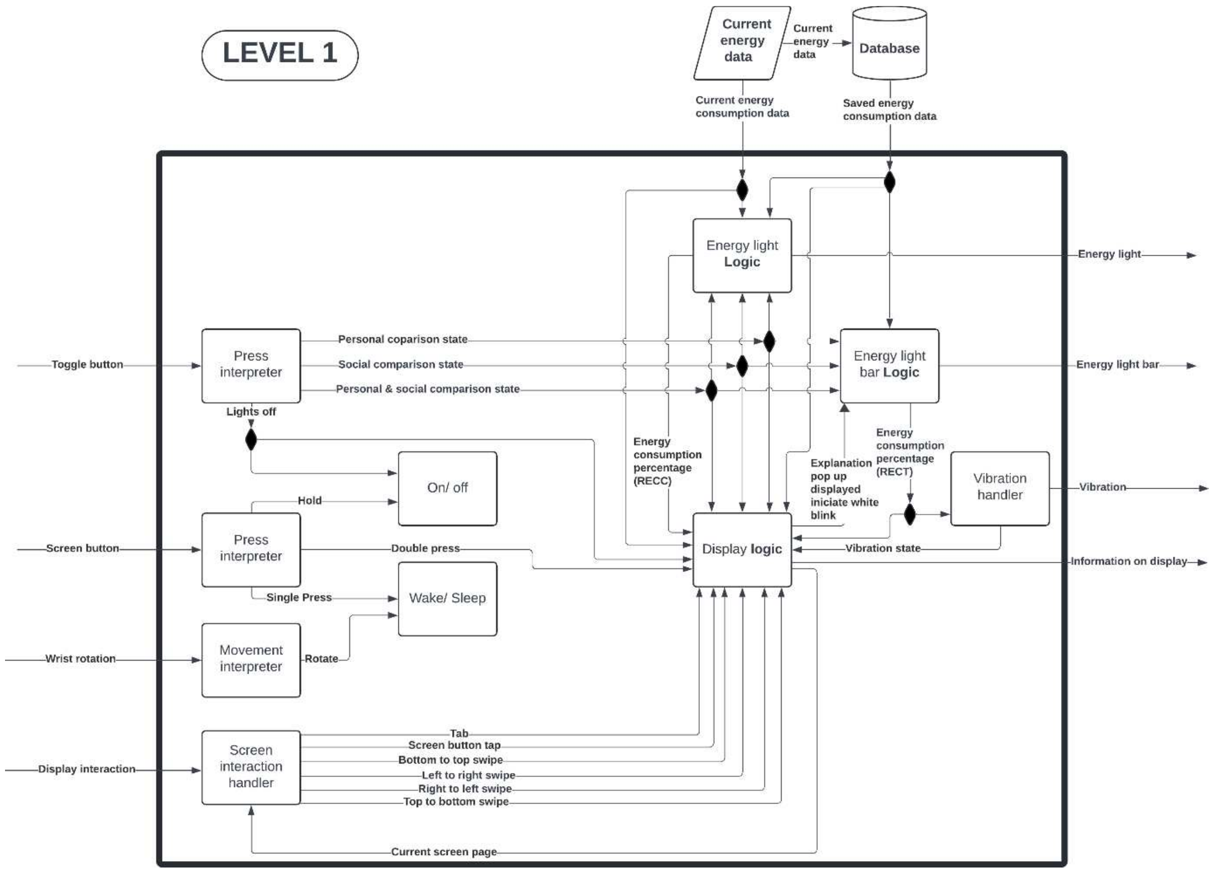


Figure 80: Illustration of the specification diagram of the intervention, level 1.

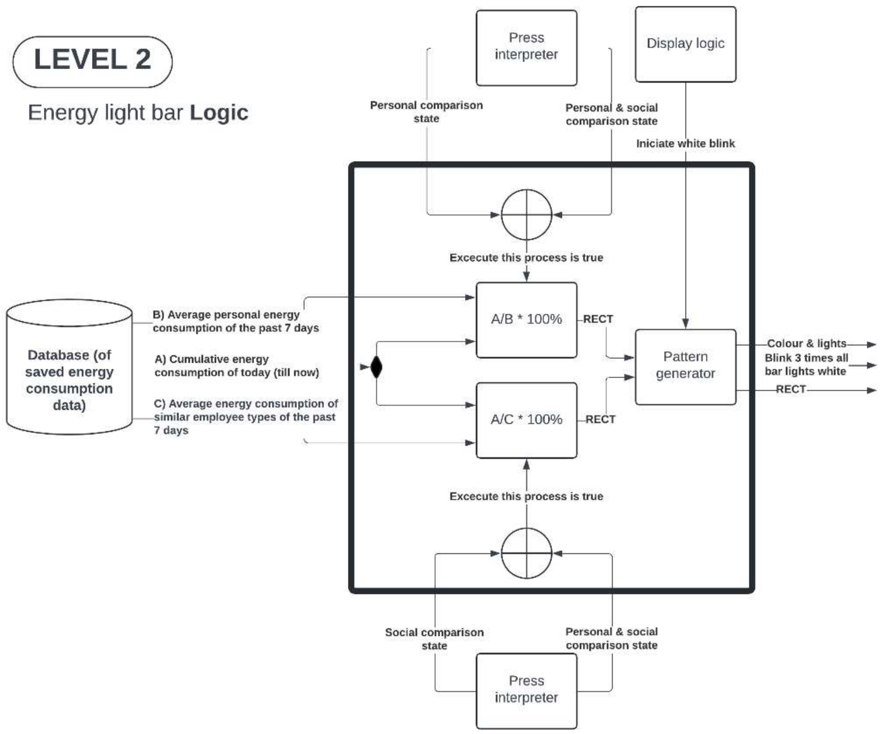


Figure 81: Illustration of the specification diagram of the intervention, level 2: the logic of the energy bar light.

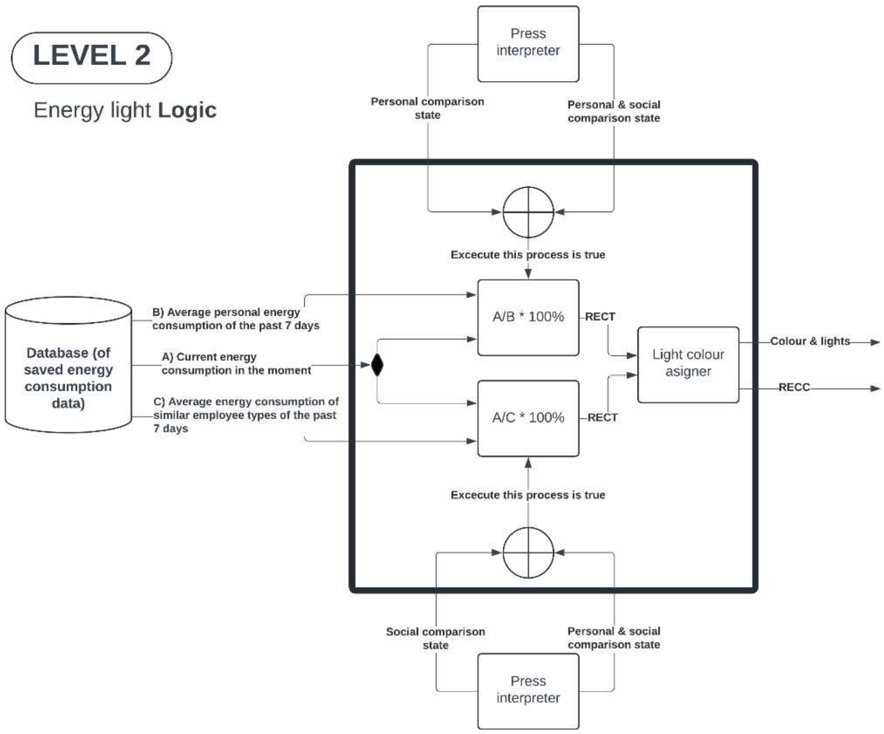


Figure 82: Illustration of the specification diagram of the intervention, level 2: the logic of the energy bar light.

Chapter 6 – Realisation

Implementation of the specification aspects

An illustration of the prototype can be found in Figure 83. A more detailed description with images of the prototype can be found in "*Appendix G: Realisation*

Appendix F: User testing method and questions

The informed consent form used in the initial and improved method can be seen in "*Appendix A: Informed consent form*

. However, the consent form for the initial method additionally states that the user test also includes a survey.

Appendix F1: Initial method

This method uses the think out loud method. The initial method consists of the following four phases:

1. Unguided familiarization: User gets time to familiarize him- or herself with the intervention.
2. Structured Familiarization: In this phase, the researcher asks the participant to perform specific tasks using the smartwatch. If something is unclear, the researcher can ask unstructured interview questions. This phase includes an unstructured interview and captures the participants' immediate reactions and thought patterns as they interact with the smartwatch though the think out loud method
3. Unstructured interview: after the familiarization phase the user is asked a set of questions. In order to get as much information as possible the interview is unstructured. This way other interesting or important topics that arise can also be discussed.
4. Survey: The user is asked to fill in a survey.

1. Unguided familiarization

A. Familiarize yourself with the smartwatch screen, the 2 buttons and the 2 potentiometers and look around.

2. Structured familiarization

A. Turn some appliances on till you have a just above average current energy consumption.

B. Put the smartwatch in the personal comparison state: 2.

C. Find out what this state does.

D. Find out what the difference is between the single LEDs and the LED bar.

E. Let's say you already used some electricity today. Slowly increase the energy consumption of today till 50% of your past 7 day average.

F. Put the smartwatch in the personal comparison state: 3. And find out what this state does.

G. You turn on the air conditioning. Increase the current energy consumption till its high.

H. By how much are you currently exceeding your average energy consumption of the last hour?

I. How well was your performance yesterday? By how much did it exceed or improve upon your average energy consumption?

J. How long is your improvement streak?

K. The day goes by… Turn todays energy consumption up to 75%.

L. You release you left some appliances on. Turn some appliances off till you are in the range of your average energy consumption.

M. The day goes further by slowly increase todays energy consumption to 135%.

O. It is the end of the day. Look up what todays energy consumption is per device. Where would you reduce your energy consumption in the future?

P. Look up when you consumed most energy during the day.

Q. Put the smartwatch in the personal comparison state: 4. And find out what this state does.

3. Unstructured interview

A. Would you intent to change your energy consumption to be more responsible when this smartwatch is implemented? Why?

B. What do you think encourages and discourages you to change your energy consumption to be more responsible regarding the smartwatch?

4. survey

Prototype testing

Dear participant,

This research project aims to create an effective behavior intervention to facilitate pro-environmental behavior among university employees, specifically targeting the responsible energy usage. Responsible

pro-environmental behavior include simple actions to reduce energy consumption

e.g. turning off the lights, turning down the thermostat, only turning on the dishwasher when it is completely filled etc. The purpose of this specific interview is to get insights in the opinions of the potential end users (university employees) of this intervention. These opinions are used to further develop ideas and prototypes. Therefore, it is encouraged to answer all the questions honestly. All feedback is appreciated!

Participating in this survey is voluntary; there

are no specific benefits to be gained by participation. It is possible to remove yourself from the study at any time. All

gathered data about your participation will then be destroyed. No personal data will be collected apart from your demographics. When you have a very specific employee function within the UT that could potentially identify you as participant this will function will be generalized. Therefore your contribution will remain anonymous. There are no known risks related

to this study.

Demographics

1. What is your Gender?

Markeer slechts één ovaal.

- ◯ Man
- ◯ Woman

- [ ] Non-binary
- [ ] Prefer not to say

2. What is your age?

Markeer slechts één ovaal.

- 18-24
- 25-34
- 35-44
- 45-54
- 55+

3. What is your job at the UT?

4. I want to improve my energy saving at work

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

5. I feel like I have control over my energy consumption at work.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

6. I believe my colleagues expect me to save energy at work.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

LED lights

7. I think it is clear what the different light states mean.

Markeer slechts één ovaal.

1 2 3 4 5

Not Very much

8. I think the LEDs are intuitive to interpret.

Markeer slechts één ovaal.

1 2 3 4 5

Not Very much

9. I think it is clear what the difference is between the two single LEDs and the LED strips/bars.

Markeer slechts één ovaal.

1 2 3 4 5

Not Very much

10. The two single LEDs showcase useful insights in my energy consumption.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

11. The insights of the two single LEDs help me to make more responsible energy consumption actions in the future.

Imagine you are actually using the prototype in real life.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

12. The LED strips/bars showcase useful insights in my energy consumption.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

13. The insights of the LED strips/bars help me to maintain or improve upon responsible energy consumption actions in the future.

Imagine you are actually using the prototype in real life.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

14. I think it is useful to see the difference in current energy consumption in the moment and the energy consumption over the whole day.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

15. I think it is useful to compare my energy consumption with averages.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

16. I think the different comparisons in the light states are useful.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

17. I think one of the following light states are unnecessary:

Markeer slechts één ovaal.

- State 1: Lights off
- State 2: Personal comparison
- State 3: Social comparison
- State 4: Personal & social comparison
- All of the states seem useful to me

18. I think the button to toggle through the light states is intuitive.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

19. I think it is intuitive when LED strips/bars reset when the relative percentage is over a multiple of 100%. (Turn today's energy consumption up and down to see this effect)

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

20. I think the color of the lights is intuitive

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

21. Do you have any more remarks about the LED lights or the toggle button?

Vibrational feedback

22. I experience the notification in the form of vibrational feedback as "loud".

Markeer slechts één ovaal.

1 2 3 4 5

much

23. I experience the notification in the form of vibrational feedback as annoying.

Markeer slechts één ovaal.

1 2 3 4 5

much

24. I think the notification in the form of vibrational feedback helps me to undertake action for more responsible energy usage.

Markeer slechts één ovaal.

1 2 3 4 5

much

25. I think the notification in the form of vibrational feedback catches my attention when doing day-to-day tasks.

Markeer slechts één ovaal.

1 2 3 4 5

much

26. I think the notification in the form of vibrational feedback is a good feedback type to warn me about my energy consumption.

Markeer slechts één ovaal.

1 2 3 4 5

much

27. Do you have any remarks about the vibrational feedback?

Touch screen pages

28. The current energy consumption unit on the home page screen is intuitive and clear to understand.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

29. It is intuitive that the bar surrounding the screen pages represent the LED strips/bars.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

30. It is clear that the bar surrounding the screen pages represent the LED strips/bars.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

31. It is intuitive that the colored box on top of the screen pages represent the two single LEDs?

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

32. It is clear that the colored box on top of the screen pages represent the two single LEDs?

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

33. It is intuitive that the symbol of ONE person in colored box on top of the screen pages represent the personal comparison state?

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

34. It is <u>clear</u> that the symbol of ONE person in colored box on top of the screen pages represent the personal comparison state?

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

35. It is <u>intuitive</u> that the symbol of TWO person in colored box on top of the screen pages represent the social comparison state?

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

36. It is <u>clear</u> that the symbol of TWO person in colored box on top of the screen pages represent the social comparison state?

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

37. The three pages about 'Yesterdays performance', the 'improvement streak' and 'current performance compared to the last hour' encourage me to utilize my energy consumption more responsibly?

Imagine the three pages would be based on your actual energy consumption data.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

38. The two pages about 'Yesterdays performance' and 'current performance compared to the last hour' showcase useful insights in my energy consumption.

Imagine the two pages would be based on your actual energy consumption data.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

39. I think the 'Todays energy consumption per device' page gives me relevant insights in my energy consumption

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

40. I think the insights from the 'Todays energy consumption per device' will improve my responsible energy consumption patterns.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

41. I think the page which showcases a graph of my energy consumption over a period of time gives me relevant insights in my energy consumption.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

42. I think the insights from the page which showcases a graph of my energy consumption over a period of time will improve my responsible energy consumption patterns.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

43. I think the interface is intuitive.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

44. Do you have any remarks about the touch screen of the smartwatch?

Control, privacy and personalization

45. I feel in control when using the smartwatch.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

46. I feel like I can protect my privacy.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

47. I am satisfied with the amount of personalization the prototype offers.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

48. What aspects do you think are missing regarding the personalization of the smartwatch?

49. Do you have any more remarks about how you experience your control, privacy or personalization when using the smartwatch?

Implementation of the prototype

50. I think the prototype would be a hassle when it would be implemented.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

51. When the prototype would be implemented I would actively have to think about it in order to use it. Meaning that it is always present in the current task I am doing when I am doing my job.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

52. I feel like peer pressure and social comparison during implementation (e.g. seeing how others are performing through the LEDs on their smartwatches) would encourage me to utilize my energy consumption more responsibly.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

53. I feel like the personal comparison (LEDs, and touch screen pages) would encourage me to utilize my energy consumption more responsibly.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

54. I think the prototype encourages me to utilize my energy consumption more responsibly.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

55. I think if the prototype got implemented I would change my energy consumption to use it more responsibly.

(This is about your intention to change your energy consumption.)

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Definitely

56. I think the implementation of the smartwatch will support me into a transition of changing habits to more responsible energy consumption.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

57. I feel rewarded when I improved or maintained my personal average energy consumption pattern.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

58. I feel unmotivated when I exceeded my personal energy average energy consumption patterns.

Markeer slechts één ovaal.

1 2 3 4 5

59. I feel rewarded when I consumed less energy than the average energy consumption of similar employee types.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

60. I feel unmotivated when I consumed more energy than the average energy consumption of similar employee types.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

61. I feel like the intervention motivates me towards a more responsible energy consumption.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not						Very much

62. I feel like the intervention teaches me about how I can work towards a more responsible energy consumption.

Markeer slechts één ovaal.

1 2 3 4 5

Not Very much

63. I feel like the intervention educates me on my energy consumption.

Markeer slechts één ovaal.

1 2 3 4 5

Not Very much

64. When the smartwatch would get implemented I would be emotionally invested.

Markeer slechts één ovaal.

1 2 3 4 5

Not Very much

65. The smartwatch makes me feel like have control over my energy consumption at work

Markeer slechts één ovaal.

1 2 3 4 5

Not Very much

66. Do you have any remarks about the implementation of the smartwatch

67. Do you have any more remarks about the smartwatch in general that you would like to add?

Appendix F2: Improved method

The user testing method was altered to exclude the learning curve of the intervention from the participants tests. This was accomplished by explaining the intervention through scenarios while the researcher interacted with the smartwatch, rather than having the users figure out how to use it on their own. This approach allowed the users to focus on answering the questions that mattered. Additionally, the survey element of the method was removed, because the first user test took up too much time. The improved method consists of the following three phases:

5. Introduction: Shortly explains what the smartwatch does.
6. Familiarization: this is the phase in which the researcher interacts with the smartwatch while discussing multiple scenarios with the participants. This phase includes an unstructured interview and captures the participants' immediate reactions and thought patterns as the researcher interacts with the smartwatch.
7. Unstructured interview: after the familiarization phase the user is asked a set of questions. In order to get as much information as possible the interview is unstructured. This way other interesting or important topics that arise can also be discussed.

Unstructured interview && Quasi experiment >> not random experiment

1. Introduction

Explain what the interventions does: it shows your energy consumption compared to the personal average or social average depending on the state. Explain what these states are.

With the potentiometers the researcher does the wizard of oz. Explain which potentiometer does what.

2. Familiarization

We will compare the energy consumption to the personal energy consumption. We can look at the energy consumption in the moment and of today. Go to the pop up for the explanation in the moment.

A. Look at it and tell me what you see. And is it clear what the colors mean

Let's you turn on some appliances like lights and laptops.

B. What do you see?

We can also go to explanation of the pop up of today.

C. Look at it and tell me what you see

D. Is it clear what the colors mean

Let's imagine the time flies by and you are consuming energy throughout the day. The energy you have consumed today in total increases. (<50%)

E. Tell me what you see

Increase to >50%

F. How do you feel now you are getting haptic feedback?

Increase to 135%

G. Tell me what you see

We can also go to another state. Let's compare your energy consumption to that of similar employees. Go to state 3. I will go to the explanation page for today.

H. Tell me what you see (difference symbol)

Then it is the end of the day. I have not really performed well compared to my personal goals cuz that was 135% but I have performed well in relation to similar employees.

I. How does this make you feel

I want to see what I can do better. I look at the energy consumption per device page.

J. Tell me what you see. What can you do to improve your energy consumption.

Can also see which times you consumed most of your energy.

K. Tell me what you see and think

Showcase the encouragement pages

L. What is your opinion about these pages?

3. Unstructured interview

A. Do you think you would use the smartwatch? Do you think other people?

B. Would you intent to change your energy consumption to be more responsible when this smartwatch is implemented? Why?

C. What do you think encourages and discourages you to change your energy consumption to be more responsible regarding the smartwatch?

D. What do you think was intuitive & what was not intuitive?

E. Which parts of the smartwatch were useful and which ones were not?

F. What would you change?

G. Do you have any remarks about the smartwatch?

Appendix G: Realisation

”.

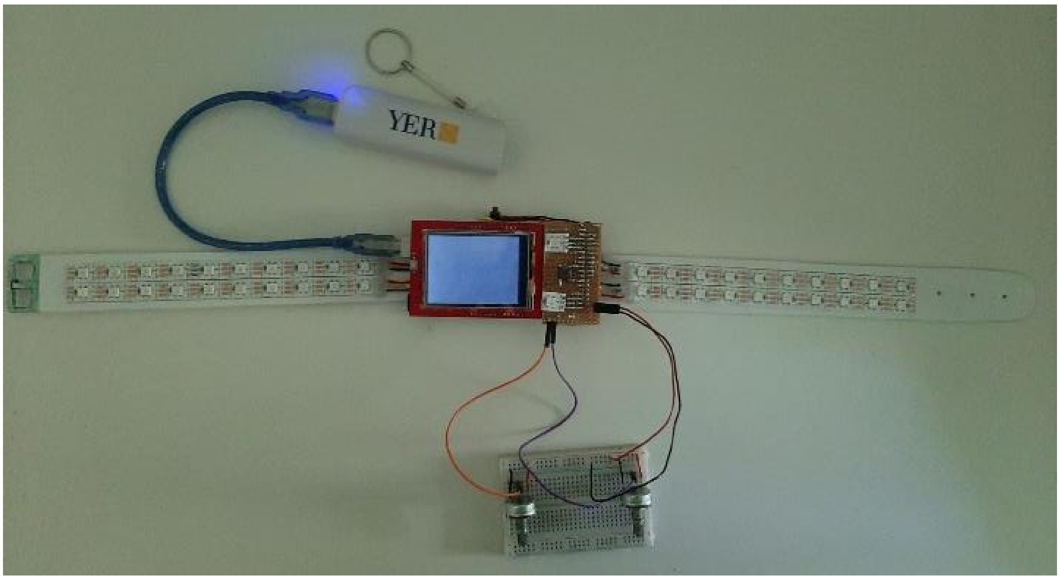


Figure 83: Overview of the smartwatch prototype.

The prototype is bigger than the actual smartwatch that is envisioned. Additionally, users can’t put it around their wrist since the wristband in the prototype is made with a specific kind of cardboard material.

Since the idea that was discussed in the specification chapter was too big to work out in the current study, a few aspects of the idea were not included within the prototype:

- **Data gathering:** Instead of adding the whole infrastructure of the smart plugs, smart phone and databases, the potentiometers, visible in Figure 83, were used to simulate the energy consumption data in the moment and the cumulative energy consumption over the whole day. Other data was simulated within the Arduino code with static global variables that were inspired by the energy consumption of a one person household on a random day.
- **Reminders that a specific device has been left on:** This aspect could have potentially been very useful to incorporate into the design as this is expected to be a very effective supportive intervention type technique. However, it is not included within the realisation of the prototype.
- **Settings page interaction:** The settings page mostly allowed for more personalization and some privacy settings. These aspects are considered to be important for a final product, but not required to encourage behaviour change.

- **Graph interaction:** The graph interaction was considered to be too much effort for too little gain. Only an indication of what the graph (and its interaction) would look like was expected to suffice.
- **Turn smartwatch on and off:** This feature was not considered to be useful within the current iteration of the prototype as the data gathering aspect of the intervention was not yet implemented and this would not have a big impact on the actual behaviour change.
- **Blinking during pop up explanations:** This was considered too much of a detail and was therefore not included. Also by changing the layout of the pop up it was expected that the energy light and energy bar light on the screen were a more intuitive representation than what was described in the specification chapter.
- **Swiping interactions:** For the prototype to function not all interactions were necessary to implement. Therefore, only the tapping interactions on the screen were implemented
- **Pop up overlays to indicate scale of light bar:** This was considered to be a detail. Something that was not necessary for the effectiveness of the intervention.

Apart from things that were not included some things were also done differently in the prototype than described in the specification chapter:

- **Pop up explanation pages:**
    - Energy bar light and energy light were illustrated the same as bar light and energy light on the screen of the standard pages (e.g. home page, settings page, encouragement pages and history pages). This was seen as more intuitive and less work as the code for these displays on the screen was already written.
    - Legend of the explanation pages was included on same page as there was more space available now that the bar and energy light were visualized as an outline on the edge of the screen. Originally these would have had their own respective page.
    - An explanation of personal and social comparison symbol was added. This information was lacking in the specification and more room was available on the same page as the bar and energy light were visualized as an outline on the edge of the screen.
    - Originally the explanation pop up would be closed via a swiping interaction. However, this interaction was not included in the prototype, so button was added instead.

Prototype construction

Materials and tools

An overview of the used materials and tools can be found int the Table 12 below.

Materials:	Tools:
1. Arduino mega 2560 (1x) 2. TFT LCD shield (1x) 3. PCB board (1x) 4. Electronic wires 5. Individual addressable LED strip: ws2812b (4x a strip of 10 LEDs) 6. Power source of 5v (1x) 7. Data cable (1x) 8. Breadboard (1x) 9. Potentiometer B10K (2x) 10. Heat shrink tubes 11. 220 ohm resistors (8x) 12. Pin headers 13. Vibration motor (1x)	1. Soldering station + tin 2. Wire cutter 3. Heat gun 4. Arduino program 5. Plier 6. Wire stripper

Table 12: Materials and tools used for the realization of the prototype.

Assembly instructions

Since the data collection aspect of the intervention is not included within the prototype it has to be simulated. This is done by utilizing potentiometers and global variables in the code. One potentiometer is used to simulate the energy consumption data in the moment and the other to simulate the cumulative energy consumption over the whole day.

For the prototype a shield was created with an PCB. This was done because of two reasons. First, this would reduce the amount of lose connections and make the prototype more reliable. Second, this increases the ease of use as it allows the prototype to be easily disassembled and assembled.

To assemble the whole prototype, first the PCB shield needs to be applied on the Arduino mega. How the PCB shield is assembled can be seen in Figure 85 and Figure 86. After this the TFT LCD shield is put on the Arduino mega as detailed in Figure 84. This order is important as wires connected to the left side of the bar lights should go under the TFT LCD shield. The LEDs of the energy bar light can be sticked to a piece of cardboard can be cut into a wristband shape. When all these things are done the result looks something like the prototype illustrated in Figure 83. The code of the prototype can be found in the attached zip file.

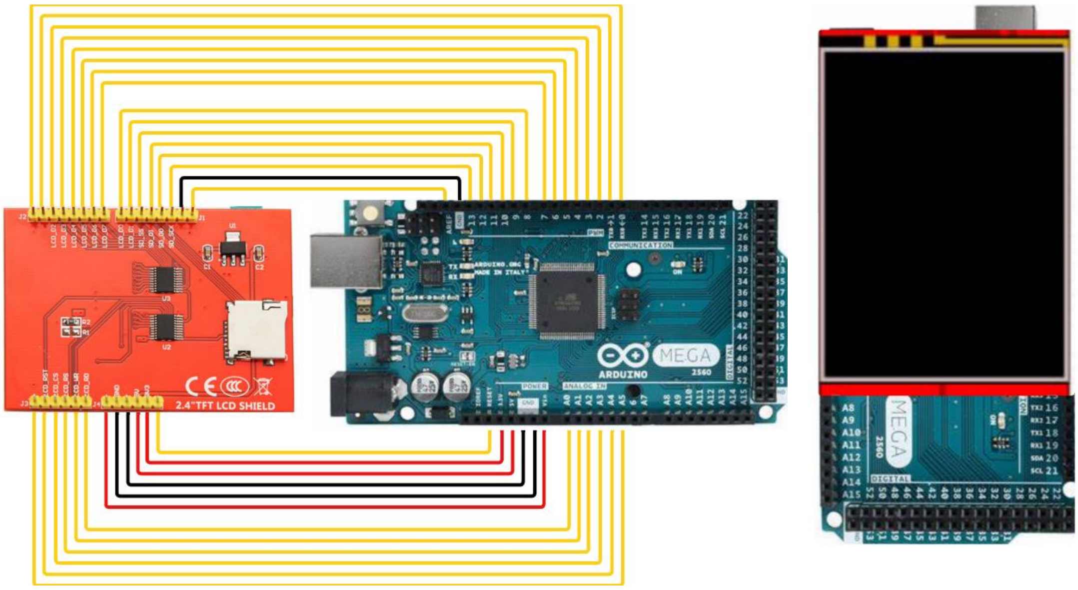


Figure 84: Put the TFT LCD screen on the Arduino mega 2560.

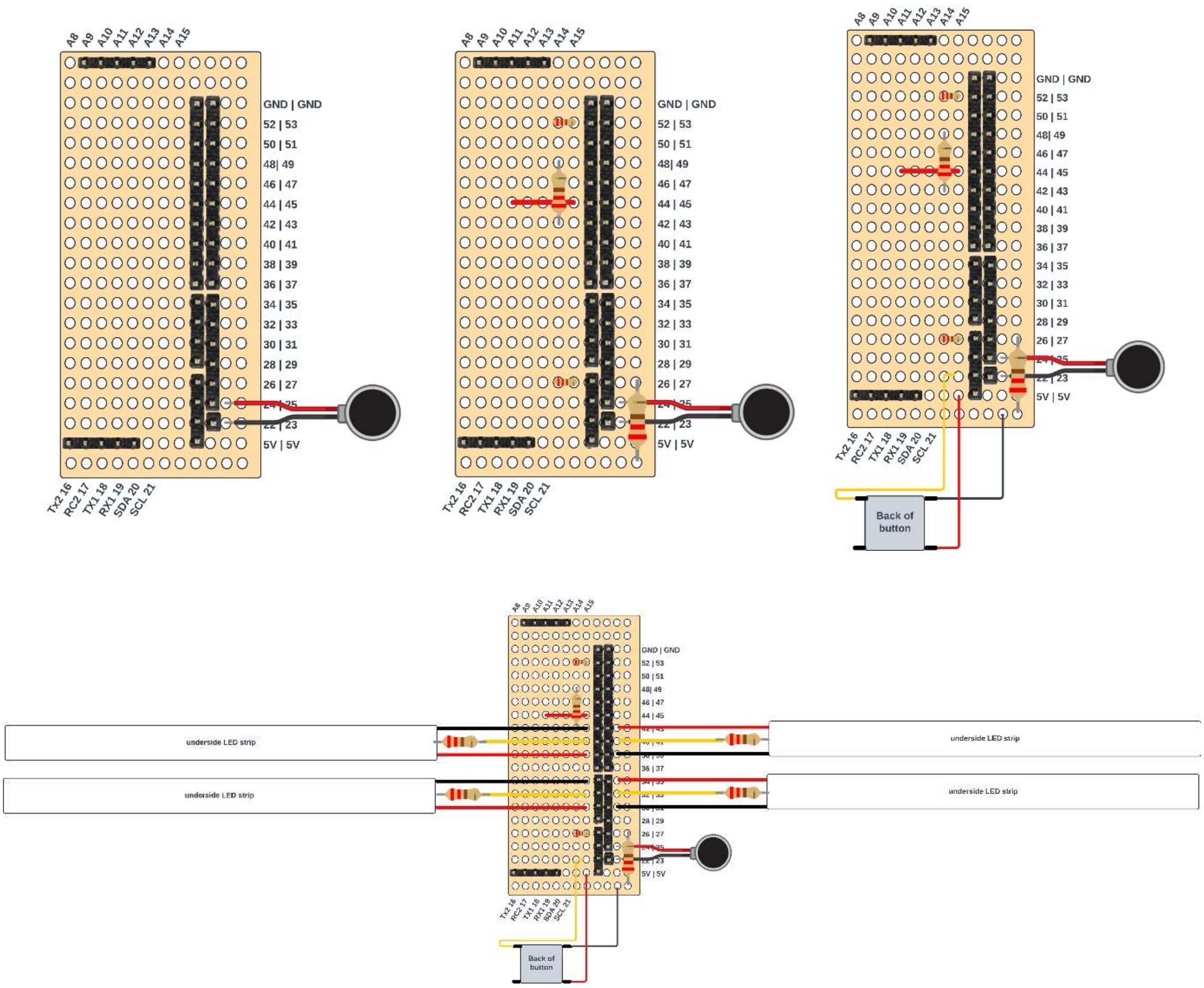


Figure 85: Tailor the PCB to the right size 12x21 holes. The figures illustrate what will be the back side of the PCB which will later be put on the Arduino mega like a shield. Apply the pin headers, vibration motor, 220 ohm resistors, the button and the LED strips like in the figures.

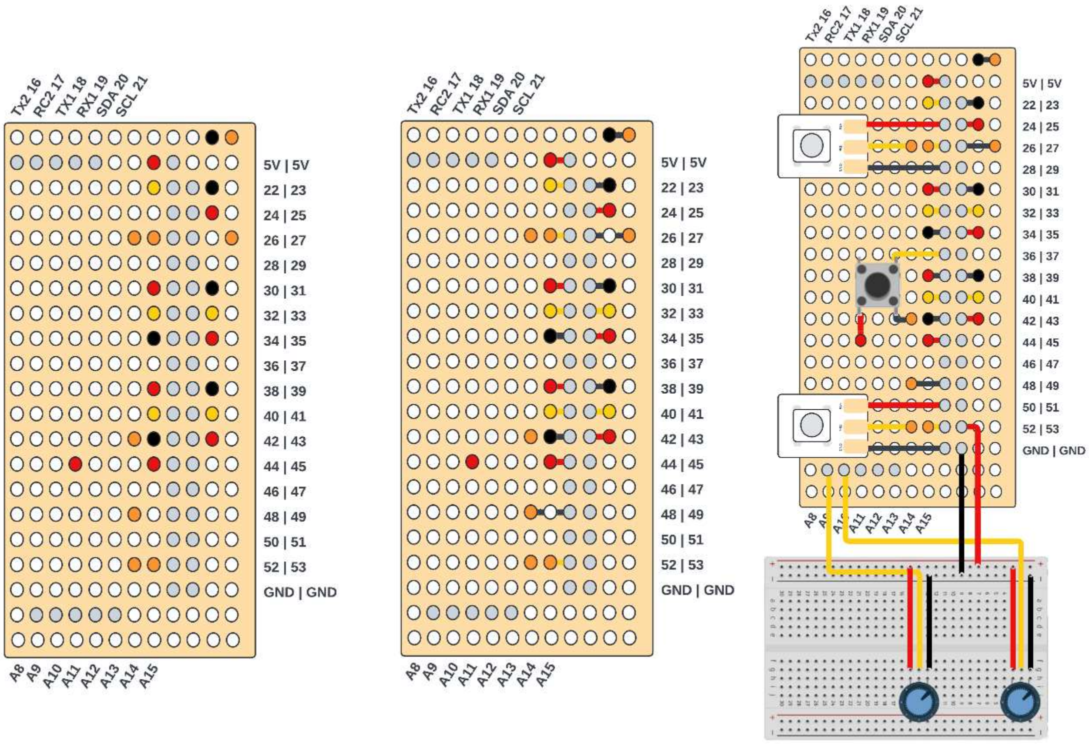


Figure 86: When turning the PCB around so that it faces upwards the following connection points can be seen in the figure on the left: grey = pin headers, Red = power, yellow = data, black = ground, orange = resistor connections. The soldering connections on the PCB can be seen in the middle and right side figures. The energy lights, the toggle button and the simulation of the data collection through the potentiometers also need to be added. These connections can be seen in the figure on the right.

Chapter 7 – Evaluation

Method

The evaluation of the prototype in chapter 7 aims to provide insights in the research question:

RQ: *How can an effective behavior intervention be designed to facilitate pro-environmental behavior among university employees, specifically targeting the responsible energy usage?*

The prototype will be evaluated on its effectiveness/ usefulness to facilitate PEB among university employees regarding their responsible energy usage. The effectiveness/ usefulness of the intervention will be evaluated through the responses to the smartwatch features and the usefulness of the different aspects of the smartwatch. Whether the smartwatch facilitates PEB among university employees regarding their responsible energy usage will be evaluated though the measure of intention. An argumentation as to why this measurement was used can be seen the section "*Evaluation*

" in the method chapter.

With the evaluation of the prototype the an overall conclusion with a discussion will answer the research question in chapter 8. An explanation on how these user tests are performed can also be fount in the "*Evaluation*

" in the method chapter and in "*Appendix F: User testing method and questions*

".

Results

A summarized version of the results of the user tests can be found in Table 13 and Table 14. These tables are colour coded for an easy overview of positive or negative reactions towards certain aspects of the intervention.

Both participant 2 and 4 stated that they thought that all aspects of the intervention were useful to support them to change their energy consumption to be more responsible. More detailed data of the participants opinions about the intervention can be found in the analysis section.

It is good to note that participant 1 in the user test did a different method then the other participants as stated in the "*Evaluation*

" in the method chapter and in "*Appendix F: User testing method and questions*

". In the initial method the learning curve of the intervention meddled too much with the results. Therefore the user test method was revised after this was observed. Participant 1 mentioned that the intervention contained too much information and was too complex. However, no participants in the revised user method stated the same.

Participant responses to smartwatch features and usage intentions

Statements v / Participants ->	1*	2	3	4	5	6
Believes the vibrational notification encourages a more responsible energy consumption.	[green]	[green]	[green]	[yellow]	[green]	[red]
Likes the reminder aspect of the vibrational notification.	[green]	[yellow]	[green]	[green]	[green]	[red]
The streak motivates the user to work towards a more responsible energy consumption.	[green]	[green]	[green]	[green]	[green]	[green]
They appreciate that others can see your energy consumption data through the wristband LEDs.	[grey]	[green]	[yellow]	[yellow]	[red]	[red]
They would use the smartwatch.	[grey]	[green]	** [green]	[yellow]	[green]	[green]
They think other people would like to use the smartwatch.	[grey]	[green]	[green]	[green]	[green]	[green]
They intent to change their energy consumption to be more responsible when the smartwatch would be implemented.	[yellow]	[green]	[green]	[green]	[green]	[green]
Every aspect of the smartwatch is useful.	[yellow]	[green]	[yellow]	[green]	[yellow]	[yellow]

Table 13: Participant responses to smartwatch features and usage intentions. Green = true, yellow = neutral/ partially/ not sure, red = false and grey = no information.

** Participant 1 had a different interview method see the "Results & assessment*

" section in the methods.

*** The smartwatch would need to be incorporated within an existing smartwatch in order for them to want to wear it.*

Explicit mentioned aspects of the smartwatch regarding their usefulness

Aspects v / Participants ->	1*	2	3	4	5	6	Amount of times explicitly mentioned to be: useful	Limited in usefulness	useless
Vibrational notification	[green]		[green]				2	0	0
Energy bar light	[yellow]		[green]		[red]	[yellow]	1	2	1
Energy light	[green]		[green]		[green]	[yellow]	3	1	0
Personal comparison		[green]	[green]			[green]	3	0	0
Social comparison		[green]			[green]	[green]	3	0	0
Circle diagram	[green]	[green]		[green]		[green]	4	0	0
Graph				[green]			1	0	0
Yesterday's performance					[green]		1	0	0
Streak							0	0	0
Performance in relation to last hour			[yellow]		[green]		1	1	0

Table 14: Explicit mentioned aspects of the smartwatch regarding their usefulness. Green = explicitly mentioned useful aspects of the smartwatch, yellow = explicitly mentioned aspects that are limited in usefulness, red = useless and white = not specifically mentioned.
** Participant 1 had a different interview method see the "Results & assessment*

" section in the methods.

Analysis

Public display of energy use via LEDs

It can be concluded that most participants raised some issues about the aspect of the intervention that other people can see your energy consumption data through the LEDs on the wristband. While the visibility of LEDs on the wristband can be motivating for participant 2 by fostering a sense of competition and awareness, most participants are concerned about privacy, potential negative social interactions and assumptions about work habits (e.g. worked a too much or too little) based on their energy consumption.

Another thing that is good to note is that even though participant 3 thought that the visibility of the LEDs raises privacy issues and could initiate bullying or harassment, he still thinks the thing that motivates him most are the bar lights which showcase his personal usage over time. These statements seem to contradict each other since the bar light are the most visible LEDs to others.

Bar lights

The most visible LEDs on the wristband are the bar lights. This was the only feature that had mostly negative responses regarding its usefulness. With one participant saying it was useful, two participants stating that it was limited in usefulness, one participant mentioning that it was useless and two others not explicitly mentioning the usefulness of this specific aspect.

Visibility of LEDs to others vs bar lights

Due to the relation of the visibility to the lights to others and the bar lights (which are the most visible LEDs), it might seem that there is correlation between the perceived usefulness of the bar lights and the opinion of the participants regarding the visibility of the LEDs to others. This suggestion arises because both participants 5 and 6 dislike the LEDs being visible to others and also feel that the bar light is either useless or not very useful. This can be seen in Table 13 and Table 14. However, when looking at their underlying arguments regarding the usefulness of the bar lights, a correlation between the two doesn't necessarily seem the case.

Firstly, the main reason participant 5 thinks the bar light is useless is because he believes that the bar lights in the social comparison state could display skewed information. When certain employees have extremely high energy usage, it could result in almost everyone classified in that employee type falling below the past seven-day average for the group. Therefore, he does not think that the averaging in the bar lights are very useful as this causes data to be hidden to the users. Additionally, he thinks it is rather difficult to understand what these averages, shown by the bar light, mean and how they are calculated.

Secondly, participant 6 reason for why he thinks the bar light is limited in usefulness does not think that the bar light is a necessity. He does think it is unmotivating when the intervention is too intrusive. He states that should not be too distracting from his work and that is has to function in the background. This description could potentially fit a correlation scenario. Nevertheless, he only mentioned the intervention to be intrusive and distracting by the fact that he has to carry it around and by the vibrational feedback. Therefore, he never specifically mentioned that it was because of the visibility of the LEDs to others.

Lastly, participant 1 also thinks that the bar light is not as useful. However, specific information on whether this participant liked the aspect of others seeing your performance through the LEDs is unclear.

Energy lights

The other LEDs that are visible to others are the energy lights. This was generally positively received with half of the participants explicitly mentioning it was useful and one out of six suggesting it was limited in usefulness. Participants generally view the energy lights positively for their intuitiveness, their insights in your energy consumption in the short term and their motivational impact on energy consumption behaviours.

Personal and social comparison vs light bar and energy light

Even though the bar lights are generally poorly received in regard to usefulness, both personal and social comparison within the intervention are generally well received. Half of the participants explicitly mentioned these comparisons to be useful. This is noteworthy as the bar lights and the energy light both showcase the information of comparison states. Therefore, there seems to be a contradiction in how this information is displayed that impacts its perceived usefulness. Additionally, this implies that the information of the comparison states itself is perceived as useful.

Within the intervention there are two ways the comparisons are displayed. Either via the LEDs or via the screen. This information might suggest that users would prefer the comparisons for the bar light on the screen instead of via the lights. On the other hand, the energy light is generally positively received. Therefore, this might indicate that the users in this case would like the comparisons to be visible via the energy lights. The possible difference in display preference with regard to the comparisons is another noteworthy thing to mention.

Another thing to be mindful about is the opinion from participant 5 that the averaging in the bar light (mostly regarding the social comparison) can showcase skewed information. Nevertheless, he also explicitly mentioned comparison to peers (social comparison) to be useful. This seems rather contradictory. However, he also mentions that the smartwatch invites the friendly competition. Meaning that the devices invites its users to share their energy data by removing or lowering the social barrier to do so. He mentions that he would show his energy consumption data to certain people in conversation and that this friendly competition part would be his main driving factor to motivate him to change his behaviour. Therefore, his description of comparisons to peers might actually be a different aspect of the intervention than the social comparison referred to above. However, this might also mean that the participant 5 has a more negative view towards the social comparison which is referred to above, because of the relation between his reason towards the dislike of bar light and the social comparison state.

Utilization of the smartwatch

All participants with available data mentioned that the they thought other people would be interested in utilizing the smartwatch. Additionally, all participants stated that they would use the smartwatch, with an exception for participant 4, who is unsure if she would use it because she believes she already has very low energy consumption. This might suggest that university employees would generally like to use the smartwatch. However, that employees with an already responsible/ low energy consumption might be less interested in trying it out.

Intended PEB change

The intent to use the smartwatch could possibly also be related to the intent to change their energy consumption to be more responsible. All the same participants mentioned again that they would intent to change their energy consumption behaviour to be more responsible when the smartwatch would get implemented. Participant 1 never mentioned anything about (not) wanting to use the smartwatch. He also never specifically got asked the question about his intent to change his behaviour. However, he did state that he would not be motivated to change his energy consumption whenever he already consumed a lot of energy. Therefore his box was coloured yellow in Table 13. Therefore, there might be a relation between wanting to use the smartwatch and intending change their energy consumption to be more responsible.

Analysing design choices with BHM

Additionally, the intent to change behaviour could be correlated with the opinion on how useful or motivating the smartwatch is. When looking at the last statement in Table 13 or to the colours in Table 14, one can see that the intervention is mostly perceived as useful with an exception of the bar light aspect. The *BHM* model in Figure 3 was used to design the intervention to facilitate pro-environmental behaviour among university employees and support them in creating more responsible energy usage habits. When analysing the underlying reasons of the perceived usefulness or encouragement of the different aspects of the smartwatch with this model many design decisions seem to be backed up by the results.

Supportive intervention type

Constant feedback

The aspects of the smartwatch related to the supportive intervention type was the constant feedback of the LEDs. This feedback was meant to be indirect and nondisruptive. However, this the feedback type was not perceived by everyone as nondisruptive. Participant 4 stated that the bar lights are too noticeable and participant 2 mentions that she can imagine that when all bar LEDs are on all the time it can become a bit annoying. The participants did not perceive the same problem with the energy lights. This suggests that the bar lights might need to be improved to be less noticeable.

It is however important to note that these are not the same participants that stated in table 8 that the bar lights were limited in usefulness or useless. Therefore, the noticeability of the LEDs does not seem to be the determining factor which makes the bar lights seem less useful.

The "*Personal and social comparison vs light bar and energy light*
" section stated that the constant feedback in the form of the energy light was very positively received. Participants 2 and 3 specifically mentioned liking the aspect of constant feedback, noting that it allowed them to gain insight into their energy consumption with just one glance at the LEDs. This supports the initial design decision regarding the constant feedback for the energy lights. However, the constant feedback regarding the bar lights should be revised.

Vibrational feedback

Table 13 shows that the vibrational feedback is mostly positively received. The reminder aspect was positively received by four out of the six participants. With participant 2 only responding to it neutrally because the vibrational feedback was perceived to make a too loud of a sound. Additionally, the table shows that four out of the six participants are encouraged to utilize their energy consumption more responsibly through the use of vibrational feedback. The vibrational notification is also explicitly mentioned to be useful by two of the six participants in Table 14. Only participant 4 was not sure if the vibrational feedback would encourage her to use her energy more responsibly, as she already believed she had a very low and responsible energy consumption. The only participant that responded to the vibrational notification relatively negative was participant 6. He stated that he finds it unmotivating if the intervention is too intrusive. He thinks the vibrations are intrusive and will distract him too much from his work. Additionally, Table 14 showed that the vibrational feedback was explicitly mentioned by two participants to be useful, because of the fact that it could serve as reminders when reaching certain thresholds.

The fact that most participants thought the vibrational feedback was useful and would encourage them to use their energy more responsibly could suggest that it would be an effective supportive intervention type aspect. However, if it actually would support the users in altering their habits remains unclear.

Emotional intervention type

The peer pressure and social comparison aspect was positively received by stating that the social comparison and competitive aspect were useful and motivating. The design decision to make the intervention visible to everyone as talked about in "*Public display of energy use via LEDs*

" section raised some issues and might need to be revised. Participant 4 stated that she missed positive reinforcement since she already thinks she does very well and feels like the current feedback of the smartwatch would demotivate her. Lastly, the streak the participants thought that aspect of the intervention was very motivating. All of the participants, except for participant 1 who lacks this specific data, thought that the streak aspect was motivating. However, it is never specifically mentioned to be useful in Table 14. That the streak would cause motivation as an emotional intervention type also corresponds to the BHM model.

Instructional intervention type

Circle diagram

The circle diagram which showcased the users energy consumption per device was explicitly mentioned by four out of the six participants to be useful. This might suggest that this is the most useful aspect of the whole intervention. Reasons for its seemingly success could be that it can show the user why they might have had a higher energy consumption during the day. This way they can look for reasons to justify their energy consumption. Additionally, it is mentioned a few times that the diagram can provides insights into the causes of your energy consumption and that it is intuitive.

Graph

The graph was generally well received. However, only participant 4 explicitly mentioned it to be useful. Additionally, participant 6 mentioned it to be a valuable addition to the smartwatch. Multiple participants stated that it could help provide insights into their energy consumption. Nevertheless, opinions about whether the graph could actively change their behaviour were dispersed. Half of the participants stated that they would like to see the suggestions or information on what they can do to can change their energy consumption. Additionally, participants mentioned that they would like to see an indication of which devices were used each hour.

Many participants suggested improvements for the graph like the two improvements mentioned above. This could imply that they might not see the graph currently as a explicitly useful aspect of the intervention now, but that they do see its potential.

Yesterday's performance and the performance in relation to the last hour.

Both yesterday's performance and the performance in relation to the last hour are generally not perceived as useful as the other pages. They are only specifically mentioned to be useful by participant 5 who thinks the things that are most useful to him are the aspects that improve your insights in your energy consumption in the short term. Participants mention that the yesterday's performance page's effectiveness may be limited if the user was not actively trying to improve their consumption. The page may only trigger action if it shows a significantly high percentage. Additionally, participant 3 thinks that while you are doing something that you already are quite aware of what is happening. E.g. if the light bar first only shows 5% of energy consumption and then at 30% of energy consumption he understands that he already used a lot of energy. Therefore, he does not really believe that the page is necessary. Nevertheless, it generally seems that the users would like to keep these pages in the intervention. The pages seem to be specifically targeting an audience who want to work on their short time improvements. Therefore, they might be less useful to an audience who is not focussed that much on this matter.

General opinion

In general the visual aids of the instructional intervention type were seen to be insightful and intuitive with one page being perceived as more useful than another. However, the participants did seem to miss suggestions on how they could improve their energy consumption. Not being aware of which actions had the most effective consequences. Therefore, the decision to not incorporate this within the design during the brainstorming session should be revised. Another educational aspect that was left out of the smartwatch was the education on why they should save energy. However, this was never once mentioned in the user tests. This suggests that this might have been a good decision. Additionally, it is mentioned that insights in one's energy consumption can be motivating. This corresponds with the BHM.

Conclusion

In conclusion, the design decisions for the constant feedback with regards to the energy lights, the vibrational feedback, the peer pressure and social comparison, circle diagram, graph and encouragement pages (e.g. streak, yesterday's performance and performance in relation to the last hour) seem to be positively supported by the results. Indicating that they effectively tackle their part of the intervention type. Design decisions about the prototype that could be revised are the constant feedback with regards to the bar lights, the visibility of the LEDs (specifically the bar lights), the incorporation of positive reinforcement and the incorporation of suggestions on how to save energy. Overall, participants state that they would intent to change their energy consumption behaviour to be more responsibly. This together with the fact that they would like to use the intervention seems like a positive indication that the smartwatch's design would succeed in facilitating pro-environmental behavior among university employees.

Meeting stakeholder requirements

Table 15 provides an overview of the stakeholder requirements, color-coded to indicate whether each requirement has been met. The prototype was able to meet all the requirements classified as 'must have'. Only the requirement to save more energy than being used has not been tested and cannot be answered. Additionally, this version of a prototype does not allow the user to put the smartwatch around their wrist. Therefore, the requirement that it should be able to be taken off has not been realized. However, design decisions have been made in the specification phase that would realize this requirement.

Multiple requirements from the 'should have' categorization have also been (partially) met. However, on some requirements some opinions were varied. Additionally, the requirement to show an overview of what type of devices are currently in use is not met however, the intervention does contain this information indirectly with other types of feedback e.g. energy light, cumulative energy consumption per device in a percentage of a whole. So, the question is if this is really needed.

Not many requirements from the 'could have' categorization have been realized. These aspects could provide examples for future improvements for the intervention in the future.

Lastly, the requirements for the 'won't have' categorization received varied opinions. Therefore they are only partially met. Furthermore, additional infrastructure was used, however it also uses already existing infrastructure in the form of a smartphone. Nevertheless, this is only a small part of the intervention.

Must have	**Should have**	**Could have**	**Won't have**
Must not require more energy to be build and function than what can be saved	Should be as small as possible	Comparison of energy consumption in relation to other employees	An additional device (only use the existing infrastructure and artifacts)
Must not sacrifice comfort for a reduction in energy usage	History reports	Top down intention to sustainable transition	Won't have very "loud" notifications
Must secure privacy	Overview of what type of devices are currently in use	Comparison with the university energy usage	Something that causes a hassle
Option to turn smartwatch on and off	A lot information visible to the user	Comparison of users energy use of a specific type of device and the average energy usage of that device	Won't be something that you have to actively think about
Option to turn lights off and on to provide option to share information instead of obligation	A clear unit to express energy savings	Compatible with other devices (e.g. smart watches)	Won't be something that you can forget
The option to not receive feedback	An intuitive interface/ easy to use	Own energy source	Won't be annoying.
Option to take the smartwatch off	A big enough screen for people to read	Precautions for colour blind people.	
Option to delete information on a certain time frame (e.g. once per month)	Should be able to monitor all of your energy consumption as a precaution against a skewed representation of the users energy consumption	Option to form social bubble to share performance information. Also the additional option to choose who to share your bubble with.	
The option to personalized feedback settings	Precautions for unfair energy consumption comparisons (e.g. office employee vs. lab employee	Contextual data shown alongside energy usage for a more complete picture when doing social comparisons	
	Subtle feedback	Notifications when having an extreme high energy consumption for a period of time.	
	Provide feedback when reducing energy consumption		

Table 15: Requirements of the core users (university employees) prioritized with the MoSCoW method colour coded in whether the prototype met the corresponding stakeholder requirements. Green = requirement met, yellow = requirement partially met, red = requirement not met and grey = requirement not applicable to current prototype.

Chapter 8 – Discussion & Future Work

The main objective of this study was to design an effective behavior intervention to facilitate responsible energy consumption among university employees. The results of this study suggest that that the smartwatch's design would succeed in facilitating pro-environmental behavior among university employees as the results showcase a clear intent to change their behaviour.

However, not everything described in the specification chapter has been realized within the prototype. This poses a limitation. Not the whole idea can be evaluated, only the part that has been realized can be evaluated. Two important aspects that worth to mention and are left out are the data gathering part of the product and the reminder for when the user left on certain electrical appliances and walked away. Future work should focus on implementing every aspect of the idea. This way it can be evaluated if the data gathering part is feasible and if it poses any impracticalities such as accuracy issues, data latency, user privacy concerns and the integration of data from multiple sources. Additionally, the effectiveness and user-friendliness of the reminder feature to change behaviour can be assessed since this addition could play a major role in the supportive intervention type aspect of the intervention.

To the best of the available knowledge, this is the first (research) project for the University of Twente to create more responsible energy consumption habits through behaviour change. It is however difficult to compare this project to other research project aiming to facilitate the pro environmental behaviour of building occupants with the regard to energy consumption. This is the case because of that fact that only intention to change behaviour has been measured. This is not the same as performing the actual action of behaviour change or the change of behaviour (habits) in the long term which is the thing that has been measured in the other studies. Therefore, there this presents a limitation in making direct comparisons.

Another limitation of the study regarding the fact that intention was the measured variable is that this research could only suggest that the smartwatch would potentially succeed to facilitate responsible energy consumption among university employees. It is not able to evaluate impacts about the effectiveness of the supportive intervention type elements of the smartwatch. Even though these might be considered to be the most important elements.

The supportive intervention type elements where however generally positively received and it was often mentioned in a positive light that they could serve as reminders. Gravert [41] states that reminders are an effective tool to change behaviour. Additionally, Cole-Lewis and Kershaw [42] conducted a review of behaviour change interventions in disease management and prevention using text messaging. Their findings indicated that 8 out of 9 studies demonstrated evidence supporting the effectiveness of text messaging as a method for promoting behaviour change. This could be similar to the vibrational feedback and its corresponding pop up which contains a text message. The text messages were often sent via SMS which could potentially also cause a similar buzz notification on one's phone. This similarity and the fact that the vibrational feedback was generally well received may suggest that this is an effective tool to change behaviour. Nevertheless, the actual behaviour change has not been measured and the studies mentioned primarily discuss reminders related to topics other than energy consumption.

Furthermore, Pirolli et al [43] and Prestwich et al [44] found that reminders of implementation intentions sent via SMS messages increase the effectiveness of behaviour change goals. Since the users of the smartwatch should set their energy consumption goals for themselves, they also set their behavioural intention themselves. Reminders of implementation intentions (or behavioural intentions) are the constant feedback types e.g. the LEDs which include the light bar and the energy lights. These constant reminders give users insight into their energy consumption, allowing them to assess whether they are meeting their personal goals or intentions. If Pirolli et al [43] found that reminders in the form of text messages increased the effectiveness of the translation from implementation intentions to behaviour change it could potentially be true for other feedback types, like constant feedback as well. However, this is a pretty bold claim and would require further testing.

Casal et al [45], conducted a study that asked participants to allocate points to different items which provide a monetary payoff. The extend of this payoff is dependent on the amount of point allocated to specific items. The participants did the task 21 times and received feedback about their performance. The result of this study showed that the continues provision of feedback (feedback after every round) did not lead to better performances than providing feedback every three rounds. The result of this study might explain why some users stated that the bar lights were unnecessary or not useful in practice. Nevertheless, the study also suggests that the similar performance outcomes might be due to the design of the feedback mechanism and the relatively short duration of the experiment, which might not have allowed for the differences to become apparent. Additionally, the consistent and non-consistent feedback might have helped participants adjust their strategies almost as effectively as in the continuous feedback condition.

Therefore a reason between the difference of the perceived usefulness between the energy light and the bar light might be due to the difference in cognitive effort and time. These are two main roadblocks that block intention to translate into behaviours. There are two reasons why the bar light might require more cognitive effort.

Firstly, is the difference in informational insight it provides. The energy light provides insight in the current energy consumption in the moment which allows the user to focus on short term improvements. In contrast, the bar light is the cumulative energy consumption over the whole day. This difference means that users need to mentally integrate and analyse information over a longer timeframe to strategize effectively for responsible energy consumption throughout the day which requires more cognitive effort and time from the user.

Secondly, Gravert [41] and Froehlich et al [12] emphasizes that all forms of reminders need to be closely tied to the specific context and moment when an action or desired behaviour occurs. For example, when the energy light is coloured red the user can directly undertake action if the context of the situation prompts it. They can for instance turn of the oven in the lab off. However, when the bar light is red their energy consumption in the moment might be low. E.g. the energy light might be coloured green. Then the feedback of the bar light is not closely related to the specific context and moment when the desired behaviour should occur. The fact that the feedback is not closely related to the context and moment of the behaviour could require some extra cognitive effort.

Since the bar light requires more cognitive effort and time from the users, the information of the bar light might be less useful, as indicated by the findings. Even though long term plans might be required to further reduce ones energy consumption, it might not be necessary to have the bar light as a constant feedback type. As the results stated, it might be sufficient to only have the bar light visible on the screen rather than also be visible through the LEDs.

Another reason to support the suggestion to leave out the bar light LEDs and only have the bar light visible on the screen has to do with the issues raised regarding the visibility of the LEDs. The results mention that the bar light LEDs could be seen as annoying when all of the bar light LEDs are on and as too noticeable and disruptive. A mentioned suggestion was to reduce the amount of LEDs on the light bar or to reduce them in size. However, if the bar lights don't require a constant feedback than this might not be necessary. Furthermore, people were concerned about privacy, potential negative social interactions when the LEDs were visible to others. The most visible LEDs are the bar lights. Therefore it is suggested to leave the bar light LEDs out of the next iteration for the prototype. This approach will also contribute to energy savings by minimizing the need for electronics in constructing the intervention, thereby reducing its overall energy consumption. Furthermore, it eliminates the need to power LEDs, which further reduces energy consumption.

Nevertheless, it could be decided to leave the bar light LEDs in as participants did mention to find it fun aspect of the smartwatch. Furthermore, when having the option to turn off the bar lights (and leaving the energy lights on) this would presumably also not have any negative effects on their behaviour. However, in this case it would be smart to look if the amount of bar light LEDs can be reduced and/ or to reduce them in size. Nevertheless, future work could possibly focus on why people thought the energy bar light was not practical or unnecessary in order to make an educated decision on whether to leave the bar lights LEDs in or not. It would also be good to check whether the energy bar lights on the screen are seen as a more useful addition.

This also brings up a question for future research in how big the LEDs of the bar light or energy light should be in order to not be annoying, distracting or disruptive while still present enough to provide the necessary information to the user. In this study the size and amount of the energy lights were not seen as annoying, distracting or disruptive. In fact the two out of the six participants in the user testing mentioned liking the aspect of constant feedback, noting that it allowed them to gain insight into their energy consumption with just one glance at the LEDs. This supports the initial design decision regarding the continuous feedback for the energy lights. Therefore, considering that three out of the six participants found the energy lights useful, they should be retained in the next iteration of the prototype.

Another issue that was raised with regards to the energy bar lights was that averaging could showcase skewed information. This was specifically mentioned for the social comparison state. In which it was feared that if one employee had an extreme high energy consumption other employees classified in the same category could potentially all be below the average energy consumption of this specific employee type.

The participant in question (participant 5 in the user testing) suggested replacing the averaging of social comparison on the bar light with a bar scale that displays information about the percentage of peers he is outperforming. However, this could result in an unintuitive interface as the personal comparison state would still showcase an average. Furthermore, the information about the percentage of peers he is outperforming is very static information. Meaning, it is not necessary for the information to be visible all the time on the screen. Participant 5 did however mention that it would be a clearer indication for their performance regarding the competitive element of the intervention. Therefore, an extra screen page which showcases the users rank of the current day could be added for extra motivation. However, it should be carefully considered on how to realise this rank. For instance, when people are on holiday they won't have any energy consumption at their workplace. Meaning that they will always be in the top. Therefore, it is suggested that only people that are working on the UT that day are included. Additionally, it is proposed to have the rank be based on the energy consumption per hour to prevent working hours from discriminating rank performances.

To solve the potentially skewed information shown in the comparison state one could do the following:

1. Eliminate outliers from the average data
1. Make new employee categories based on new insights into required energy consumption per job type.
2. Split existing employee categories up into different ranks. The users can move up and down the ranks and will compare their energy consumption to people in the same rank. Some suggestions for possible ranks:
    - **Energy master:** Your energy efficiency is outstanding compared to others.
    - **Energy expert:** You're doing better than most in conserving energy.
    - **Intermediate:** You're on track with your energy efficiency efforts.

- **Energy explorer:** There's room to improve your energy conservation practices.
- **Energy novice:** You have a lot to learn about energy conservation practices.

There could however be a few downsides to these solutions. The first solution delete valuable data since the outliers could sometimes represent legitimate variations or anomalies that provide insights into energy consumption patterns. Moreover, determining what counts as an outlier can be subjective and might vary depending on the context.

The second solution requires data of employees energy consumption per job type and perhaps even per building which can influence the amount of control over their energy consumption. This might not always be available or reliable.

The last proposed solution could foster competitiveness. This might motivate some employees but could also undermine teamwork and collaboration efforts as employees solely focus on their individual performance. Moreover, it can create feelings of pressure or stigma among those in lower-ranked categories. This begs the question if the categories borders are stationary or that if they are dependent on the people within the ranks. The last option would mean there would always be employees that would be categorized as "energy novice". This would probably be very demotivating. However, when having stationary borders people can improve. Therefore, this would presumably be the most effective option within this solution.
When trying to apply this solution within the smartwatch in the specification phase it was decided to leave this aspect out, because of the complexity and difficulty of implementation. The borders of the different ranks can only effectively determined with supporting data. However, this data was not available then. Furthermore, the aim of the intervention is to facilitate responsible energy consumption. Not to reduce the energy consumption to zero. This aspect motivates the users to reduce their energy consumption towards zero instead of thinking about what is responsible. Another thing to keep in mind when implementing is over which time span the ranks are determined (e.g. per week, per month etc.). Lastly, environments and context can influence the ranks. Think about weather, amount of meetings etc. How does the smartwatch make sure that the ranks are fair and don't discriminate? Nevertheless, it could still be a very encouraging aspect to be added to the intervention when executed correctly. However, it might is probably too complex to implement.

The last concern raised about the bar lights were the intuitiveness of the resetting of the lights. The fact that the resetting of the bar was not seen as intuitive is contradictory to the findings in the "*Interface design for a bar or gauge*

section in the state of the art. This implies that the experience bars that were analysed were not a good example to base design decisions on. This could either be because the information that was shown in the experience bars and the energy light is too different or that the physical representation of the energy bar light is too different from the experience bars in the games. Even though the participants said that the energy bar lights were unintuitive they did state that they thought the visual representation of the bar lights were clear once they understood how it worked.

Suggestions that the participants mentioned to make the energy bar light more intuitive was that when you reached your average (100%) you don't turn the LEDs off. Instead you let a new colour creep in the old colour. For example, when 100% is reached all lights are green. Then when it is bigger than 100% the green of the first LEDs on the right of the smartwatch would change to yellow while the rest of the LEDs stay green. This could be a good improvement. However, when the RECT percentage is over 160% the lights turn red. Meaning that when the bar light does its second round (e.g. RECT > 200%) no indication of the percentage is shown anymore. This was the initial reason for resetting and turning of the light bar. Nevertheless, this suggestion could potentially make the bar light more intuitive if the bar 'lights' on the screen have a symbol or indicator for the last 'light' that was on. Think for example of an arrow or a dot. Another option is to alter the outline of the bar lights on the screen. For instance making the outlines of the bar 'lights' on the screen thicker up to the last 'light' that is on. A solution for the bar light LEDs is not needed since it is proposed to leave the light bar LEDs out of the next design. Therefore, this is only applicable to the light bar on the screen.

Having discussed continuous feedback it's now crucial to explore other potential enhancements for more effective behaviour change. Results show that the effectiveness of the graph to actively change behaviour are varied. This could be because participants need to invest more cognitive effort to gain relevant insights into their energy consumption compared to other visual aids, such as the circle diagram. When analysing the graph, users themselves have to think about the context of their energy consumption each hour and determine what it means. In the circle diagram the context is less abstract. To reveal more of the context to the user in the graph the following suggested improvements could be made:

1. When clicking on a specific device in the circle diagram, a graph should be shown indicating how much the device has been used each hour. This graph will feature double bars: one bar will represent the device's energy consumption as a percentage of the total energy usage for that hour, and the other bar will indicate the distribution of the device's energy consumption per hour relative to its total energy usage. To enhance clarity, colour code the graph to match the device's colour in the circle diagram. (This might make the current graph page unnecessary.)
2. Instead of showing the energy consumption per hour in watt, showcase the energy consumption per hour in percentages relative to the average energy consumption per hour. Colour code the percentages with green, yellow, orange and red so the users can immediately see which hours they went over their energy consumption.
3. When clicking on a bar in the bar graph, show a circle diagram of the different device's contribution of the energy consumption in that specific hour.

4. Only display the working hours and give notifications if the energy consumption after work hours is still high (this notification could serve as a reminder to turn off left on electrical equipment)

For a next prototype iteration it is proposed to make all four of the adjustments. The reason why the graph from suggestion 1 should showcase two bars is because the first bar showcasing the device's energy consumption as a percentage of the total energy usage for that hour will provide the user with insights in whether the device was a main driving factor in that hours energy usage. However, it would also be necessary to showcase to the user when the total energy consumption was high and low. This is necessary for the following reason: Imagine if you have a work light on the whole day, but you are also utilizing many high powered energy devices in your lab. Than during all the hours your work light will have a low percentage in the graph since it did only contributed a little bit to the total energy consumption of the hour. However, when you finish the work with the lab equipment and turn it off suddenly it is only the work light that is all of your energy consumption. Therefore, this is now 100% in the graph. This might mislead the user to think she used the work light way more than in the hour that she finished with her lab equipment which is not the case. This is where the second bar comes in. This will indicate the distribution of the device's energy consumption per hour relative to its total energy usage. With this information the user should be able to get a better understanding about the context of their energy consumption per device and per hour.

The reason the suggestions visualize their data in percentages it was mentioned that watt was not a clear unit. If all participants in this study shared the same opinion is unclear. However, the participants that mentioned it explained that they did not really know what it meant or when something was a lot. Providing comparisons through percentages instead may address this issue.

Suggestion 2 will provide a more intuitive overview to the user to see which hours their energy consumption was high compared to others than the current graph in the prototype. suggestion 3 provides insights in the context of the energy consumption that hour. It gives the users insight into which devices were the main contributors for the energy consumption that hour. Something that was lacking in the current graph.

An important thing to consider when implementing suggestion 2 is that exceeding the average hourly energy consumption does not necessarily indicate a problem. For example, university employees are likely to use less energy during breaks, this means their energy consumption during work periods may naturally be higher than the average. To assess whether this is an issue, further testing would be needed. Alternatively, excluding break hours from the calculation of the average hourly energy consumption could be a viable solution.

By implementing all these solutions the graph and circle diagram will be more closely correlated. Making it supposedly easier for the users to grasp the context of their energy consumption. This would improve the educational aspect of the intervention and the reduce the required cognitive effort and time to make sense of the provided information. Therefore the implementation of these suggestions would likely more effectively facilitate the behaviour change among university employees.

An alternative suggestion could have been to show in the graph in the current prototype which hour which devices were used. With the devices being colour coded the same way as in the circle diagram. However, this suggestions was discarded as it might make the screen a bit too crowded, overwhelming or busy.

Some other things to mention are that the intervention might not be motivating for university staff members that already utilize their energy in a more responsible manner like participant 4 in the users testing. This is not per se a big issue as they already poses the desired behaviours. However, one can always improve and it is these employees that should set an example and share their best practices with other employees. This sharing of best practices could be encouraged if they were also wearing the intervention. Then other employees can also see that they are doing very well. To engage employees that already poses responsible behaviours participant 4 suggests to add more positive notifications. This participant mentions that she would mostly receive reminders about her energy consumption while she knows she is doing very good which demotivates her.

Then there are still a few screen pages that have not been discussed. It is suggested to keep the yesterday's performance and the performance in relation to the last hour pages in the intervention. They were not seen as the most useful aspect of the intervention. However, it was never mentioned that they would have liked for the pages to be left out. Except for participant 1. However, this participant experienced the learning curve of the intervention which made him think the intervention contained to much information. However, none of the other participants mentioned this. Therefore, this opinion is probably related to the learning curve aspect of the intervention. Additionally, these pages where found especially useful by one particular participant. This participant thought the short term insights into his energy consumption was most useful. Therefore, the yesterday's performance and the performance in relation to the last hour pages can be left in the intervention for this type of user.

An improvement for the performance in relation to the last hour page is to add colours to indicate improvement, decline or stabilisation. Participants thought it was unintuitive that the percentage sometimes showed an improvement and other times a decline. Even though it was visible in the text above, they suggested to add the colours red for decline, yellow for stable and green for improvement to make this directly clear from one glance.

The last page to be discussed is the streak page. The reason that the streak is probably not specifically mentioned to be useful is because it is an emotional intervention type with only causes motivation, but no insights. All participants mentioned to find the streak motivating, but none mentioned it to be especially useful. Therefore, this page can also be included into the next prototype to increase the engagement and motivational aspects of the intervention.

Other improvements that have not been mentioned yet:

- **Circle diagram:** Delete the category 'other' in the circle diagram
- **Switch between comparisons on the screen:** Switch on the screen between social and personal comparison for the energy bar light and energy light by clicking on the energy light.
- **Similar legends:** Make the legend of energy light and energy bar light the same. This way the users knows that when you have the same color on the energy light the whole day you will also end up having this color for the energy bar light at the end of the day.
- **Suggestions for actions:** An important improvement to mention is to add suggestions for actions. Half of the participants stated that they would like to see the suggestions or information on what they can do to can change their energy consumption.
- **Add other users:** Allow the users to add friends. Add a page or an option where users can compare themselves with friends. Additionally add that users can fill in that they share an office together and the option to compare to other rooms as well.
- **Incorporation into a smartwatch:** Include this intervention into an existing smartwatch. The pages on the screen can be part of an application. It should be made sure that all pages fit into this smaller screen. The wristband with the lights can be a separate product that the user can buy to switch out with his or her existing smartwatch wristband. If it is not possible for pages to fit onto the smaller screen one could consider to include the application on the phone to show specific detailed information.

Other future work that has not been mentioned yet:

- **Reminder types:** Which reminder types work best and how to effectively implement them for behaviour change?
- **Life Cycle Assessment:** Do an LCA to check if the intervention saves more energy than it uses.
- **Data gathering method with less infrastructure:** Look into different data measuring techniques that would meet the requirements of the data gathering mentioned in the "*Data gathering*
- " section and which requires less infrastructure.
- **Improving comparisons among employees:** This could, for instance, entail that employees provide the number of hours they spend as office employees, lab workers, or professors. The hours per function type can then be analysed to estimate an average for similar employee types.
- **Other average time frame:** Comparing university employees with their energy consumption over the last 7 days is expected to be a relevant time frame for comparison due to weather and season changes. However, other variables like whether the employee was in the office are not taken into

account. The employees are not in the offices during the weekend. Therefore, maybe a 5 day comparison might also already suffice. It is advised to only let the days count for which the employee was in the office. Meaning if an employee has a 5 day work week and it is Wednesday he or she is only compared to last Wednesday, Thursday, Friday, Monday and Tuesday. Measuring if an employee has been near the office can be realized through the measuring of a Bluetooth connection with the smart plugs in the office. Nevertheless, the time frame of the averaging was not tested within this study. Therefore, real conclusions about this aspect and the necessity of these mentioned adjustments can’t be made.

Things that can be done differently next time intention is measured, is to measure the change in intention instead of intention itself. From the findings now it is unclear whether the users would already have an intention to save energy without the intervention. The statement was phrased:

“They intent to change their energy consumption to be more responsible when the smartwatch would be implemented.”

To improve future measurements, it would be beneficial to assess the initial intention levels before introducing the intervention and then measure the change in intention afterward. This approach would provide a clearer understanding of the intervention's impact on users' intention to save energy. The same counts for measuring responsible behaviour. To improve future measurements the change in responsible behaviour should be measured with a measurement before the implementation of the intervention and a measurement after the implementation of the intervention.

Chapter 9 – Conclusion

While the role of changing universities employees energy consumption behaviour to be more responsible is still a untouched energy saving topic within the Campus & Facility Management (CFM), it can play a vital role in significantly advancing the CFM's mission with limited funding while reducing energy costs. This study demonstrates through user tests that the intervention design supports both the intention to adopt more responsible energy consumption behaviours and the willingness to use the intervention among university employees.

The Behavioural Habits Model (BHM), which integrates elements from the Theory of Planned Behaviour (TPB), Geller's model, and Stern's theory, emerges as an effective framework for designing pro-environmental behaviour interventions aimed at promoting responsible energy usage.

Key techniques identified to facilitate responsible energy consumption behaviour changes include:

- **Motivational Interventions:** Energy consumption streaks were particularly effective, utilizing gamification to encourage responsible behaviour.
- **Instructional Interventions:** Providing real-time insights into current energy consumption, comparisons and clearly contextualized information, particularly per device, proved beneficial. Conversely, insights into consumption per specific time units like hours were less useful, likely due to the additional cognitive effort that was required.
- **Emotional Interventions:** Competitive elements were found to be most motivating.
- **Supportive Interventions:** Reminders, real-time feedback and actionable suggestions for responsible energy use were found to be most useful to reinforce desired behaviours. No detailed analysis was created for the goal setting BCT. Therefore, no indefinite conclusions can be drawn. The background literature stated that goal setting generally proved effective to change behaviour.

These key techniques can be supported by the collection of electricity consumption data through smart plugs. Smart plugs allow for individual data collection per device and facilitate easy linkage of staff to the specific energy usage of these individual devices.

The study concludes that a multifaceted design approach, combining motivational, instructional, emotional, and supportive interventions, is most effective for promoting responsible energy consumption among university employees. By utilizing the strengths of the BHM model and integrating these techniques into energy consumption behaviour changing interventions, the University of Twente can achieve significant energy savings and advance their sustainability goals with limited financial resources.

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Appendix A: Informed consent form

Information sheet for reducing energy consumption among university employees through behaviour change

Dear prospective participant,

Thank you for considering taking part in this interview. This research project aims to create an effective behaviour intervention to facilitate pro-environmental behavior among university employees, specifically targeting the responsible energy usage. Responsible pro-environmental behaviour include simple actions to reduce energy consumption e.g. turning off the lights, turning down the thermostat, only turning on the dishwasher when it is completely filled etc. The purpose of this specific interview is to get insights in the opinions of the potential end users (university employees) of this intervention. These opinions are used to further develop ideas and prototypes. Therefore, it is encouraged to answer all the questions honestly. All feedback is appreciated!

Participating in this interview is voluntary; there are no specific benefits to be gained by participation. It is possible to remove yourself from the study at any time. All gathered data about your participation will then be destroyed. No personal data will be collected apart from your demographics. When you have a very specific employee function within the UT that could potentially identify you as participant this will function will be generalized. Therefore your contribution will remain anonymous. The interview will be audio recorded. This will be saved in the personal files of the researcher secured with passwords. The data will be used and transcribed in the bachelor thesis report. After completion of the bachelor thesis the audio files will be destroyed. There are no known risks related to this study.

Contact details: Nienke Dik, N.e.dik@student.utwente.nl, 06 81252163

Contact information for questions about your rights as a research participant can be found in the consent form.

Consent Form for reducing energy consumption among university employees through behaviour change

YOU WILL BE GIVEN A COPY OF THIS INFORMED CONSENT FORM

Please tick the appropriate boxes	**Yes**	**No**
Taking part in the study		
I have read and understood the study information dated 04/05/2024, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	◻	◻
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	◻	◻
I understand that taking part in the study involves a audio-recorded interview and data recording via written notes. The audio will be transcribed. The audio will be destroyed after the graduation project has been completed.	◻	◻
Use of the information in the study		
I understand that information I provide will be used for reports and possible knowledge sharing for future research studies.	◻	◻
I understand that personal information collected about me that can identify me, such as my name, will not be shared beyond the study team.	◻	◻
I agree that my information can be quoted in research outputs	◻	◻
Future use and reuse of the information by others		
I give permission for the recorded audio files and information that I provide to be archived in anonymized transcripts in a report. I give consent that this report will be visible at the UT site along with all the other student theses so it can be used for future research and learning. No names will be mentioned and specific employee functions will be generalized.	◻	◻

Signatures

______________________ ______________________ ________

Name of participant [printed]

Signature Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

__________________________ ____________________ _________

Researcher name [printed] Signature Date

Study contact details for further information: Nienke Dik, N.e.Dik@gmail.com

Contact Information for Questions about Your Rights as a Research Participant

If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Secretary of the Ethics Committee/domain Humanities & Social Sciences of the Faculty of Behavioural, Management and Social Sciences at the University of Twente by ethicscommittee-hss@utwente.nl

Appendix B: Stakeholder interview questions

1. Explanation of the Graduation Project

My graduation project focuses on sustainability, specifically on energy conservation. I investigate how users can be engaged in the process of energy conservation. (20%) The scenarios for energy conservation are shown in the image. To change these scenarios and save energy, people's behaviour needs to be adjusted.

2. Demographics

Explain that when the participant's demographics refer to the participant as a person, this is adjusted so that this is no longer the case.

Age:

Gender:

Nationality:

Occupation:

A. How much control do you have over your personal energy consumption?

B. What is your opinion on sustainability or energy conservation?

C. Do you feel that you have a good understanding of why it is important to save energy?

D. What are personal points of improvement regarding your energy usage?

E. What do you consider important for an intervention that enables you to save energy? When would you use such a product? Show Figure 28.

3. Show and explain BHM

Mention that intention does not automatically lead to pro-environmental behavioural habits; supportive intervention is needed for this.

(Unconscious) incompetence entails importance, knowledge and skill.

Policy support is the willingness to make economic sacrifices to protect the environment (e.g., by paying much higher taxes or prices, supporting modes of transportation other than a car, giving people control over energy-consuming devices)

Subjective norms are the perceived social pressure or expectation of an individual to engage in a particular behaviour.

A. Which intervention type do you think you would personally benefit from the most? (and others?) Why? Which one is least applicable to you? Why?

B. What do you consider important for these intervention types to have?

4. Show Figure 37 & explain the figure

A. What is your initial impression of this idea in general? (What is good, what is bad. Any comments?) Would you do things differently and why?

B. I want to create a wearable device because then you always carry the intervention with you and it can help you in any environment. (most impact) A wearable could be, for example, a bracelet, badge, glasses, etc. (just something you carry with you) Would you be willing to wear a wearable device to save energy? Why (not)? When would you (not) agree to wear it? What does it depend on?

C. Are there scenarios in which you would not want to receive feedback? e.g., meetings, sleeping, etc.? Is unobtrusive feedback desired in these scenarios? e.g., light, etc. And are these also sufficient in other scenarios? What should the feedback meet? Do you have preferences for certain types of feedback? Visual, audio, etc.

5. Show the initial idea of Figure 38

A. What is your initial impression of this idea in general? (What is good, what is bad. Any comments?) Would you do things differently and why?

B. Which aspects of the idea are most important to you? Are there aspects that are not necessarily needed? Why?

C. Do you think certain aspects are missing? Or can you think of any improvements?

D. How do you want high and low energy consumption to be displayed? Do you want this on a fixed scale of what high and low energy consumption is compared to other users or compared to your average energy consumption from the previous day? Or something else?

E. Are there other things you would like to display differently? For example, compared to others instead of your total energy consumption? Would it be better if you also receive feedback when an energy-saving scenario is detected?

F. Do you see any potential problems that you could encounter when implementing this idea?

G. Do you have any further comments?

Appendix C: Personas

Figure 87: : Persona for the supportive intervention type.

Type
EMOTIONAL/ REWARD

Annika

LAB EMPLOYEE

ABOUT ME

AGE: 29 years
GENDER: Female
NATIONALITY: Dutch

Annika likes cool gadgets and thinks time efficiency is very important. Her home is fully automated and she likes to not have to perform many actions.

- Time efficiency
- Competitive

PERSONAL DEVICES

BEHAVIOURAL INFORMATION

Annika does not see a reason why she should perform an action if the automatic systems can do it for her. She often leaves devices on in the labs because they take a long time to turn on. This way it is easier. She does the same with her laptop.

EMOTIONAL INTERVENTION TYPE

REWARD INTERVENTION TYPE

She does however perform small actions which do not compromise inefficiency.

ENGAGEMENT

Awareness
Concern
Influence of actions
0 25 50 75 100

Low power of resources

Small network

PERCEIVED CONTROL OVER ENERGY CONSUMPTON

When in the lab you have a high control over the environments. However, due to multiple people working at once devices are often left on after use.

In the lab
In office
At home
0 25 50 75 100

MOTIVATION & FRUSTRATIONS

Puts time efficiency first, then sustainability

- Planet and sustainability
- Saving money

- Unfair energy consumption comparison
- Ease of use & time

Annika thinks the energy consumption comparison between lab employees and office employees are unfair. She will always use more energy since this is what her job requires. However, that she has a higher energy consumption does not say much about how responsible the energy consumption is used.

Figure 88: Persona for the emotional intervention type. This persona also additionally takes into account the rewards intervention type.

Figure 89: : Persona for the instructional intervention type. This persona also additionally takes into account the rewards intervention type.

Appendix D: Toggle button pop ups

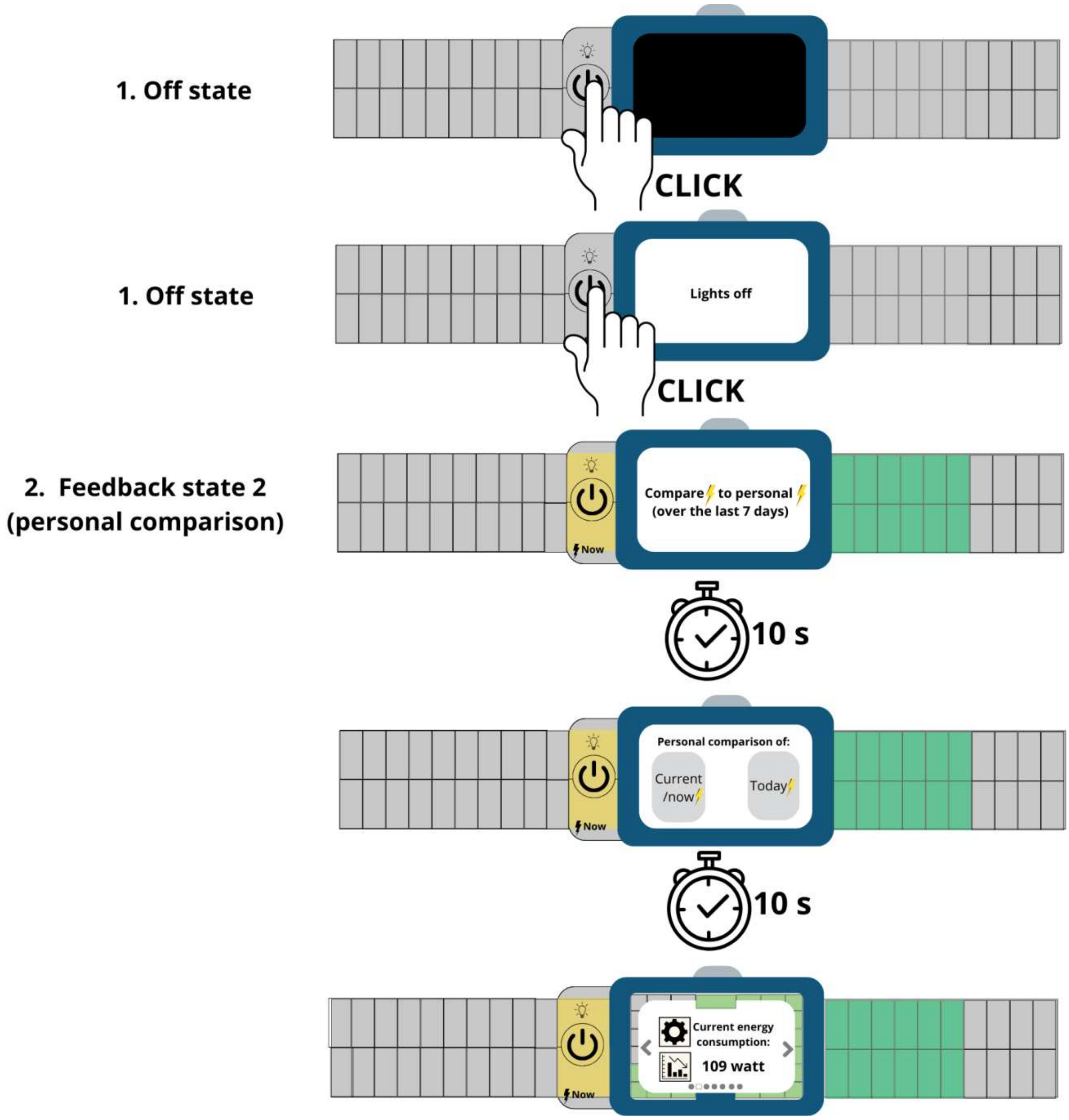
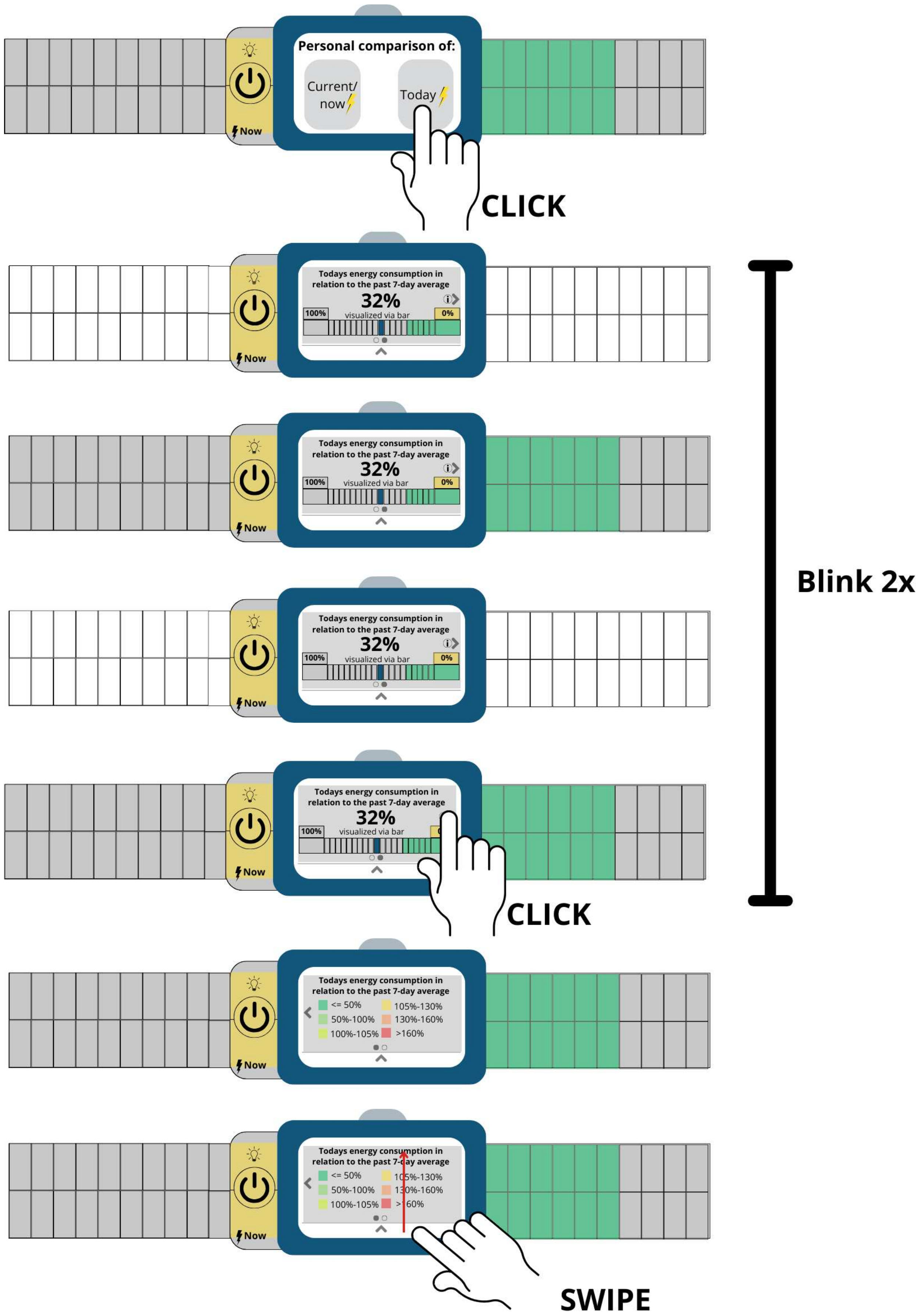


Figure 90: Overview of the second state when toggling with the light button. Apart from turning on the light bar, the energy light and showing the corresponding feedback to the user the screen also turns on. This is to display extra information regarding the meaning of the lights. After two ten of displaying the "Compare ϟ to personal ϟ (over the last 7 days)" on the screen the text disappears and another page is displayed. Now the information is shown with what the comparison is made. The user can click on the grey buttons to get more information about how this feedback is visualized. An illustration regarding the interaction with these buttons can be found in Figure 91. After ten seconds of displaying the page with the buttons the home page is shown. Within these delays it is still possible for the user to interact with the buttons or tab somewhere (NOT ON THE BUTTONS) to skip the delay time.


Personal comparison of:
Current/ now
Today
Now
CLICK
Todays energy consumption in relation to the past 7-day average
32%
visualized via bar
100%
0%
Blink 2x
CLICK
<= 50%
50%-100%
100%-105%
105%-130%
130%-160%
>160%
SWIPE

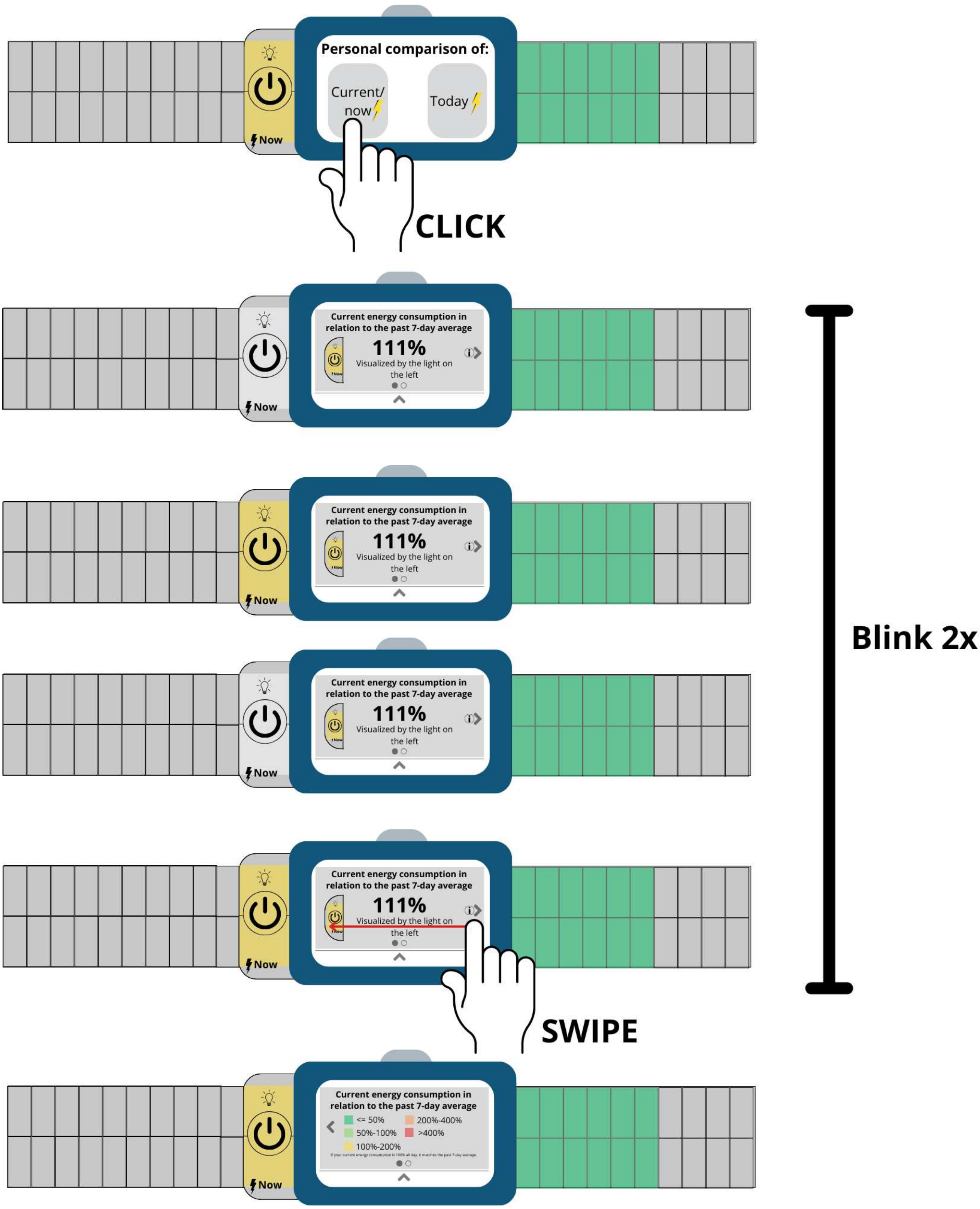


Figure 91: The user can click on the grey buttons to get more information. This will show how the feedback comparison with the current energy consumption or the todays energy consumption is visualized. Regarding the current energy consumption comparison: when your current energy consumption is exactly 100% during the whole day, then it matches the 7-day average energy consumption. When blinking the lights turn white.

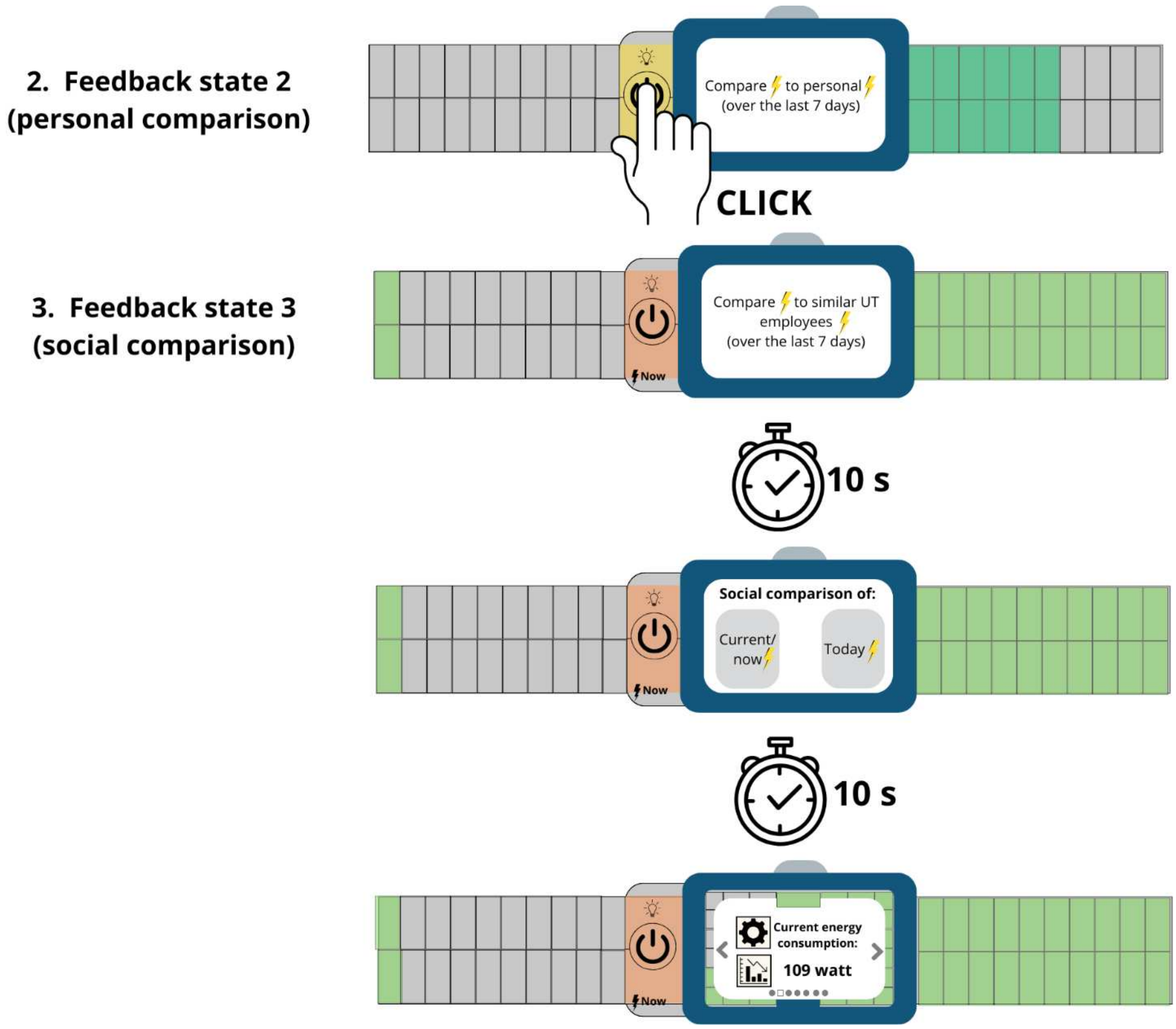
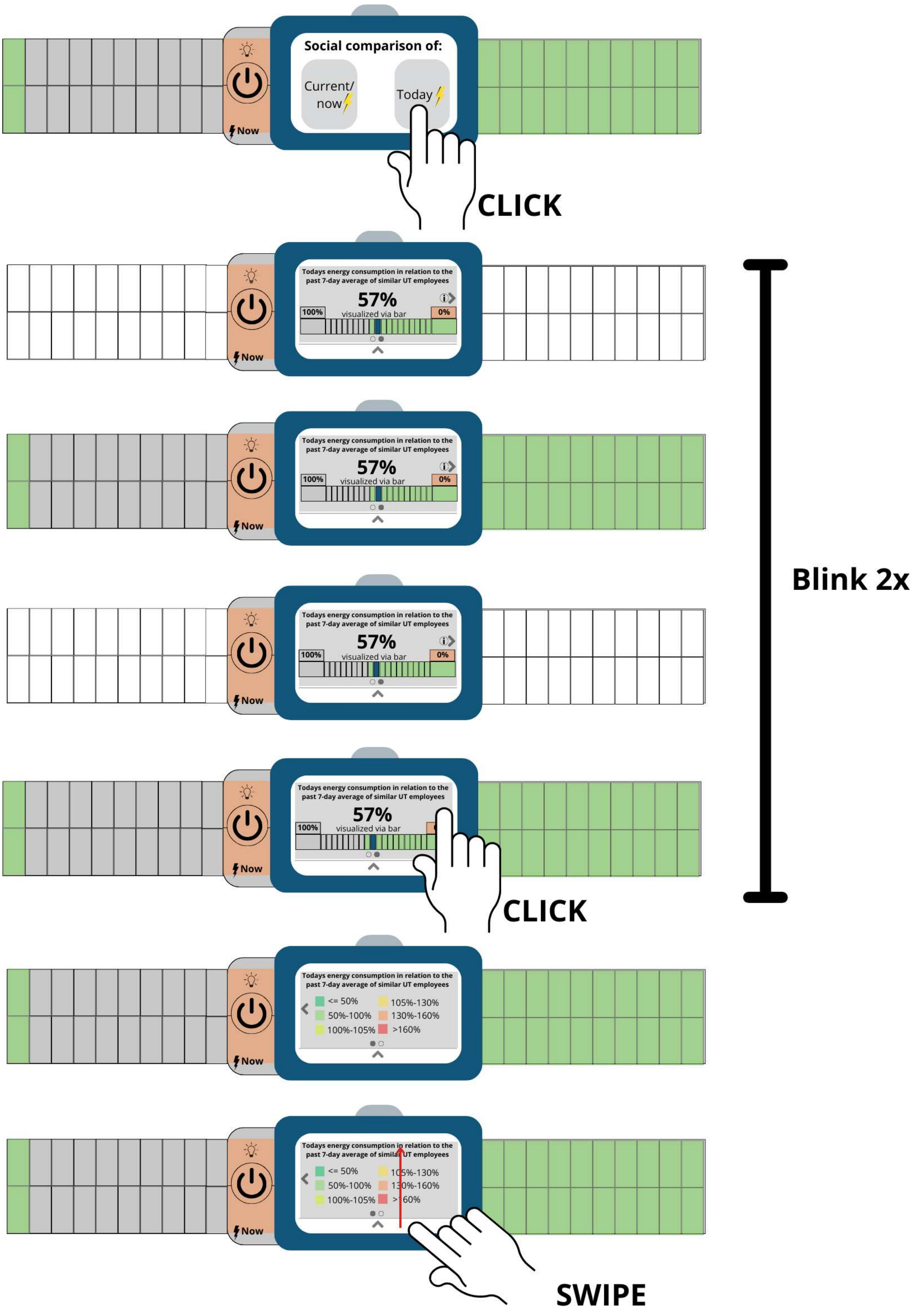


Figure 92: Overview of the third state when toggling with the light button. Apart from turning on the light bar, the energy light and showing the corresponding feedback to the user the screen also turns on. This is to display extra information regarding the meaning of the lights. After ten seconds of displaying the "Compare ϟ to similar UT employees ϟ (over the last 7 days)" on the screen the text disappears and another page is displayed. Now the information is shown with what the comparison is made. The user can click on the grey buttons to get more information about how this feedback is visualized. An illustration regarding the interaction with these buttons can be found in Figure 93. After ten seconds of displaying the page with the buttons the home page is shown. Within these delays it is still possible for the user to interact with the buttons or tab somewhere (NOT ON THE BUTTONS) to skip the delay time.


Social comparison of:
Current/ now
Today
Now
CLICK
Todays energy consumption in relation to the past 7-day average of similar UT employees
57%
visualized via bar
100%
0%
Blink 2x
CLICK
<= 50%
50%-100%
100%-105%
105%-130%
130%-160%
>160%
SWIPE

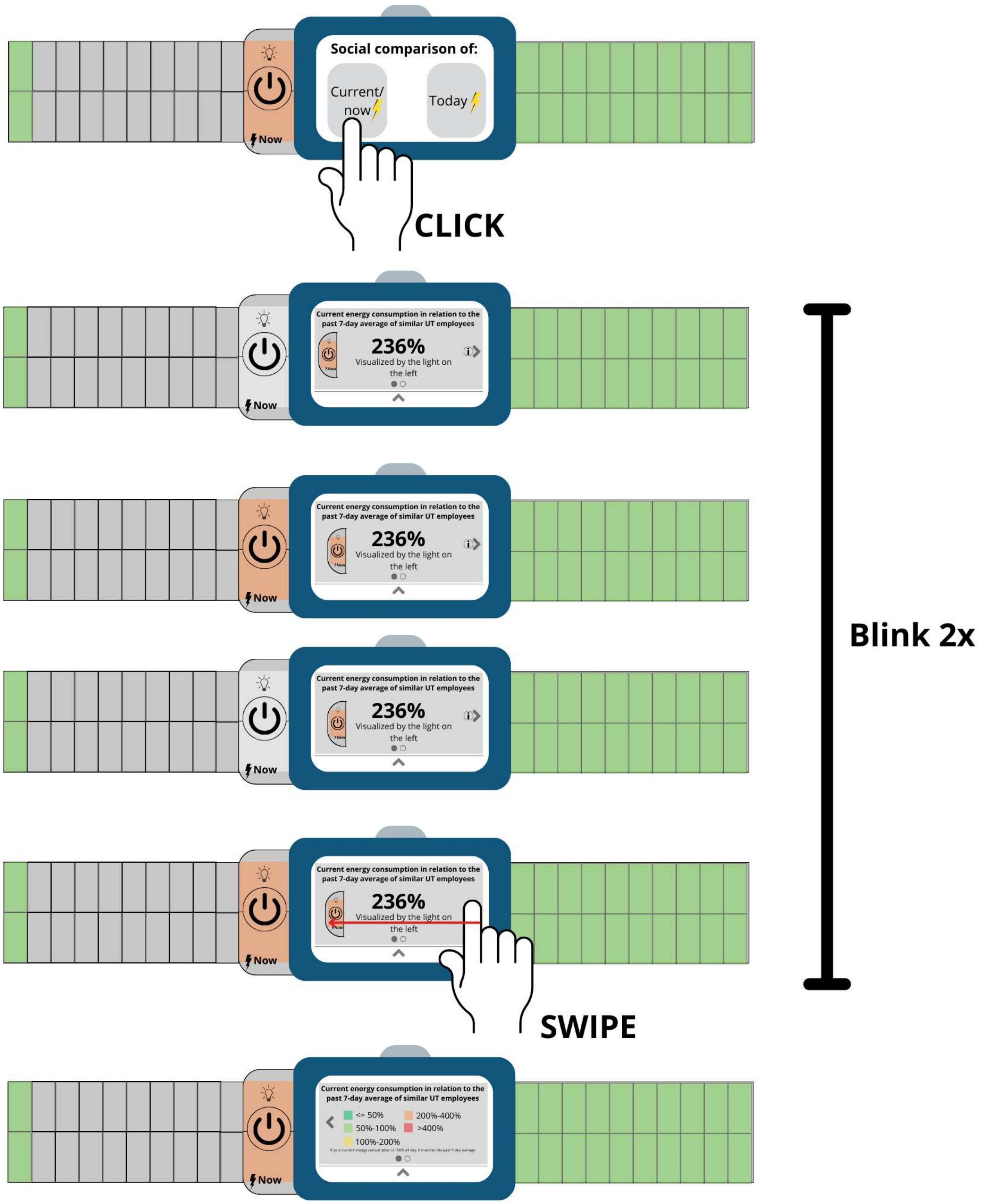


Figure 93: The user can click on the grey buttons to get more information. This will show how the feedback comparison with the current energy consumption or the todays energy consumption is visualized. Regarding the current energy consumption comparison: when your current energy consumption is exactly 100% during the whole day, then it matches the 7-day average energy consumption. When blinking the lights turn white.

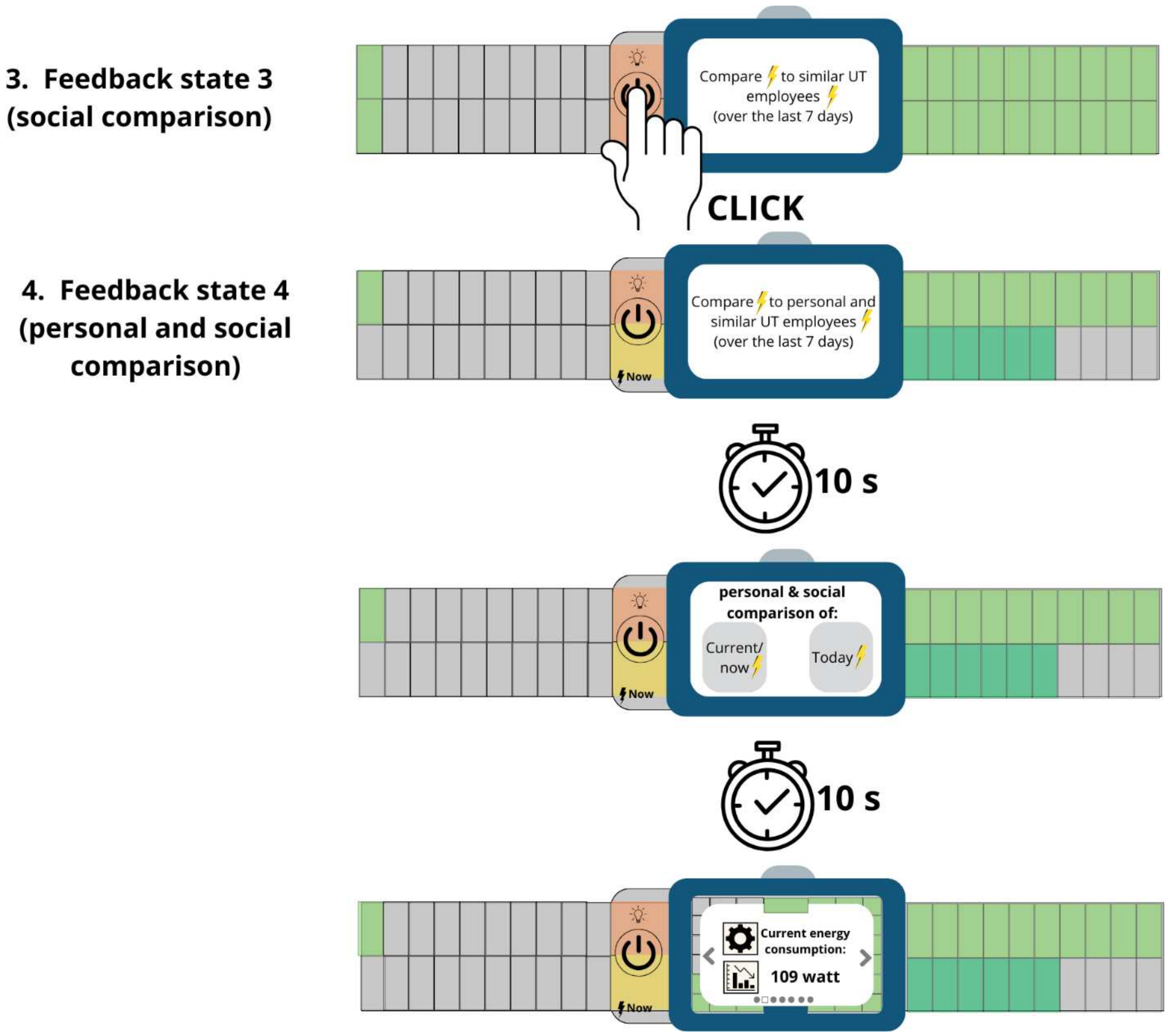


Figure 94: Overview of the fourth state when toggling with the light button. Apart from turning on the light bar, the energy light and showing the corresponding feedback to the user the screen also turns on. This is to display extra information regarding the meaning of the lights. After ten seconds of displaying the "Compare ϟ to personal and similar UT employees ϟ (over the last 7 days)" on the screen the text disappears and another page is displayed. Now the information is shown with what the comparison is made. The user can click on the grey buttons to get more information about how this feedback is visualized. An illustration regarding the interaction with these buttons can be found in Figure 95. After ten seconds of displaying the page with the buttons the home page is shown. Within these delays it is still possible for the user to interact with the buttons or tab somewhere (NOT ON THE BUTTONS) to skip the delay time.

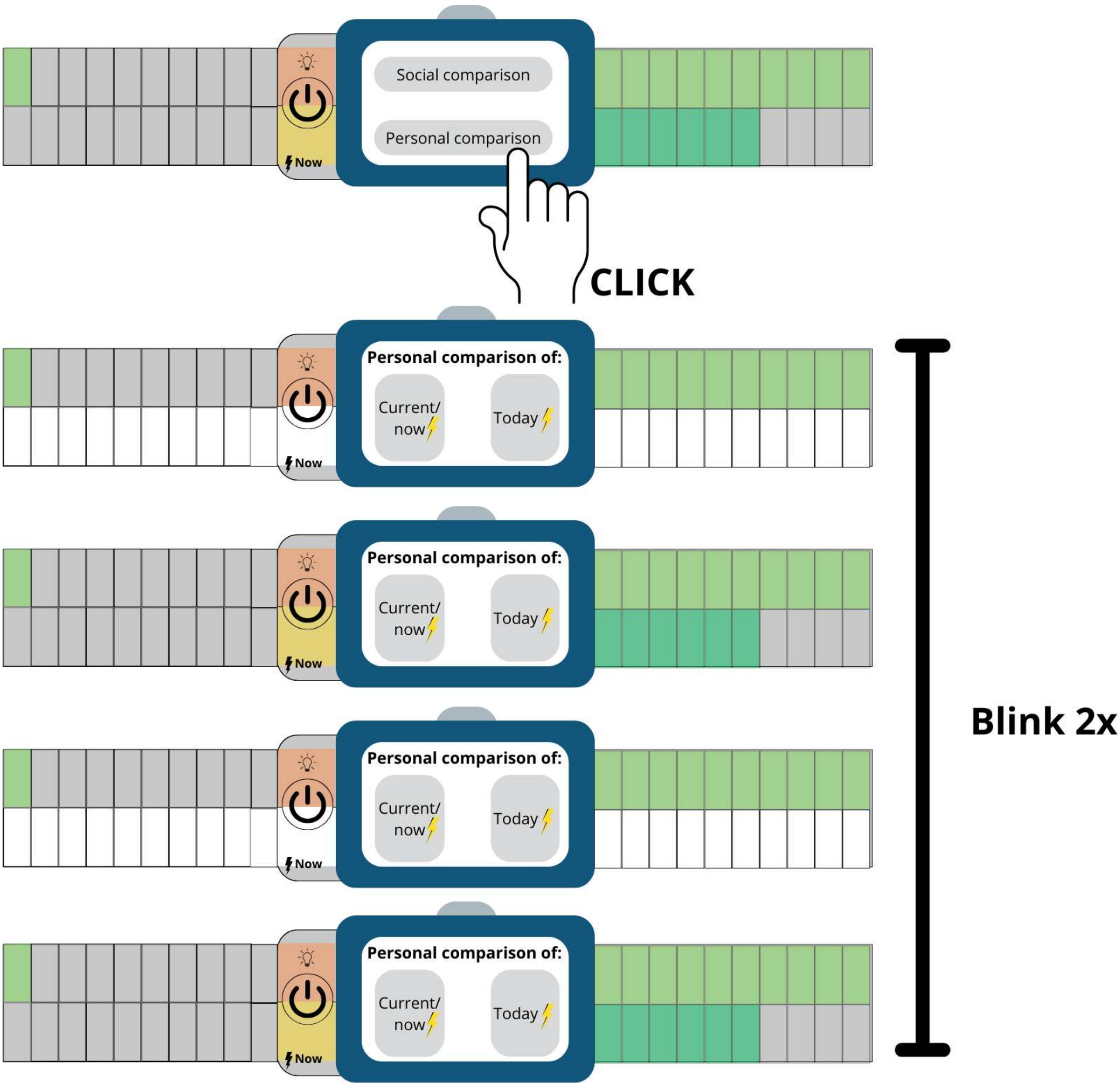


Figure 95: The user can click on the grey buttons to get more information. In this example first the "Personal comparison" is selected. This will route the user to the personal comparison page on the screen. While doing this the bottom row of the lights on the wristband (the energy light and the lights bar) blink or pulse with white light. The interactions in the personal comparison screen page can be seen in Figure 91. Had the user selected the "Social comparison" instead, then the user would have been routed to the social comparison page. An overview of this page can be found in Figure 93. When clicking this option the top light bar and energy light of the wristband would blink with white light instead.

Appendix E: Screen button interactions

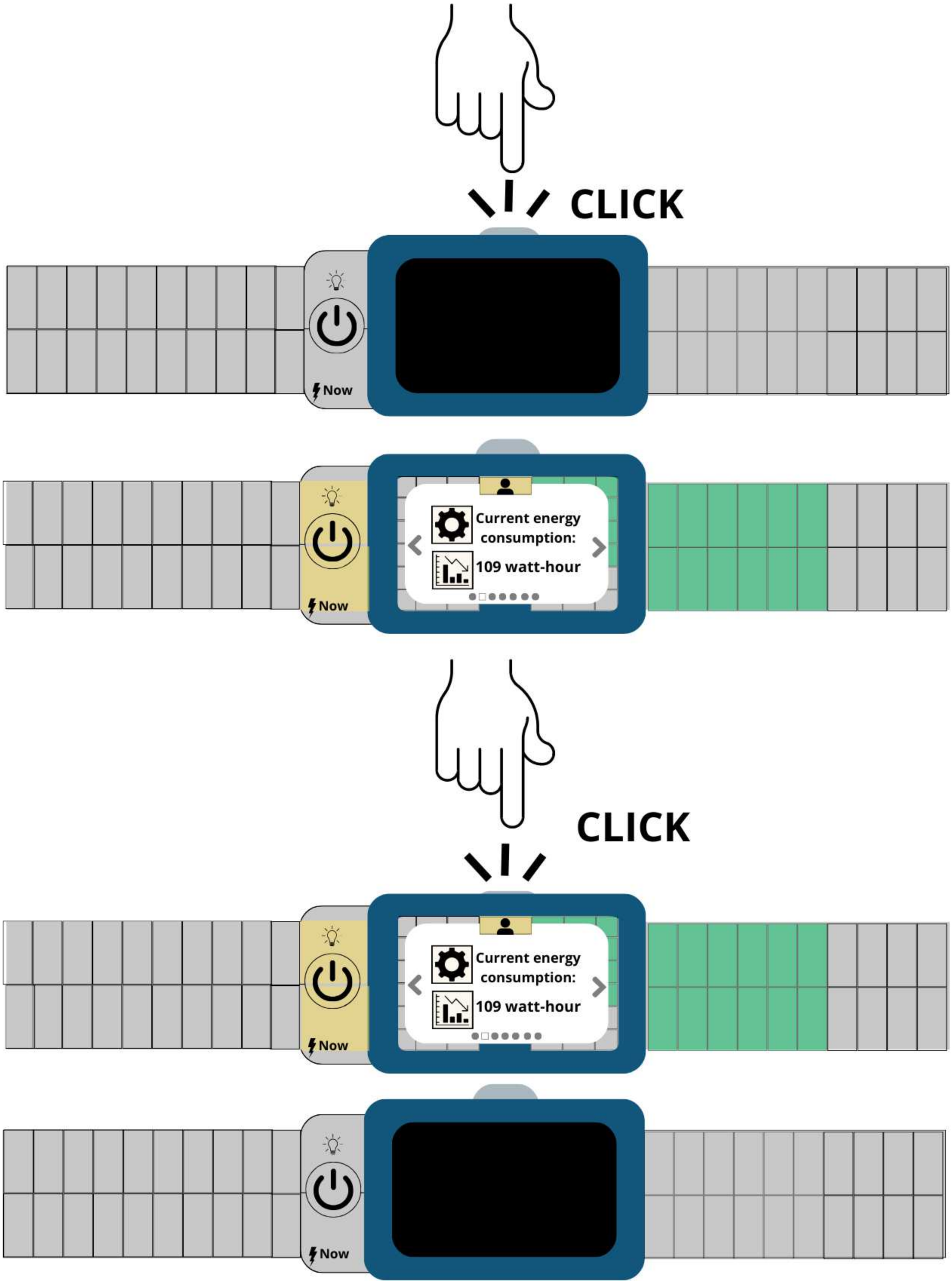


Figure 96: Putting the screen and lights into sleep mode and waking them by clicking the button.

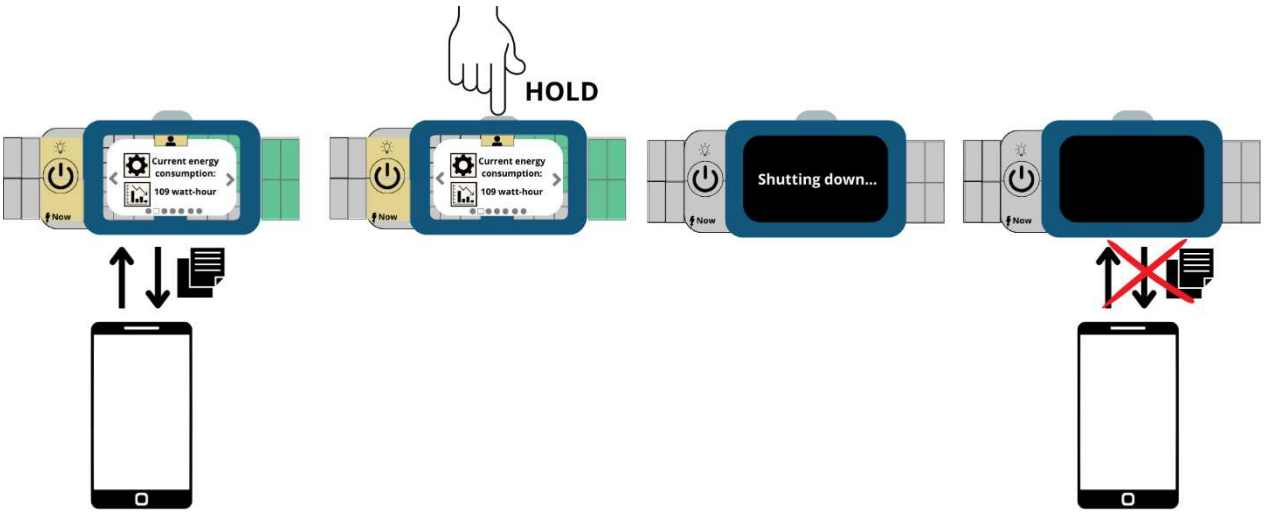


Figure 97: Shutting the smartwatch down is done by holding the screen button. When it is completely turned off the smartwatch no longer communicates with the phone to measure and calculate the energy consumption.

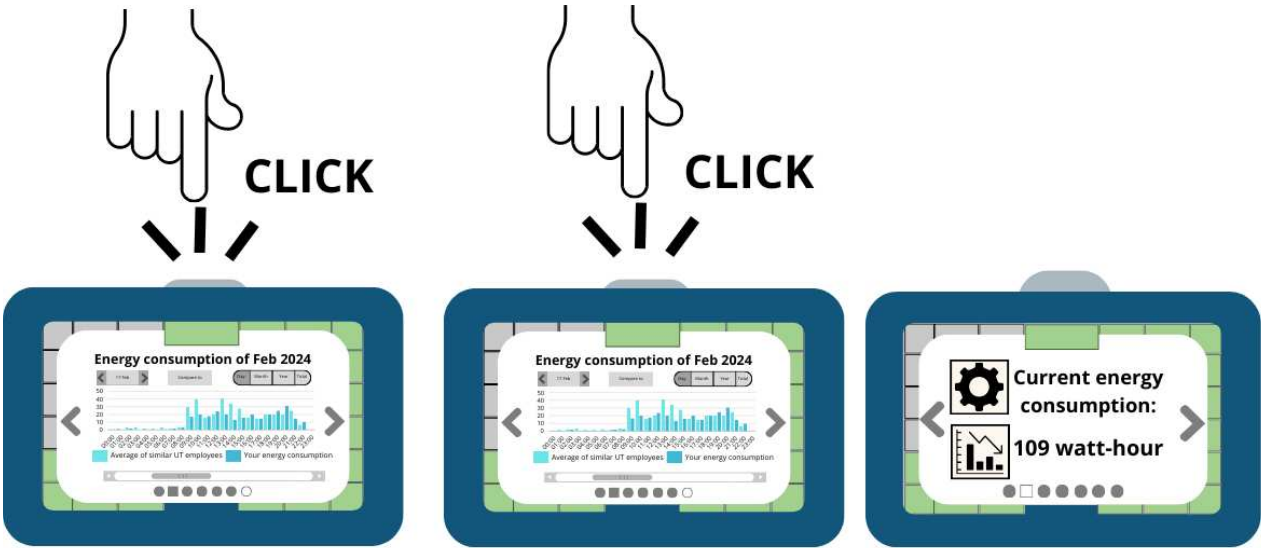


Figure 98: To go immediately back to the home screen the screen button on the smartwatch can be pressed twice.

Appendix F: User testing method and questions

The informed consent form used in the initial and improved method can be seen in "*Appendix A: Informed consent form*

. However, the consent form for the initial method additionally states that the user test also includes a survey.

Appendix F1: Initial method

This method uses the think out loud method. The initial method consists of the following four phases:

8. Unguided familiarization: User gets time to familiarize him- or herself with the intervention.
9. Structured Familiarization: In this phase, the researcher asks the participant to perform specific tasks using the smartwatch. If something is unclear, the researcher can ask unstructured interview questions. This phase includes an unstructured interview and captures the participants' immediate reactions and thought patterns as they interact with the smartwatch though the think out loud method
10. Unstructured interview: after the familiarization phase the user is asked a set of questions. In order to get as much information as possible the interview is unstructured. This way other interesting or important topics that arise can also be discussed.
11. Survey: The user is asked to fill in a survey.

1. Unguided familiarization

A. Familiarize yourself with the smartwatch screen, the 2 buttons and the 2 potentiometers and look around.

2. Structured familiarization

A. Turn some appliances on till you have a just above average current energy consumption.

B. Put the smartwatch in the personal comparison state: 2.

C. Find out what this state does.

D. Find out what the difference is between the single LEDs and the LED bar.

E. Let's say you already used some electricity today. Slowly increase the energy consumption of today till 50% of your past 7 day average.

F. Put the smartwatch in the personal comparison state: 3. And find out what this state does.

G. You turn on the air conditioning. Increase the current energy consumption till its high.

H. By how much are you currently exceeding your average energy consumption of the last hour?

I. How well was your performance yesterday? By how much did it exceed or improve upon your average energy consumption?

J. How long is your improvement streak?

K. The day goes by… Turn todays energy consumption up to 75%.

L. You release you left some appliances on. Turn some appliances off till you are in the range of your average energy consumption.

M. The day goes further by slowly increase todays energy consumption to 135%.

O. It is the end of the day. Look up what todays energy consumption is per device. Where would you reduce your energy consumption in the future?

P. Look up when you consumed most energy during the day.

Q. Put the smartwatch in the personal comparison state: 4. And find out what this state does.

3. Unstructured interview

A. Would you intent to change your energy consumption to be more responsible when this smartwatch is implemented? Why?

B. What do you think encourages and discourages you to change your energy consumption to be more responsible regarding the smartwatch?

4. survey

Prototype testing

Dear participant,

This research project aims to create an effective behavior

intervention to facilitate pro-environmental behavior among university employees, specifically targeting the responsible energy usage. Responsible

pro-environmental behavior include simple actions to reduce energy consumption e.g. turning off the lights, turning down the thermostat, only turning on the dishwasher when it is completely filled etc. The purpose of this specific interview is to get insights in the opinions of the potential end users (university employees) of this intervention. These opinions are used to further develop ideas and prototypes. Therefore, it is encouraged to answer all the questions honestly. All feedback is appreciated!

Participating in this survey is voluntary; there

are no specific benefits to be gained by participation. It is possible to remove yourself from the study at any time. All

gathered data about your participation will then be destroyed. No personal data will be collected apart from your demographics. When you have a very specific employee function within the UT that could potentially identify you as participant this will function will be generalized. Therefore your contribution will remain anonymous. There are no known risks related

to this study.

Demographics

68. What is your Gender?

Markeer slechts één ovaal.

- Man
- Woman
- Non-binary
- Prefer not to say

69. What is your age?

Markeer slechts één ovaal.

- 18-24
- 25-34
- 35-44
- 45-54
- 55+

70. What is your job at the UT?

____

71. I want to improve my energy saving at work

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

72. I feel like I have control over my energy consumption at work.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

73. I believe my colleagues expect me to save energy at work.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

LED lights

74. I think it is clear what the different light states mean.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

75. I think the LEDs are intuitive to interpret.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

76. I think it is clear what the difference is between the two single LEDs and the LED strips/bars.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

77. The two single LEDs showcase useful insights in my energy consumption.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

78. The insights of the two single LEDs help me to make more responsible energy consumption actions in the future.

Imagine you are actually using the prototype in real life.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

79. The LED strips/bars showcase useful insights in my energy consumption.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

80. The insights of the LED strips/bars help me to maintain or improve upon responsible energy consumption actions in the future.

Imagine you are actually using the prototype in real life.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

81. I think it is useful to see the difference in current energy consumption in the moment and the energy consumption over the whole day.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

82. I think it is useful to compare my energy consumption with averages.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

83. I think the different comparisons in the light states are useful.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

84. I think one of the following light states are unnecessary:

Markeer slechts één ovaal.

- ◯ State 1: Lights off
- ◯ State 2: Personal comparison
- ◯ State 3: Social comparison
- ◯ State 4: Personal & social comparison
- ◯ All of the states seem useful to me

85. I think the button to toggle through the light states is intuitive.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

86. I think it is intuitive when LED strips/bars reset when the relative percentage is over a multiple of 100%. (Turn today's energy consumption up and down to see this effect)

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

87. I think the color of the lights is intuitive

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

88. Do you have any more remarks about the LED lights or the toggle button?

Vibrational feedback

89. I experience the notification in the form of vibrational feedback as "loud".

Markeer slechts één ovaal.

	1	2	3	4	5	
not a	◯	◯	◯	◯	◯	very much

90. I experience the notification in the form of vibrational feedback as annoying.

Markeer slechts één ovaal.

	1	2	3	4	5	
not a	◯	◯	◯	◯	◯	very much

91. I think the notification in the form of vibrational feedback helps me to undertake action for more responsible energy usage.

Markeer slechts één ovaal.

	1	2	3	4	5	
not a	◯	◯	◯	◯	◯	very much

92. I think the notification in the form of vibrational feedback catches my attention when doing day-to-day tasks.

Markeer slechts één ovaal.

	1	2	3	4	5	
not a	◯	◯	◯	◯	◯	very much

93. I think the notification in the form of vibrational feedback is a good feedback type to warn me about my energy consumption.

Markeer slechts één ovaal.

	1	2	3	4	5	
not a	◯	◯	◯	◯	◯	very much

94. Do you have any remarks about the vibrational feedback?

Touch screen pages

95. The current energy consumption unit on the home page screen is intuitive and clear to understand.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

96. It is intuitive that the bar surrounding the screen pages represent the LED strips/bars.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

97. It is clear that the bar surrounding the screen pages represent the LED strips/bars.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

98. It is intuitive that the colored box on top of the screen pages represent the two single LEDs?

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

99. It is clear that the colored box on top of the screen pages represent the two single LEDs?

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

100. It is intuitive that the symbol of ONE person in colored box on top of the screen pages represent the personal comparison state?

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

101. It is clear that the symbol of ONE person in colored box on top of the screen pages represent the personal comparison state?

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

102. It is intuitive that the symbol of TWO person in colored box on top of the screen pages represent the social comparison state?

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

103. It is clear that the symbol of TWO person in colored box on top of the screen pages represent the social comparison state?

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

104. The three pages about 'Yesterdays performance', the 'improvement streak' and 'current performance compared to the last hour' encourage me to utilize my energy consumption more responsibly?

Imagine the three pages would be based on your actual energy consumption data.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

105. The two pages about 'Yesterdays performance' and 'current performance compared to the last hour' showcase useful insights in my energy consumption.

Imagine the two pages would be based on your actual energy consumption data.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

106. I think the 'Todays energy consumption per device' page gives me relevant insights in my energy consumption

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

107. I think the insights from the 'Todays energy consumption per device' will improve my responsible energy consumption patterns.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

108. I think the page which showcases a graph of my energy consumption over a period of time gives me relevant insights in my energy consumption.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

109. I think the insights from the page which showcases a graph of my energy consumption over a period of time will improve my responsible energy consumption patterns.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

110. I think the interface is intuitive.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

111. Do you have any remarks about the touch screen of the smartwatch?

Control, privacy and personalization

112. I feel in control when using the smartwatch.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

113. I feel like I can protect my privacy.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

114. I am satisfied with the amount of personalization the prototype offers.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

115. What aspects do you think are missing regarding the personalization of the smartwatch?

116. Do you have any more remarks about how you experience your control, privacy or personalization when using the smartwatch?

117. I think the prototype would be a hassle when it would be implemented.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

118. When the prototype would be implemented I would actively have to think about it in order to use it. Meaning that it is always present in the current task I am doing when I am doing my job.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

119. I feel like peer pressure and social comparison during implementation (e.g. seeing how others are performing through the LEDs on their smartwatches) would encourage me to utilize my energy consumption more responsibly.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

120. I feel like the personal comparison (LEDs, and touch screen pages) would encourage me to utilize my energy consumption more responsibly.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

121. I think the prototype encourages me to utilize my energy consumption more responsibly.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

122. I think if the prototype got implemented I would change my energy consumption to use it more responsibly.

(This is about your intention to change your energy consumption.)

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Definitely

123. I think the implementation of the smartwatch will support me into a transition of changing habits to more responsible energy consumption.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

124. I feel rewarded when I improved or maintained my personal average energy consumption pattern.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

125. I feel unmotivated when I exceeded my personal energy average energy consumption patterns.

Markeer slechts één ovaal.

	1	2	3	4	5	
	◯	◯	◯	◯	◯	

126. I feel rewarded when I consumed less energy than the average energy consumption of similar employee types.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

127. I feel unmotivated when I consumed more energy than the average energy consumption of similar employee types.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

128. I feel like the intervention motivates me towards a more responsible energy consumption.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

129. I feel like the intervention teaches me about how I can work towards a more responsible energy consumption.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

130. I feel like the intervention educates me on my energy consumption.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

131. When the smartwatch would get implemented I would be emotionally invested.

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

132. The smartwatch makes me feel like have control over my energy consumption at work

Markeer slechts één ovaal.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very much

133. Do you have any remarks about the implementation of the smartwatch

134. Do you have any more remarks about the smartwatch in general that you would like to add?

Appendix F2: Improved method

The user testing method was altered to exclude the learning curve of the intervention from the participants tests. This was accomplished by explaining the intervention through scenarios while the researcher interacted with the smartwatch, rather than having the users figure out how to use it on their own. This approach allowed the users to focus on answering the questions that mattered. Additionally, the survey element of the method was removed, because the first user test took up too much time. The improved method consists of the following three phases:

12. Introduction: Shortly explains what the smartwatch does.
13. Familiarization: this is the phase in which the researcher interacts with the smartwatch while discussing multiple scenarios with the participants. This phase includes an unstructured interview and captures the participants' immediate reactions and thought patterns as the researcher interacts with the smartwatch.
14. Unstructured interview: after the familiarization phase the user is asked a set of questions. In order to get as much information as possible the interview is unstructured. This way other interesting or important topics that arise can also be discussed.

Unstructured interview && Quasi experiment >> not random experiment

1. Introduction

Explain what the interventions does: it shows your energy consumption compared to the personal average or social average depending on the state. Explain what these states are.

With the potentiometers the researcher does the wizard of oz. Explain which potentiometer does what.

2. Familiarization

We will compare the energy consumption to the personal energy consumption. We can look at the energy consumption in the moment and of today. Go to the pop up for the explanation in the moment.

A. Look at it and tell me what you see. And is it clear what the colors mean

Let's you turn on some appliances like lights and laptops.

B. What do you see?

We can also go to explanation of the pop up of today.

C. Look at it and tell me what you see

D. Is it clear what the colors mean

Let's imagine the time flies by and you are consuming energy throughout the day. The energy you have consumed today in total increases. (<50%)

E. Tell me what you see

Increase to >50%

F. How do you feel now you are getting haptic feedback?

Increase to 135%

G. Tell me what you see

We can also go to another state. Let's compare your energy consumption to that of similar employees. Go to state 3. I will go to the explanation page for today.

H. Tell me what you see (difference symbol)

Then it is the end of the day. I have not really performed well compared to my personal goals cuz that was 135% but I have performed well in relation to similar employees.

I. How does this make you feel

I want to see what I can do better. I look at the energy consumption per device page.

J. Tell me what you see. What can you do to improve your energy consumption.

Can also see which times you consumed most of your energy.

K. Tell me what you see and think

Showcase the encouragement pages

L. What is your opinion about these pages?

3. Unstructured interview

A. Do you think you would use the smartwatch? Do you think other people?

B. Would you intent to change your energy consumption to be more responsible when this smartwatch is implemented? Why?

C. What do you think encourages and discourages you to change your energy consumption to be more responsible regarding the smartwatch?

D. What do you think was intuitive & what was not intuitive?

E. Which parts of the smartwatch were useful and which ones were not?

F. What would you change?

G. Do you have any remarks about the smartwatch?

Appendix G: Realisation

Appendix G1: General overview

The images below showcase the prototype in more detail.

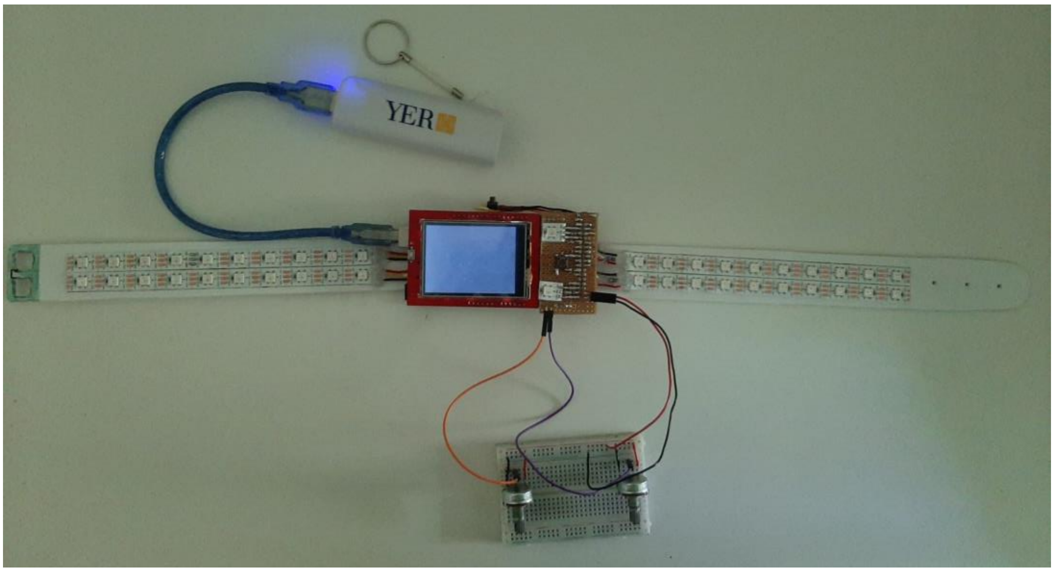


Figure 99: Illustration of the smartwatch prototype when in sleep mode. Consisting of a display, the energy lights, the energy bar lights, potentiometers to Wizard of Oz the data and a power bank to power the prototype.

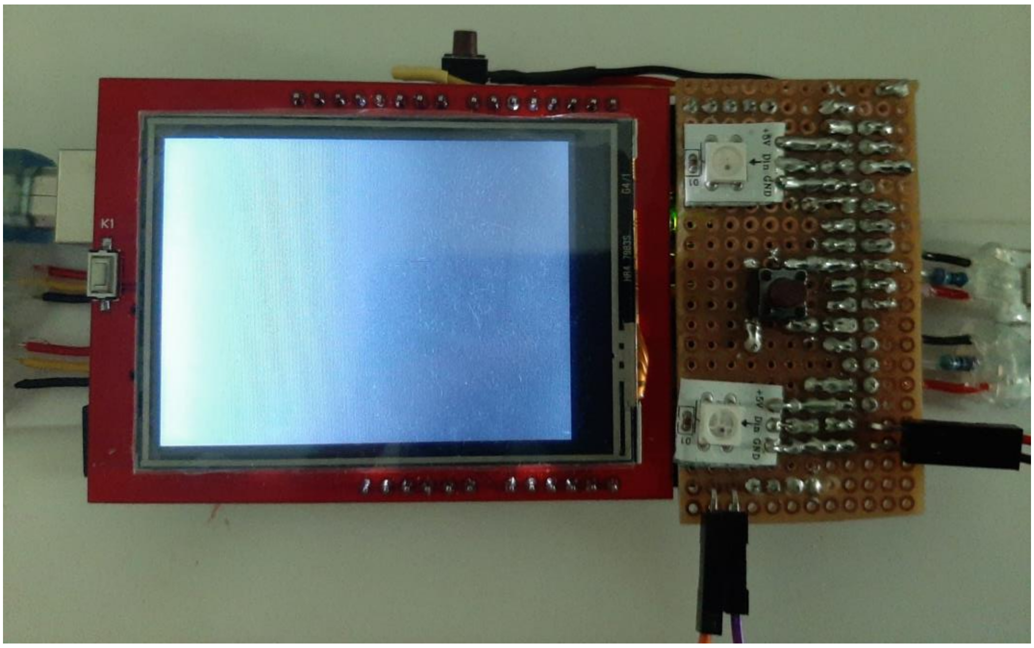


Figure 100: A close up of the display in sleep mode. The button on top of the display is the on/off button. With one press the user can switch between the sleep and wake state. With two fast presses the user can immediately go back to the home page. The button on the PCB board to the right of the display is the button the user can use to toggle through the different states of the smartwatch. The LED above and under the button on the PCB board are the energy lights.

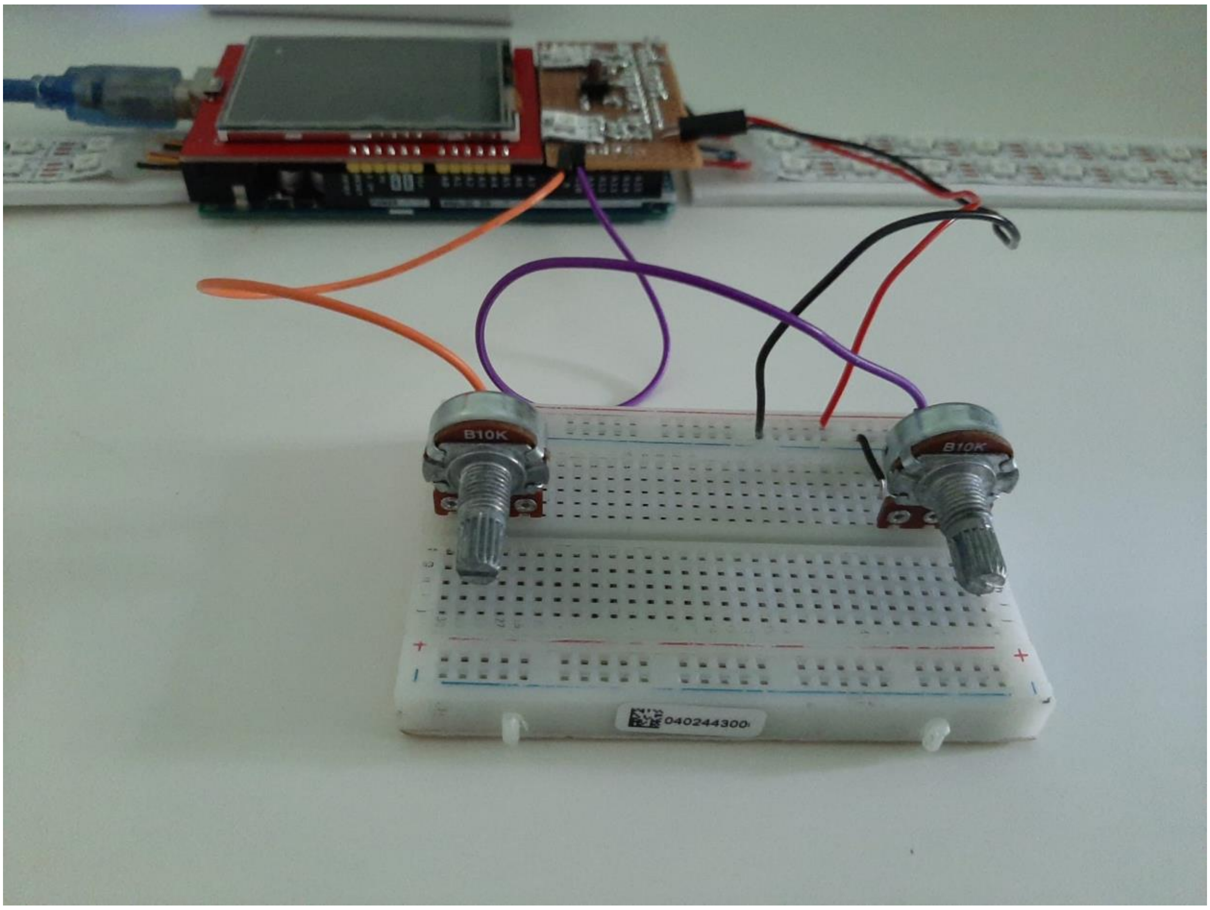


Figure 101: The potentiometers can be attached to the smartwatch by the wires. These potentiometers are used to simulate the energy consumption data of the user. One simulates the cumulative energy consumption of today and the other the energy consumption in the moment from all the electrical appliances that are on at the moment.

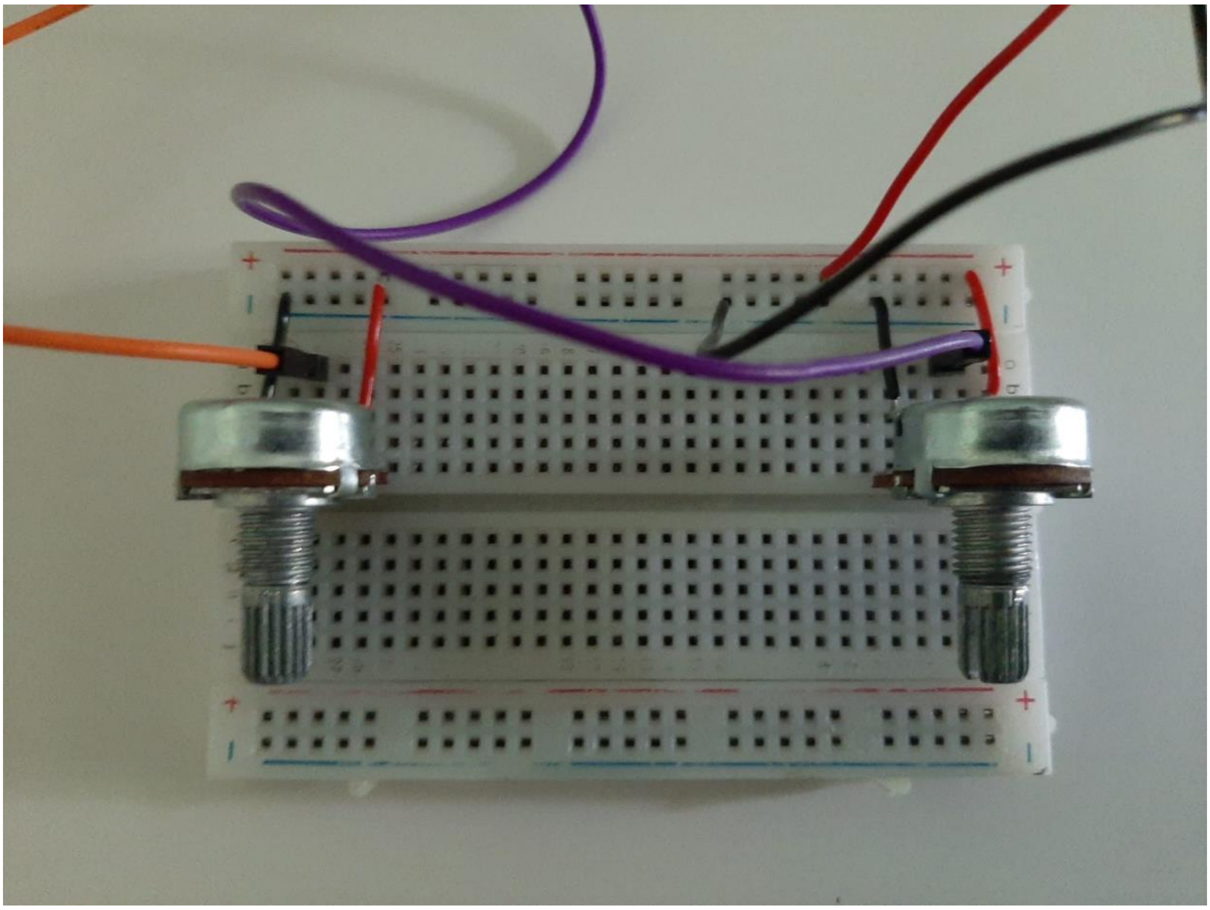


Figure 102: A close up of the wiring of the potentiometers on the breadboard.

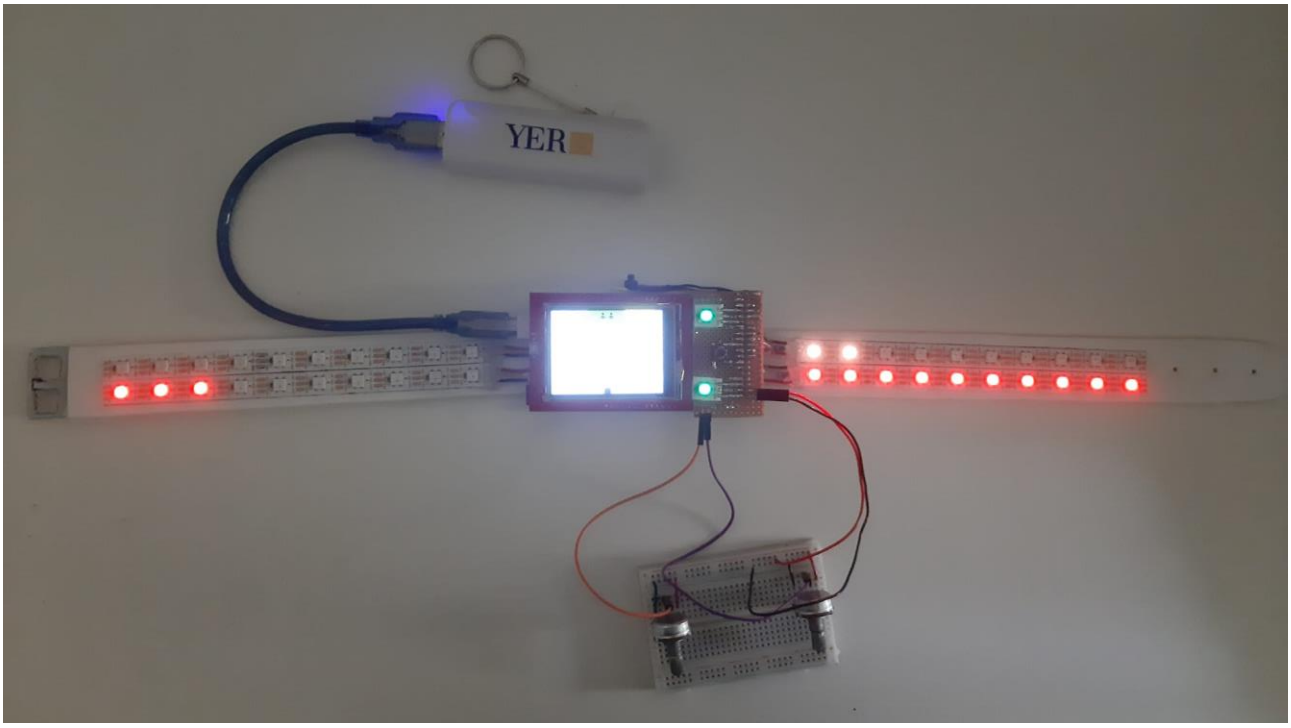


Figure 103: Both the energy light and energy bar light can change colour. The smartwatch is now in state four. (Personal and social comparison state). The amount of LEDs that are on of the energy bar light can change depending on the simulated data.

Appendix G2: Screen pages

All screen pages have an energy light and energy bar light visible on the screen. For all the examples below the energy consumption in the moment and the cumulative energy consumption of today is zero. The smartwatch is in these examples in state 1 meaning that the lights of the wristband are all off and that the energy light and energy bar light on the screen switch between the personal comparison and social comparison every 10 seconds. The comparison is indicated through the symbols in the energy light. Two people indicates a social comparison and one a personal comparison. On the bottom of each screen page the user can orient him- or herself with the dots. The rectangle is an indication for the home page. The user can click the arrows on the left and right side of the screen to move through the different screen pages.

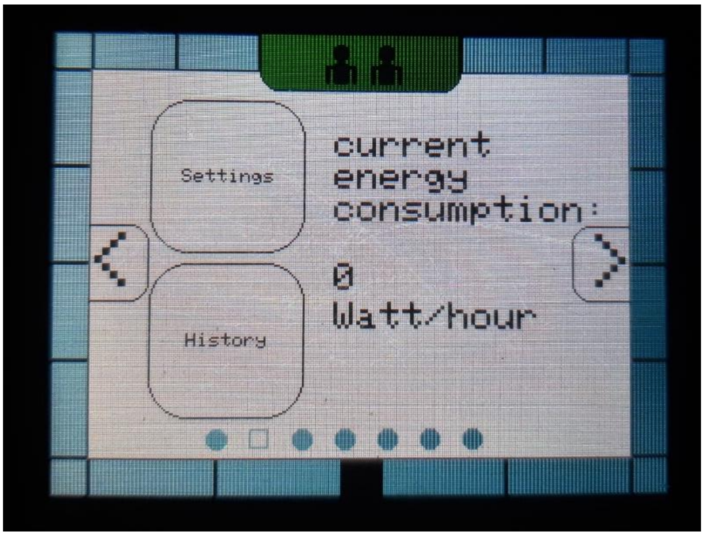


Figure 104: A illustration of the home page of the prototype. Users can click the 'Settings' button to go directly to the settings button or click the 'History' button to go directly to the history pages (Circle diagram).

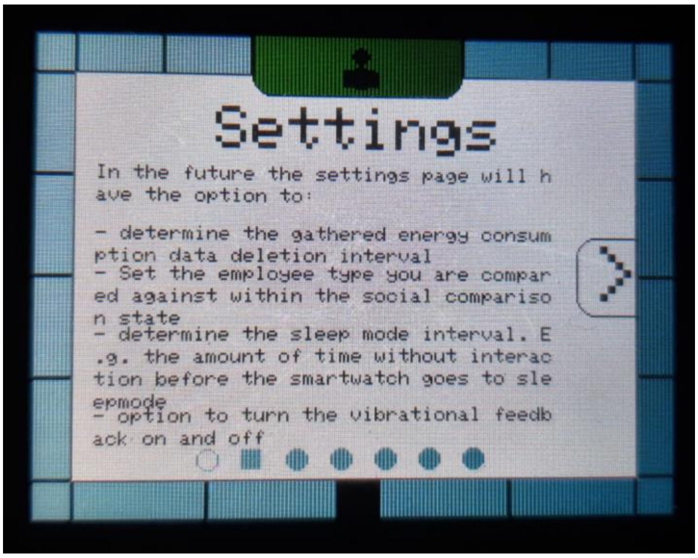


Figure 105: The settings page was included in the layout of the prototype but not realized. Instead it only displayed a text of what would be in the settings page would it have been realized.

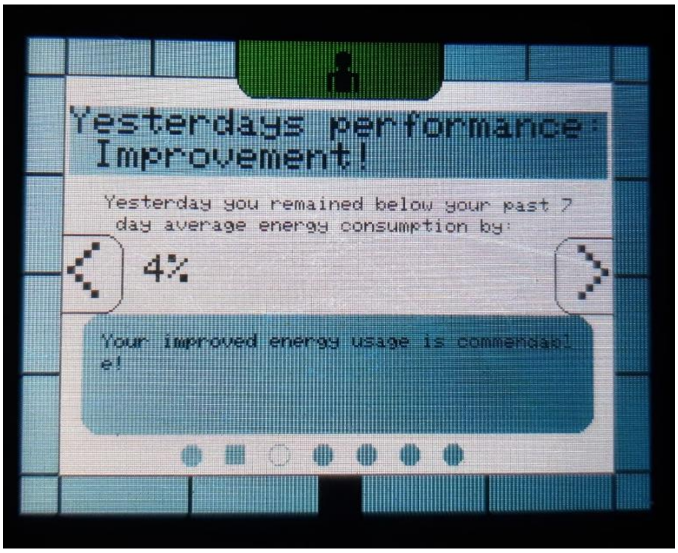


Figure 106: An illustration of yesterday's performance page. The 4% was calculated with static set global variables in the code. The encouraging text in the blue box on the bottom is randomized. Meaning that it showcases a different text each time this page is opened. The yesterday's performance page is the first of the three 'encouragement' pages.

Figure 107: An illustration of the streak page. The 15 day long streak was a random number that was chosen. Again, the encouraging text in the blue box on the bottom is randomized. Meaning that it showcases a different text each time this page is opened. The streak page is the second of the three 'encouragement' pages.

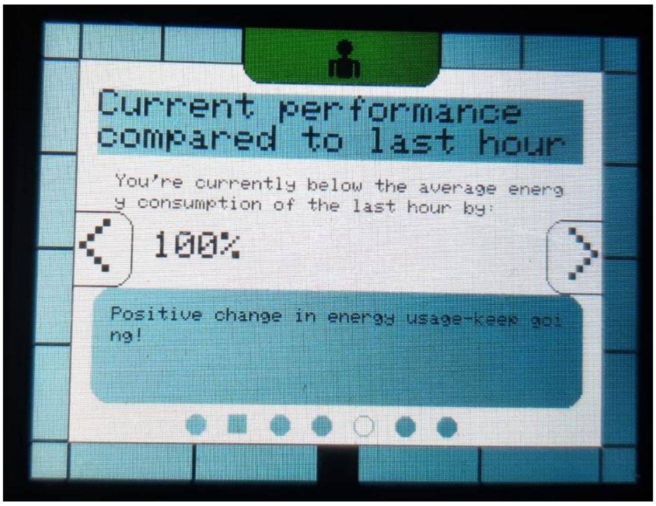


Figure 108: An illustration of the current performance compared to last hour page. The percentage is calculated from a static set global variable in the code that was based on the data from the energy consumption of a one person household during a random day like in Figure 54 and the simulated current energy consumption in the moment. Again, the encouraging text in the blue box on the bottom is randomized. Meaning that it showcases a different text each time this page is opened. The streak page is the last of the three 'encouragement' pages.

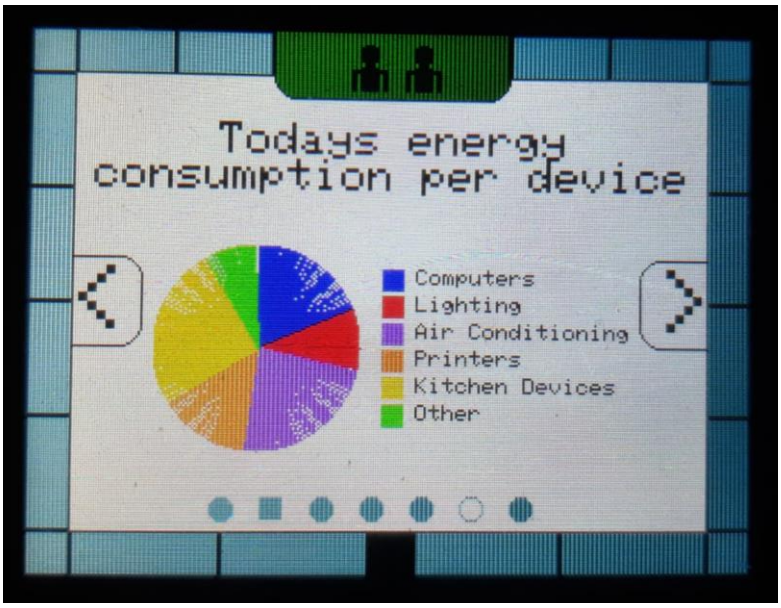


Figure 109: An illustration of the circle diagram page which showcases how much each device contributed to the cumulative energy consumption of the current day. The different devices were set in advance within the code and cannot change. The amount that they contributed to the whole is random. Meaning that each time the circle diagram is displayed it showcases different information. The circle diagram is the first page of the two history pages.

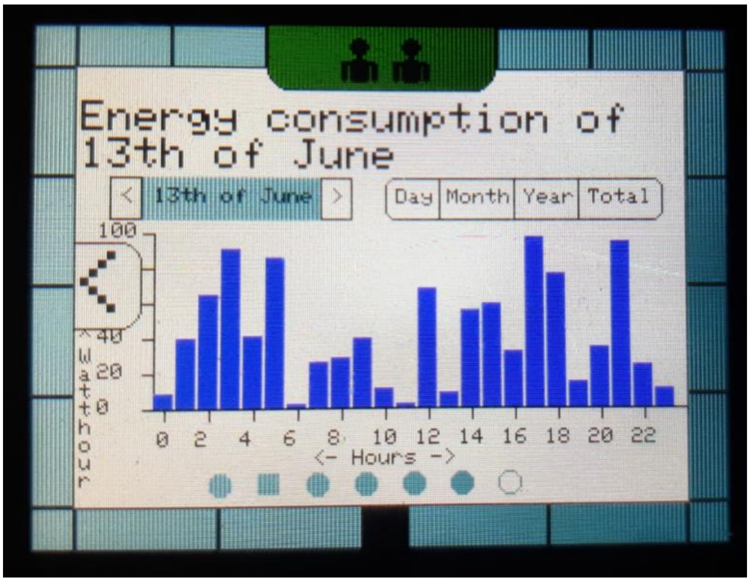


Figure 110: An illustration of the graph page which showcases the users energy consumption over a specific period of time. The showcased data is random. Meaning that each time the graph is displayed it showcases different information. In the specification chapter it was mentioned that the graph would have some interactions with the buttons below the title to alter the period of time in which the energy consumption data is displayed. These buttons are displayed in the prototype, but they are not functional. This page only shows an indication of what it would look like when correctly realized. The graph is the second page of the two history pages.

Appendix G3: Changing states pop ups

To toggle trough the different states the user pressed the toggle button. When it is pressed the first time a pop up of the current state appears. The state is then not yet changed. Only when the toggle button is pressed another time it changes the state if there is still a pop up visible. Every individual pop up which indicates the smartwatch state is visible for 10 seconds. After 10 seconds the next pop up appears or if there is no next pop up the pop up disappears and the last visible screen page gets displayed again. When you are on one of the explanation pages for the states you have to click a button on the bottom of the screen to close the pop up. These pages don't automatically disappear after 10 seconds. Also it is good to note that when making pictures of the display the photos, became very dark. Meaning that only the display and the energy lights are visible.

Appendix G3.1: State 1

For all illustrations in the pop ups below the energy consumption in the moment is simulated to be zero and the cumulative energy consumption simulated to be 22% when compared to the users personal energy consumption over the last 7 days and 15% when compared to similar employee types energy consumption over the last 7 days.

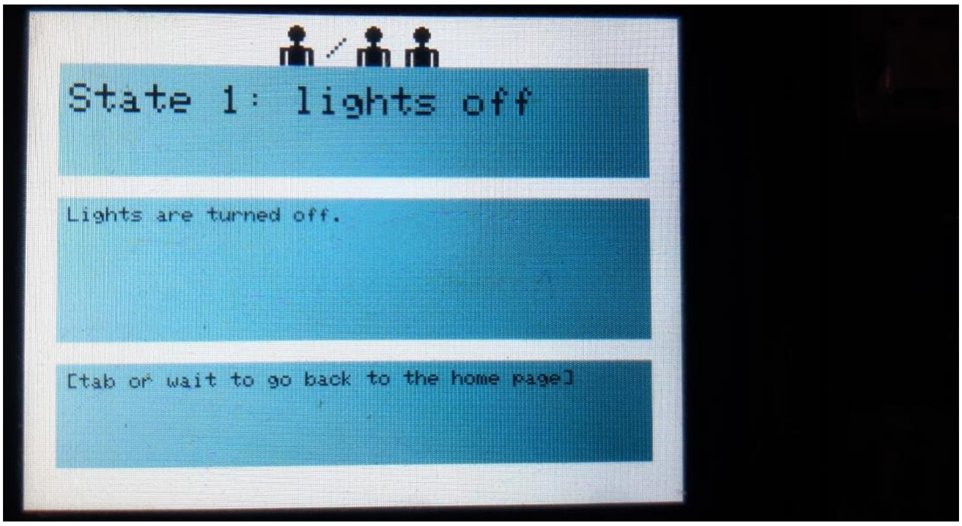


Figure 111: Illustration of the state 1 pop up. This page gets displayed when it the state is changed to state 1 or if the current state is state 1, but no pop up is being displayed yet. In state 1 the lights on the wristband of the smartwatch are off like in Figure 99. However it can still display the energy light and energy bar light on the screen. It switches every 10 seconds between the personal and social comparison as indicated by the figures on top of the pop up display. After 10 seconds it automatically displays the previous visible screen page again.

Appendix G3.2: State 2

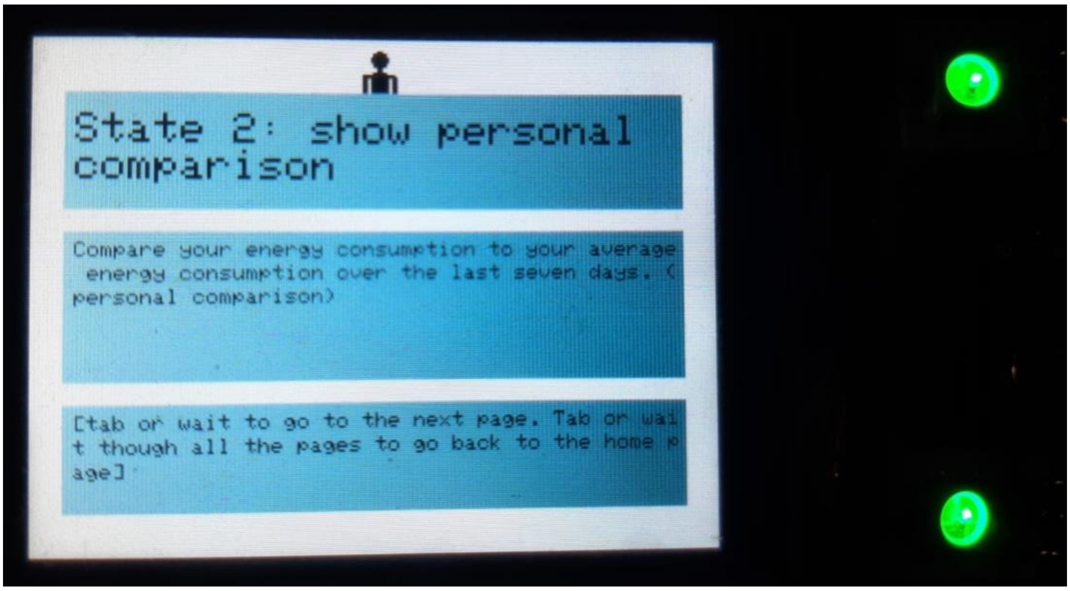


Figure 112: Illustration of the state 2 pop up. This page gets displayed when it the state is changed to state 2 or if the current state is state 2, but no pop up is being displayed yet. In state 2 the lights on the wristband of the smartwatch are turned on in the personal comparison state. After 10 seconds or when the screen is touched it displays the pop up in Figure 113.

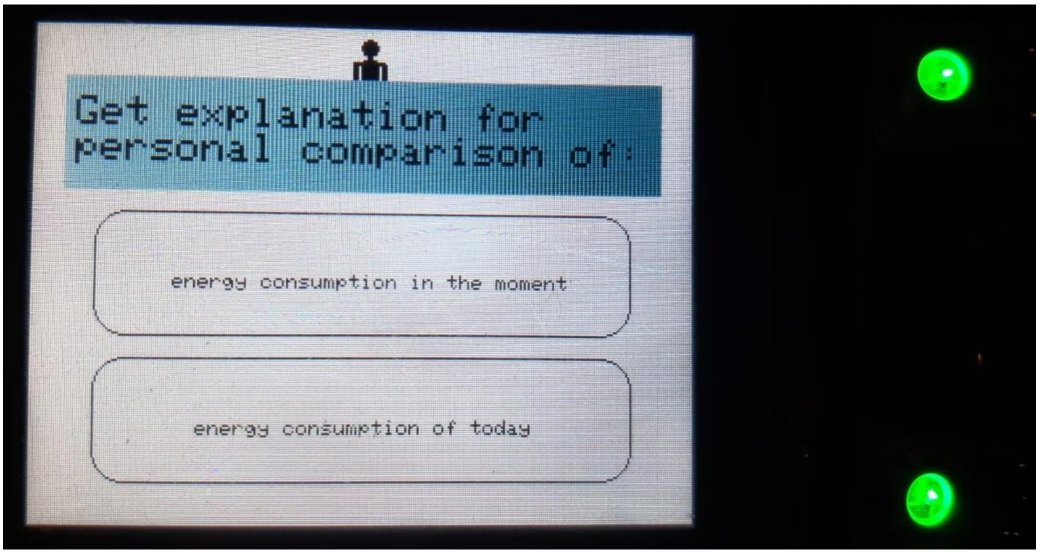


Figure 113: Pop up that is being displayed after the pop up in Figure 112 has been displayed. After 10 seconds or when the screen is touched, but not the buttons, then it automatically displays the previous visible screen page again. If the button 'energy consumption in the moment' is pressed the pop up in Figure 114 is displayed. When the 'energy consumption of today' is pressed the pop up in Figure 115 is displayed.

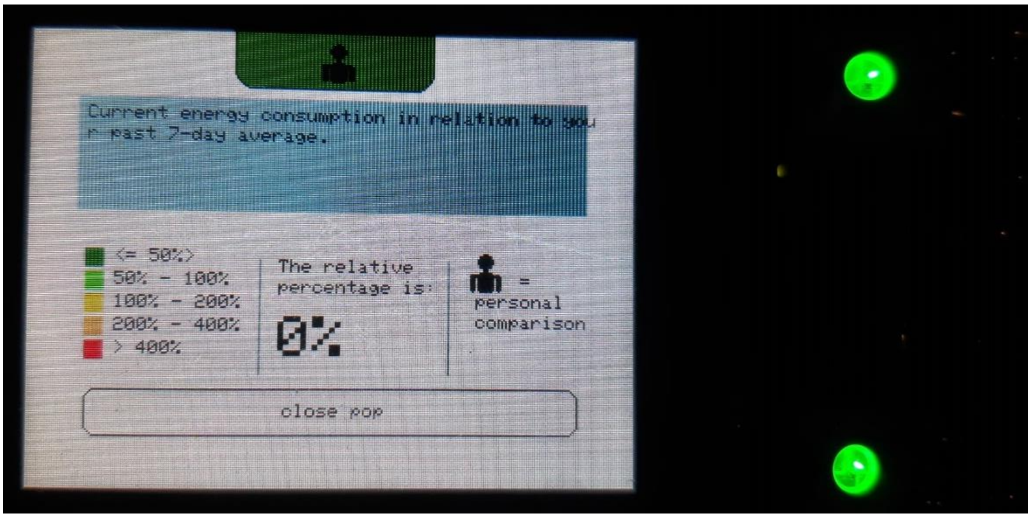


Figure 114: Illustration of the explanation page of the energy lights for the personal comparison state. This is the pop up that is being displayed after the button 'energy consumption in the moment' in the pop up in Figure 113 has been pressed. When the user presses the 'close pop up' button then the previous visible screen page is displayed again.

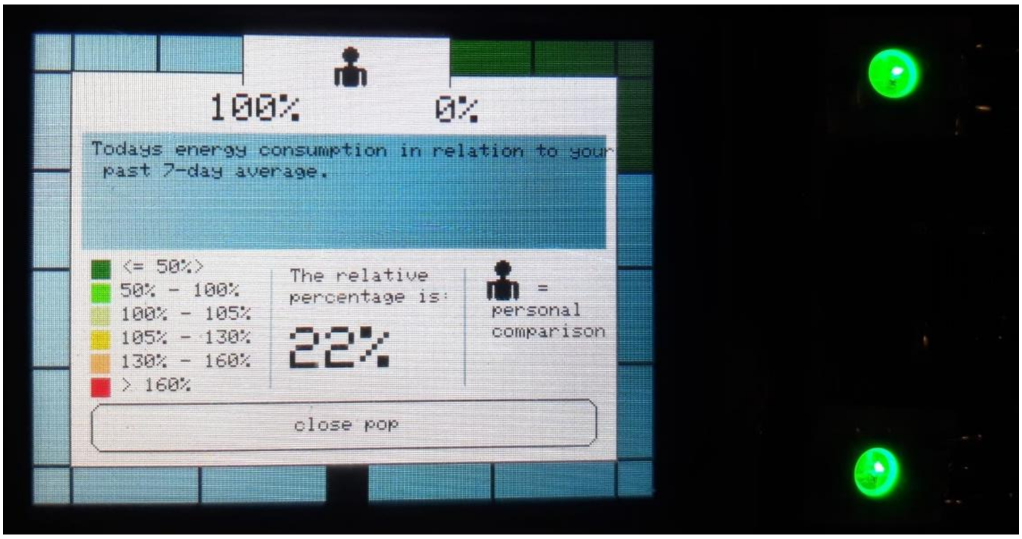


Figure 115: Illustration of the explanation page of the energy bar lights for the personal comparison state. This is the pop up that is being displayed after the button 'energy consumption of today' in the pop up in Figure 113 has been pressed. When the user presses the 'close pop up' button then the previous visible screen page is displayed again. The 100% and 0% indicate the scale of the bar lights on the screen. When the relative percentage would display 134% then this scale would be adjusted to 200% and 100% respectively.

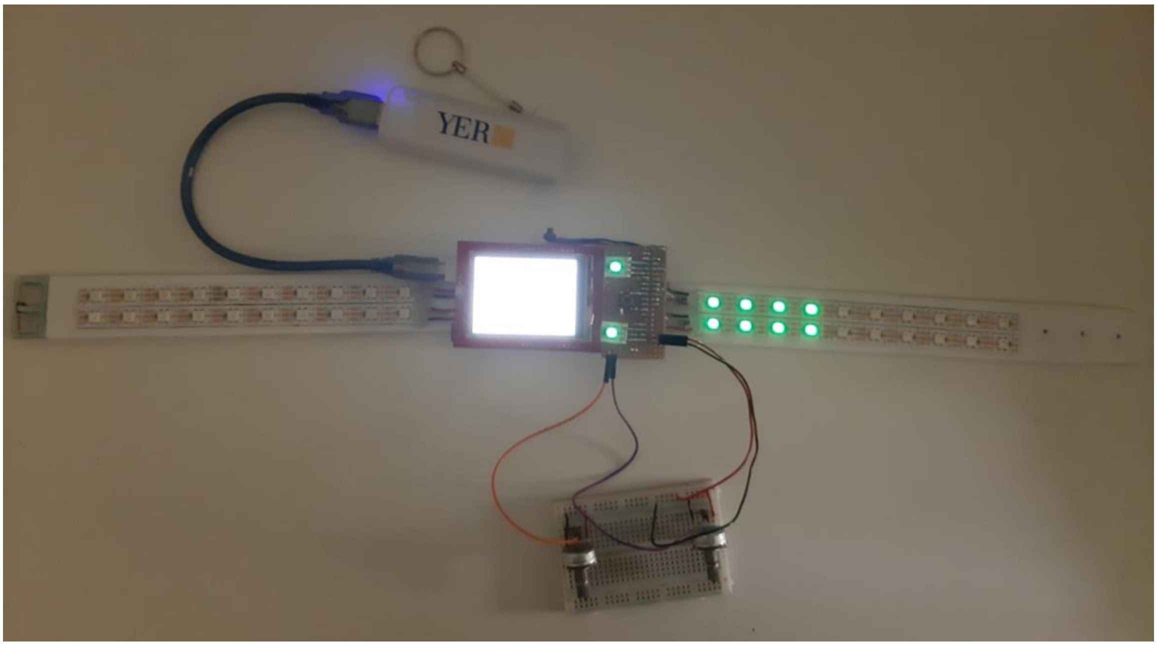


Figure 116: A general overview of what the lights in the wristband look like when in the personal comparison state.

Appendix G3.3: State 3

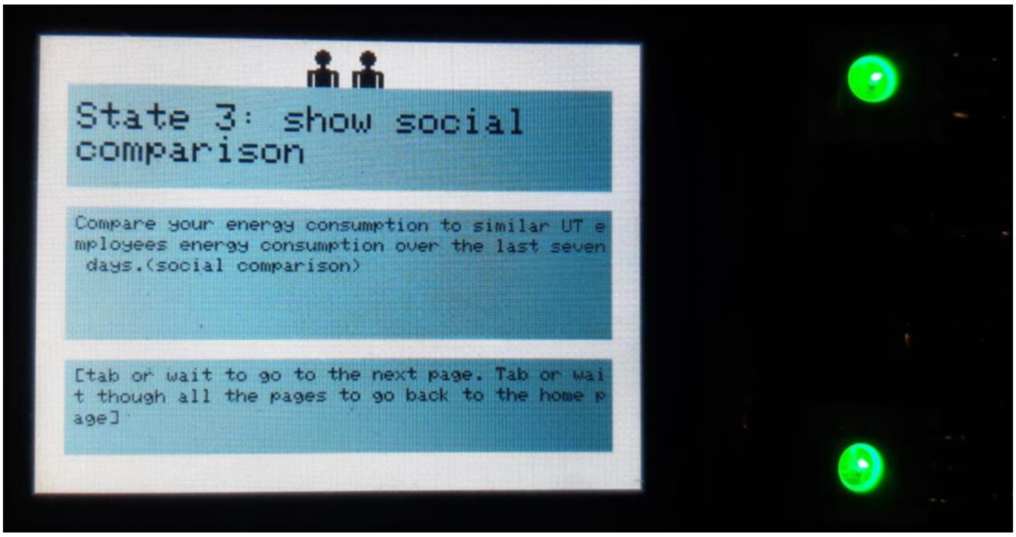


Figure 117: Illustration of the state 3 pop up. This page gets displayed when it the state is changed to state 3 or if the current state is state 3, but no pop up is being displayed yet. In state 3 the lights on the wristband of the smartwatch are turned on in the social comparison state. After 10 seconds or when the screen is touched it displays the pop up in Figure 118.

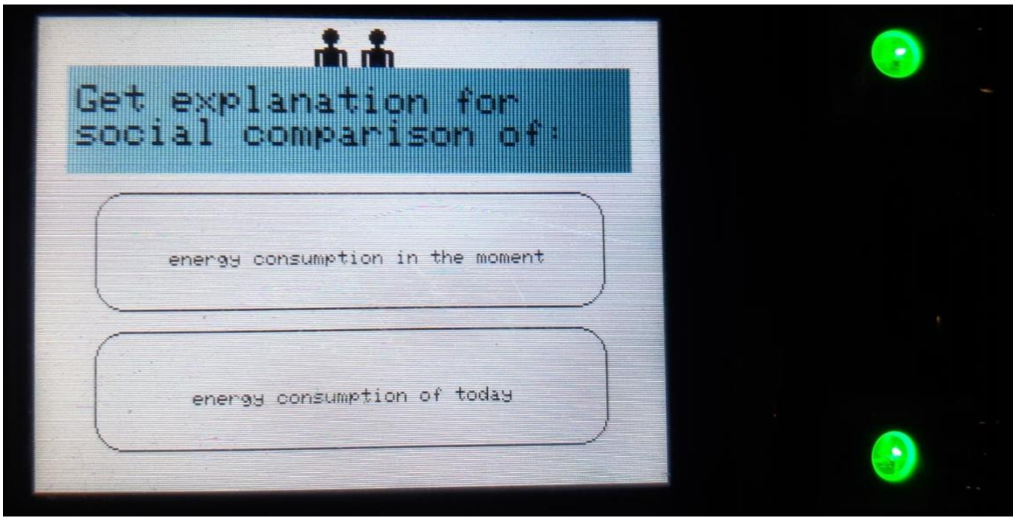


Figure 118: Pop up that is being displayed after the pop up in Figure 117 has been displayed. After 10 seconds or when the screen is touched, but not the buttons, then it automatically displays the previous visible screen page again. If the button 'energy consumption in the moment' is pressed the pop up in Figure 119 is displayed. When the 'energy consumption of today' is pressed the pop up in Figure 120 is displayed.

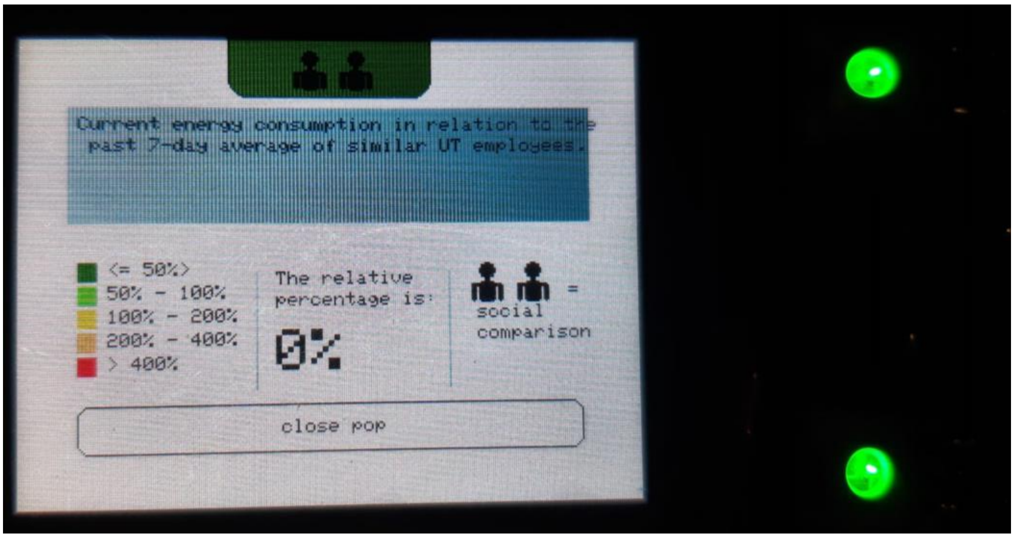


Figure 119: Illustration of the explanation page of the energy lights for the social comparison state. This is the pop up that is being displayed after the button 'energy consumption in the moment' in the pop up in Figure 118 has been pressed. When the user presses the 'close pop up' button then the previous visible screen page is displayed again.

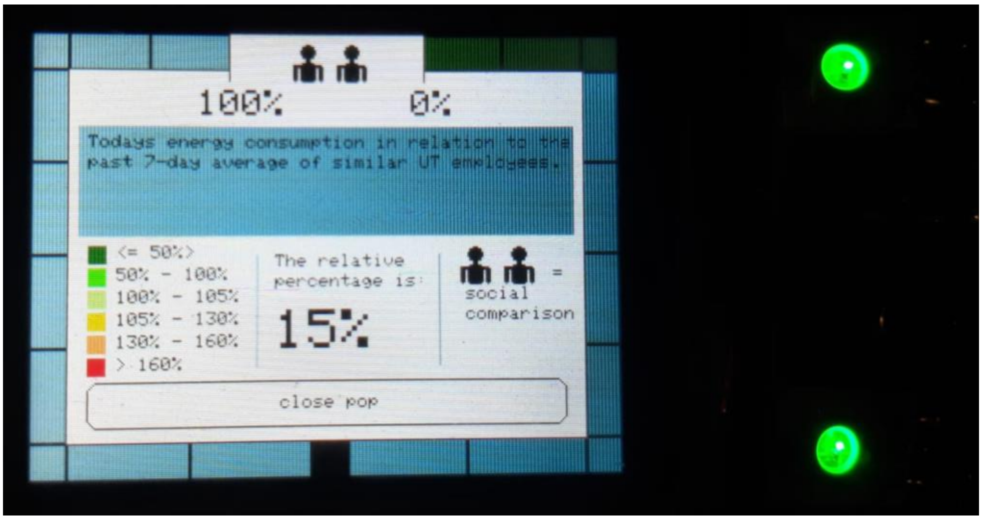


Figure 120: Illustration of the explanation page of the energy bar lights for the social comparison state. This is the pop up that is being displayed after the button 'energy consumption of today' in the pop up in Figure 118 has been pressed. When the user presses the 'close pop up' button then the previous visible screen page is displayed again. The 100% and 0% indicate the scale of the bar lights on the screen. When the relative percentage would display 134% then this scale would be adjusted to 200% and 100% respectively.

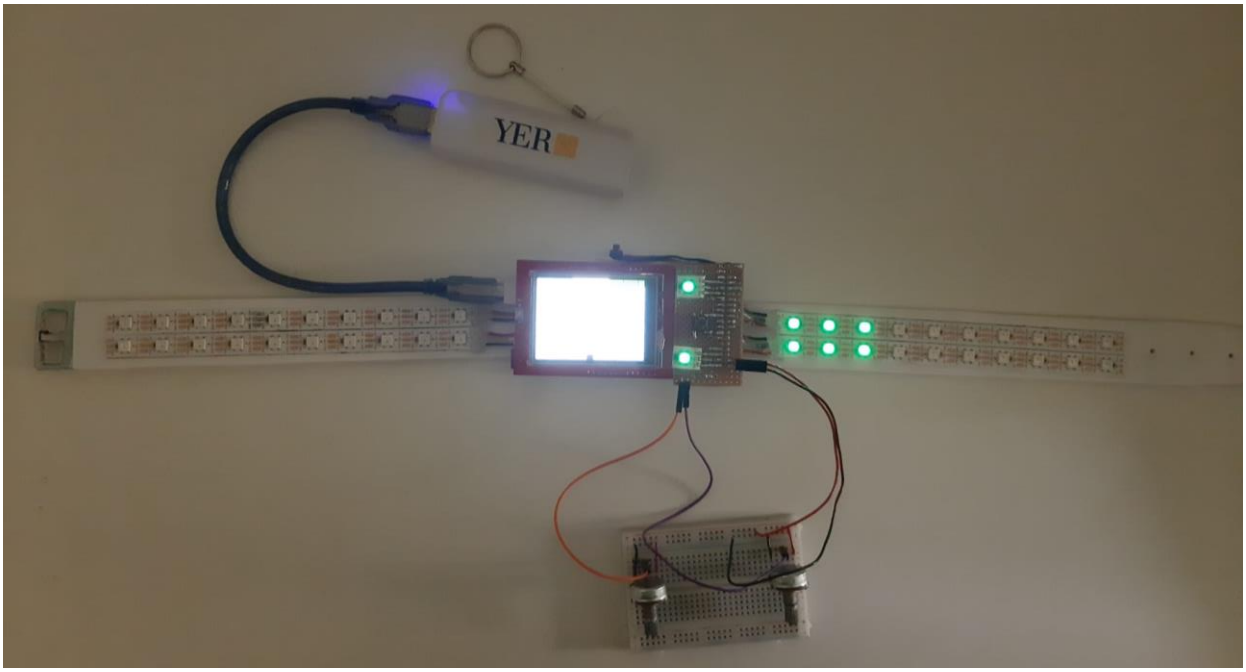


Figure 121: A general overview of what the lights in the wristband look like when in the social comparison state.

Appendix G3.4: State 4

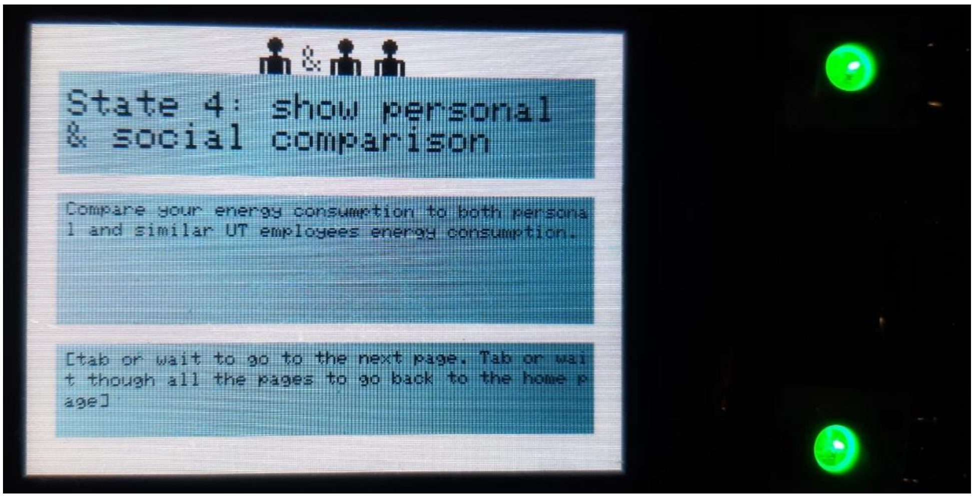


Figure 122: Illustration of the state 4 pop up. This page gets displayed when it the state is changed to state 4 or if the current state is state 4, but no pop up is being displayed yet. In state43 the lights on the wristband of the smartwatch are turned on in the personal and social comparison state. After 10 seconds or when the screen is touched it displays the pop up in Figure 123.

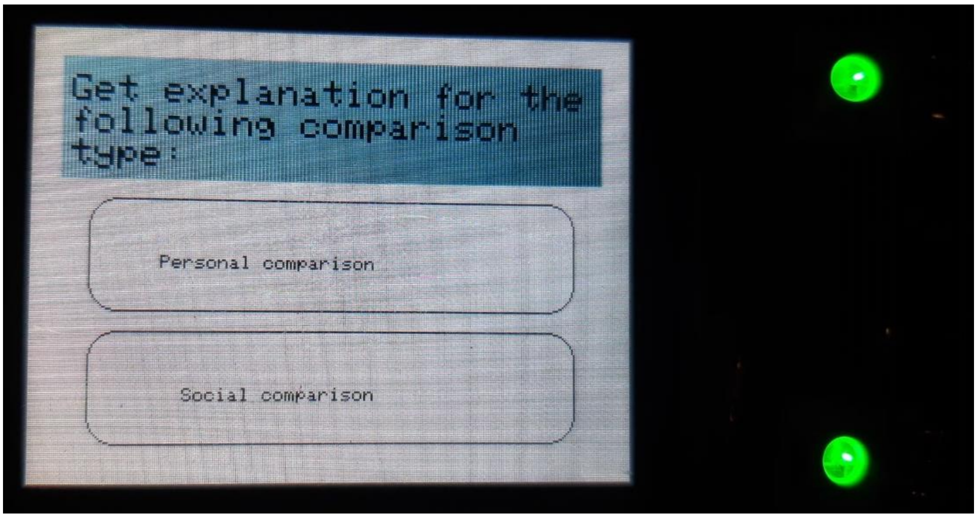


Figure 123: Pop up that is being displayed after the pop up in Figure 122 has been displayed. After 10 seconds or when the screen is touched, but not the buttons, then it automatically displays the previous visible screen page again. If the button 'Personal comparison' is pressed the pop up in Figure 113 is displayed. When the 'Social comparison' is pressed the pop up in Figure 118 is displayed.

Appendix G4: Buzz pop ups

The buzz pop ups have also been incorporated within the design for all different percentages specified in chapter 5. The figures below show examples of what these pop ups look like in the prototype.

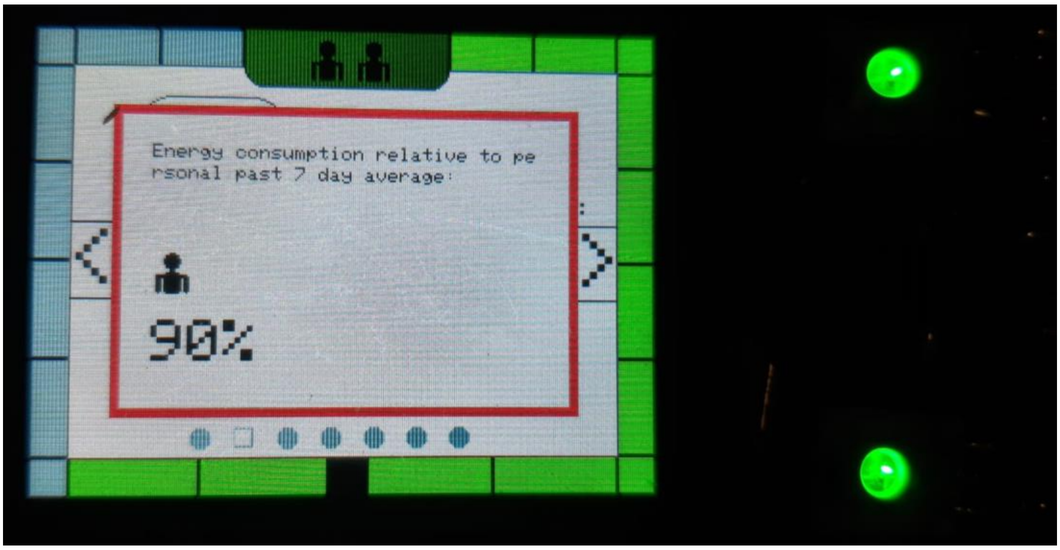


Figure 124: Example illustration of a buzz notification pop up when the user reached 90% of their energy consumption relative the their personal average energy consumption over the last 7 days.

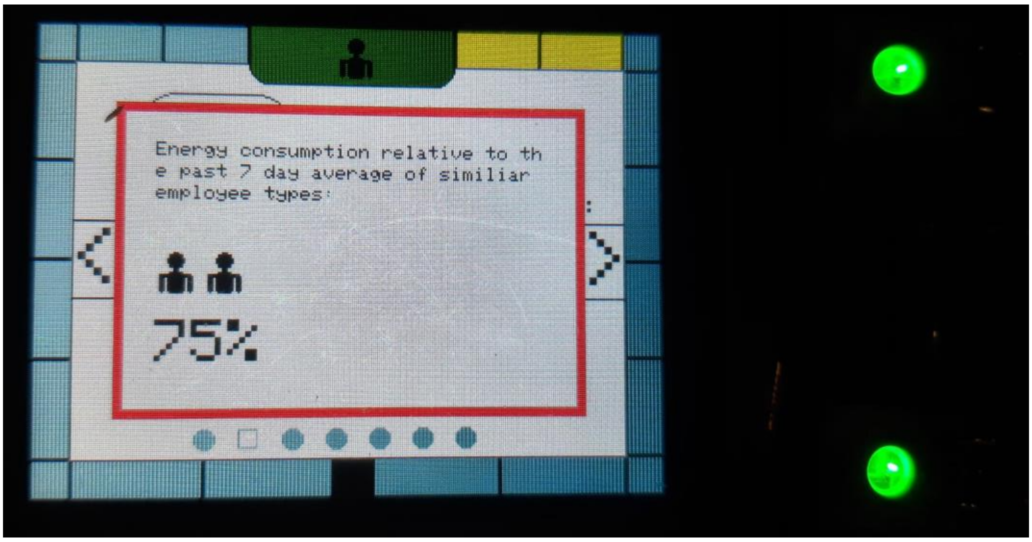


Figure 125: Example illustration of a buzz notification pop up when the user reached 75% of their energy consumption relative the average energy consumption of similar employees types over the last 7 days.

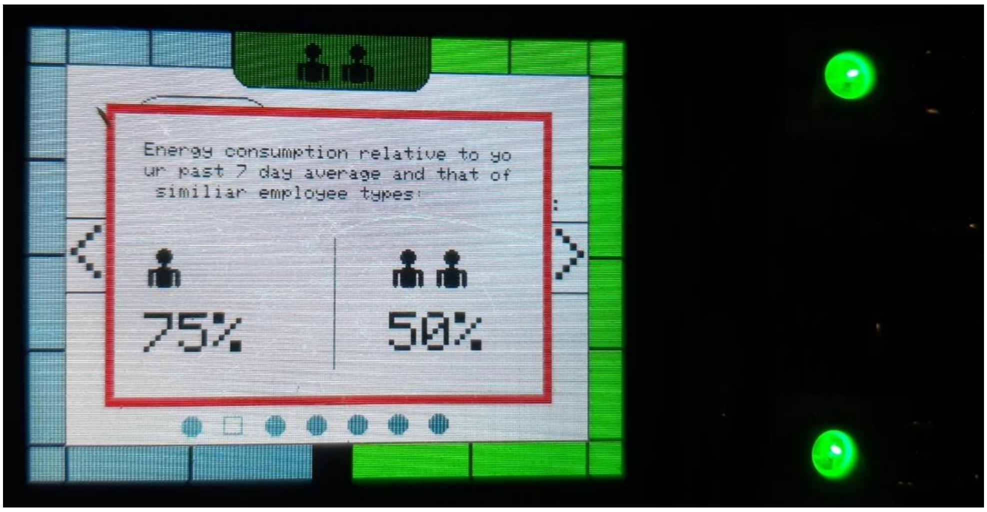


Figure 126: Example illustration of a buzz notification pop up when the user reached 75% of their energy consumption relative the their personal average energy consumption over the last 7 days at the same time they reached 50% of their energy consumption relative to their average energy consumption of similar employee types over the last 7 days.

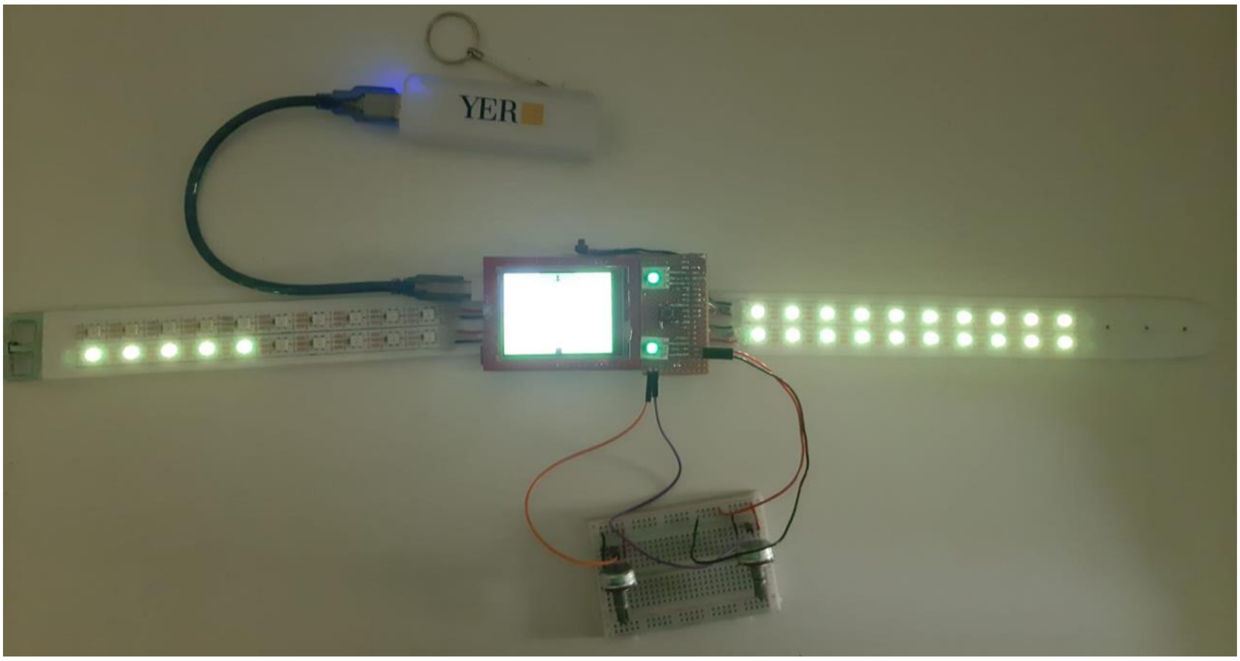


Figure 127: A general overview of what the energy bar lights in the wristband look like when both 75% and 50% is reached at the same time in the personal and social comparison state. (E.g. state 4).