Internet of Things for Circular Economy, design of a Pay-per-Use smart PSS eco-system

Master's thesis Design for Interaction by Diana Lorena Gonzalez Sanchez

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EXECUTIVE SUMMARY

RELEVANCE

Internet of Things can support Circular Economy in its goal of decoupling economic development from finite resources consumption in multiple ways. These include, for instance: optimizing resources consumption by providing information on products localization, condition or availability, and unlocking new business models as Pay-per-use or adding value to the service through data.
The expected growth of the IoT market in the coming years is massive, which suggests that applying IoT to contribute to the transition to Circular Economy is a promising combination for innovation and value creation. In this thesis, the collaborations between these two topics are explored in the framework of products as services, which work as a strategy for products life extension, specifically in the context of Pay-per-Use service using HOMIE start-up as a case of study.

THE COMPANY

HOMIE was created as a response to the high household environmental print and aims to reduce it by offering home appliances on a Pay-per-use model. The service rolled out with washing machines that are delivered to the users and maintained for free, whereas users are charged according to the program used. The machine is connected to HOMIE's database through a tracker that sends the data of users' consumption.

FINDINGS

Product-as-services as a circular business strategy relies on the service provider as the main actor for product circulation, the product use as an intensive resource consumption part of the lifecycle and its relationship with users' decision is not contemplated. However, for this project, considering the use phase proved to be relevant for HOMIE, as well as to contribute with the research on how to fill this gap. That is why sustainable behavior design strategies are also included in the project as a complementary concept to Circular Economy.
This study found out that smart products, such as HOMIE washing machines, have a special relation with sustainable behavior strategies, since connectivity enable in great extent the design of eco-interactions. These are designed features that try to intentionally lead to more sustainable practices whether by creating awareness, by leading users towards certain actions through affordances and constraints or by making decisions on behalf of the user like technology control. The research community has found that providing feedback with the intention of awareness creation is not enough to drive long term behavior change, therefore the use of connectivity for the design of complementary strategies turns especially relevant. This relation between IoT capabilities and sustainable behavior design strategies is detailed in a theoretical framework developed during the project.
Additionally, IoT is considered itself a source of value creation, which can be exploited in the development of service features that by means of connectivity solve issues that were not tackle before, as well as being an enabler of partnerships. Thus, more attractive value propositions can be created, which is crucial for Circular Business Models due to its low tangible value when removing ownership. As considered in human centered design, a value proposition rooted in user needs is likely to increase consumer adoption.

USER RESEARCH INSIGHTS

A user research was carried out and complemented with a quantitative analysis of HOMIE data. This was done to understands users' behavior and experience when doing laundry. The main results showed that current experiences with washing machine are marked by uncertainty due to the lack of feedback by the machine or the lack of knowledge by the users, for instance, when they do not know how much detergent to pour. Furthermore, all the decision making when doing the laundry is based on habits more than in a reflection and understanding of the variables.

Regarding sustainability, most users were interested in it, but the washing machine does not allow them to translate those concerns into actions since there is not information about how to be sustainable when washing. It was also found that personal concerns overrule any other interest in more sustainable practices, that is, users are willing to be more sustainable only if that does not interfere with their personal goals and if no extra effort is required.

|The results of the analysis phase were translated in a customer journey that showed three points of

intervention on HOMIE's service that would improve the experience and could be used as well to reduce the environmental impact of the washing machine. The environmental impact reduction is limited to two main actions. First, to motivate users to adopt the service, with what it is expected to raise product circularity, and second, to foster more sustainable practices. The latter is defined as reducing wash temperature, doing full loads and using the right amount of detergent.

CONCEPT DEVELOPMENT

With these clear intervention points, the design of a Smart PSS was developed through an iterative approach. A creative session was carried out as well as personal ideation. The collected ideas were clustered giving as a result four concept directions. These depicted the design of an eco-system with three service touchpoints: webpage, washing machine and an app. The directions were evaluated with the defined theoretical framework and an interview with an expert. Finally, the concept with the highest level of connectivity was selected and complemented with the eco-feedback component of another concept.

With the selected concept, the application of interaction design defined the features that belonged to each component of the eco-system and translated them into user interfaces. These interfaces were iterated in two loops, a paper prototyping and user test.

RESULTS

The final improved design is a Smart PSSs eco-system integrated by 3 devices, the webpage, the washing machine interface and an app. All together aim to improve the experience of use of HOMIE's Pay-per-Use service while fostering more sustainable practices. Therefore, they are built with a strong sustainable behavior design rationale. This is a clear example of how connectivity can be used to improve a circular business model and therefore reduce the environmental impact of products.
The results of this project in terms of research and design can be used by HOMIE to improve their value proposition and the user experience based on real user's concerns. Also, to visualize strategies that can strength their proposition in terms of sustainable behavior fostering.

ACKNOWLEDGEMENTS

Thanks to Nancy Bocken, Emilia Ingemarsdotter and Gerd Kortuem for setting up this amazing project that joined the two topics I was interested about, IoT and Circular Economy, and that has been a wonderful experience of learning. Thanks for your support and wise advice, for inviting me to move beyond my comfort zone and guide me to achieve the best of the project.

Special thanks to Emilia for having always the door open for me and my doubts, for not giving me only answers but invite me to think and reflect in the process. Thanks for your friendliness and willingness to help me.

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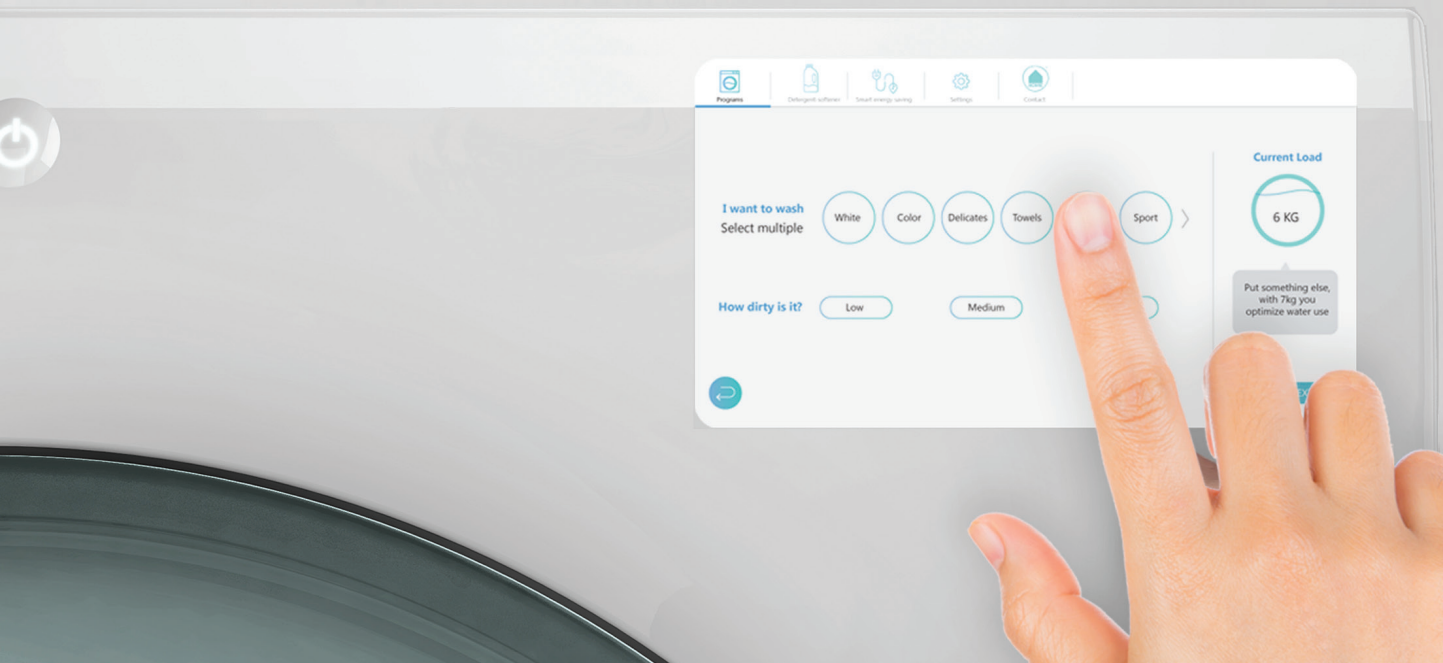

Programs
I want to wash
Select multiple
White
Color
Delicates
Towels
Sport
Current Load
6 KG
Put something else, with 7kg you optimize water use
How dirty is it?
Low
Medium

INTRODUCTION

BACKGROUND AND RELEVANCE

More households own washing machines than cars. Depending on the personal needs the machine can be of low or high quality. The quality of the machine has implications for material and energy consumption. Given similar material compositions and production processes, replacing five 2,000 cycle (expected lifespan) machines with one of 10,000 cycle machine yields almost 180 kg of steel savings and more than 2.5 tons of CO2e savings.

Regarding the use phase, it is estimated that the energy consumption for doing laundry in the EU in 2015 was 35TWh (approximately 30% of all the electrical energy consumption in the Netherlands in a year) due to the use of warm cycles (Commission Regulation (EU), 2010). Additionally, 840 million washing machines are used worldwide, its use accounts for the 2% of the total electricity of the residential sector (Barthel & Dietz, 2013). A study researching potential savings if both technology and user's behavior is changed towards better practices (full capacity and use of low temperatures) shows that it is possible to save up to 50% of both energy and water, which means more than 12TWh of electricity and about 870 million m3 of water (Pakula & Stamminger, 2015).

In response to this high environmental impact, HOMIE was created as a TUDelft start-up. Starting with washing machines, HOMIE offers them to the public on a Pay-per-Use model. Customers get a washing machine installed at their residences and are charged every time they use it, depending on the selected washing program. This PSS, based on a Circular Business Model, aims to extend the products' life by removing user's ownership and this way encouraging the service provider to circulate the product through multiple loops (e.g. of maintenance) in order to keep its condition as good as possible for the longest time possible.

Importantly, this service is enabled by a built-in tracker that sends information to HOMIE database on users' consumption when every wash is done. Thus, a connected product is created and consequently a Smart PSS. The latter fact opens multiple opportunities for the growing start-up.

PROBLEM DEFINITION

Products as services have a low tangible value but are highly resource efficient, thus a strong value proposition and consistent experience is needed to motivate users to adopt the service. Given this, all different layers of the PSSs must fulfill the right user needs. Hence, a human centered approach is especially relevant.

Considering connectivity as a main aspect of HOMIE service, a design opportunity was found in the exploration of how Internet of Things can support Circular Economy and in this case, a Pay-per-Use model, in its aim of reducing the environmental impact of products, materials and assets. This is done specifically in the framework of User Experience since it is the most pertinent for current company state. Therefore, the assignment goal was defined as:

To explore how product connectivity on a Pay-Per-Use model can support Circular Economy. Based on that, shape the interaction design of HOMIE's washing machine service to ensure a consistent User Experience (UX) with their value proposition.

Even though product circulation is the principal proposition of Circular Economy to increase products sustainability, the use phase can be the most polluting in washing machines, which is why HOMIE also aims to promote more sustainable practice. The latter brought to the project a hint on the direction of the project toward sustainable behavior design strategies as a potential relation between IoT and the reduction of washing machines environmental impact.

RESEARCH QUESTIONS AND DELIVERABLES

By considering the above mentioned, the main project research question was defined as:

How can connectivity support Circular Economy on a Pay-Per-Use business model?

To answer it, four sub-research questions were stated. The two first sub-research questions provide an overview of the project relevant topics from the current literature and state of the art. The two last ones, on the other hand, focus on the application of the found insights into HOMIE, as the current case of study.

1. How are Circular Economy, sustainable behavior and IoT related?

Deliverable: Literature research, which provides insights into possible relations between the topics studied as well as a potential direction for the project. Also, theoretical framework that can support that direction and the design process.

2. How are current connected products and Circular PSS making use of connectivity to drive sustainable behavior change?

Deliverable: Benchmarking, in this the main question is divided into 3 sub-questions that explore: the design, application of sustainable behavior strategies and UX opportunities of smart washing machines, energy monitors and circular PSSs. A more detailed framework, based in literature research findings is used to analyze the relation of connectivity with the mentioned topics.

3. Which are user needs when doing the laundry? Which behavior patterns do users have?

Deliverable: User research, it details into user's habits, knowledges and concerns as well as their current experience with washing machines. This is obtained through analyzed qualitative user-research. Additionally, both qualitative and quantitative data from HOMIE are analyzed.

4. Considering the outcome of the analysis phase, how can current HOMIE service UX be shaped by using connectivity to increase adoption and foster sustainable behavior while fulfilling user needs?

Deliverable: This question is answered starting with the design scoping and through all design process until the final design. The process shows a clear case of study of the use of connectivity in a Circular Economy business model.

PROJECT SETUP

The project was divided in two main phases, analysis and design phase, the latter as the case of study. Both are developed by a double diamond design process. The analysis phase provides insights into the project topics from various perspective with the literature research, benchmarking, company analysis and user research. The insights obtained are then narrowed down to a design brief with a specific direction to focus upon. These direction is detailed in a customer journey as three points of intervention in HOMIE current service and a specific target group.

The second diamond, that correspond to the case of study design starts with the ideation process. Multiple potential solutions are developed with a creative session and personal ideation that are transformed in idea cards. These are afterwards clustered to find four design directions. These directions are evaluated with a theoretical framework and an expert interview to finally select the most appropriate, which is developed through and iterative approach that included the definition of the smart eco-system components as well as their features, wireframing, paper prototyping and user testing. The final Smart PSSs of 3 parts, webpage, washing machine interface and app, the concept is presented through an eco-system map, a touchpoint matrix and the embodiment of the UI design.

APPROACH

This project takes a human centered approach to be able to define user's perspective and to evaluate what capabilities and characteristics of a Smart PSSs are strategic and relevant for both the user and the environment. For example, how can the collected data be transformed in valuable information and knowledge for the user, and how is that information presented through the different service touchpoints.

Although the emphasis of the project is on user-centered design solutions, a strong sustainability proposition is considered throughout all the design, given that this design requires to balance users' needs with a specific sustainable goal. These sustainable goals are defined according to the potential impact that each step of the service could involve. For example, the reduction of the washing temperature. So, the idea was not only to create a feature that satisfied a specific user's wish but also to use it to foster sustainable practices.

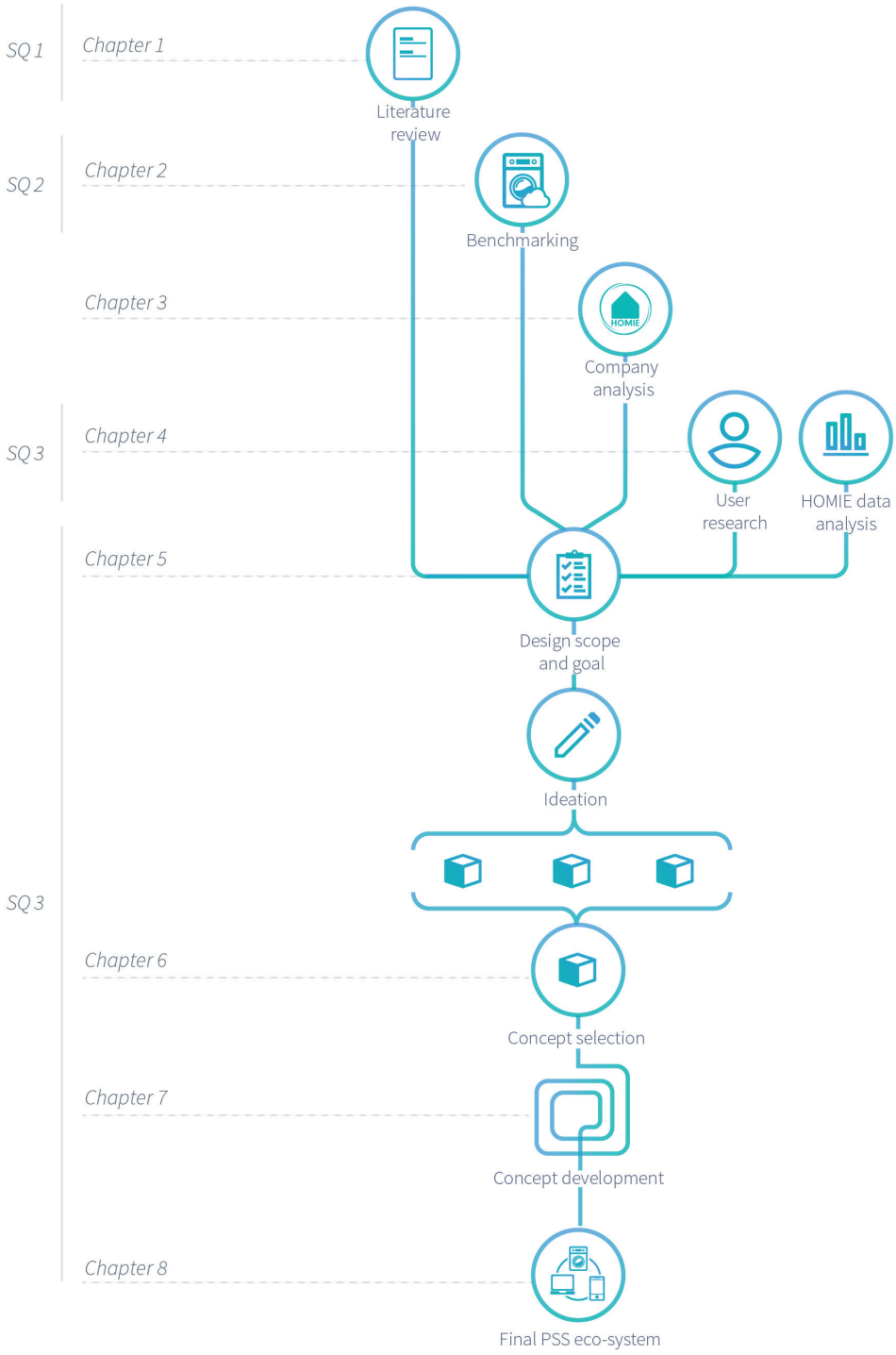
REPORT STRUCTURE

The report is structured in 8 chapters. The first chapter explains Circular Economy, IoT and Sustainable behavior concepts as well as their relations. The second chapter

explores 3 smart washing machines, 3 energy monitors and 4 circular PSSs and provide insights into its design and how connectivity is used in it. The third chapter presents an overview of HOMIE service by analyzing its value creation, capture and delivery, as well as a service mapping. The fourth part focuses on the understanding of users' current experience with washing machines to gain insights into behavior, habits and concerns. These are obtained through user-research and data analysis.

The insights obtained from all the analysis are narrowed down in the fifth chapter where the design focus and goal are presented, along with a customer journey mapping and an analysis on laundry sustainable practices. The latter is used as a main input for the design process that is developed in chapters 6 and 7, describing the ideation and selection of the concept, and development of the concept, respectively. The final chapter explains the final design concept. Lastly, a reflection is stated as well as recommendations for further research.

READING GUIDE



1.LITERATURE REVIEW

The literature review aims to provide a better understanding of the three major topics of this project, as well as its potential relations: Circular Economy (CE), Internet of Things (IoT) and Sustainable Behavior (SB). Firstly, Circular Economy is defined along with its principles and characteristics, followed by an exploration of one of its main drivers, Circular Business Models (CBM) with a focus on Pay-Per-Use. Likewise, an analysis of Product Service System (PSS) in the frame of Circular Economy is provided. Secondly, Internet of Things market, opportunities and challenges are defined, special attention is paid to Smart PSS and UX design in the IoT context. Finally, Sustainable Behavior during the use phase is considered including eco-interactions.

Common ground is found between Circular Economy and Internet of Things as complementary concepts to boost innovation and resources optimization. In this matter, there is a clear design opportunity on a service and interaction level to use Smart PSSs characteristics to unlock new value streams for user experience as well as to promote sustainable behaviors through eco-interactions design.

1.1.CIRCULAR ECONOMY (CE)

Human activity in resource-intensive economies during the past century has caused an environmental change that is overruling the natural dynamism, consequently leading to environmental problems such as biodiversity loss, climate change and pollution among others (Harris, 2014). Furthermore, population is expected to reach 9 billion by 2050 and as population increases so will do the consumption of natural resources, which is estimated to triplicate in the coming years (EMF, 2013). The above-mentioned factors are producing and enormous pressure on global resources that will not be sustainable in a long term.

In the current industrial economy, raw materials are available in nature at a relatively low cost, so it is neither a priority nor a need to get back those materials. The result is a “linear model” or “take-make-dispose” model in which companies extract raw materials, produce with low cost labor and lots of energy for a short product lifespan and use. For example, laptops are currently used for about 4 years while 7 years would be the ideal lifespan from a sustainable perspective (Bakker, Wang, Huisman, & den Hollander, 2014). Finally, when the product is discarded most of the materials are never recovered. It is estimated that from all the waste generated in Europe in 2010 only 40 % was re-used, recycled or composted (EMF, 2013).

1.1.1.Definition

The CE concept promises to be a noteworthy alternative to the linear economy. It aims to “decouple global economic development from finite resource consumption” (EMF, 2015b). Different definitions have been explored in literature to frame CE goal, characteristics and principles. (See table 1)

1.1.2.Principles

Ellen MacArthur Foundation (EMF) has been a crucial agent in the recent diffusion of the CE concept by involving business, government and academia in its development. EMF proposes the butterfly diagram as a representation of the three CE core principles which applies for both natural and technical cycles (See figure 1) (EMF, 2015b).

The second principle states that resources can be optimized by circulating products, components and materials through various loops which keep those at the highest utility at all times (EMF, 2013). All these circles offer opportunities for value creation that do not rely on new product manufacturing but in the continue flow of materials (Bocken, de Pauw, Bakker, & van der Grinten, 2016). Thus, loops where products and materials are

Autor	Definition
Ellen MacArthur Foundation (EMF, 2013)	An industrial economy that is restorative by intention; aims to rely on renewable energy; minimizes, tracks, and eliminates the use of toxic chemicals; and eradicates waste through careful design
Ellen MacArthur Foundation (EMF, 2015a)	An economy that is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles.
Mentink, 2014	An economy with closed material loops.
Scott, 2013	A concept used to describe a zero-waste industrial economy that profits from two types of material inputs: (1) biological materials are those that can be reintroduced back into the biosphere in a restorative manner without harm or waste (i.e: they breakdown naturally); and, (2) technical materials, which can be continuously re-used without harm or waste
Geissdoerfer, Savaget, Bocken, & Hultink, 2017	A regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing and recycling.
Accenture, 2014	In a Circular Economy, growth is decoupled from the use of scarce resources through disruptive technology and business models based on longevity, renewability, reuse, repair, upgrade, refurbishment, capacity sharing, and dematerialization.

Table 1. Circular Economy definitions

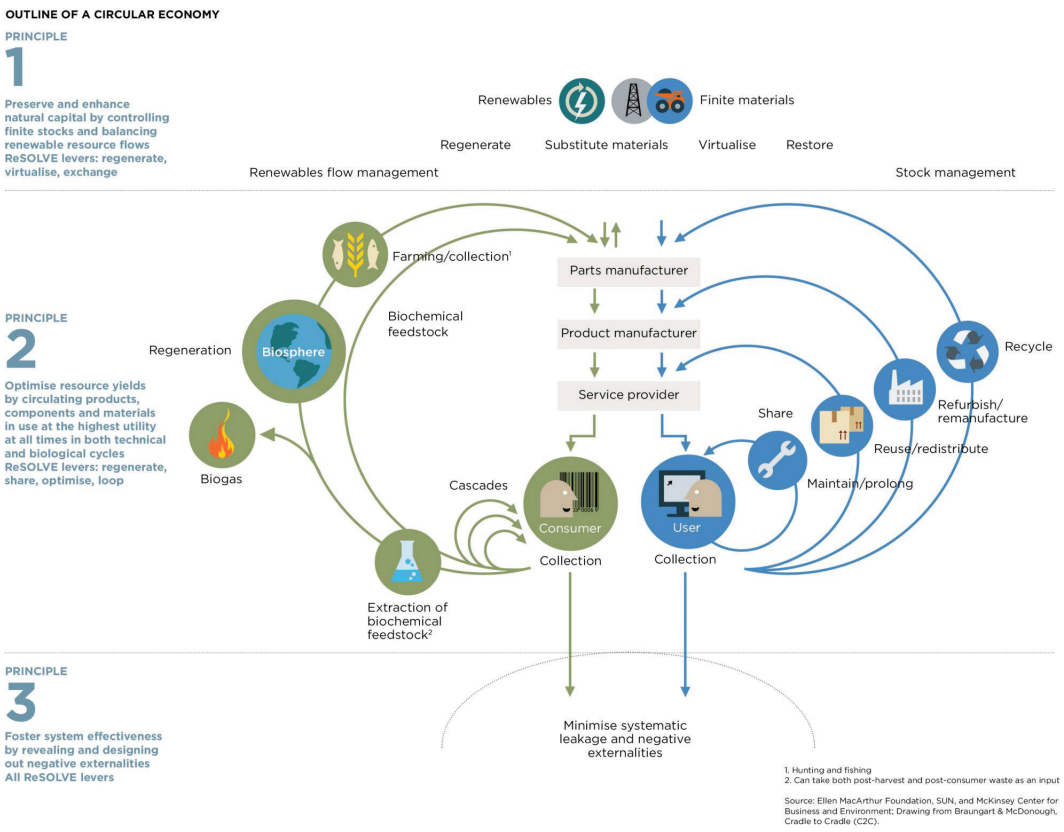


Figure 1. Butterfly diagram an "outline of a CE" (EMF, 2015b)

shared, maintained/prolonged, re-used/redistributed, refurbished/remanufactured and recycled are crucial means for moving economy towards a CE. Also, the smaller the circle the better, given that product value is more preserved, e.g. a shared product vs a recycled one (EMF, 2013).

1.1.3.Opportunities and challenges

According to Planing (2015), three main reasons have motivated the growing interest in CE. Firstly, the increasing price of raw materials and its volatility that create and unpredictable market. Secondly, the advancement of Information Technology that enables the design of new business models. And finally, consumer behavior which is shifting from ownership to a more performance oriented attitude. Two other factors are mentioned by Mentink (2014): the increase in resource efficiency legislation and new schemes of collaboration in the supply chain. In this matter, EMF (2016) predicts that CE development will create significant economic value by reducing the exposure to price volatility, achieving savings in materials and increasing innovation and job creation (EMF, 2016).

CE focuses in resource efficiency, thus leaving aside the ***human*** component of sustainable development. Furthermore, Mentink (2014) argues that the wide exploration and conceptualization of CE have created a disbalanced implementation with a focus in only the business advantages, which is accompanied by a lack of discussion on social issues.

1.1.4.Circular Business Models (CBM)

New business models are fundamental for closing loops in the adoption of a CE. Circular Business Models (CBMs) can optimize the use of resources and extend product lifespan by prioritizing access to services rather than product ownership and/or creating attractive value propositions to promote product circulation (EMF, 2013; Planing, 2015). In addition, CBMs support the development of new concepts and tools to encourage CE cooperation and acceptance, then inspiring others to participate and innovate (Bocken, de Pauw, et al., 2016).

Bocken et.al (2016) define a business model as a holistic framework, that connects different actors (firm, suppliers and other partners) to create value for the customers. Essentially, a business model compounds a value proposition (product/service offering), value creation and delivery (how is the value provided) and value capture (how money or other forms of value are captured (Bocken, Weissbrod, & Tennant, 2016).

Value creation and design strategies

In CE context, the business value creation is based on economic value that can be retained after or during the products' use. This means that value is created when loops are closed or extended (Linder & Williander, 2017). Bocken et al. (2016) identify two design strategies to create value from the loops: Business models that close resource loops (the inner circle) and slow loops (circling longer). When closing the loops, the value is captured from by-products or waste at an either macro or micro level. For slowing, the product is reused/shared or its life is extended through business model innovation (See figure 2).

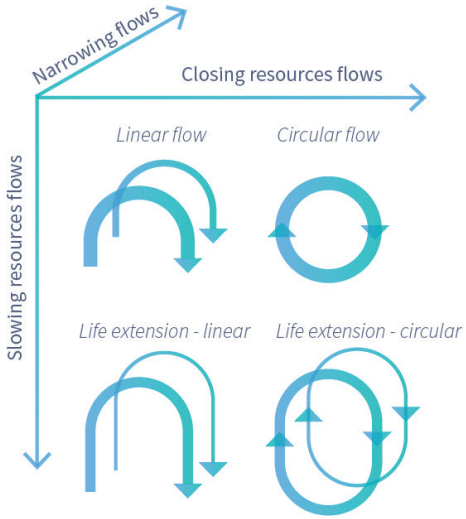


Figure 2. Categorization of linear and circular approaches (Bocken, Weissbrod, et al., 2016)

Every CBM is both linear and circular in some extent since 100% circular models do not exist yet. A complete circular model would imply no loss in the system and an infinite material loops what is not possible due to technological limitations (Lewandowski, 2016; Mentink, 2014). Nevertheless, slowing and closing loops can be mutually reinforced to increment the impact of the model (Bocken, de Pauw, et al., 2016).

Experimentation is an essential part of the development of sustainable business models. This process of learning by doing is crucial to explore different possibilities of value creation and to define what might work in which specific situations (Bocken, Weissbrod, et al., 2016).

Product Service System (PSS)

PSSs are widely mentioned in the literature as being crucial in the transition towards a CE. Multiple authors

refer to PSS as an effective instrument to shift from product-oriented business to service-oriented (EMF, 2013; Jelsma & Knot, 2002, 2002; Planing, 2015; Prendeville & Bocken, 2016; RSA, Action and Research Center, 2013; Tukker, 2004), what in theory will allow companies to fulfill user's needs with less environmental impact.

Tukker (2004) defines a PSS as *"an integrated bundle of products and services which aims at creating customer and generating value"*. PSSs can be classified in three main categories: product-oriented, use-oriented and result-oriented (See figure 3).

Product-oriented PSSs are still thoroughly connected to the product and the user keeps the ownership. In this category only a few services are commonly added to the product. In use-oriented PSSs, although the product is still central, it belongs to the service provider as for example in leasing or renting models. Finally, in result-oriented PSSs the product as such is not central anymore but the focus is on the result or function of the product.

In PSSs the service provider is encouraged to increase products utilization capacity to optimize company resources, thus extend product life cycle (Planing, 2015). Additionally, when involving collaborative consumption and shared economy the cost of ownership might be reduced, hence benefiting both the user and the environment (Mentink, 2014).

As previously stated, PSSs are considered an approach to reduce the environmental impact of consumption, however some limitations and drawbacks have been identified that might challenge that belief. Tukker (2014) even states that PSSs are not necessarily more resource efficient than products.

Product-oriented PSS can improve maintenance but the business is still focused on selling as much as possible presumably leading to programmed obsolescence. On the other hand, use-oriented PSS might stimulate careless behavior and the extensive use could rapidly reduce the product value. Finally, in most services the product is produced by a third party, which limits the innovation opportunities (Tukker, 2004, 2015).

The depicted classification is extensively used as reference in literature, however Van Ostaeyen et al., (2013) argues that the complexity of PSSs is not completely captured by the three proposed types for several reasons. Firstly, the definition of use-oriented PSS is too restricted, because it is characterized by the removal of ownership, however there are some examples of services which capture revenue based on use but do not remove the ownership. Secondly, there is a difference between usage in terms of availability (product available in customers location) and operationality (customers actually using the product) that is not covered by use-oriented type. Thirdly, the functionality delivered by a result-oriented type can be interpreted in various levels of abstractness, (e.g Pay-Per-Use of washing machine or a delivery service of laundry have the same result, clean cloth) what is not considered in Tukker's classification.

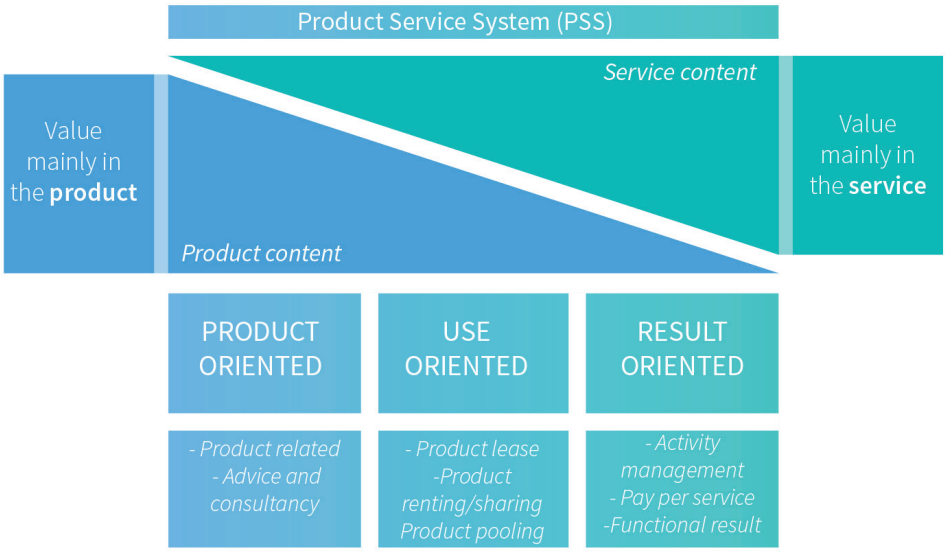


Figure 3. Product Service Systems (PSS) classification (Tukker, 2004)

Besides the potential positive environmental impact, PSS is a strategic alternative for companies. In the current product-oriented industry most products are similar and high quality, hence limiting companies' differentiation and competitive advantage (Tukker, 2015). In contrast, a PSS solution might unlock new value streams by implementing more integrated solutions and experiences, it also promotes stronger and longer relationships with clients and therefore insights on customer behavior and consumption. The latter might as well speed up innovation while raising customer loyalty (Mentink, 2014).

Adoption challenges:

Despite the advantages of PSSs over product-oriented business their implementation has until now been relatively low (Prendeville & Bocken, 2016; Tukker, 2015). This can be related to two main reasons:

Firstly, poor consumer acceptance. Ownership adds to esteem and hence has intangible value, it can also increase comfort or convenience (e.g. owning a car) (Tukker, 2015). Additionally, users tend to evaluate the cost of a product at the point of sale, when a long-term PSS might not seem as attractive as ownership (Prendeville & Bocken, 2016). Consumer behavior is based in habits and routines. This means that previous concepts and beliefs about products can rise resistance to change and reduce users' openness to innovation. Only information about technological and economical advantages of switching to a CBM will probably not be enough to change long-learned behaviors. It is important to understand the intangible values that frame consumer behavior. For instance, a PSS that is functional but not easy to use, will not achieve wide adoption (Prendeville & Bocken, 2016).

Secondly, complex and uncertain corporative changes. PSSs require a high up-front investment and take longtime to generate revenue (Mentink, 2014)., specifically in use- and result-oriented services. Furthermore, most companies have product-oriented experience, so the change to a service approach is challenging to its current capabilities and sometimes it is not clear if it would actually optimize resources (Tukker, 2015). Finally, although service-oriented companies might be bigger, their revenue could be less than in product-oriented ones. (Tukker, 2015)

Even though poor consumer acceptance is a widely mentioned aspect of PSSs slow adoption, literature also points out to a growing trend towards collaborative consumption (e.g zip car, Airbnb, car2go) (Mentink, 2014) and no-ownership (EMF, 2015a; Planing, 2015), especially among millennials who seem to value experiences over things (Morgan, 2015).

Pay-Per-Use service

Most research regarding Pay-Per-Use has been developed from an overview of result-oriented models, little information is found about its specifics. Additionally, literature predominantly details a theoretical viewpoint of the service rather than a practical one. No consistent empirical evidence of its practical side has been explored yet (Gebauer, Saul, Haldimann, & Gustafsson, 2016).

Result-oriented services are characterized by multiple authors with a similar spirit. *Performance based* by Van Ostaeyen et al. (2013) and Lewandowski (2016), and *Access and performance model* (Bocken, de Pauw, et al., 2016). All agree that the user does not buy or own the product but the result or performance of it. Also, the revenue streams are defined in accordance to the level of use. That "result" or "function" can be interpreted in distinct levels of abstractness, which are detailed by Ostaeyen et al. (2013) as solution oriented, effect oriented or demand oriented (See figure 4). In the solution-oriented level, the revenue is defined by the functional performance indicator of the product (e.g. heat efficiency transference of a radiator). Effect oriented, on the other hand, generates revenue according to the environment functional performance, it is measured according to its direct effect on the environment (e.g. time that the temperature is a certain level). Finally, demand oriented is determined according to a subjective functional performance, i.e. it is related with customers' satisfaction (e.g. percentage of people dissatisfied).

Figure 4. Performance based services typology (Van Ostaeyen et al., 2013)

The key aspect that distinguish Pay-Per-Use services from other result-oriented PSS is the "unit" of consumption. That unit might vary according to the type and level of performance, for instance time can be measured from seconds to hours. It can also be a specific solution-oriented (Van Ostaeyen et al., 2013) measurement like

pages or washes. The working definition for Pay-Per-Use is:

A Product Service System without ownership in which the functional use/consumption/performance is measured in a specific unit (magnitude of quantity) and the revenue is defined accordingly.

On the advantages side, Pay-Per-Use can encourage a more conscious use of the resources since the payment is defined by performance (Tukker, 2004, 2015). Next, the payment by consumption increases the perception of price fairness and the low payments without upfront investment might increase consumer engagement (Reason street, n.d.). On the drawbacks side, a high upfront investment is required from the service providers (Mentink, 2014; Tukker, 2004), so they should be able to accurately estimate consumption and additionally it might not suit frequent users' needs (Reason street, n.d.).

Finally, when designing a Pay-Per-Use service special attention should be paid to the billing so as to provide a simple, transparent and easy to understand process. Flexibility (e.g. monthly subscription) is also recommended to increase customer adoption.

1.1.5.Design, opportunities to go circular

Having detailed some of the challenges of CBM shaped as PSSs, design as a problem-solving discipline must be able to tackle them. In that regard, the Action and Research Center (RSA) (2013) identified four design opportunities to support CE: Design for longevity, Design for leasing/service, Design for reuse in manufacture and finally Design for material recovery (See figure 5). Service design

Figure 5. Design opportunities to support CE (RSA, Action and Research Center, 2013)

stands out as the most relevant for this project due to its close relation with CBMs, PSSs and interaction design.

Service design can through a human centered approach support the design of appealing value propositions that overcome PSSs' drawbacks and promote consumer adoption of circular PSS. This value proposition should be based on a deep understanding of people's motives, norms, habits and routines (Planing, 2015) and reduce the inconvenience that users could face by probably providing additional benefits (Lewandowski, 2016). Additionally, service and interaction design can shape intangible values into usable and tangible elements of the User Experience (Prendeville & Bocken, 2016), which is crucial to ensure that user needs are fulfilled.

1.2.INTERNET OF THINGS

The Internet of Things is described as one of the most disruptive technologies of this century with potential to impact most industries (McKinsey Global Institute, 2015). By incorporating sensors and actuators IoT is expected to boost productivity, enable new business models and constitute and strategic asset for value creation. When incorporated in products, so-called connected ecosystems are created, which are offered through a service approach. The union of the smartness provided by connectivity with PSS has potential to extend service capabilities (e.g monitoring, control, optimization, autonomy), this way adding digital value and promoting innovation. The design of such services in the framework of a fast-developing technology as IoT arises challenges in the design of the User Experience such as technology limitations, complex value propositions, multiple context uses and touchpoints.

1.2.1.Definition

Due to its fast development, several similar technologies evolution and multiple industries involved, there is not a widely accepted definition of IoT in literature. In the context of physical products and for this project the working definition for IoT is:

"The connectivity of physical object (things), equipped with sensors and actuators, to the internet via data communication technology, enabling interaction with and/or among these objects." (Kees, Oberlaender, Roeglinger, & Rosemann, 2015)

Importantly, those IoT enabled Smart Products (SP) must be physical products that could work without IoT

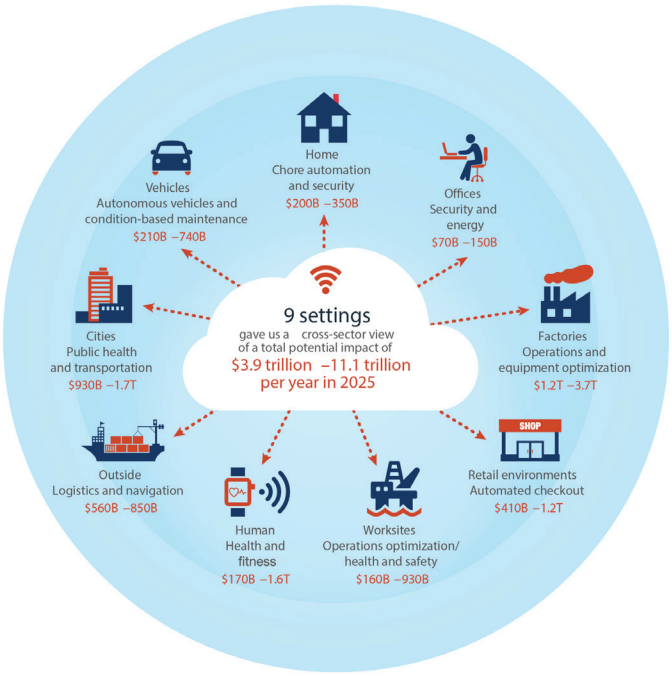


Figure 6. IoT projected 2025 market(McKinsey Global Institute, 2015)

technology, it means that laptops, smartphones and tablets are not considered (Kees et al., 2015).

1.2.2.Market

IoT market is expected to have an economic impact of 11.1 trillion per year in 2025. This will be the equivalent to 11% of the world economy by that year (McKinsey Global Institute, 2015) (See figure 6). Despite this enormous potential, IoT has a complex market with lots of actors involved and a fast developed but rather new technology (Wortmann & Flüchter, 2015), hence, certain conditions must be given and settled to unlock all its potential. For instance, better tools and methods to analyze data as well as a considerable improvement in interoperability. The latter is required to capture 40% of the potential IoT value (McKinsey Global Institute, 2015).

Only at the home industry, IoT products and services are estimated to have an economic impact of 200 to 350 billion by 2025 (McKinsey Global Institute, 2015). In this regard, chore automation, energy management, safety and security, usage based design (appliances) and pre-sales analytics are specific fields expected to grow.

1.2.3.Opportunities and challenges

Smart Products are usually offered as PSS, a reason why some advantages overlap between both. For example, IoT is considered a differentiator of a service, a resource for value creation independent from the product and an asset to strength the relation with customers. Additionally, continuous flows of data enable companies to obtain customer's insights and consequently be able to regularly iterate both product and service (Porter & Heppelmann, 2015).

From a productivity perspective, the transformation of business processes by means of predictive maintenance, improvement of assets utilization and time saving will certainly boost productivity. Furthermore, it is likely to unlock new business model creation especially in relation with products as services (McKinsey Global Institute, 2015). IoT is also envisioned to support and develop solutions for current social challenges as climate change, food security, health/wellbeing and energy use. IoT will likely joint efforts to decouple economic growth from resource usage (Atzori, Iera, & Morabito, 2017), with solutions in energy consumption, product tracking resources optimization and smart cities, among others.

"IoT systems in a city environment could achieve a 50% reduction in energy consumption as well as an 80% improvement in water usage" (EMF, 2016).

Regarding the challenges, technologically speaking, standardization, interoperability and internet scalability are among the most common concerns. On the organizational side, companies must adapt to the new working structures and capabilities that dealing with this type of product require; accordingly, some fixed cost might increase like software development and cloud storage (Porter & Heppelmann, 2015). Interestingly, the

reduction of product demand is expressed in literature as a likely drawback of Smart Products. However, that assumption seems to be based on a "linear economy" approach; if a CE perspective is taken, reduction of product demand can indeed be an advantage.

Privacy is one of the main worries about IoT. Confidentiality and the integrity of data are crucial for a community to trust any connected service (Atzori et al., 2017). Several products and services will base their value proposition and business model on data collection, for this reason transparency on what data is collected and its use is a company responsibility, as well as ensuring data protection. Security is also relevant when talking about privacy. While connected products offer increases, more opportunities for cyberattacks will appear, which in some cases could not only lead to access violation but physical harm as would be the case of self-driving cars. (McKinsey Global Institute, 2015). Finally, another significant factor threatening privacy is the ubiquitous monitoring of our daily life by products and services (Atzori et al., 2017).

1.2.4.Connectivity capabilities

Connectivity creates new product capabilities that can vary according to the embedded technology, infrastructure, product features and design. Those are: Monitoring, Control, Optimization and Autonomy (See figure 7) (Porter & Heppelmann, 2015).

Some of these capabilities rely on data collection which is considered a fundamental component of Smart Products. However, it is not itself a competitive advantage, to transform data in actual value, companies must find a way to translate data into insights (Porter & Heppelmann, 2015). Besides data collection, how data flow and enable interactions between consumers, things and business define in great extent the characteristics of both product and service.

1.2.5.Smart Products as PPSs

Smart Products are offered as PSS, creating a Smart PSSs in which both the product and service are jointly offered to solve a specific user need. These are usually integrated by multiple devices and digital components that create an interaction ecosystem (See figure 8) (Rowland, Goodman, Charlier, Light, & Lui, 2015). Notably, what makes these services "smart" is not only to provide connectivity but to offer attributes of a Smart Product that finally improves user's performance (Valencia, Mugge, Schoormans, & Schifferstein, 2015). Smart PSSs are relatively new, but due to IoT fast development they will surely catch more attention in the near future (Valencia et al., 2015).

Some characteristics of the Smart PSSs identified in literature can result meaningful in the context of CE (See figure 9). As shared experience and product ownership to promote disownership, or customer empowerment and continuous growth to foster more sustainable practices. On the other hand, Smart PSSs can be complex offers with multiple and different users as well as touchpoints and contexts, whereby a deep understanding of user and service limitations are crucial for the design of a successful value proposition (Valencia et al., 2015).

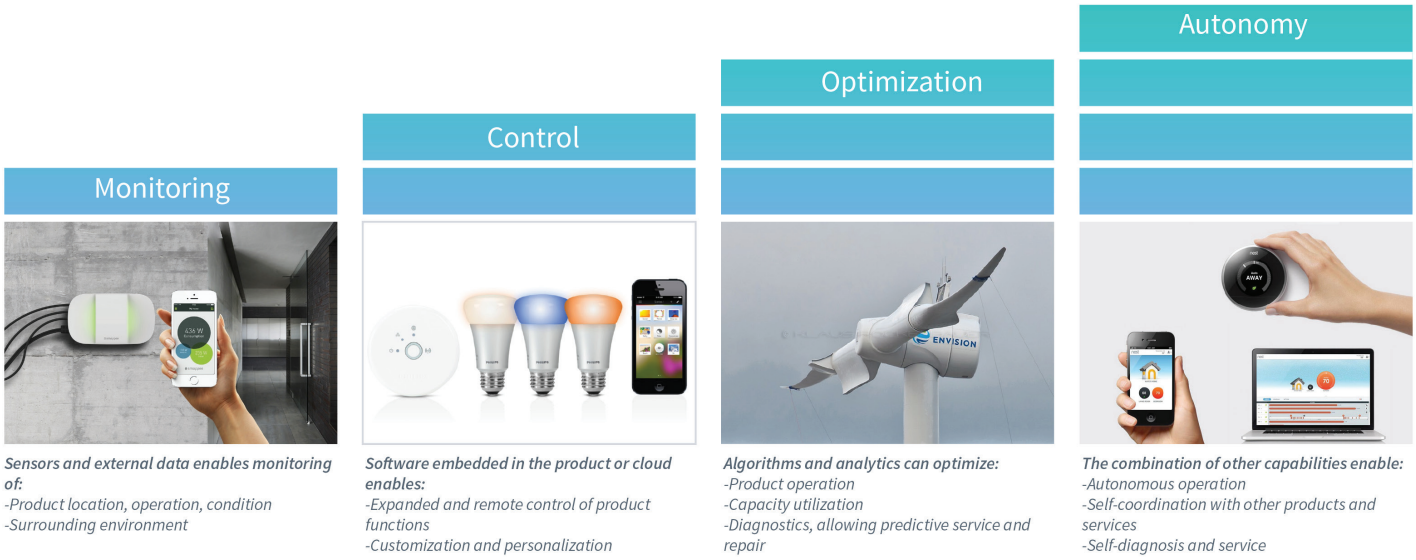


Figure 7. Smart connected products capabilities. Adapted from: Porter & Heppelmann (2015)

Figure 8. Nest thermostat ecosystem

Characteristic	Description	Example
1. Consumer empowerment	Enabling consumers to make decisions or take action on their own terms. Enabled by: – Providing feedback (i.e., relevant information) to consumers: • Transforming data into information. • Information regarding product/service status • Information about product/service features prior to purchase – Providing them with options.	– Showing graphs that allow consumers to track development over time. – Using time estimates to indicate availability and/or maps to show location. – Product/service descriptions and/or user reviews. – Implementing extensive libraries with content, which consumers can explore.
2. Individualization of services	Making consumers feel important by addressing them as unique individuals.	– Identification of consumers. – Use of digital servicescapes to communicate directly with consumers. – Using a human-like 'tone' when communicating with consumers.
3. Community feeling	Facilitating the communication between consumers.	– Enabling social media platforms, such as blogs, Facebook, or email to share content/information.
4. Individual/shared experience	Enabling a shared experience (with other consumers) through the Smart PSS.	– Encouraging consumers to simultaneously use the Smart PSS (e.g., game) and share experiences.
5. Product ownership	Defining who is responsible for the product over time.	– Rented product. – Product owned by consumer. – Product owned by consumer but shared with others (e.g., car pooling).
6. Service involvement	Facilitating/promoting the recurrent interaction between consumer and service provider.	– Encouraging daily or weekly interaction with gaming strategies. – Renewing the experience of consumers through content.
7. Continuous growth	– Facilitating the growth/evolution of the system. – Maintaining the Smart PSS and its perceived value relevant over time.	– Introducing new content/functionalities periodically. – Opening the system to independent developers to create functionalities/services around the smart product. – Providing tools to consumers to facilitate the development of their own content.

Figure 9. Characteristics of Smart PSSs (Valencia et al., 2015)

1.2.6.UX in connected products

Based in "Designing connected products" (Rowland et al., 2015)

User Experience (UX) i s a key aspect of PSS and Smart PSS design and therefore relevant for both CE and IoT. This oversees that the value proposition is consistent with what the users experience and that users are satisfied with what is offered. UX is defined as follows:

"User experience design in industry is to improve customer satisfaction and loyalty through the utility, ease of use, and pleasure provided in the interaction with a product." (Kujala, Roto, Väänänen-Vainio-Mattila, Karapanos, & Sinnelä, 2011)

UX in connected products is determined by different layers of design which are integrated to provide a positive experience (See figure 10). It is crucial that all layers are well integrated, because an amazing UI cannot hide a bad service design. The level of detail of each layer depends on, among others, the maturity of the technology, the context, user expectations and complexity of the service (Rowland et al., 2015).

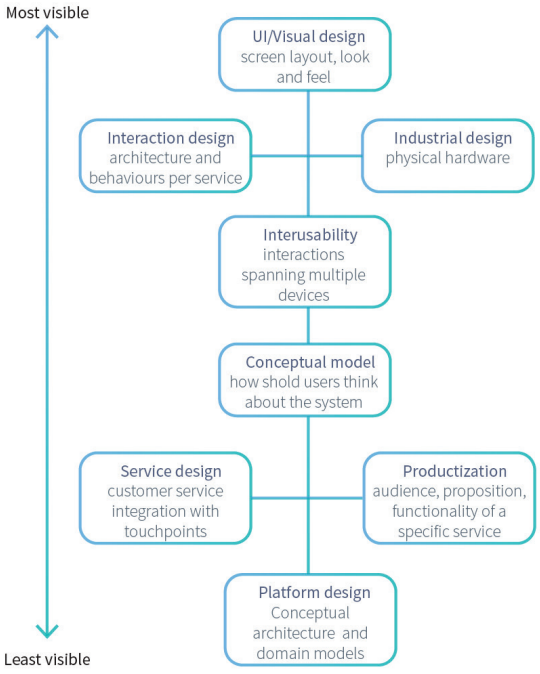


Figure 10. Connected products design components (Rowland et al., 2015)

UX in connected products have some special considerations that differ from a common service's or product's UX. In Smart PSSs, the UX is strongly related with data and how that can data be meaningful for the service (e.g users' feedback). Besides, due to the multiple devices, sensors and actuators present in diverse contexts the integration on daily life might be challenging as it should be seamless, intuitive and practical, but that is not always the case (Atzori et al., 2017).

Regarding technology, multiple devices can be asynchronous since data is sent to the cloud before connecting to another device, this way affecting the responsiveness of the components. Also, technology can be intermittent, as any internet connection, but we do not expect the physical world to glitch as does the internet. And finally, the interoperability of devices is difficult give the diversity of protocols and brands in the market. These challenges can be counteracted by clear feedback, data saving and by mapping what can go wrong.

It is not possible to design a positive experience if the value proposition is not clear to the user in the first place. The value proposition in user experience refers to users' understanding of the service values and how that resonates with their needs. If that message is clear then it can be translated into the service functionalities and the experience of use (See figure 11). The former is done by interaction design which defines the device behavior, the sequences of actions between the users and devices needed to achieve a goal as well as the service and product features along with its characteristics.

Figure 11. Value proposition and UX relation (Rowland et al., 2015)

Connectivity can unlock diverse functionalities in multiple devices, therefore, it is important for the ecosystem to be flexible enough so that the devices can be added, removed and swapped without changing its core functioning. A balance between service functions, the value proposition and the user needs is required. If too many functions are visible, it can mislead user's attention to less important aspects of the service, likewise it can cause doubts on the service quality and its core functionality.

1.2.7.Interaction channels

With each device in the eco-system multiple interaction channels are created, which allow users to interact with the product or service.

Web UIs and mobile apps are the most common channels to both monitor and control the smart device for several reasons. Firstly, it is easy to update and adapt them to new requirements. Secondly, there is a great community developing and using them what means also several available resources. Thirdly, smartphones and computers have processing power to unlock certain features that the product itself might not be able to perform. Besides, smartphones are personal devices, that according to the target group, most of the users might have, so it is a channel for notifications regardless of user's location. Lastly, Web UIs and apps can help the system to provide less used and complex features while keeping the product rather simple.

At the same time web UIs and mobile apps have disadvantages. Users might turn them off or have them in silent mode, have dead batteries and lost signal. In certain cases, using the smartphone can be slower than using directly the device (e.g house locks). Also, the access to multiple users is limited given that smartphones are personal items. Finally, users who are not good with modern electronic technology can have problems to have access to the features in web UIs and apps.
Another key factor to consider in UX design is the increasing number of devices that people owe as well as the applications in those. Hence**,** interfaces that require low attention, less cognitive load and are less intrusive will be more effective into providing a seamless experience.

1.3.DESIGN FOR SUSTAINABLE BEHAVIOR

Government intervention in sustainable issues has been mostly focused in technological intervention, policies and education, but those seem to not be enough to reduce the impact of product use, especially in products with an intense and polluting use phase as cars and washing machines. Lilley et al. (2005) even argues that the effectiveness of education in creating sustainable behavior change is debatable. Literature indicates that technological interventions, policies and education measures must be complemented with a change in users behavior (Fletcher, Dewberry, & Goggin, 2001; Jelsma & Knot, 2002; Lilley, Lofthouse, & Bhamra, 2005; Mckenzie-Mohr, 2000)

Notably, a great part of environmental impact of products is caused during the use phase, especially in energy consumption (Wever, Van Kuijk, & Boks, 2008). Nevertheless, sustainability actions in design have focused on reducing the impact of products manufacturing and disposal, whereas the use phase has not received too much attention (Lilley et al., 2005). There is potential environmental benefit during the use phase worth to be explored, given that who uses the products and how these are used have a direct impact in sustainability (Jelsma & Knot, 2002).

There is an intrinsic relation between the context, behaviors and habits during product use that impact consumption (Wilson, Bhamra, & Lilley, 2010). In this regard, design and specially human centered design is mentioned as a promising approach to research user behavior, needs and skills and integrate those insights into the design to unlock positive patterns of behavior while negatives are reduced (Lilley et al., 2005; Wever et al., 2008).

1.3.1.Relevance

Psychological research indicates that human beings have two systems of reasoning: the rule-based that is slow and make decisions based on facts and evidence, and the associative system that is outside of the conscious control and responds to familiarity. Many of our decisions are taken by the associative system that works in an automatic, unconscious way, hence even if we are aware of environmental issues, that reasoning may not be reflected in our actions (Manning, 2009).

Considering this, there are two potential ways to foster sustainability: to facilitate sustainable actions for the associative system, or to get the rule-based system attention to reflect on the action, or even better do both. Habitual behavior is part of the associative systems, which are created based on frequency, lack of awareness, efficiency, difficulty of controlling the behavior and identity (Wilson et al., 2010). Lastly, the context has a high impact into decision making since it constrains or offer certain options, thus a change in the context can also trigger a change in behavior (Wilson et al., 2010).

The attempt to improve technological interventions have resulted in the design of *"eco features"*, whose effectiveness is low given that those only have an impact if the user deliberately choose to use them (Wever et al.,

2008). For example, in washing machine cycles where the eco wash is an option but not the default, users can still choose a 90° wash instead of ***eco*** (Lilley et al., 2005).

1.3.2.Design strategies

Multiple strategies have been developed in design to facilitate actions of the associative system or to encourage the reflection of the rule-based one, for instance using feedback, guiding the user towards certain actions or forcing certain functionalities through defaults. The underlying reasoning is that by identifying factors that determine the behavior and overcoming its limitations (e.g habitual behavior), behavior change is stimulated. As a result, the environmental impact of product use is reduced (Lockton, Harrison, & Stanton, 2008).

Zachrisson & Boks (2012) propose that sustainable behavior design strategies be distributed according to the control spectrum: At top, it is up to user's decision if a sustainable action is executed or not while at the bottom the product takes the decision.

Four key issues for encouraging pro-environmental behaviour.
I. Which behaviours should be changed to improve environmental quality? 1. Select behaviours having significant negative environmental impacts 2. Assess the feasibility of behaviour changes 3. Assess baseline levels of target behaviours 4. Identify groups to be targeted
II. Which factors determine the relevant behaviour? 1. Perceived costs and benefits 2. Moral and normative concerns 3. Affect 4. Contextual factors 5. Habits
III. Which interventions could best be applied to encourage proenvironmental behaviour? 1. Informational strategies (information, per suasion, social support and role models, public participation) 2. Structural strategies (availability of products and services, legal regulation, financial strategies)
IV. What are the effects of interventions? 1. Changes in behavioural determinants 2. Changes in behaviours 3. Changes in environmental quality 4. Changes in individuals' quality of life

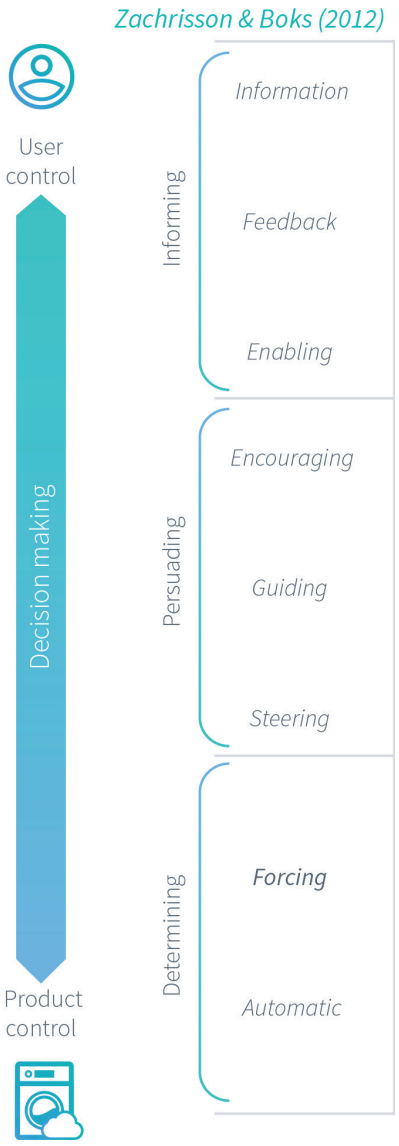


Figure 12. Key issues for encouraging environmental behavior (Steg & Vlek, 2009)

Lilley et al. (2005) (2009)	*Lockton et al. (2008)*	*Wever et al. (2008)*	*DBIM (Tang, 2010)*
Eco-Feedback Inform users about their consumption or impact in order to persuade them. "Provides tangible aural, visual or tactile signs as reminders to inform users of resource use"	**Persuasion and feedback** Users are friendly invited to change his or her behavior by providing information about consumption. It might include social comparison.	**Eco-Feedback** Information is provided to the user to encourage reflection, it means that is left to user's criteria what to do with the received information.	**Eco-Information** To make consumption visible, understandable and accessible to encourage user's reflection. **Eco-Choice** Encourage users to reflect on their use and take responsibility for it by providing more sustainable options or features. **Eco-Feedback** Real time follow up about user's consumption, by different interaction channels.
Scripts and behavior steering It aims to guides users, without determining their actions, to do what the designer intended through the design of constrains or affordances	**Affordances and constrains** Affordances or constrains are used to lead, guide or limit user's actions to follow certain behavior. It might include, defaults, limits and targets and physical constrains	**Scripting** The design leads to sustainable use by creating obstacles for unsustainable use or making behavior so easy that the user does not think about it, thus enabling the desired behavior.	**Eco-Spur** Provide rewards and or penalties for sustainable and unsustainable usage respectively. **Eco-Steer** Affordances and constrains for guiding and facilitating the adoption of the new behavior
'Intelligent' Products and Systems Also called persuasive technology. Some decisions are taken by the product itself, which is assumed to be "intelligent" to mitigate control or block unsustainable user behavior.	**Context based** It combines the two previous strategies, each one is triggered according to user's behavior at a specific time. This strategy is dependent on Smart Products, which adapt the features, affordances or constrains according to information input or environment conditions.	**Forced functionality** Intelligent products that adapt to changing circumstances or strong obstacles to prevent unsustainable behavior. **Functionality matching** Sustainable consumption is more likely to happen if service or product functions match with user's desired functions. This will avoid redundant functionalities and the implementation of more effective functions.	**Clever Design** The design itself induce environmental actions without requiring user's engagement. **Eco-Technology** Use technology to automatically restrain, persuade or control user's behavior

Figure 13. Design strategies for sustainable behavior overview by author

Steg & Vlek (2009) state that these design interventions are generally more effective when they are systematically planned, implemented and evaluated. First, the behavior to be changed should be identified. Second, the factors underlying this behavior should be analyzed. Third, the interventions are designed and applied to change the most relevant behavior and finally the effects or the intervention are measured (See figure 12).

Four authors with their corresponding colleagues were analyzed to present an overview of sustainable behavior design strategies, findings are briefly summarized in the figure 13.

Lilley et al. (2005) (2009)

Lilley (2005), then proposes three interventions for promoting sustainable behavior during the use phase

which do not completely rely on users consent and do not require them to be committed with sustainability. These are Eco-feedback, Behavior steering and 'Intelligent' Products and Systems. Regarding Eco-Feedback author argues that even though the right feedback can encourage users towards an environmental behavior, information does not necessarily lead to action, that is why other interventions to strengthen feedback are recommended to delegate responsibility to users and match his or her actions with the change, for example: goal setting, financial incentives and rewards. Moreover, if scripts and behavior steering matches the user's logic then the impact is expected to be higher.

Lockton et al. (2008)

The authors propose three strategies to persuade or guide the users to use products in a more sustainable way. Persuasion and feedback, affordances and constrains and context based.

Feedback is more effective if applied when users are still able to change their behavior, than only as reflection on the past. In this strategy, social comparisons can be used as a persuasive strategy to send a normative message. Also, showing financial cost can be implemented to enhance feedback impact.

Affordances and constrains are based on the idea that how features are presented have an impact in user's decision making. In this case designers must have defined the expected behavior to reflect it in the design. If interventions are perceived as extreme they might result annoying and consequently lose its impact. Some examples of its implementations are: choice of defaults that make environmental-friendly options easy to select to increase its likelihood to be used, limits and targets that highlight resources limitation, and physical constraints that limit the size of the product, For example: smaller sinks or rubbish bins. All these strategies can be complemented with "persuasive technology" methods (See appendix 1)

Wever et al. (2008)

Knowing that several studies shows that technology does not automatically lead to sustainable user behavior, Wever et al (2008) propose four strategies with a focus on user-centeredness, Eco-Feedback, Scripting, Forced functionality and functionality matching. These aim to help designers to choose a preferred strategy from a human-product interaction perspective. Forced functionality, is included as an additional strategy not considered by other authors. This takes into account users as the main driver of the design and therefore, if the product or service features are designed to fit users desired functions the intervention will be more effective.

Design Behavior Intervention Model (DBIM) (Tang, 2010)

Tang proposes several strategies in one model as an expansion of Lilley (2009) model. This is so far the most complete and promising model in the context of sustainable consumption with a focus on energy. It relates a design approach with social-psychological theories as well as behavior models (See figure 14). On the left, 3 essential elements of behavior change are presented: intention, habits and control along with some aspects that influence them. According to the state of behavior change: declarative, knowledge compilation or procedural stage, distinct design strategies are suggested as more appropriate. In the early stage for example feedback is recommended to guide the change based on users voluntarily attitude. On the other hand, when there is already a habit, steer strategies are favored to reinforce the behavior.

Eco-technology and clever design have the potential to tackle some of the steering and feedback strategies disadvantages since the change is imposed by the technology. Nevertheless, those rise some concerns: firstly, the lack of user's responsibility and awareness might not sustain a long-term behavior change. Secondly, the easiness for the user might cause unexpected rebound effect as more consumption. Thirdly, its coerciveness can limit user behavior, consequently reduce acceptance. And finally, all the ethical issues resulted from an Artificial Intelligence system making decisions on behalf of a person.

An equally significant aspect of the model is the relation between the decision-making power between both user and product (See figure 15), the strategies and the likelihood of the intervention to be accepted or to have an environmental impact. For instance, a high product control ensures a behavior change with a high environmental impact but it might have problems of user acceptance and lack of motivational change.

1.3.3.Ethics

Due to the persuasive character of sustainable behavior strategies, ethics must be considered. Rebound effects are possible, which means that the intervention might lead to unexpected, or even negative, environmental, economic or social impact. For example, if an user finds that his or her consumption is lower than the community average that can trigger a negative change in behavior.

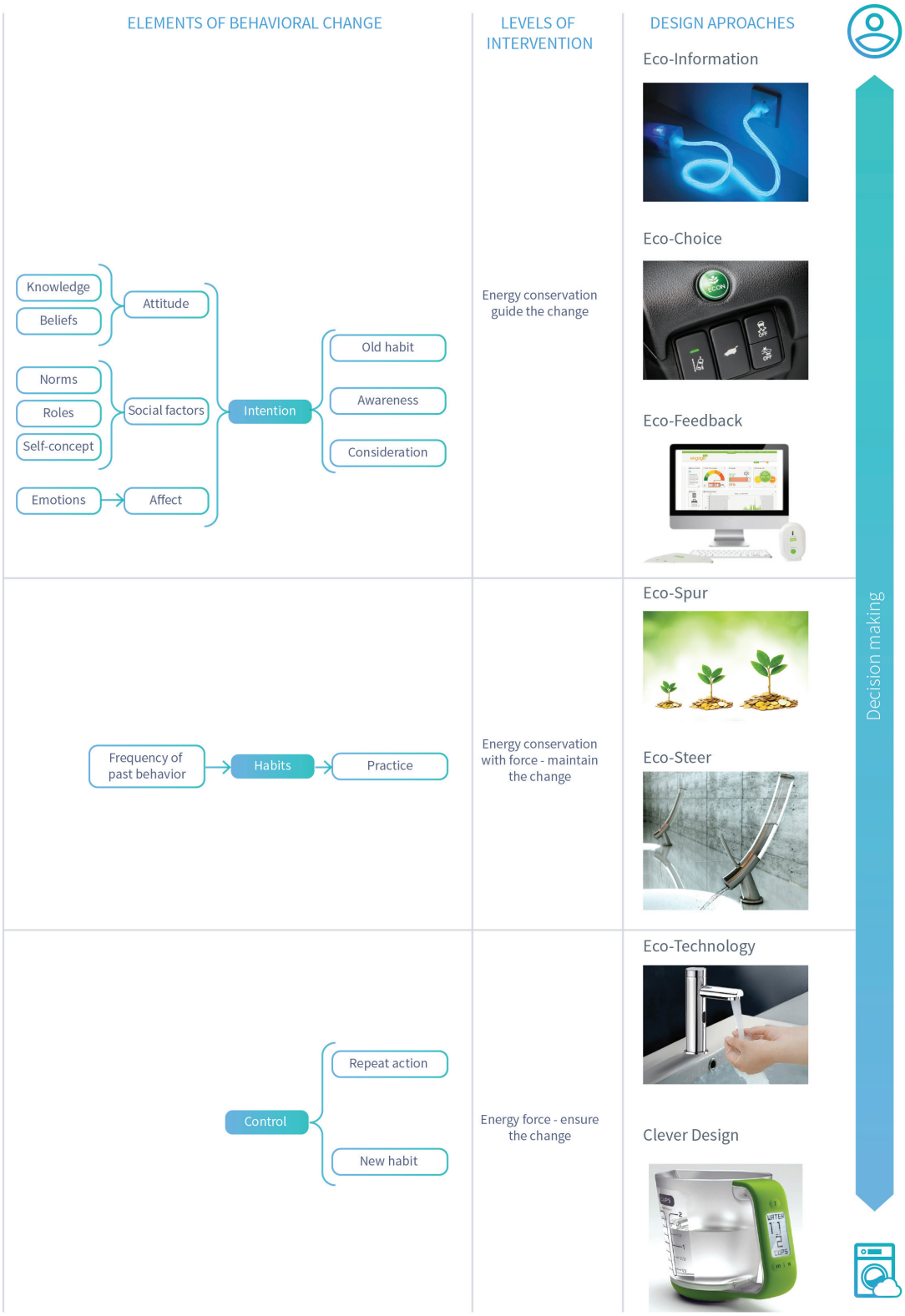


Figure 14. Design behavior intervention model (Tang, 2010)

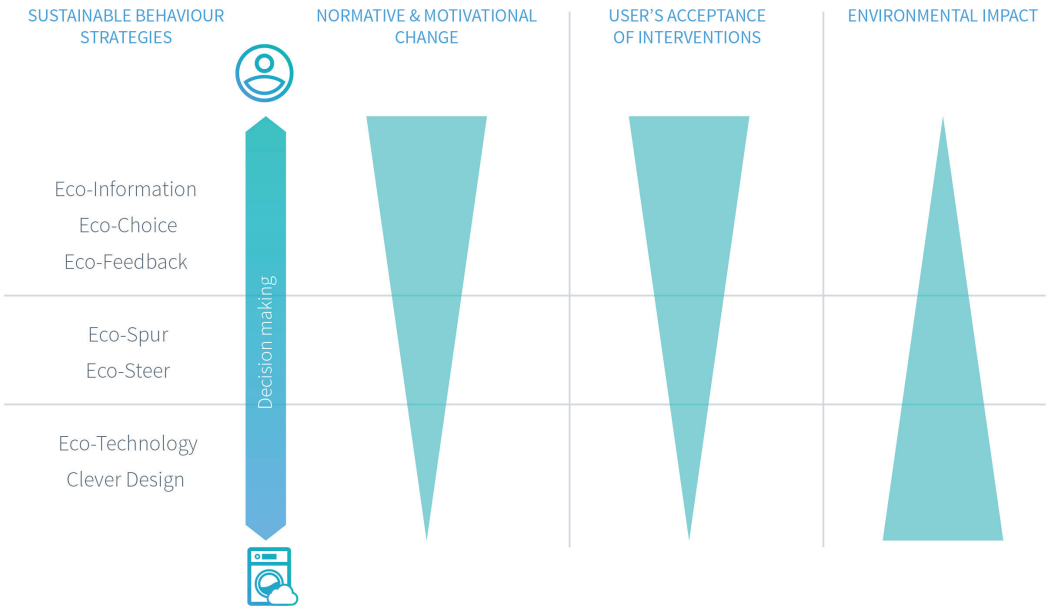


Figure 15. Interventions relation with motivation, users acceptance and environmental impact (Tang, 2010)

Some of this concerns have been outlined before, especially in relation with forced functionality and/or intelligent systems that take decisions on behalf of human beings for the sake of the environment. For example, replacing user's decision making and therefore responsibility for their own actions might lead to rebounds or lack of awareness (Lilley et al., 2005). More details about ethics principles of persuasive technology can be found in Appendix 2.

1.3.4.Eco-interactions and IoT

The benefit of smart or intelligent products have been mentioned several times as an alternative to counteract user's automatic behavior. This strategy is called 'Intelligent' Products and Systems by Lilley et al. (2005), context-based by Lockton et al. (2008), forced functionality by Wever et al. (2008) and eco-technology and clever design by Tang, (2010). When complemented with Eco-Feedback this strategy is defined as eco-interactions, especially in context of energy saving. These are specifically defined as interactions between humans and smart devices where eco-feedback and predictive control are used to minimize energy use while it is still beneficial for users (Yang, Newman, & Forlizzi, 2014). Even though the eco-interaction concept has been mostly developed in the context of energy saving, it is expected that some of its findings to reflect other resource consumption activities.

Interestingly, eco-interactions do not only make use of products autonomous decisions but of feedback to raise intervention effectiveness. Eco-feedback's aim as a human centered solution is to create awareness, but given its low efficiency in driving behavior change, it is complemented with a technologic approach which make decisions or makes recommendations for resources saving. Besides, eco-interactions consider how interfaces, infrastructure and functions facilitate the interaction. Nevertheless, the use of steering strategies is not considered yet, which is recommended in order to achieve a more balanced sustainable intervention.

The Nest thermostat is the most representative example of eco-interaction design: The product gives access to schedule and temperature in real time while the app and web UI show energy history along with eco-feedback. The *smart* part is added by the Auto-schedule and Auto-away features, which use machine learning and motion sensoring to decide the most efficient temperature. These functions' goal is to counteract common troublesome behavior in thermostat settings: customers not using setback temperatures and schedules, and forgetting to change temperature patterns.

A study into Nest's challenges and opportunities depicts interesting results of its eco-interaction (Yang et al., 2014). With the new product for example: user's awareness and engagement increased, schedule was a more interactive process and using setback temperatures was easier. In

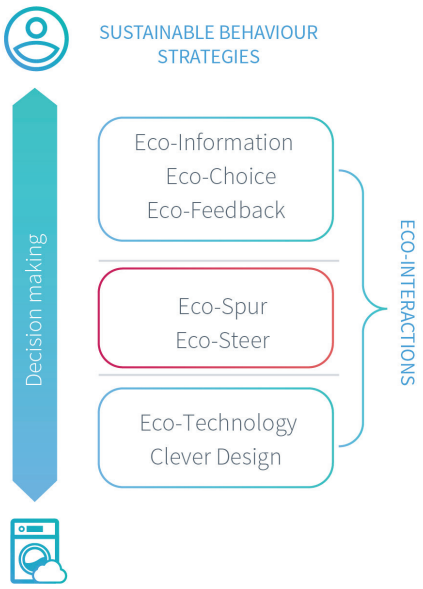


Figure 16. Eco-Interactions

contrast, after some time, user's interaction with Nest dropped as well as their motivation for improving energy consumption, this means that the change in behavior was not sustained. This phenomenon is due in some extent to users' trust in Nest smart capability of configuration, what is not always true.

Around this situation some recommendations were built to increase effectiveness in Nest eco-interactions design, that could be used as reference for other interactions: It is important to prolong user's engagement but to preserve at the same time the autonomy and automation. Balancing user's comfort with energy saving can also lead to maximize energy savings, so if the default is an eco-function the user will have to search for its comfort if that function does not fulfill it. Spontaneous and enjoyable interactions to promote engagement are worth exploring. There should be a balance between a plan for energy saving and its easiness of implementation. Finally, continuous feedback loops between users and the system are required to keep product efficiency at maximum level, so stimulating reflection and reassessment by catching user's attention might be part of the design in long term. In the context of eco-interactions for energy saving a trends toward smart grids and solar energy was as well identified, not particularly relevant for this project though (Bourgeois, van der Linden, Kortuem, Price, & Rimmer, 2014; Risteska Stojkoska & Trivodaliev, 2017).

1.4. CONCLUSIONS

Circular Economy

To summarize, Circular Economy's aim is to decouple economic growth from finite resources consumption. For this aim circulation of products' components and materials through loops is proposed to keep those at its highest value the longest time. Furthermore, CE implementation can also result in an economical advantage since it can unlock new value streams by saving materials and increasing innovations.

Concerning Circular Business Models, its innovation and experimentation are essential for the adoption of CE. In this matter, the most common approach is to create PSSs that focus on access rather than ownership, hence extending the product life span. In CBM the value creation must be related to either closing loops or slowing loops. However, due to technological limitations, complete circular models are not possible yet.

PSSs allow companies to fulfill user needs with less environmental impact when the service provider is encouraged to extend products life cycle in order to increase products utilization capacity. Nevertheless, this must not be taken for granted since product type, service, ecosystem and company capabilities influence business sustainability and viability. Additional to the environmental benefits PSS can also promote stronger relations with clients by enabling more integrated solutions and experiences. Despite these benefits PSS adoption is rather low due to complex and uncertain comparative challenges and poor consumer adoption. The latter especially in relation with ownership intangible values as well as pre-conceptions that limit user's openness to innovation. That is why changes in consumer behavior are fundamental for circular PSSs adoption. Intangible values, habits and routines, and previous beliefs should be thoroughly integrated in the value proposition as well as in the service design to ensure its success. Even though the literature focuses on poor consumer adoption due to ownership values, there is also a global trend towards collaborative consumption.

Result-oriented is theoretically the most promising type of PSS in sustainability terms, but its advantages have not been empirically proven yet. Pay-per-Use as a result-oriented service allows users to pay only for a product functional result, use, consumption or performance, which is measured in a specific unit, so that the revenue is defined accordingly. This type of service promotes a more conscious behavior since payment is defined by

use, increases the sense of price fairness and reduces the price barrier for adoption.

Products as services have a low tangible value but are highly resource efficient, thus a strong value proposition and consistent experience is needed to motivate users to adopt the service. Besides that, human centered design can boost customer satisfaction and competitiveness by considering user needs and desires, leading then to assertive value propositions and experiences. Interestingly, interaction design is not considered in the literature as a design strategy for supporting CE.

Internet of Things

IoT constitutes a source of value creation for both product and service by improving user performance and experience as well as boosting productivity by means of predictive maintenance, assets optimization and utilization. Data collection is an essential part of IoT business models but it is only a source of value when it is translated into insights.

In the context of products, IoT is embedded in Smart Products that are offered as services, denominated Smart PSSs. This new type of PSS makes possible the implementation of new business models (e.g shared economy) and the extension of service capabilities to functions as: monitor, control, optimization and autonomy. Smart PSSs can also integrate multiple devices and digital components to create an eco-system.

The increased complexity of Smart PSSs eco-systems creates challenges for the UX, which is essential for PSS adoption since it is the translation of the value proposition into what users experience. UX is perceived through all the interactions with the service eco-system, hence a holistic view is crucial to ensure design and experience consistency. Technology is not completely reliable. Asynchrony, intermittent connection, interoperability issues and glitches are common, hence negatively impacting the experience of use. Three aspects must be balanced in Smart PSSs, the level of functionality, the devices and channels of interaction. Those must be consistent with user needs and consequently with the value proposition and business model. Data collection allows the customization and the design of meaningful feedback the user can act upon. Web UIs and mobile apps are the most common interaction channels, these provide a way to extend service functionality. Finally, easy-to-use and less intrusive interfaces are preferred.

Design for sustainable behavior

Education, policies and technological intervention are not enough to reduce the impact of product use. Due to real-life decision-making processes, knowledge about environmental issues is not always translated into actions; habits and automatic unconscious behavior can overrule these concerns. Design strategies for sustainable behavior that do not completely rely on users' interest in sustainability and decision making are therefore relevant, especially in products with an intense and polluting use phase like washing machines.

Design strategies for sustainable behavior are extensively explored in literature. A control spectrum between user and product is defined to categorize them. With subtle differences among authors, feedback, steering and the forced functionality (autonomous product control) could be drawn as the three main strategies. Even though product control is a promising approach for a guaranteed behavior change it can lead to lack of awareness and responsibility. On the other hand feedback is not enough to drive change since information does not necessarily lead to actions. The selection of which design intervention is the most appropriate depends on the context and the product or service itself. In any case balance in the intervention strength is required not to get to an annoying level where the design loses its impact. Ethics must be considered during the design as it is designers' responsibility to avoid potential rebound effects and propose transparent interventions.

Eco-interactions are more balanced interventions which complement eco-feedback with autonomous control in the products to increase design effectiveness. Eco-interactions should, however, promote long term engagement and provide continuous feedback to stimulate reflection and reassessment.

Circular Economy and Internet of Things

According to EMF (2016), IoT and CE is a promising combination for innovation and value creation. The values of both concepts seem to pair to create a wide range of opportunities. Four main opportunities were found during the literature research between IoT and CE (See Figure 17)

Firstly, IoT makes possible to monitor and measure a specific product consumption as well as its availability, hence enabling new CBM as Pay-per-Use or shared economy models. Secondly, when the service is built with connectivity, it is possible to track the product's condition, location and availability, and therefore being able to

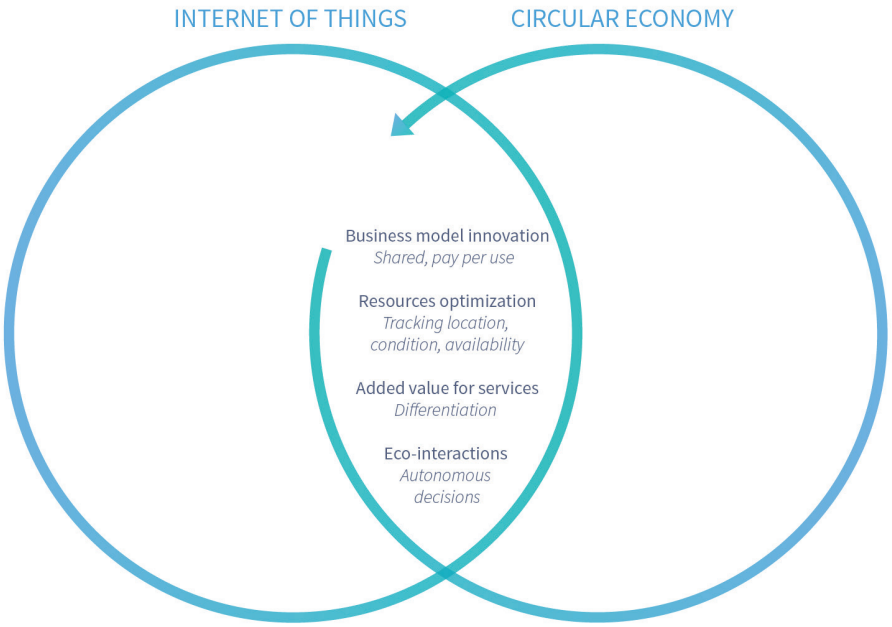


Figure 17. IoT and CE common ground

optimize resources. Besides location, condition and availability of the product, IoT is itself a source of value creation from a service and interaction perspective. PSSs require unlocking value streams to create differentiation and consumer acceptance. In this matter IoT can become a strategic partner.

Finally, Eco- interactions as a strategy for fostering sustainable behavior are highly dependent on Smart Products. Even though there is not a clear exploration about Eco-Interactions in Circular Economy, this analysis has shown that the use phase is a crucial part of product foot print. Eco-interactions can even be considered an additional strategy for slowing loops.

The reduction of the product's environmental impact can be achieved by various means. Circularity aims to optimize materials and resources through circulation, which means that product material's impact is reduced. Additionally, by offering products as services, the maintenance is guaranteed and therefore the product life extended, which can be complemented with the adoption of a Pay-per-Use model that theoretically drives a more conscious behavior. However, the previous mentioned strategies rely on the service provider as main actor, the fact that a high proportion of the environmental impact of product use is caused by the user decisions is not considered. That is why it is relevant to complement circularity with sustainable behavior strategies. The latter can be enhanced by Smart Products, which allow the design of Eco-Interactions (See Figure 18).

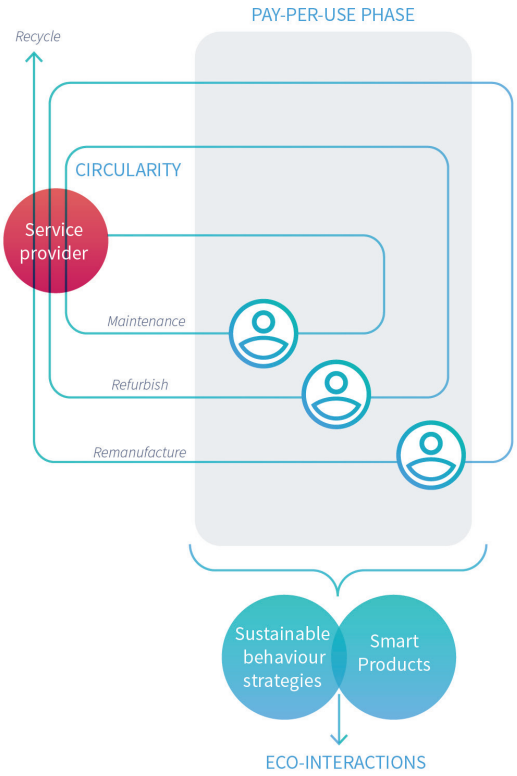


Figure 18. Circularity, Pay-per-Use, sustainable behavior strategies and Smart Products relation

2.CONNECTIVITY USE FOR CIRCULARITY AND SUSTAINABLE BEHAVIOUR, A BENCHMARKING

The empirical study presented in this chapter aims to research how are current connected products and Circular PSS making use of connectivity to drive sustainable behavior change. This is done by understanding its design, analyzing its features in terms of sustainable behavior and IoT, and finally finding relations between both. Even though, both products and services have different designs (See Figure 19) it was possible to analyze them by using the same frameworks. As a final point, the UX design applied in the cases is briefly explored.

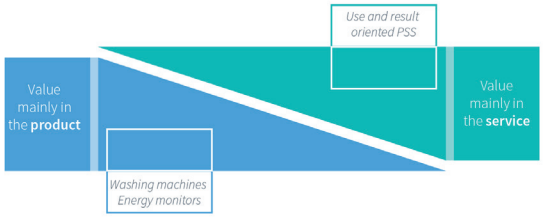


Figure 19. Circularity, Pay-per-Use, sustainable behavior strategies and Smart Products relation

This chapter provides an overview of the goal, research questions, analysis and results of the benchmarking. Due to the rather deep exploration required to answer all the research questions, the analysis focused on few products but profound analysis. Three washing machines, three energy monitors and four Circular PSS were analyzed (See Figure 20). The results show that indeed the Circular PSS and connected products analyzed do indeed make use of connectivity to foster sustainable practices. However, these are limited and thus can be strengthened.

It should be considered that online research has limited access to product and service details, as well as to user's perception. This highly constrains the results of the study. Hence, this analysis is considered the only source of inspiration to gain insights on the mentioned topics and to create a framework for design and conceptualization phases.

2.1.GOAL

To gain understanding into connected products at home (smart washing machines, energy monitors) and circular PSSs design and how are those making use of IoT to foster sustainable behavior. Identify challenges and opportunities in terms of UX.

Smart washing machines and energy monitors are selected as relevant products for this study. Washing machines are chosen due to its direct relation with HOMIE service while energy monitors due to its relationship with eco-feedback at home context. The latter has received great attention from the research community regarding sustainable behavior design, this it is relevant for gaining insights into Eco-Feedback design.

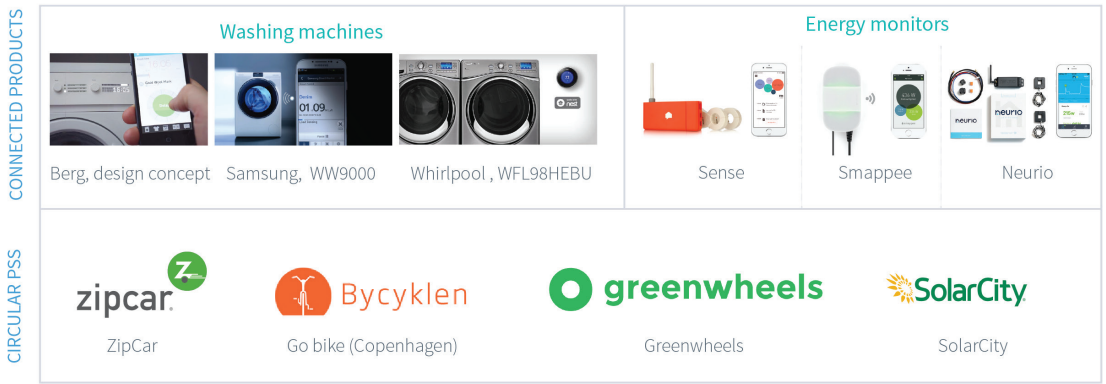


Figure 20. Analyzed products and services overview

Regarding Circular PSS, both use and result-oriented PSSs are considered in the analysis, Zip car, GoBike, SolarCity and Green wheels services were studied (See Figure 20). The literature research highlighted the crucial role of the value proposition, value delivery and value capture for the consolidation of a CBM, so their definition allows to define whether and how sustainability is considered in the service structure as well as the most common used values in this type of services. Furthermore, considering sustainable behavior design as a strategy for potentially slowing products loops, it makes sense to analyze if current circular PSSs are implementing those strategies and how. Also, a critical viewpoint is stated when assessing gaps where is room for sustainable behavior fostering that have not been implemented yet.

2.2.RESEARCH QUESTIONS

- How are the smart washing machines, energy monitors and circular PSS designed?
- Are smart washing machines, energy monitors and circular PSS making use of product connectivity to foster sustainable behavior? If so, which strategies for sustainable behavior are used and which ones could be potentially implemented?
- Which challenges and opportunities are present in the UX of smart washing machines, energy monitors and circular PSS?

2.3.METHOD

In order to answer these research questions, the analysis is divided in 3 main parts: understanding the design, analyzing both IoT capabilities and sustainable behavior strategies, and finally evaluating User Experience (See Figure 21).

First, potential products and services to be analyzed were identified. For both cases the information online was limited, what restricted the selection process to the services with more available data. For Circular PSS, services that involve connectivity were preferred due to the project approach. Second, detailed information about both products and services design was obtained through desk research, this was then organized according to the fields required for the analysis (See Figure 21)[1]

With a clear design description, an empirical study was performed based in two frameworks retrieved from the literature review. First, sustainable behavior was evaluated in terms of interactions and features that enable more sustainable practices by using the Design Behavior Intervention Model (Tang, 2010) (See 2.3.2 Design for sustainable behavior) Secondly for the connected products, IoT capabilities were assessed with Porter & Heppelmann (2015) framework (See 2.2.3 Connectivity capabilities). Next, the results of both frameworks were crosschecked to find potential relations. Additionally, other sustainable behavior strategies that could be implemented in the service were also explored. Based on the use of both IoT and sustainable behavior model analysis, a new framework that related both is proposed in order to relate their capabilities.
Finally, user perception on the product or service was investigated by consulting user's self-reports in online reviews and forums.

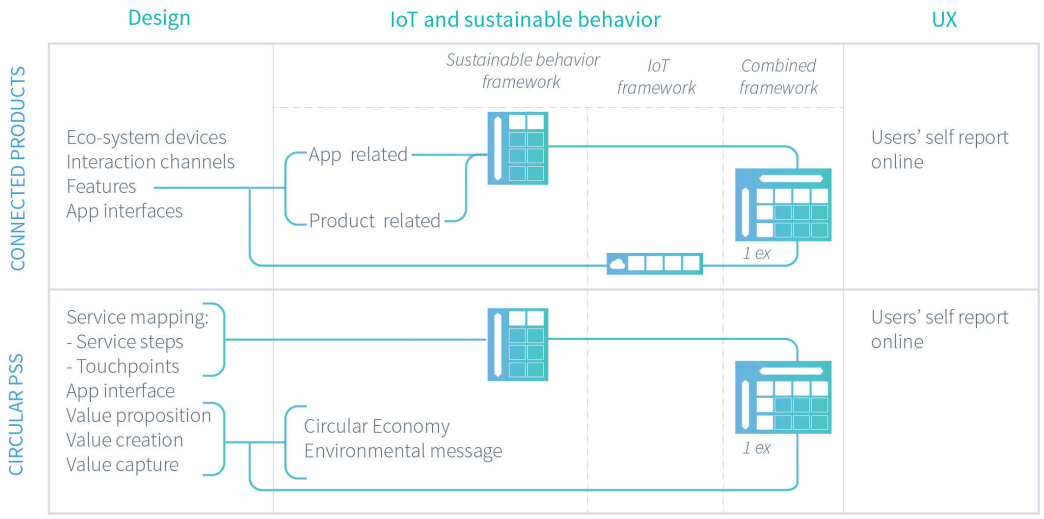
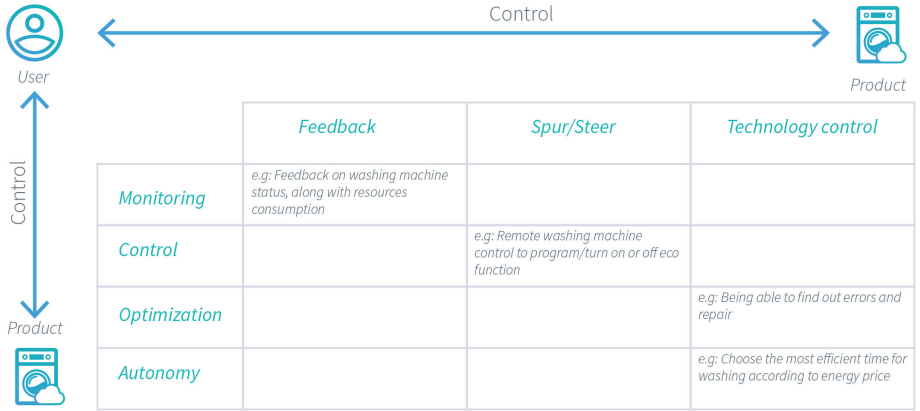


Figure 21. Benchmarking analysis structure

1 For this process, the web tool "real time board" was used: https://realtimeboard.com/app/board/o9J_k01Vgd4=/



	Feedback	Spur/Steer	Technology control
Monitoring	e.g: Feedback on washing machine status, along with resources consumption		
Control		e.g: Remote washing machine control to program/turn on or off eco function	
Optimization			e.g: Being able to find out errors and repair
Autonomy			e.g: Choose the most efficient time for washing according to energy price

Figure 22. IoT capabilities and sustainable behavior strategies framework

2.4.ANALYSIS

The analysis is structured in three parts: design, IoT and sustainable behavior relation and User Experience. However, since connected products and Circular PSS have a different design approach, the former is product-oriented and the latter service-oriented, each step is developed in a different way (See Figure 21). For more details about the analysis see Appendix 3.

Design: For connected products at home, the information collected through desk research was structured in: devices in the connected eco-system, interaction channels and features. All the selected products use apps as main or complementary interaction channel; thus, apps interfaces and its features were as well considered.

Regarding the Circular PSS services, a rough service journey mapping was developed based on online research; in this, service steps were defined along with its corresponding touchpoints. The service app interface was studied through a brief exploration of the main screens (if available). Additionally, the value proposition, value creation and value capture were defined considering the core message in the official web page and the service structure.

IoT and sustainable behavior: To analyze the relation between sustainable behavior and IoT in smart washing machines and energy monitors, their features were divided in product and app related. Then, these features were located in both IoT and sustainable behavior frameworks. Additionally, potential features but currently not explored to enable sustainable practices were detailed in the same frameworks.

For circular PSSs three perspectives were complemented. Firstly, the PSS type was determined to state how the service responds to Circular Economy principles. Secondly, whether the value proposition conveyed an environmental message, and finally how the service features make use of sustainable behavior strategies.

As final step of this part of the analysis, the findings of both IoT and sustainable behavior strategies were related in a new proposed framework to find relations and patterns. One representative example with high connectivity of each: washing machine, energy monitors and circular PSS was detailed in the framework (See Figure 22). This framework presents, on the left, the IoT capabilities and, on the top, the main groups of sustainable behavior strategies. The underlying idea is that connectivity levels enable different features and interactions for fostering sustainable practices. This framework is also used in the company analysis in order to identify spaces where connectivity can be used to enhance current sustainable design interventions (See figure 22). It is also used for evaluating in the company analysis and for the concepts evaluation.

User experience: Users' self-reports retrieved from forums and reviews were classified in both positive and negative, defining this way pain-points and opportunities. For circular PSSs, users' reviews were also located in the journey step they belong to.

2.5.RESULTS

Connected products at home

IoT solutions at home are characterized as expensive and luxury items which are currently crossing the chasm between early adopters to early majority, therefore there are not too many customers yet. Users commonly face glitches and flaws; value propositions are complex

and the value behind them is not clear. However, opportunities arise since 75% connected products at home are purchased through service providers ("McKinsey Connected Homes," n.d.).

The main purpose of Smart Products at home is to increase convenience and comfort through task optimization. For this goal, centralized smart house control is the most common approach. Interoperability is still a big issue in the design of Smart Products at home. That is why there are multiple alternatives for ecosystem configurations which limit user's choice to pre-selected products of the same brand or hub.

Smart washing machines

Washing machines market is dominated by big brands like Samsung, Bosch, Miele and Whirlpool. Multiple models incorporate diverse levels of connectivity, from complete monitoring and control to only failure checking. Furthermore, some brands have designed ecosystems where multiple appliances are connected and/or controlled from one app or hub, what seems a strategy for solving smart home interoperability issues. Three washing machines were studied: Berg cloudwash design concept, Samsung WW9000 and Whirlpool WFL98HEBYU.

The analysis showed that smart washing machines are indeed making use of connectivity to foster sustainable practices. The sustainable behavior interventions are located mostly at the area of scripting and technology control while Eco-Feedback is rather underdeveloped. This might be due to the high connected capabilities the machines are equipped with.

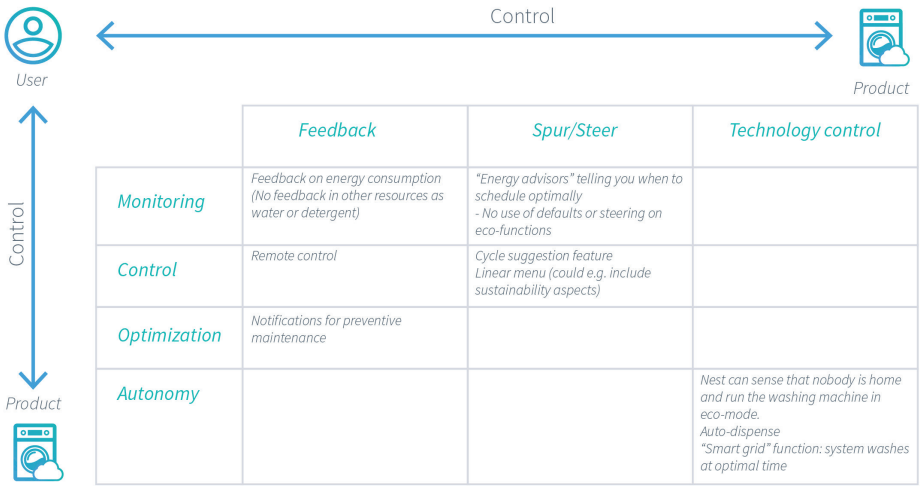
Whirlpool washing machine is the most interesting case in terms of eco-interactions, it has implemented all connectivity levels as well as sustainable behavior strategies (See Figure 23). In the technology control level, smart grid and Eco-boost connection with Nest catch attention as innovative solutions to facilitate sustainable decisions by providing automaticity. In this case, Nest works as an autonomous trigger of a sustainable action. This example also shows that one single feature can include multiple strategies for sustainable behavior, as smart grid which provides feedback on energy price, does recommendations to steer behavior and works autonomously if activated. Regarding Samsung's design, it is more focused on enhancing users comfort than in sustainability. This is reflected in the limited use of sustainable behavior strategies.

In the Whirlpool case, current feedback is limited to energy feedback and there is no use of defaults or steering strategies for eco-functions.

Some inspiring features include linear menus for steering towards a sustainable program, shortcuts as an adaptation of defaults and bundles to ensure the use of high efficient detergents. Also, personalized suggestions, history of consumption and social comparison are potential strategies for reducing consumption.

Regarding the general design, the washing machine interface and the app are the interaction channels. The latter is used as an extension of product information and features. The app allows users to monitor cycles in terms of time and stage but not on resources consumption. Remote control is also offered. High end machines are commonly equipped with detergent and softener self-dispense.

In terms of UX, users appreciate to have a remote control



	Feedback	Spur/Steer	Technology control
Monitoring	Feedback on energy consumption (No feedback in other resources as water or detergent)	"Energy advisors" telling you when to schedule optimally - No use of defaults or steering on eco-functions	
Control	Remote control	Cycle suggestion feature Linear menu (could e.g. include sustainability aspects)	
Optimization	Notifications for preventive maintenance		
Autonomy			Nest can sense that nobody is home and run the washing machine in eco-mode. Auto-dispense "Smart grid" function: system washes at optimal time

Figure 23. Whirlpool washing machine analysis

	Feedback	Spur/Steer	Technology control
Monitoring	Real time energy use monitoring. Details by appliance. If configured, also an option for water and gas monitoring.		
Control	Remote control of plugs	Plugs can be configured to work automatically.	
Optimization			
Autonomy			

Figure 24. Smappee, energy monitor analysis

as well as notifications but those do not work properly if the machine lacks connectivity, what is a common issue. These glitches in connectivity that limit the product "smartness" have a high impact in UX given that Smart washing machines are expensive and perceived as a luxury item, so the users' expectations are set accordingly.

Finally, potential functions for the machine include: calendar feature for booking the machine in shared spaces and ensure the freshness of the cloth with delay functions or other technological solutions.

Energy monitors

Energy monitors market is dominated by start-ups which have proposed rather similar services with different nuances in their value proposition. Three products-services were analyzed: Sense, Smappee and Neurio.
As expected energy monitors' sustainable interventions focus in Eco-Feedback. All provide real time monitoring and consumption details per appliance and sometimes per room (See Figure 24). About Eco-Feedback some interesting insights were obtained. Firstly, feedback on energy consumption can not only increase awareness but also help users to identify energy leaking and in some cases, if accompanied with appropriate suggestions, it can drive behavior change. Secondly, feedback visual design and the interactions with it might impact the potential of awareness creation. Multiple interactions allow users to deeply understand, compare and reflect on their use. Timelines (day, month, year), use trends, lists, bubbles, consumption-price relation are some examples on consumption visualization.

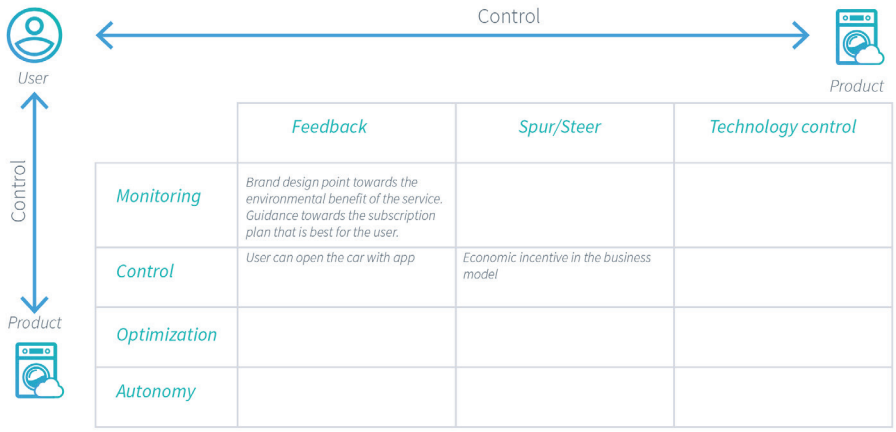
Unlike washing machines, the energy monitor itself is not an interaction channel, all functions are embedded in the app. In this product, steering-strategies as goal setting and recommendations are provided. Interoperability can be explored to provide autonomy to the services.

The promised smartness of these energy monitors does not always fulfill user expectations due to its technological limitations. The product takes some time to identify appliances and the result might not be accurate or reliable. The training process of the monitor can take advantage of human intervention to enhance its performance. That collaboration between the product's machine learning and the user is not always considered. Finally, reliability of both connectivity and feedback is essential for a positive UX.

Circular PSS

The analyzed cases are examples of a trend towards shared economy and disownership where IoT is an enabler of the business model. Four connected CBM were analyzed: ZipCar, GoBike, SolarCity and GreenWheels. With exception of SolarCity, all the analyzed cases are use-oriented PSS, which can be framed as sharing/renting services due to the monthly fee. However, consumption is measured as Pay-per-Use (hours and or/km). This means that service classification is not strict and can be adapted to company needs.

The most common values highlighted by the services are: Flexibility, easiness, convenience, worry free, worthwhile alternative and affordable. Service flexibility is clearly reflected in the value capture when services offer multiple plans with different conditions, in some cases to different target groups. Interestingly, sustainability is not advertised as a service value, and even though all the services promote more environmental friendly consumption and use, as car sharing, bike use, solar panels, there is not a clear pattern on conveying an environmental message in their value propositions. Economic saving potential is more advertised than environmental benefits.



	Feedback	Spur/Steer	Technology control
Monitoring	Brand design point towards the environmental benefit of the service. Guidance towards the subscription plan that is best for the user.		
Control	User can open the car with app	Economic incentive in the business model	
Optimization			
Autonomy			

Figure 25. GreenWheels analysis

GreenWheels is the only service that includes sustainability in the value proposition (See Figure 25). However, sustainable behavior interventions are limited and their proposal can still be strengthened through complementary strategies. For instance, there is no offer of hybrid cars and no feedback is provided about resources consumption and saving. This example shows that even if the service considers sustainability as part of the value proposition, that does not necessarily mean that this concern has been translated into actions to enhance user's sustainable behavior during the use phase.

In general, the analyzed PSSs implement less sustainable design interventions than in the products. Most of the interventions are located at the area of Eco-Feedback and Steering. Technology control has not been developed yet. Moreover, monetary incentives, personalized suggestions, tailored eco-feedback and offer of sustainable products are recommended strategies to complement current ones.

Regarding the design, it is common for the services to rely on apps or web services as the main or secondary interaction channel, where all management, registration and follow-up happen. These digital interactions are therefore an important service component. Additionally, the offered product is embedded with some level of connectivity to track consumption and provide "smartness" to the experience. The latter, however, should be developed to actually improve user's performance. Some examples showed that available smart features relationship with the value proposition and its purpose of facilitation or optimization is weak, and consequently the UX is negative.

Easiness is the most appreciated value in UX, as in the case of ZipCar and GreenWheels booking. Also having a sense of control is important, specially to avoid the service block-out in case the connectivity fails. Few comments about environmental convenience were found in the UX analysis.

Interface details can have a great impact in how users perceive the service. Details as the availability of options when they expect, intuitive and assertive interaction gestures and reliability of information are essential to ensure a positive experience. Furthermore, the payment step is a high-risk spot of the services, common complains are found there, hence, transparency and clarity in this topic is recommended.

2.6.CONCLUSIONS

Both Circular PSSs and connected products are making use of connectivity to stimulate more sustainable practices. The way this is reflected in the design and the achieved level differ from case to case. However, according to the framework analysis, in general the interventions are limited and can be strengthened with more robust implementation of all the levels of both sustainable behavior strategies and product connectivity.

Smart washing machines features are characterized for increasing comfort, easiness and control over the laundry process while energy monitors focus in feedback and its helpfulness in saving resources. This is reflected in the level of connectivity and interventions that both achieve (See figure 26). In washing machines, connectivity level is high, which has been translated in automation and interoperability features, as is the case of Whirlpool machine. On the other hand, energy monitors, have a have

a strong proposition around eco-feedback strategies, which according to users' self-reports has increase their awareness. About feedback design, energy monitors analysis showed that the way feedback is presented and how users interact with it might influence the potential of awareness creation.

Circular PSSs' value proposition highlight values as flexibility, easiness, convenience, worry free, worthwhile alternative and affordable, which are then reflected in the service offers and value capture model. Interestingly, even though all the analyzed services promote more sustainable practices through share and disownership, there is not a clear environmental message in their value proposition to create awareness. And even if the value proposition includes a sustainable value, this is not necessarily translated into interventions to foster sustainable behavior, as is the case of GreenWheels.

Circular PSSs sustainable behavior strategies implementation is more limited than in product (See Figure 26 and 27), specially at technology control side. Thus, to join well designed connected Smart Products with Circular PSS has the potential of enable more balanced and complete implementation of sustainable practices.

The analysis also worked as a source of inspiration for IoT related sustainable features such as: linear menus, shortcuts, bundles, personalized suggestions and notifications and goal settings. Not all connected features are related with sustainability though, some are included as added value for the experience of use, as the case of remote control of smart washing machines.

Smart washing machines, energy monitors and connected Circular PSS commonly rely in apps and Web UIs as main or secondary interaction channel. Touchpoints are multiple but mostly digital where all management, registration and follow up happened.

Users expectation regarding products and services smartness are high. That is why any failure in the product's connectivity and smartness have a negative impact in the experience. These glitches can be balanced with reliable connectivity and consistent feedback. Easiness is always appreciated, it can be said that the simplification of processes is an interesting strategy for motivating consumer adoption of services. Also, the visual design of the interface has a great impact on the users' perception of service quality. This should be intuitive, assertive and reliable. Finally, payment is a high-risk part of the service, thus, transparency is recommended.

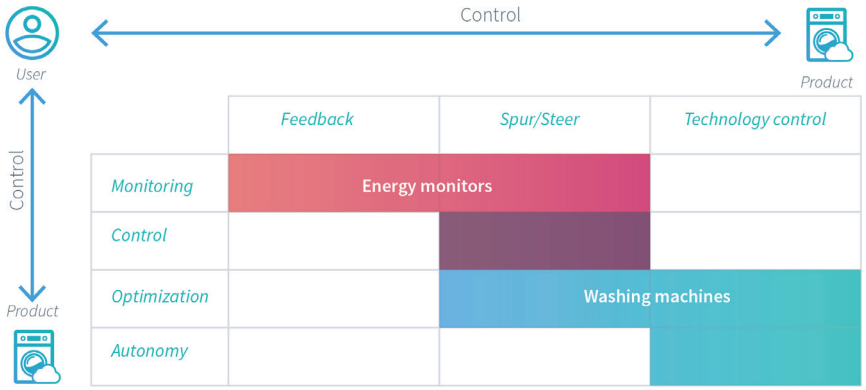


Figure 26. Energy monitors and Smart washing machines interventions

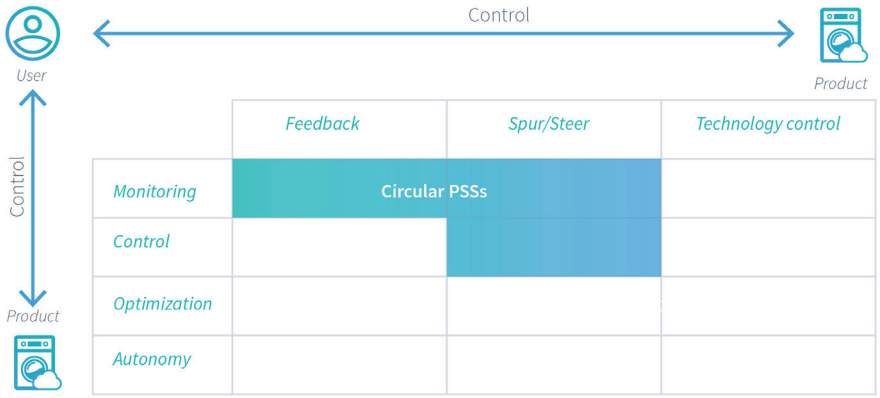


Figure 27. Circular PSSs interventions


Выкл.
Синтетика
Тёмное бельё
Рубашки
Outdoor
Спортивная
Чувствительная
Супер 30115'
Хлопок
+Предв. стирка
Интенсивная
Смешанное
Тонкое бельё
Шерсть
Полоскание
Отжим/Слив
Быстрая
Эко
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3.COMPANY ANALYSIS

HOMIE was founded in 2016 in response to the high impact of home appliances in household footprint. It is an innovative spin-off from TU Delft that operates at the forefront of the Circular Economyby proposing, developing and testing new circular business models with consumers that reduce people's need for 'stuff' and helps to reduce their environmental impact in the home significantly.

Starting its concept with washing machines, HOMIE provides them to users on a Pay-per-Use model. HOMIE charges their customers every time they use their washing machine depending on the selected washing program, the water and energy cost is also included in the price. The service also includes the installation and reparation when needed.

This chapter provides an overview of HOMIE Pay-per-Use value creation, proposition and delivery along with its future vision and an analysis of how the service is currently tackling circularity and sustainable behavior through product connectivity.

3.1.HOMIE'S GOAL

By using a Pay-per-Use service model HOMIE is able to remove ownership from home appliances and consequently being able to reduce their environmental impact and empirically evaluate multiple aspects of a service type as: the actual environmental impact of product life extension when products are circulated, if Pay-per-Use could indeed lead to more conscious consumption as assumed in literature, if there is a market for this innovative type of service and if the use of strategies for sustainable behavior along with IoT have an impact in environmental awareness and consumption. The latter, due to product connectivity, gives opportunity to explore IoT and sustainability potential relations and to exploit "smartness" as a source of value creation and to drive behavior change. So, HOMIE's innovation does not only rely on product circularity but also on sustainable behavior changes during the use phase.

Regarding circulation, HOMIE as the service provider is the principal articulator of the loops (See Figure 28). In relation with the user it enables reuse, ensures maintenance and updates old technology washing machines while collecting the old ones. HOMIE also ensures that those old machines are sent to the product manufacturer, parts manufacturer or are recycled. Each one of these loops has a positive impact on the preservation of product and material values and reduces the environmental impact of the product disposal while extending its use life.

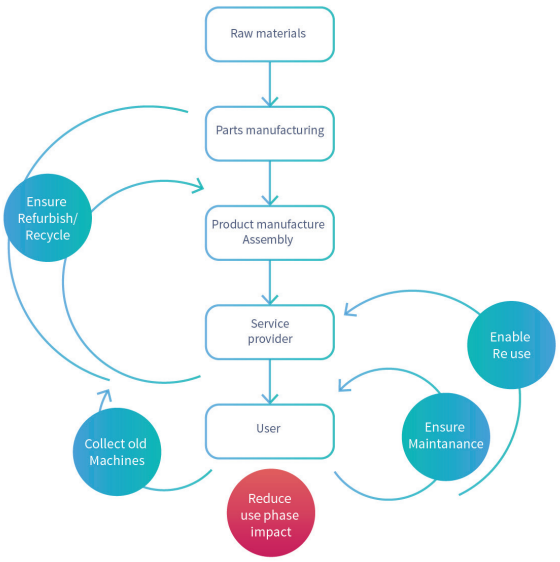

Figure 28. HOMIE potential impact in product lifecycle

Even though, disposal and production are usually the focus of product sustainability interventions, as shown in the literature research, the use per se is a high resource consumption phase and could be the most polluting, particularly in products with intense resources use like washing machines. For this reason, HOMIE also aims to

reduce resource consumption during the use phase by applying sustainable behavior strategies.

3.2. BUSINESS MODEL ANALYSIS

Current HOMIE service is analyzed by exploring the three main components of a business model, value proposition, value delivery and value capture.

3.2.1.Value proposition

The following value proposition is proposed by HOMIE:
HOMIE offers environmentally-friendly home appliances using a Pay-per-Use service model without the upfront costs, installed, maintained and replaced for free, so customers never have to save up for or worry about their machine again.

From the value proposition it is possible to highlight three main values that reflect HOMIE's intention to fulfill customer needs. These are: affordability, worry free and environmental friendliness as the key values of HOMIE Pay-per-Use service. Additionally, HOMIE also generates social value when removing the upfront cost and hence allowing users with low income to have access to a high quality yet cheap washing machine.

Three main customer segments have been identified by HOMIE according to current users (See Figure 28). Each HOMIE value seems to match each customer segments interest, low income users are more drawn by convenience and its affordability, roamers by the worry-free aspects and finally green millennials by the service environmental friendliness.

3.2.2.Value creation and delivery

Value is created when HOMIE values are translated in service and product features that convey their meaning, as follows:

- **Affordability** is given by the reduction of the upfront cost and the fact that the payment is done only when the machine is used (e.g. no payment in holidays).
- **Worry-free** is related with installation, maintenance and replacement for free as well as the certainty that there are no hidden fees.
- **Environmental friendliness** is approached from the circularity of the product, replacement of old washing machines with energy efficient ones and through monthly feedback and suggestions that promote a more efficient washing machine use.

Regarding the technology, HOMIE offers a Zanussi A+++ Washing machine, with capacity of 7 kg and 1400 rpm and delay-start function of up to 20 hours (See figure 30).

Figure 29. HOMIE values and customer segments

Figure 30. Zanussi washing machine

Figure 31. Zanussi washing machine interface

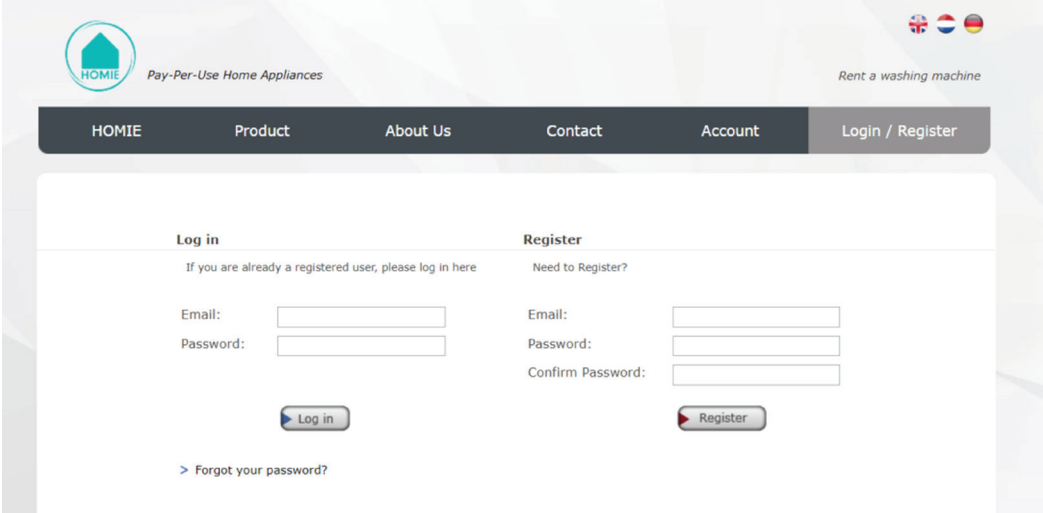

Figure 32. Zanussi washing machine interface

It is equipped with multiple regular cycles named by both clothes type and material, and a Cotton ECO function that is only available for 40° and 60° degrees wash (See Figure 31).

By using a built-in tracker in this commercial machine, HOMIE collects data on the washing machine use. The collected data includes: temperature, program, start time, date and user. This data is sent to HOMIE's server every 10 min or when the wash starts and is immediately reflected in the webpage, visible for both company and user. Besides, after each wash users automatically receive a payment request by e-mail which lead them to the service portal (See figure 32). Collected data is currently used in two processes. First to keep track of use and second to provide feedback about use and do recommendations on how to make a more efficient and cheaper use of the service.

Value capture.

With Pay-per-Use, users only pay fee for each wash with an all-included price, it means that the cost of water and electricity is included. This is an attempt to reflect real consumption cost, a value of Circular Economy. Furthermore, there are no hidden costs (e.g. deinstallation). The cost for water and energy is reimbursed at the end of the month.

Since there is a significant difference in energy consumption between washing temperatures, the price varies accordingly to it. This is proposed as an incentive to reduce temperature and is a win-win for both the users by reducing cost and the environment by consuming less energy.

- A cold wash costs €1,37 (incl. VAT)
- A 30°C wash costs €1,42 (incl. VAT)
- A 40°C wash costs €1,55 (incl. VAT)
- A 60°C wash costs €1,71 (incl. VAT)

- A 90°C wash costs €1,93 (incl. VAT)
- The machine's rinse, drain and spin program are offered for free

Additional to use fees, HOMIE's intention is to repair and reuse the washing machines to lengthen their lifespan and reduce materials waste, this way keeping the product value at its highest level for the longest time possible, what constitutes a key implementation of Circular Economy.

Challenges and opportunities

Currently HOMIE is in the initial service roll out with approximately 25 users in the area of Delft, Rotterdam and The Hague. The connectivity is successfully working and a scale market test has been developed achieving a positive response.

The future vision includes the offer of additional products, characterized by a high resource demanding use phase and that could benefit for new energy efficient products, as dryers and dishwashers, and to offer the service in other countries. However, Pay-per-Use implementation rises financial challenges, specially related with the washing machine upfront cost and the long-time revenue takes.

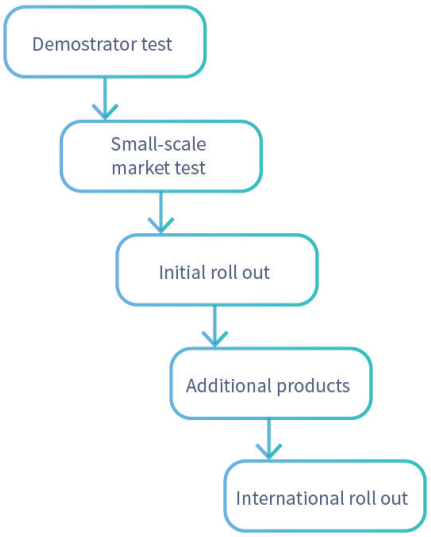

Figure 33. HOMIE implementation process

In terms of technology, HOMIE is currently testing the use of independent embedded connectivity in the machine by using SIM cards. This way the service is able to ensure connectivity independent of users wi-fi connection. For testing this, they have designed a digital washing machine to emulate washing data (See figure 34).

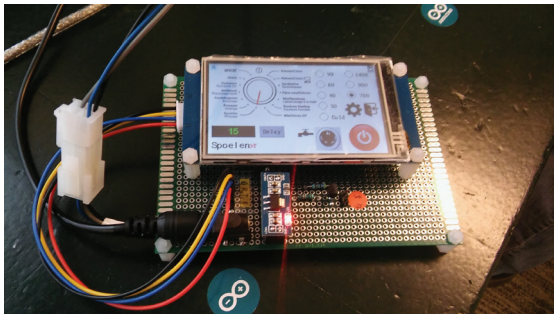

Figure 34. Digital washing machine, connectivity test

As mentioned before, data is captured in each wash and is used to provide feedback and track consumption. This data can create additional sources of value that has not been explored yet, such as the creation of partnerships with detergent, energy, water and maintenance companies, or its exploration to have a better understanding of user behavior for service iteration. In this regard, the fact that all users have the same washing machine facilitates measurement, analysis and implementation of design interventions. The involvement of partners is also a scale up opportunity, for example with washing machine suppliers HOMIE will be able to intervene the washing machine design and to include preventive maintenance in the service.

As part of their growing intentions and with the support of this project HOMIE is willing to strengthen their value proposition during the experience of use. In relation with the environmental friendly aspect, the changes will involve a more accurate translation of circularity and sustainable consumption into the experience of use. As mentioned in the literature research, a clear value proposition rooted in user desires and needs with a consistent User Experience is essential for consumer adoption.

3.3.SERVICE DESIGN

To gain understanding of the service a service mapping was developed. It provides a holistic overview of all the service process by considering both service provider a user perspective (See Figure 35). The journey details the service main stages and steps per stage. These steps are shortly described afterwards by detailing customer actions. Eleven touchpoints were identified, including both physical and digital, which are highlighted according to their use in each stage. Awareness stage considers users first encounter with the service through either advertisement (google adds, marktplaats[2]) or the webpage. Contact stage indicates users' willingness

2. Marktplaats.nl is a classified advertising site based in the Netherlands

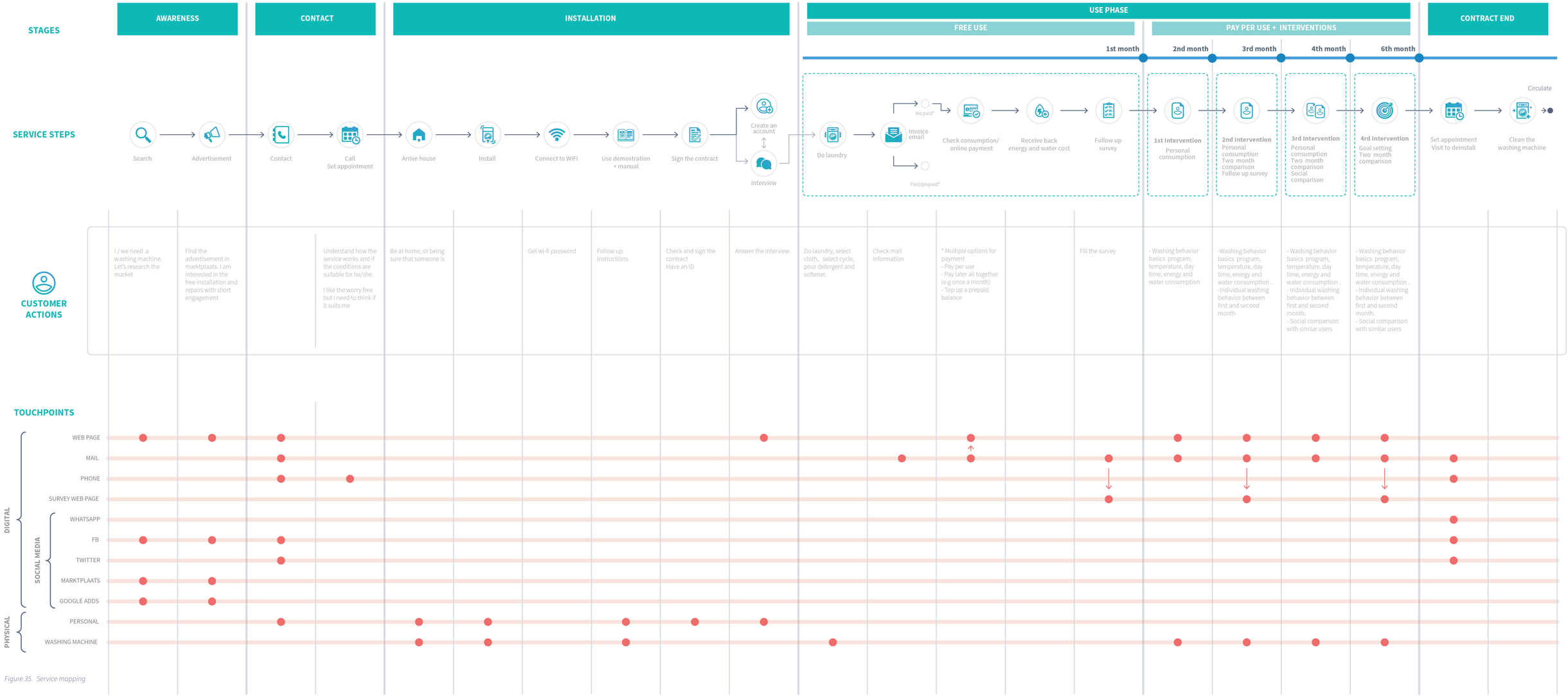

Figure 35. Service mapping

SERVICE MAPPING

to acquire the service, in this stage a user's potential engagement is evaluated and installation appointment is set up. The latter is done by either email or call what can result time consuming. During the installation, the washing machine is connected to wi-fi and a short explanation of the machine programs and functionalities is performed (See figure 36). Besides, users create an account to be able to relate the machine tracker with the corresponding user. Next, the contract is signed and a digital survey performed.

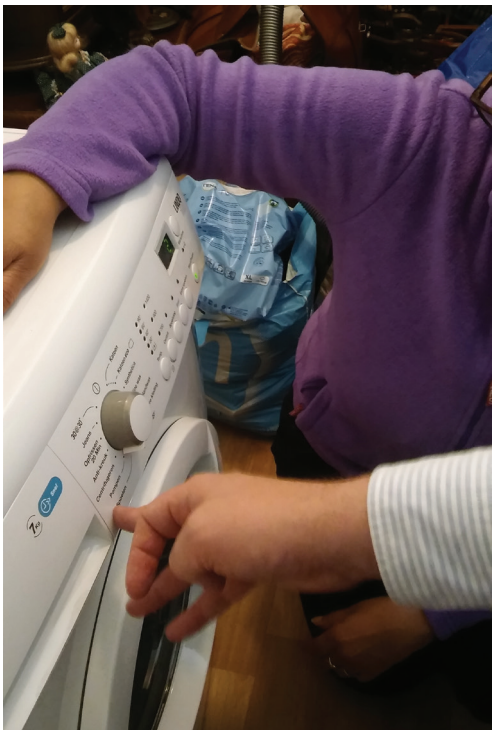

Figure 36. Use instructions during installation

Once the washing machine is installed, the use phase starts. The first month is offered for free, and from the beginning of the second month the user is charged and feedback is provided.

There are multiple touchpoints, mostly digital. Google ads and marktplaats are used in advertisement, directing users to the webpage where the service is explained. Various contact channels are available, mail, phone, social media and the webpage contact form, the latter is the most common one.

The installation is done personally. After that personal interaction, all the user's relation with the company is moved to digital touchpoints, unless maintenance is required. During the digital interaction, surveys, payments and feedback consultations are fragmented in different platforms, there is not a centralized site that allow users to easily consult their consumption, fill surveys or pay.

Interventions

Due to HOMIE's interest in not only using a circular business model level but to create awareness and reduce consumption during the use phase by making use of product connectivity, three eco-information and eco-choice interventions and one eco-spur interventions have been developed and implemented based on DBIM Tang's model (2010) (See table 2).

Current feedback is sent by email at the end of the month, it is not real-time feedback, therefore eco-feedback level is not achieved and potential reflection during the decision-making process is absent. This, according to the literature review could reduce the strength of the intervention. Additionally, to feedback emails there is price incentive to reduce temperature, this intervention begins when users start paying.

The impact of the interventions in users washing practices has not been evaluated yet and is part of the scope of this project to do so.

IoT and sustainable behavior analysis

Washing machine connectivity is the main enabler of this Pay-per-Use service, which at the same time allows the creation of price incentives and data collection that is used to provide feedback and therefore creates environmental awareness. However, as shown in the literature research, interventions at different levels of both connectivity and sustainable behavior can be achieved. By using the framework designed in the benchmarking, HOMIE's current capabilities and interventions are analyzed (See figure 37).

Evidently, HOMIE interventions are limited to feedback and price incentive, both in a level of monitoring. Therefore, relying on the users' decisions to reduce environmental impact. This, as shown in literature might not be efficient in driving a long term behavior change. There is great room for advance in the design of sustainable interventions by taking advantage of connectivity, thus increasing the service impact in behavior change.

3.4.CONCLUSIONS

HOMIE aims to reduce environmental impact of household appliances through all its lifespan by using Pay-per-Use as their business model and implementing sustainable behavior strategies. Its purpose is also to test the impact of both in a real case of study. Its main relation with Circular Economy lies in value capture through both Pay-per-Use and product life extension.

Level	HOMIE intervention (See design details in Appendix 4)
Eco-information	First month: Email feedback. Own consumption in terms of programs used, temperature, time of the day, total energy and water consumption. Second month: Email feedback. Comparison of two months programs, temperature and time. Total energy and water consumption. Third month: Email feedback. Comparison of two months programs, temperature and time. Total energy and water. Social comparison Fourth month: Email feedback. Social comparison.
Eco-choice	First month: Suggestions Second month: Suggestions Third month: Tailored suggestions Fourth month: Goal setting
Eco-spur	Price incentive to temperature reduction from the first month.

Table 2. HOMIE sustainable behavior strategies

HOMIE current interventions for fostering sustainable behavior are focused in feedback and price incentives for temperature reduction. Both interventions are located on a connectivity level of monitoring, what means that there is room for new strategies implementation that can strengthen the impact in users' behavior.

HOMIE's convenience and worry-free values are consistent with the values used by other Circular PSS explored in the benchmarking. Other values that could be potentially explored are flexibility and affordability.

HOMIE is willing to strengthen their value proposition and translate both the aspects of circularity and sustainable consumption into the service experience. As mentioned in literature a clear value proposition founded in user desires and needs, with an also consistent User Experience is essential for consumer adoption.

Connectivity is an essential component of HOMIE service, which enables its Pay-per-Use service, data collection for feedback and price incentive. However, data use is limited. Other potential values have not been explored yet.

Besides the washing machine, the service relies mostly on digital interactions, from which the webpage (including the customer portal) can be considered the main touchpoint for both prospective users and current customers.

The process of surveys, payment and feedback is fragmented in different platforms, so there is not a centralized touchpoint.

Figure 37. HOMIE IoT and sustainable behavior analysis

4.USER RESEARCH

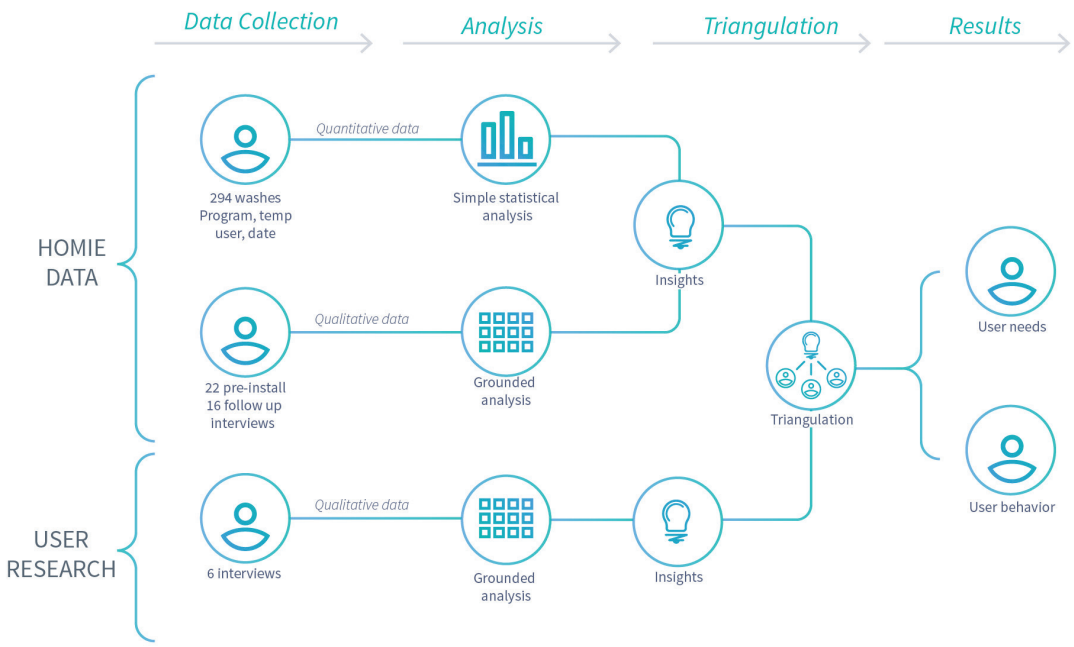

Figure 38. User research process

This user research aims to generate insights about user needs and behavior when doing the laundry as well as about HOMIE Pay-per-Use service perception. And respond to the research questions: Which are user needs when doing the laundry? Which behavior patterns do users have? The generated insights are afterwards used to define the design brief, more specifically to provide a human centered approach to the problem and goal definition.

The research had two main information inputs, data collected by HOMIE during the service offer and an extended user research to gain better understanding on user's behavior (See Figure 38). This chapter provides an overview of the analysis of both and presents the final insights in terms of user needs and behaviors.

4.1.RESEARCH APPROACH

HOMIE qualitative data analysis was used to evaluate users' perception about HOMIE service and its specific washing machine as well as to find general user needs and behaviors, quantitative data analysis, on the other hand, focused in finding washing patterns. However, his data left some questions regarding the underlying reasons of users' behaviors and decision-making process. That is why, an extended user research was performed with a focus in understanding the laundry process along with its habits and concerns. The following sub-research questions summarize the user research purpose:

HOMIE data

- What is the users' perception about HOMIE service?
- Do users report to have been influenced by current design interventions?
- Which patterns can be found in the users' washing behavior?

Extended user research

- What are the users' main concerns and needs when doing the laundry? Which are more important?
- How do users sort, select the cycle, choose temperature and pour detergent?
- Which habits and knowledge drive this process?
- What is the users' perception about current HOMIE feedback interventions?

4.2.HOMIE DATA ANALYSIS

Details on the complete analysis can be found in the appendix 5, users' quotes of the qualitative analysis in the appendix 6 and quantitative analysis graphs in the appendix 7.

4.2.1.Data

Quantitative data:

The received data from HOMIE included: 294 washes (Temperature, program, users, time, date) for 19 users during April. Since the data is only one month, it can represent use patterns assuming that washing behavior is steady throughout time. Time series are not considered in the analysis. Additionally, interest and knowledge about sustainability, and corresponding variation when using HOMIE reported in the pre-installment survey for 22 households and follow up surveys for 16 households, those divided in: first week, first, third and sixth month. It is worth to notice that since users start in different months, there are multiple surveys missing and consequently the analysis is limited to few complete data.

Qualitative data:

Regarding qualitative data, it included: pre washing machine installment survey for 22 households and follow up surveys for 16 households divided in: first week, first, third and sixth month. The pre-installment survey shows an overview of user's habits and knowledge when doing the laundry, while the follow up survey provides more interesting insights into HOMIE service perception, its influences in user's behavior and washing machine programs and functions. Some insights are repeated in both pre-installation and follow up survey.

4.2.2.Method:

Quantitative data was analyzed through a simple statistical test. It was grouped and visualized through dynamic tables in Microsoft Excel. Twelve visualizations resulted from the analysis in which different relations between the groups were explored (See Figure 39). Some of these groups were also normalized as is the case of personal consumption.

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4.2.3.Results:

The insights generated by both quantitative and qualitative data were compared and triangulated, the results are presented as answers to the initial research questions.

What is the users' perception about HOMIE service?

The most appreciated characteristics of HOMIE are: saving the upfront cost of the machine, good low price, better overview of the costs (fair and all included),

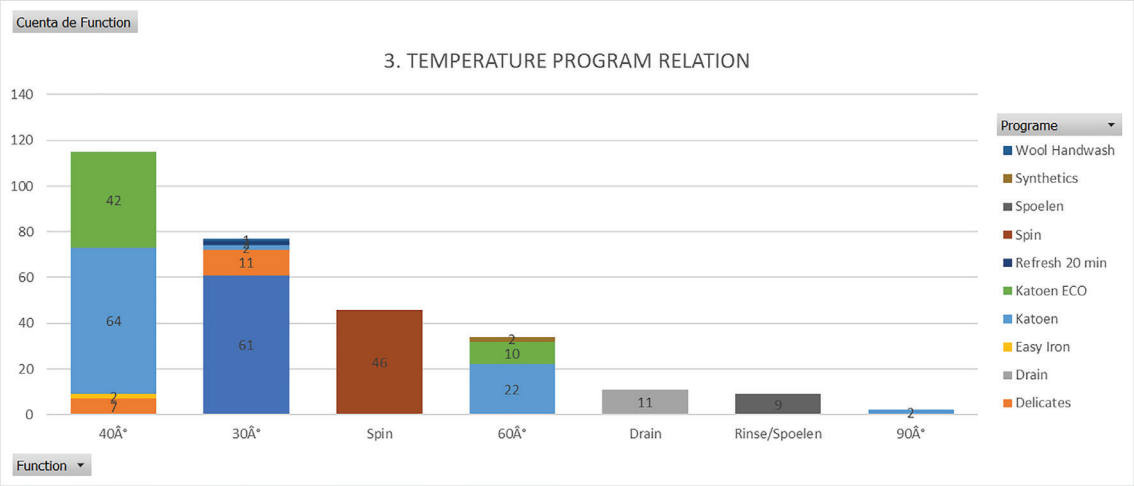


Figure 39. HOMIE quantitative analysis, temperature program relation

trustable quality and economic machine, it is a startup, provides nice suggestions, it's sustainable, and has an easy and quick installation, maintenance included. Users appreciate suggestions on how to wash better and are willing to receive more detailed ones. Most users would recommend HOMIE to friends since they consider it is easy to use and cheap. On the other hand, users would like to have more statistics, graphs and background information on the webpage and the relation between temperature and sustainability is not always clear.

Do users report to have been influenced by current design interventions?

According to qualitative data, the service might have created awareness to some users when selecting the cycle and temperature, lower temperature, more use of eco. For some users suggestions matters, as well as to economize when they know (are aware) which is the most economic cycle. This can be due to a combination of suggestions and price incentives. Some users are not affected by the suggestions and price. However, it is not common to analyze the price of each laundry, especially during the free month. In this stage suggestions might be more impactful.

Even though some users report that HOMIE has influenced their interest in sustainability in the metrics, that is not reflected in the overall interest scale. It is interesting though, that the qualitative analysis reports that some users are more aware of the program and temperature use as well as water consumption.

Which patterns can be found in the users' washing behavior?

The quantitative analysis shows that the consumption can varies according to household composition, but there is still a considerable difference among similar compositions. There is room for reducing and steering towards more sustainable programs and temperature selection.

Habits:

- There is a common understanding that the higher temperature the cleaner the laundry. This applies specially for towels, bedsheets and white cloth.
- Towels and bedsheets are commonly washed in high temperature cycles (60-90); some users do it occasionally (once a month) instead of all times.
- Users decide when to wash based on different concerns: whenever it suits the schedule, when the basket is full, weekends or according to other events (performance) are the most common patterns.
- It is common to sort clothes in white (clear), black (dark), color, bedsheets, delicate and towels. Or everything together.
- Time is a key factor considered when selecting the cycle (that is why a display is required). There is a common request for shorter cycles.
- Selecting the cycle might be troublesome since users need to balance the personal available time along with the wished program and the time it takes.

Programs and temperature:

- The selection of three or less temperatures per household indicated in the quantitative analysis is consistent with the classification of cloth, if cloth is classified different temperatures or programs might be used according to the clusters. This does not happen in all cases though.
- It is interesting that even though the most common way to sort out the cloth is by color and type (general, bedsheets, towels) the cycles are named by material. It can be assumed therefore, that the programs' naming can facilitate the selection process and consequently work as a steering strategy.
- Most of the washes are done in cotton cycles and in either 40° or 60° temperatures, 40° is the most common.
- The second most popular program is 30-30. Its wide use might reflect users need to balance time and cleanliness. Also shows that the name of the cycles by type of material is not necessarily required for the user's willingness to select a cycle.
- Both 90 degrees and cold program are barely used. The same is found for detailed name programs (synthetics wool, hand wash)
- Most households use 3 or less types of programs according to the quantitative analysis. This is consistent with reports in the qualitative analysis that point out to multiple unused functions or the habit of using just a few. Washing more does not relate to using more programs
- Eco function is only available for 40 and 60 degrees' temperature. This limits the user's choice who, according to the qualitative analysis, are willing to use it in less temperature. Other factor that influences the rather low use of this function is that it takes longer than a normal cycle and that time is mentioned as one of the main user's concerns when selecting the cycle.
- Even though a relation between the laundry sort out and temperature/program was found, it is not clear yet which knowledge and habits are involved in the decision-making process. Additionally, some

concerns were identified that could influence the selection process, as cleanliness, time, available personal time, type of cloth, social events, however the importance given to each one is not defined. It is essential to gain insights into a deeper layer of user's behavior to be able to design a solution that better fit their concerns.

4.3.EXTENDED USER RESEARCH

Considering the gaps in HOMIE data analysis this research aims to understand deeper layers of user's behavior that define washing practices, for details see Appendix 8.

4.3.1.Method:

Focusing on qualitative research a semi-structured interview was performed to the participants (See Appendix 9). The questions were structured to systematically explore all the laundry steps, starting with sorting and finishing with detergent (See figure 40). With the intention to promote reflection during the sorting and program selection an exercise with paper pieces of clothes was executed by the users and the program was selected in the current HOMIE washing machine interface (See figure 41). Card sorting methodology was used to identify the most relevant concerns for each user (See figure 42).

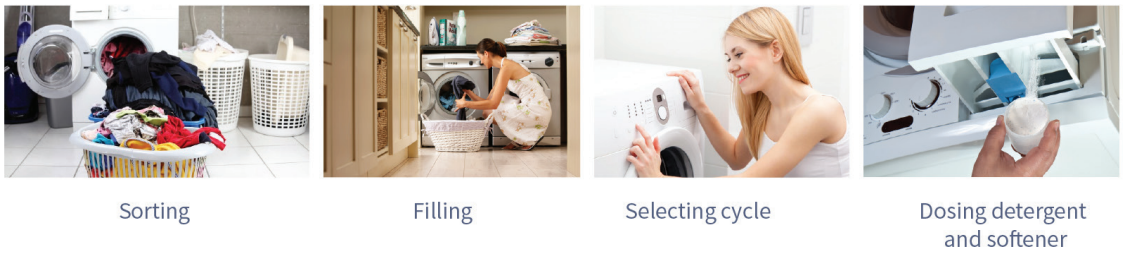


Figure 40. Laundry steps

Figure 41. User selecting cycle for clothes category

Figure 42. Concerns card sorting

Figure 43. Feedback evaluation

along with its potential interaction channels. Qualitative information was collected to evaluate the clearness of the feedback.

4.3.2.Participants:

Six participants from different nationalities who fit the customer profile of green millenials were interviewed, as follows:

Participant	Nationality	Age	Occupation
User 1	Colombian	26	Msc Design- Student
User 2	Mexican	27	Strategic designer
User 3	Swedish	27	Phd student
User 4	Dutch	25	Msc Physics - Student
User 5	Dutch	25	Msc Design- Student
User 6	Greek	27	Strategic designer

4.3.3.Analysis

After the information was collected, a qualitative analysis was performed to find patterns and insights into user's behavior. First, quotes and general data were clustered according to the laundry step, potential concerns, feedback and interaction channels. One color was assigned per user. Afterwards, information was synthesized and re-clustered according to found patterns, two main groups were grouped: One related with washing behavior and one with the feedback (See figure 44 data organization and synthesis).

Figure 44. Data organization and synthesis

4.3.4.Results:

The results are briefly presented as answers to the research questions, more details about the insights with quotes can be found in the Appendix 8.

What are the users' main concerns and needs when doing the laundry? Which are more important?

Clothes condition and cleanness are the main users concern, this means maintain quality and ensure cleanness. These needs completely overrule any other factor, including consumption. Even though, users are concerned about their clothes they rarely check the washing recommendation labels, this is only done with expensive items or items they care about. Some users never do it.

How do users sort, select the cycle, choose temperature and pour detergent?

When sorting, users mix and match different factors, as color, temperature and material. Other less common factor is closeness to the skin (layers). Color is classified in color, dark and white, sometimes including delicates as well. Material in hard and soft. Temperature in high and low according the desired result.

- Different clothes categories respond to different personal concerns and are consequently washed in different programs, the most common are:
- Delicate: "The clothes I really care about, susceptible to get damage" Picky
- White: "Well if bought it white, it must remain white, right" Careful
- All the rest/Color: "All these can go together, why not" Careless
- Towels and bedsheets: "I want to be sure all bacteria are gone" Hygienic

Cotton is seen as the generic, average cycle. Therefore,

most users selected it and changed the other features as temperature and spinning, others only relied in the default option.

Users ideas to wash more sustainable include: temperature reduction, shorter programs and do full load. This washing machine does not have a load indicator though.

In general, users have no idea on how much detergent to pour. Intuition is the most common method. Even though bottles do indicate the recommended amount, the instructions are not clear, the units are hard to measure and level of dirtiness is a subjective measure.

Which habits and knowledge drive this process?

There is a general lack of knowledge about the difference between different programs, how is water, energy, time and temperature regulated, and how that impacts clothes. This lack of knowledge about the most suitable (efficient) program settings in relation with the type of clothes lead to doubts when selecting the cycle. The machine does not guide or inform users in that matter, so the program selection process is seen as troublesome. The perception of low or high temperature vary from user to user. High temperature is related with better cleanness, and it is used mostly in hard materials that can resist the temperature without getting damaged, it provides a feel of safety. Low temperature is related with ensuring clothes condition, usually used in delicate and especial items (expensive or with personal value). In this items cleanliness is moved to a second level of importance.

Regarding sustainable washing, it is not clear what the eco-function does. There is, however, an assumption that eco uses/ regulates less energy and water. So, even if there is interest in energy and water consumption, that interest cannot be translated into actions due to the lack of information for a conscious decision making. Users are open to suggestions in more sustainable programs.
Some users are not concerned about length of the cycle if they are at home to wash, so “quick” was seen as an efficient way to clean occasionally

What is the user’s perception about current HOMIE feedback interventions?

There is no clear relation between the used program and its energy and water consumption, this way is hard to identify which is better in terms of sustainability. Similarly, to the results in the user research, there is not a clear understanding of how the eco function affect the consumption. Users would like to see a progression in time to evaluate how their consumption has changed. The units of water and energy are not understandable on practical terms, it is too abstract. Pie chart are not visually comparable then users are required to calculate, consequently consumption is not easy to read. Users are willing to receive feedback in terms of good and bad actions, what exactly was done wrong and how to improve it as well as personalized suggestions

5. DESIGN FOCUS: FROM INSIGHTS TO SCOPE

To define project limitations and scope, this chapter establishes the boundaries for the design and opportunities of intervention in current HOMIE service from a user perspective. For this purpose, a human centered approach and an iterative process are considered. A customer journey was developed by mapping out the analysis results in terms of User Experience. Here, the most promising points that could both improve UX and support HOMIE in its aim of reducing environmental impact of washing machines were detailed.

5.1.APPROACH

A human centered approach is relevant due to users' reluctance to engage in more environmental practices if that interferes with their own goals and needs or if extra effort is required, as shown in the literature research and User Research. Moreover, it has been shown that addressing customers' needs with a well-defined value proposition and a consistent UX is crucial for adoption and user satisfaction.

5.2.CUSTOMER JOURNEY

A Human centered design approach is applied in this project to support HOMIE in its goal of reducing washing machine environmental impact through all its lifecycle. Three insights from the analysis are relevant in this matter.

1. A value proposition rooted in user needs and desires is likely to increase consumer adoption of Pay-per-Use services by offering a more attractive service than ownership. This value proposition is crucial for service design and must be reflected in the User Experience.
2. The use phase is an intensive resource consumption part of products lifecycle. In washing machines this phase can be the most polluting one. Consequently, fostering sustainable practices is crucial if considering that provide information (e.g feedback) is not enough to drive behavior change.
3. Product connectivity is an enabler of Pay-per-Use service and a promising asset for value creation for both user and service. It can be explored to bring smartness to the experience of use, design data-driven features and facilitate partnerships.

For establishing design opportunities for a better UX and sustainability boosting, a customer journey was developed (See figure 45). This is divided in two main parts, user experience and business opportunities since the goal is to balance both. Firstly, the journey states users' goals, expectations and relate them with the current experience. Secondly, sustainability and business goals are defined, it means service actions to meet user expectations and where more sustainable practices can be promoted or service values highlighted.

HOMIE data analysis indicated that users are satisfied with the service values and that those match their interests and solve typical problems of ownership, affordability is distinctively appreciated. Consequently, the journey mapping focuses in the translation of those values in the experience of use. For this evaluation, it is essential to provide a holistic overview of all the services as follow.

Three opportunities are found in the journey that are relevant for HOMIE goal and could benefit from UX improvements along with the use of connectivity.

First, users typically experience uncertainty when trying new services and doubts arise, especially if those challenge a long-learned behavior as ownership.

Therefore, a clear and easy understandable overview of how the service works, which are its values and advantages in comparison with buying a machine could motivate users to move from ownership to Pay-per-Use and finally get the service. This interaction is mainly given in the webpage as it is the main service exploration touchpoint.

Second, when interacting with the washing machine users lack knowledge about programs and its results in terms of cleanliness and clothe condition, then experiencing hesitation when selecting the cycle. If it is wrongly selected, some resources are unnecessarily wasted and in some cases clothes' lifespan is shortened. At this point, multiple strategies for fostering sustainable behavior could be implemented to both enhance the experience of use towards a more certain and easygoing experience and reduce its environmental impact.

Third, consumption reported in the users' web portal and in the monthly feedback is fragmented on different platforms, therefore lacking brand consistency and restricting users' consultation. Moreover, according to the user research, feedback visualization and its purpose is not always clear, interactivity has not been considered and users are not able to reflect on their behavior over time.

Even though, these points are considered the principal opportunities for design interventions, a holistic view of the service will be considered during the design process, which implies also the translation of HOMIE values in other steps of the service.

5.3.LAUNDRY SUSTAINABLE PRACTICES

If considering the key issues for encouraging pro-environmental behavior given by Steg & Vlek (2009) , it is crucial to define which behaviors should be changed to improve the environmental impact, followed by which factors determine that behavior, after which it turns possible to design appropriate interventions. The user-washing machine interaction has been already defined as a relevant point of intervention since the use phase of clothes, detergents and washing machines is the step where most energy is demanded in all their lifecycle. This can also, depending on the energy source, be the most contaminating one (Laitala, Boks, & Klepp, 2011). Therefore, a short analysis was done to gain understanding about washing machine consumption and the potential role of behavior change in resources saving.

Horizontal axis washing machines are the most common in west Europe (Laitala et al., 2011). This technology relies in varying the temperature to achieve cleanliness while using a reduced amount of water. Water consumption per cycle depends mainly on the washing machine technology, while energy consumption is essentially defined by the temperature (Pakula & Stamminger, 2010). The average temperature used in Europe is 45.8° C (Stamminger, 2009).

Since users decide the frequency of washing as well as the temperature, load, type and amount of detergent and dry practice, their behavior and practices have a high impact in resources consumption. The research community agrees that if changed, user behavior is an effective measure to save resources when doing laundry (Laitala et al., 2011; Pakula & Stamminger, 2015; Stamminger, 2009). Considering this, Schmitz & Stamminger (2014) point out three aspects of washing that have a great impact in sustainability and are caused by user's decisions:

First, the machine filling, which is intrinsically related with a more optimal amount of washes and therefore of resources used (water, energy and detergent) (Pakula & Stamminger, 2015). A full load reduces both water and energy consumption per item as well as the amount of washes. This seems a commonsense statement but research has found that users tend to overestimate the amount of laundry filled into the washing machine (Pakula & Stamminger, 2015) and that, on average, colored and white clothes are washed in 3.7 kg/cycle when full capacity is 5 or 7 kg (Kruschwitz, Karle, Schmitz, & Stamminger, 2014).

Second, detergent dosage, the correct dosage and type of detergent influences the removal of soiling and consequently the final personal satisfaction, as well as it reduces potential extra rinses. Overdose of detergent on the on other hand, causes additional chemicals in the ecosystem. As in the cleaning performance, detergent dosage depends of various factors like the type of detergent, water hardness, soil level and amount of laundry, parameters that together can be calculated to define the right amount (Conrady, Kruschwitz, & Stamminger, 2014), which is not an straightforward decision. In fact, research has shown that users tend to use more washing powder that they need to ensure good results (Lilley, Lofthouse, & Bhamra, 20 05).

The amount of detergent can be reduced when washing small loads and lowly soiled textiles. (Laitala et al., 2011)

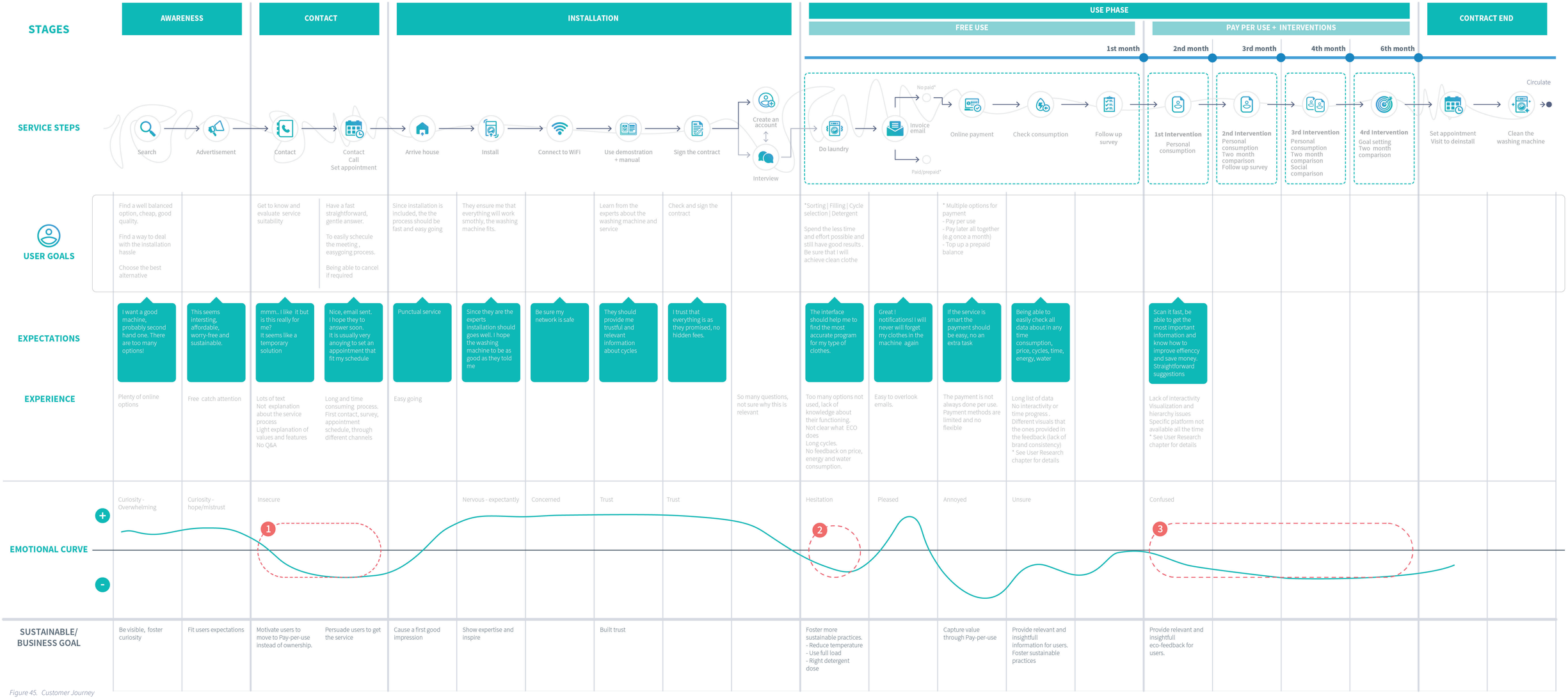


Figure 45. Customer Journey

CUSTOMER JOURNEY

Finally, washing temperature is the biggest influence in energy consumption, its reduction can save a remarkable amount of energy (Pakula & Stamminger, 2010), besides it can also extend the textile's lifecyle (Laitala et al., 2011). Research has found that washing at 30°C uses 29.6% less energy than washing at 40°C, and 58.7 % less than washing at 60°C (Laitala et al., 2011). If temperature decreases, then users can save money, energy and ensure clothe condition.

The cleaning effect of today's detergents is suitable for low temperature washing. This means that the soil is satisfactorily removed at 30°C instead of 40°C when washing colored clothes.

Many textiles are prone to lose more color and strength if they are washed at higher temp (60°C) than at 40°C. (Laitala et al., 2011)

However, as noticed above, these aspects are not part of user's practices yet. The research community has identified some barriers that limit user's adoption of these.

- Machine filling: Hard to measure indications, fear of worse washing results (wrinkles) or that the machine could get damage, previous bad experiences, habits that users do not want to change (e.g. not willing to wait for having too much laundry) (Conrady et al., 2014), users' diverse wardrobes, lack of knowledge.
- Detergent dosage: Lack of knowledge, more detergent gives the feeling of safety, gut feeling and habits, previous bad experiences (Conrady et al., 2014)
- Low temperature use: Lack of knowledge, the feeling of safety and cleanliness, fear of inferior washing results because of low temperatures, cultural biases (Conrady et al., 2014).
- Other barriers: External loss of control, why change if no one does it, feeling that personal actions are not significant, negative previous experiences, economic limitations, culture biases, resistance to change the habits since routines are strong barrier, limited sources of information.

The mentioned findings, about what are indeed more sustainable practices when doing the laundry and the barriers for their adoption, are used as input for the design phase.

5.4.DESIGN GOAL

Enhance HOMIE Smart Pay-per-Use service User Experience while designing interventions to reduce washing machine environmental impact through all its lifecycle. This by motivating the adoption of the Pay-per-Use service and fostering sustainable behavior practices during the use phase through product connectivity.

This means that the three intervention points: service exploration, laundry process and follow up will be addressed by consistently fulfilling user needs and promoting sustainable practices. Another key point is to strengthen HOMIE ***Smart Pay-per-Use service*** value proposition in the experience of use to improve it while fostering sustainable practices.

5.5.TARGET GROUP

As indicated in the company analysis, HOMIE is currently targeting three customer profiles: low income, roamers and green millennials. However, to facilitate a straightforward decision-making process of the design, that is,the selection of the most appropriate features, visual design and eco-system components, it is recommended to select a specific target group that better matches the service values. In this case, green millennials were selected since they might also represent roamers and they are inherently interested in sustainability as a service value.

So, who are the millennials? They are a demographic group born between the early 80s and mid 90s or early 2000s, or who reached adulthood around the 21st century (NG, 2007), what makes them highly familiarized with communications, media and digital technologies. Therefore, they are probably more open to product connectivity.

"Millennials are 2.5x more likely to be an early adopter of technology than other generations (Millennial Marketing, n.d.)"

Additionally, multiple marketing studies have found that millennials are not only more environmentally conscious than older generations (Eco-Business, 2016; Millennial Marketing, n.d.)., but that they are willing to pay more for products and services from companies that have a positive social and environmental impact, or that support a cause they believe in (Millennial Marketing, n.d.; Nielsen Holdings PLC, 2015).

"66% of global (millennial) respondents say they're willing to pay more for products and services that come from companies that are committed to positive social and environmental impact, up from 55% in 2014, and 50% in 2013."(Nielsen Holdings PLC, 2015)

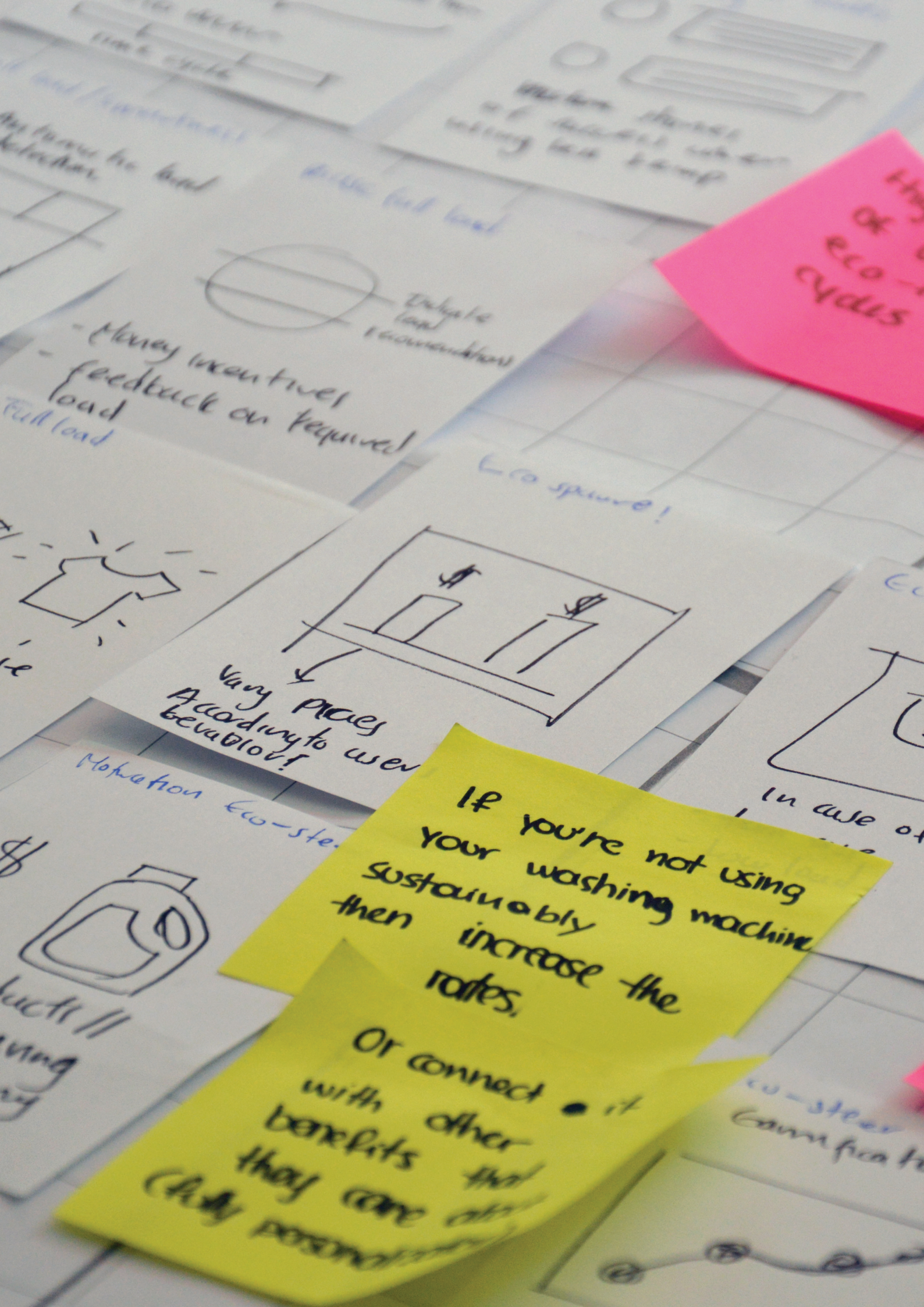
Finally, millennials are more likely to engage in services without ownership (Morgan, 2015).

5.6.REQUIREMENTS

Design requirements and wishes resulted from all the analysis and user research are detailed in the table 3.

Requirement (must)	Wish (should)
Balance different sustainable behavior strategies, eco-feedback, steering and eco-interactions that together compensate each other's drawbacks (sustainable behavior framework).	Being implementable by HOMIE within short or medium term
Strategically use product connectivity as a source of value creation for the service. For example: providing beneficial features along with meaningful feedback to the user, creating tailored suggestions, promoting partnerships, or improving UX.	Use scientific informed facts regarding washing performance to incentive user behavior changes in the three main sustainable goals.
Provide a service experience consistent with HOMIE value proposition values, environmental friendly, convenient and worry free.	Give importance to personal actions in environmental issues.
Balance level of functionality, type of devices and interaction channels in the design of the ecosystem parts (IoT framework). The interaction channels should be intuitive assertive and reliable.	Target particular users' habits and interests with assertive suggestions. Due to the differences in cultural and personal perception of hygiene users should be approached according to their personal perception and not general from a general one.
Provide, certainty and control in the experience of use	Incorporate sounds as part of the design
Link sustainable actions with personal benefits that address user's current values, goals and needs	
Allow users to translate their interest in sustainability in more environmental friendly practices when washing.	
Implement solutions for the negative insights found into current feedback design evaluation.	

Table 3. Design requirements


If you're not using your washing machine sustainably then increase the rates,
Or connect it with other benefits that they care about

6.IDEA GENERATION AND EVALUATION

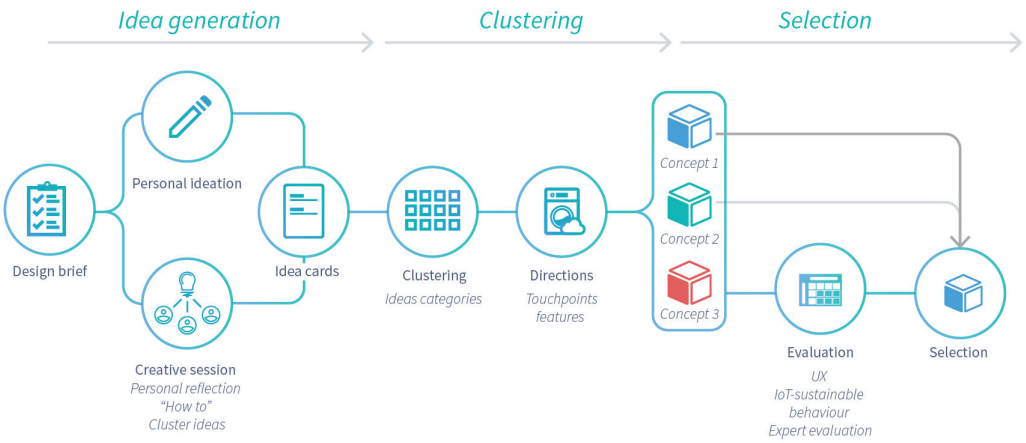


Figure 46. Idea generation process overview

Considering the outcome of the analysis phase, this chapter along with all the design process responds to the research question "How can current HOMIE service UX be shaped by using connectivity to increase adoption and foster sustainable behavior while fulfilling user needs? Accordingly, the chapter provides an overview of the idea generation process followed by concept selection (See Figure 46). The design goal and its considerations are used as main input to carry out a creative session and personal ideation, afterwards a set of idea cards was developed and clustered according to found patterns. These patterns depicted four potential design directions which were evaluated through the IoT- sustainable behavior framework and with HOMIE's CEO to finally select the most suitable concept for further development.

6.1.CREATIVE SESSION

To generate ideas that respond to the defined design goal a creative session with six TUDelft design students was carried out (See Figure 47).

Figure 47. Creative session

First, an introduction of the project and design brief was done, followed by a personal reflection about laundry experience to encourage empathy. Next, in groups of three, participants were invited to state what they consider are the user's physical and emotional needs when doing the laundry. Afterwards, a brainstorming session was guided through a "How to" exercise. For this step, some inspirational tools were provided as: target users definition, sustainable behavior framework and IoT framework. The questions for the brainstorming were:

- How to persuade users to get HOMIE Pay-per-Use service rather than buying a washing machine?
- How to improve the User Experience of "doing the laundry"?
- How to create awareness about sustainability when doing the laundry?
- How do you envision the future smart washing machines? (features, service)
- How to make/allow/persuade/motivate/force users to be more sustainable?

6.2.DIRECTIONS AND CONCEPTS

With the ideas collected from the creative session and personal ideation, idea cards were developed. These were clustered to identify potential ideas that together could lead towards a certain direction (see figure 48). This process gave as a result three concept-directions and multiple complementary features that if available in the webpage would increase users' willingness to adopt the service (For webpage features see Appendix10).

All the concepts consider the service main touchpoints to be: the webpage, the washing machine interface and an app. The app was added to the current service due to its potential of extending service capabilities beyond the washing machine interface and providing a closer interaction channel with users. Besides, it is a rather easy-to-implement channel with high flexibility for improvements (Rowland et al., 2015)

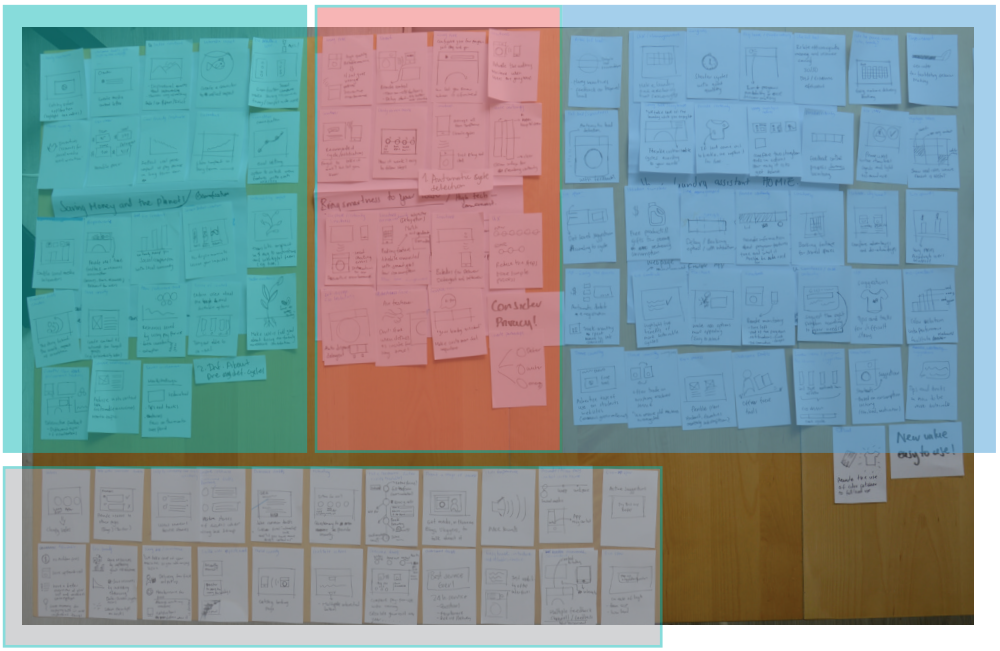
.

The first design concept deeply explores the smartness that connectivity could bring to the experience of laundry. It is therefore a high-tech alternative, with multiple activities being automated to reduce the laundry hassle (See Figure 49). The second concept, on the other hand, focuses on environmental awareness creation and providing a funny and engaging experience through gamification and social comparison as extrinsic motivator (See Figure 50). Finally, concept three tries to provide certainty and an easygoing experience through monitoring and calendar features (See Figure 51).

Your laundry assistant

Saving money while saving the planet

Bring smartness to your house



Webpage features

Figure 48. Design directions clustering

BRING SMARTNESS TO YOUR HOUSE

Direction	How?
High connectivity to optimize the laundry process.	High autonomy allows the machine to make decisions on behalf of the user, thus reducing the laundry steps. Enable remote control in the app provides more flexibility to the laundry (i.e activate it before coming home). This concept could also create partnerships with energy, water and detergent providers

Features

Machine	App	Web
- Detergent and softerner direct order - Automatic program selection - Smart error report and checking, - Detergent autodispense - Automatic load detection	- Calendar for smart grid connectivity - Check consumption, statistics and payment - Cycle creation with suggestions - Notifications	- "How it works" easy steps - Customer portal for household (multiple users) - Highlight smartness

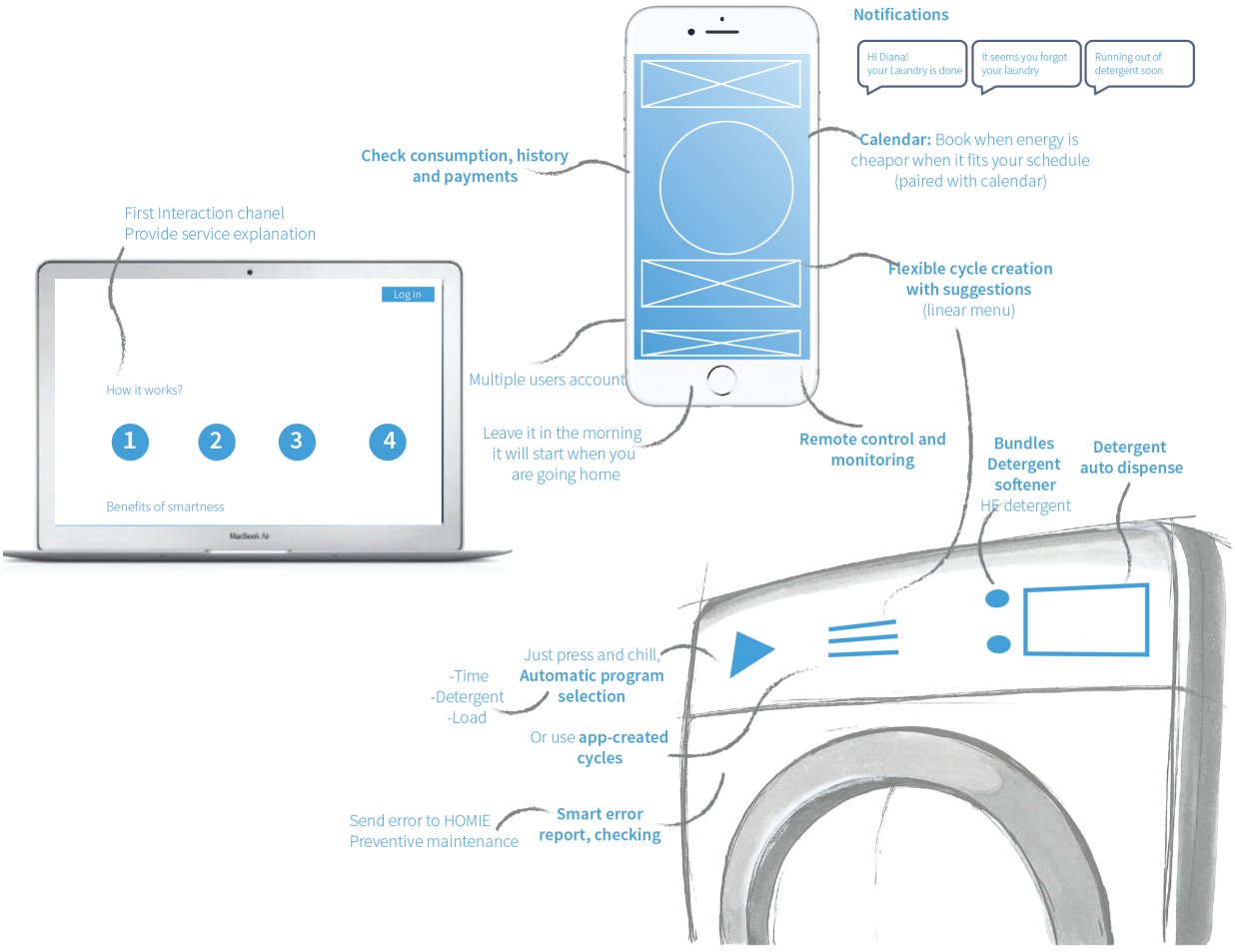


Figure 49. Concept 1 "Bring smartness to your house"

SAVE MONEY WHILE SAVING THE PLANET

Direction	How?
Awareness creation, gamification with social comparison	Focuses in motivating users to improve their performance by external motivators, as social comparison, social media and gaming. Month games are planned to maintain interest. Users are able to play with how feedback is provided.

Features

Machine	App	Web
- Real time feedback on pre-set cycles consumption - Eco-index to ease decision making - Load feedback	- Gamification, social comparison and goal setting. - Customizable feedback - Social media sharing - Tailored suggestions	- The story behind Pay-per-use - The real price of washing

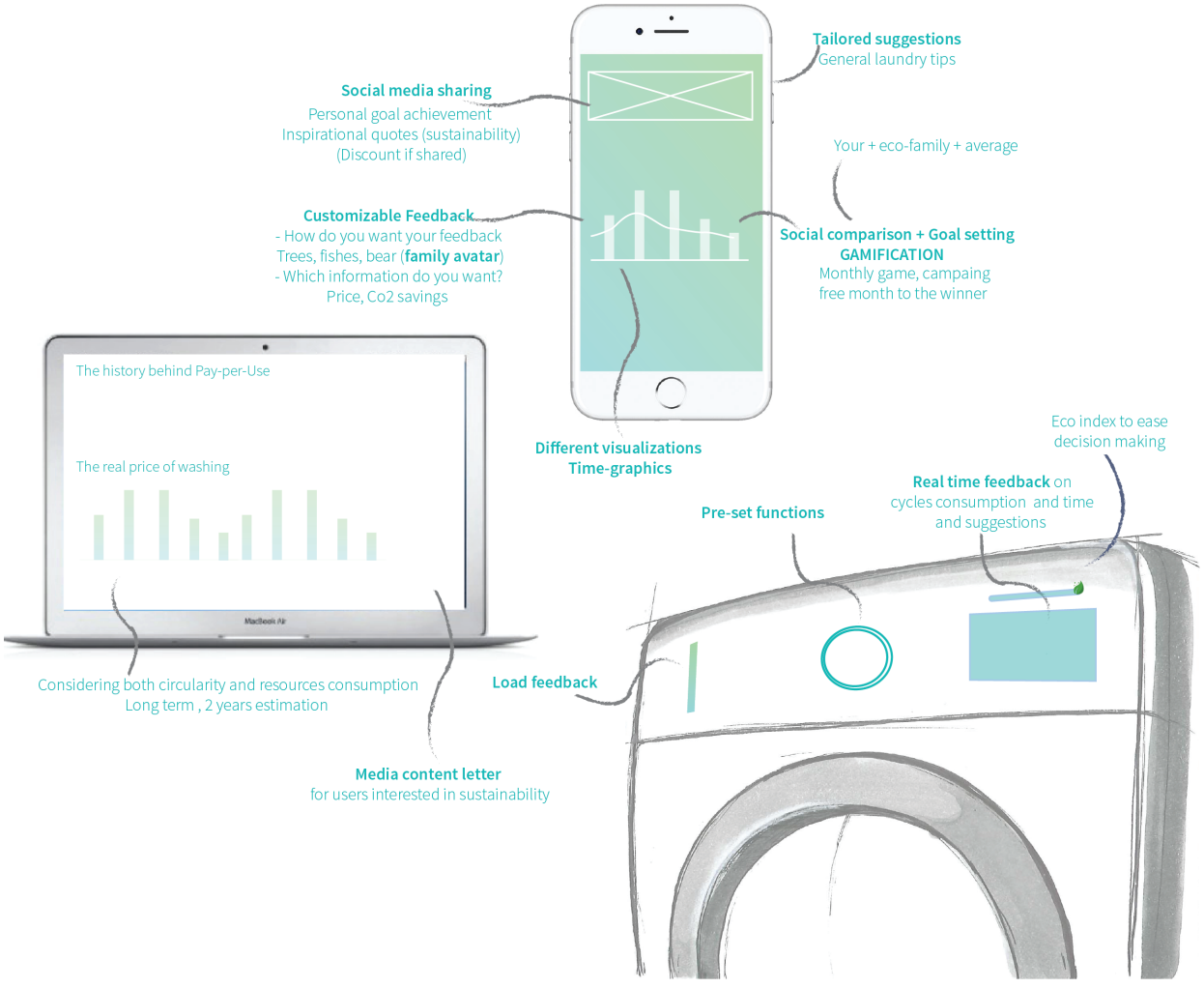


Figure 50. Concept 2 "Saving money while saving the planet"

YOUR LAUNDRY ASSISTANT

Direction	How?
Provide an easygoing and certain process through monitoring	Through the implementation of calendar and remote monitoring users are able to follow the laundry process. The cycle selection process is done based on a linear menu. Shortcuts are also provided to ease daily washes

Features

Machine	App	Web
- Linear menu for cycle creation - Shortcuts to fav cycles - Detergent level indicator - Automatic load detection with price incentive	- Remote monitoring - Calendar for checking availability - Consumption history - Notifications - Order detergent	- Comparison of ownership vs Pay-per-Use - Flexible plans

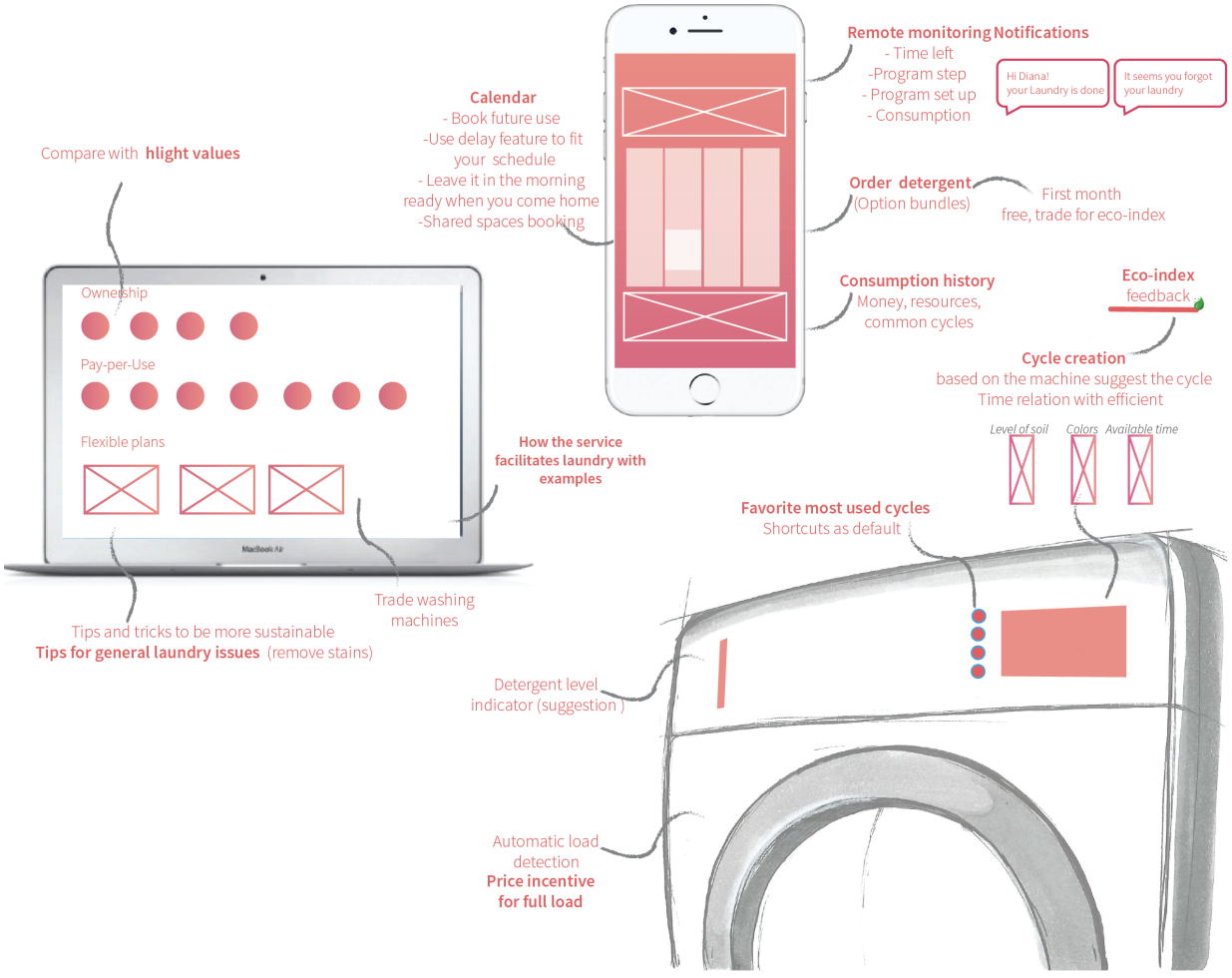


Figure 51. Concept 3 "Your laundry assistant"

6.3.CRITERIA AND CONCEPT SELECTION

To evaluate how each concept fulfilled the design goal three main aspects were taken into account. First, whether or not and how the concept responds to the user needs identified during the user research. Second, how are IoT and sustainable behavior considered in the design. And finally, an expert evaluation carried out by HOMIE's CEO, Colin Bom.

Figure 52. Concept evaluation criteria

User experience was heuristically evaluated by analyzing if the concept features included the following aspects and at what extent: provide control and certainty, enable or support time management and offer the opportunity of translating sustainable concerns into the use phase.

On the other hand, sustainable behavior strategies were assessed by using the IoT-Sustainable behavior framework. The latter was filled per concept with the features that would potentially correspond to each level. Furthermore, an evaluation session was performed with HOMIE's CEO to evaluate the business aspects and relevance of each concept in HOMIE future vision (See Appendix 11).

All the above-mentioned aspects were finally joined in a matrix. Points were assigned for each aspect according to the level achieved (See Appendix 12). Based on this analysis the concept 1 "Bring smartness to your home" was selected as the most suitable for further development, however due to the weakness identified in eco-feedback, it was recommended to complement this concept with some aspects of the concept 2 "Save money while saving the planet".


ON-OFF
90°C
60°C
40°C
30°C
1000
900
700
500
DYNAMIC
DYNAMIC
4 kg


Statistics-Washes
Pre-Set-1
file:///C:/Users/user/Desktop/new%20prototype/app/index.html#/screens/244518795
8:02
Eco-index average
More
EUR
1.35
1.35
1.35
2.35
25th August 20:30
Quick wash
25th August 20:30
Delicate
23th August 17:30
Sport
20th August 19:30
White
Washes
Energy
Water
Smart grid

7.CONCEPT DEVELOPMENT AND EVALUATION

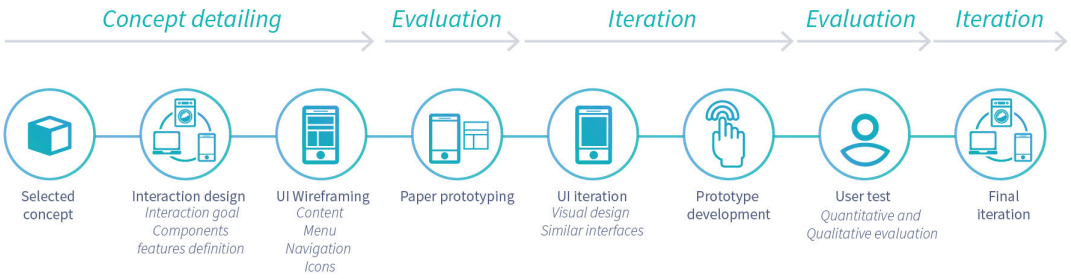


Figure 53. Concept development process overview

This chapter describes the process of concept detailing through an iterative approach. First, the features belonging to each component of the connected ecosystem (webpage, washing machine interface and app) were defined, followed by the interfaces' wireframing and a paper prototyping carried out with HOMIE's CEO. Afterwards, an iteration was executed and the design screens detailed to build a prototype for the user testing. The user testing was performed with 6 general users belonging to green millennials target group and 3 HOMIE users.

7.1.CONCEPT DETAILING

Interaction design, Smart PSS ecosystem features

As mentioned in the literature research the value proposition is the foundation of UX, it states what the service promises and it is translated into features to define the service experience. Interaction design is in charge of defining these service and product features, as well as its relationship with user behavior, to achieve a certain goal in a consistent and seamless way into daily life. For this translation, it is recommended to balance service functions, value proposition and user's needs.

When considering the service steps, the three defined touchpoints (i.e. webpage, washing machine and app) become relevant in different steps of the journey. The webpage constitutes the main touchpoint with the service offer as well as the main contact channel for new users, the washing machine is the use phase principal interaction channel and the app complements the use phase with monitoring and enhance reflection through feedback. Consequently, since each component is used in different steps and time, their purpose in terms of interaction are expected to differ as well. It is important to notice, however, that consistency should be achieved throughout all the components. With this in mind a definition of each component goal into the experience and its corresponding features was developed, this by considering the selected design direction "bring smartness to your house" (See figure 54).

Some changes were done to increase this direction feasibility without losing its essence. The detergent auto-dispense feature was removed for being considered too expensive, what would risk the service affordability. Similarly, automatic cycle selection was replaced with a more frugal version that ask users input instead of using sensors. And finally, complete remote control was updated with only delay that is considered the most relevant functionality for user.



Interaction goal	To motivate users to adopt the service, this by clearly communicating the service value proposition, facilitating contact and access to relevant information.	To provide a certain process that ensure the clothes cleanliness while optimizing resources. Allow users to translate their environmental concerns into actions.	To allow cycle monitoring and control if relevant. To provide feedback on resources consumption.
Environmental goal	Raise product circulation.	Reduce higher temperature use. Ensure full load washes. Support detergent doses.	Reinforce environmental awareness.
Features	Highlight values •*Our promise* How it works The story behind circular economy Price User's Review s Online booking Q&A Customer portal •*Check consumption* •*Payment* •*Account settings*	Create new, suggested cycle based on • *Select dirty level* • *Select type of clothes* Favorites or most used Pre -set cycles Delay cycle Feedback •*Load* •*Detergent* Smart grid Order detergent, softener	Monitoring if washing •*Display: Time left, time finishes* •*Controls: delay rinse* •*Notifications* Statistics, relate with suggestions •*Water and energy* •*Social comparison* •*Eco-index* Washes list with direct payment Suggestions Order detergent, softener Settings •*Feedback: App/ email/sms* •*Invite other users (house account)* •*Payment: connected to ideal app* •*Contact*

Figure 54. Smart PSS components and features

Due to the iterative approach and time limitation only the most important features for evaluating the interaction goal were prototyped (See 7.2.1 User test scope).

Wireframing and paper prototyping

Wireframes per touchpoint were developed to translate the defined features in the User Interface (UI). Different menus and navigations were proposed per each interface as well as content displayed and icons (See Figure 54) (Screen details in the Appendix 13). For the evaluation of the wireframes a paper prototype was performed with HOMIE's CEO. This process gave as a result a preferred menu and navigation per interface, as well as the most relevant content and early detected usability problems as counterintuitive navigation, small fonts and missing information.

For the web interface, the "focus in current washing machines offer" option was preferred over the "long term offer of home appliances" because it is not clear when the integrated home appliances service will be available. Additionally, a straightforward and clear proposition of the current service is expected to have a greater impact the service adoption. Regarding the washing machine, touchscreen was selected due to its high adaptability and possibility of improvements in the future. Given that the washing machine is expected to last longer than a common one, the flexibility offered by a touchscreen is particularly significant. Finally, a "tab" menu for both washing machine and app was chosen to offer easy access to all the options during the navigation. By using the same menu type in both devices, it is expected to achieve consistency between them.

User Interfaces iteration

Subsequently, all the interfaces were further detailed for the purpose of prototype development. The visual design, some navigation and feedback details were inspired in an exploration of similar interfaces. All the interfaces screens were designed in Adobe Illustrator and the transitions programmed in InVisionapp.

The design rationale behind the washing machine interface and app design was thoroughly grounded in sustainable behavior strategies. The webpage main inspiration, on the other hand, was the benchmarking researched companies (See details of the concept rationale in the appendix 14).

7.2.USER TEST

To evaluate the connected ecosystem interfaces in terms of both User Experience and usability a user test was performed. User Experience evaluated how users experience the intended values of the design while

Figure 55. Interfaces wireframing alternatives

Figure 56. Paper prototyping

usability assessed information hierarchy, menu structure, feedback and navigation of the interfaces. The test aimed to answer the following research questions with the purpose of improving the design concepts.

- How do non- HOMIE users experience each one of the designed touchpoints (including usability flaws)?
- How do HOMIE users experience the web page and app?
- How likely are users to use the proposed features of: smart grid and detergent delivery?
- How are the strategies for sustainable behavior (eco-feedback, steering and technology control) impacting users' decision making?

7.2.1.Scope

Since service features are widespread through the different touchpoints and each interface should enhance and transmit different values and experience, a prioritization of the functions to prototype was done to achieve consistency between the prototype and the research questions.

Webpage: It focuses on evaluating the message of the service values, general impression of the service and the booking feature. For this aim the main scroll page and details of the service were prototyped as well as the booking feature.

Machine: User experience is evaluated in terms of control and guidance given during the cycle selection. Additionally, the likelihood of using the new service features, smart grid and detergent delivery, was evaluated. For the assessment of these aspects the following parts were prototyped: navigation for program selection and smart grid, detergent overview.

App: Due to its focus on feedback and monitoring, the feedback and monitoring screens were developed to evaluate the relevance and understanding of these.

7.2.2.Method

Similarly to the User Research the test was guided with a semi-structured interview, users were also asked to perform certain tasks or explore the device features in the prototype (For interview details see appendix 15). The test was structured to explore the three design concept touchpoints. First the webpage to get to know the service, followed by the washing machine and finally the app. For HOMIE users the interview was remotely performed.

One-to-ten scales were used to quantify certain aspects of the interfaces and to enable information triangulation (See table 4). These were complemented with System Usability Scales (SUS), a standard method to evaluate systems usability, and Net Promoter Score (NPS) to identify user's overall satisfaction with the service (See scales details in appendix 16).

1. How clear is the service offer for you?
2. How sure are you about the performance of the program in relation with your clothes?
3. How in control did you feel when selecting the cycle?
4. How guided by the interface did you feel?
5. How likely would you be to use the detergent delivery service?
6. How likely would you be to use smart grid?
7.1 How clear is your consumption of water and energy? MACHINE
7.2 How clear is your consumption of water and energy? APP
8. How clear is the comparison with other users?

Table 4. User test scales

Figure 57. User filling scales during the test

7.2.3.Participants:

Six participants from different nationalities that fit the customer profile of green millennials performed the test. Additionally, three current HOMIE customers were remotely interviewed, this interview focused only in webpage and app and did not include quantitative data collection.

General	Nationality	Age	Occupation
User 1	Korean	26	Msc Design-student
User 2	Greek	25	Msc Design-student
User 3	Dutch	25	Msc Design-student
User 4	Dutch	24	Msc Physics - Student
User 5	United States	32	Computer scientist
User 6	United States	30	Msc Design-student
HOMIE	Nationality	Age	Time in HOMIE
User 7	Dutch	-	6 months
User 8	Dutch	-	1 year
User 9	Dutch	-	9 months

Table 5. User test participants

7.2.4.Analysis:

The quantitative data collected during the user testing included: eight scales that assessed different aspects of the interfaces, System Usability Scale (SUS) and Net Promoter Score (NPS). All these data were tabulated in Excel and visualized in Box Plots to depict the data distribution, the central value and potential outliers (See Figure 58 and 59).

On the other hand, based on users' performance during the test, a qualitative analysis was executed. First, all insights were located in the relevant interface screen (See Figure 60) (For all the analysis See Appendix 17). Next, patterns among them were identified which displayed both achievements and drawbacks of the proposed design. These main findings were finally triangulated with the quantitative results to answer the research questions.

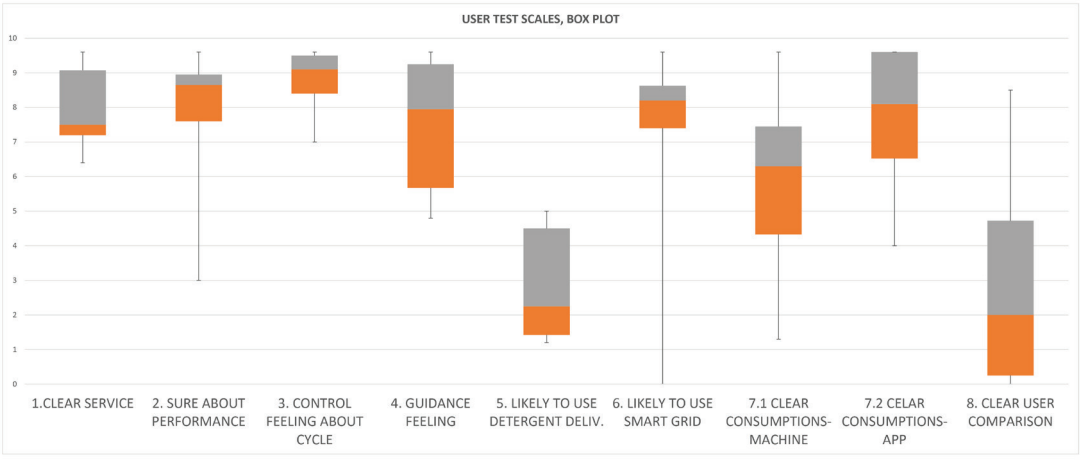


Figure 58. User test scales Box Plot

Figure 59. Net Promoter Score and System Usability Scale

7.3.RESULTS

The triangulation of quantitative and qualitative analyzed data led to the answer of the research questions. In these only the most relevant experience and usability problems and its relations are detailed.

How do non- HOMIE users experience each one of the designed touchpoints (including usability flaws)?

The overall experience is positive as the SUS and NPS values indicate (See Figure 59). The SUS above 68 points means that users have experience a good usable system. This is confirmed by their high likelihood of recommending the service. However, weaknesses were identified in both UX and Usability in all the interfaces that if corrected could potentially enhance the service experience and adoption.

Webpage:

Service offer and values are clearly communicated. This is confirmed by the scale 1 (See Figure 58) which scored above 7 in a 1-10 scale. In general, the visual design was appreciated as stylish and clean, what convey trustworthiness. The service components are clear and easily related with its values of affordability, convenience and sustainability, which match user needs. The service environmental friendliness is a plus for the target group

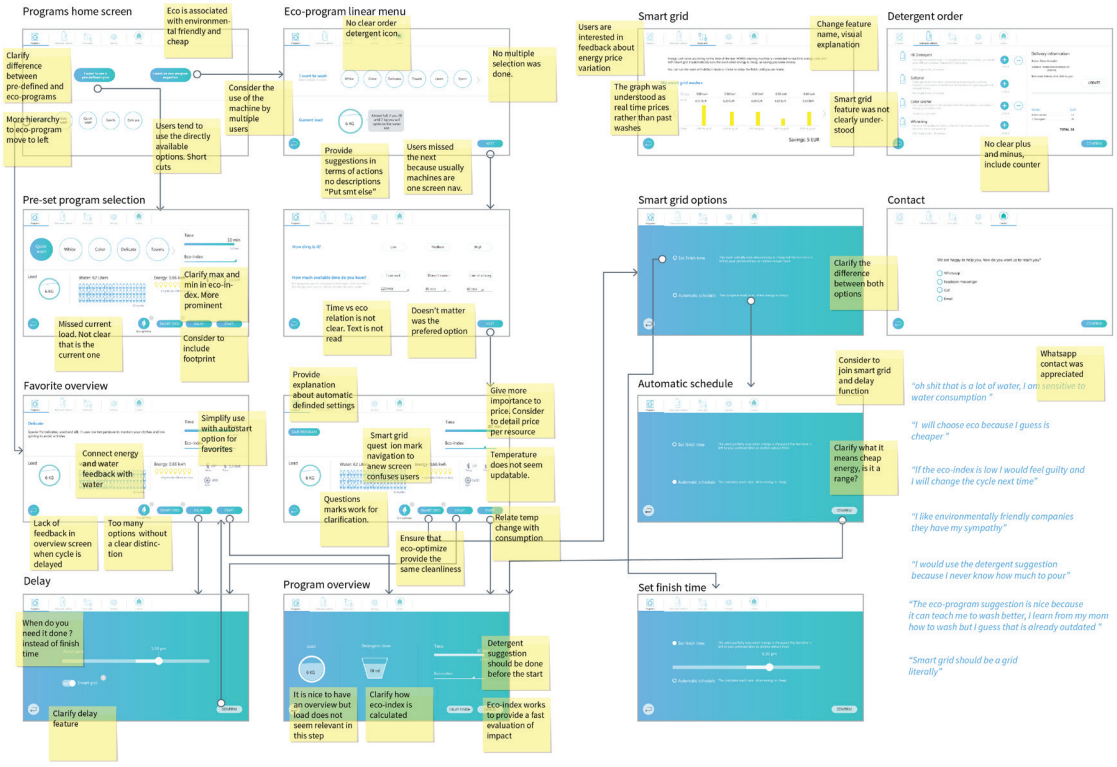


Figure 60. Qualitative user test analysis, example

since it resonates with their personal concerns and interests. Finally, online booking feature is perceived as convenient and its navigation as trouble-free.

Despite the positive findings, it is required to complement the page content with more practical information that allow users to fully trust the service, such as payment information, how water, energy and detergent are involved, contract terms and washing machine specifications. Improvements should also tackle the found navigation issues in the "sustainability" tab, provide easy access to order online and depict more visual content instead of long texts.

"Stylish and neat, what makes it look trustworthy"
User 1

"Clear first page icons"
User 3

Washing machine interface:
The overall experience was judged as easygoing and clear. The interface cycles and clothes options (color, white, delicate, etc.) match user's expectations, this complemented with the opportunity to choose clothes dirtiness seem to increase user's sense of confidence in the selected cycle. The latter is confirmed by the scale 2 (See Figure 58) in which users reported to be highly sure about the program performance. Interestingly, the fact that the machine decided the cycle features (temperature, spin etc.) did not cause distrust in the expected washing performance.

The washing machine eco-program suggestion menu for cycle selection successfully guided users and provided a sense of control which was not conveyed by the pre-defined cycles option. Scale 3 depicts a high reported users control, while scale 4 (See Figure 58) shows a relatively high perceived guidance but wide distribution, this can be due to usability problems found in the linear menu, as the wrong-placing of detergent suggestion, a missing "next" button and lack of understanding of the "available time" option.

Delay function is perceived as convenient but its functioning was not always clear. Similarly, due to Smart grid novelty and complexity, this was not easily understood. The proposed interface and name for it does not clearly convey its functioning and advantages, the name of the feature was also reported as not clear. Regarding eco-optimization it was not clear how it influenced the settings and if the result would have the same quality as the previous one.

"Smart grid should be a grid literally"
User 6

App:
As expected the most appreciated features in the app were monitoring and delay, followed by chat contact and washes overview. Statistics on water and energy, on the other hand, were found useful and interesting but will not be used often. Although, consumption is relatively clear in the statistics, as can be observed in the scale 7.2 (See Figure 58), the layout axes were not explicit and the font small, what limited its fast recognition. Besides, social comparison was not noticed by most users what lead to a low rating of the scale 8 (See Figure 58).

How do HOMIE users experience the web page and app?
Webpage:
The overall impression was positive, a message focusing on "taking care" of their washing machine was described as different than the value proposition they knew, which were more focus in sustainable behavior. Households with than 2 persons reported the service to be more expensive than they expected and that in long term it would had been better to buy a high efficient energy machine instead of paying per use. Nevertheless, the service offer shown in the page matches what they have experienced in the service, specially the convenience value.

Finally, HOMIE users reported a subtle change in behavior, they now tend to use more eco, full loads and reduce temperature.

App:
Interestingly, as they have been already receiving feedback for some time, a more long-term focus is expected. For instance, gamification features such as rewards and acknowledgements. Furthermore, payment features in the app were missing since this is one of the current service pain-points. This was not included because HOMIE's plan is to implement automatic debit soon. Finally, a high likelihood of downloading the app to both monitor the washes and their consumption was reported, these features are considered the added value of the app.

"I would like to see stars and stickers to make my life worthwhile or at least keep it funny" User 8
"This is just freaking amazing" (about monitoring feature) User 7

"I don't like the online environment in my phone, so it is either app or a website mobile friendly"
User 9

How likely are users to use the proposed features of: smart grid and detergent delivery?

There is low interest in the detergent delivery service by non-HOMIE users as demonstrated in the scale 5 (See Figure 58). Users perceived it as potentially troublesome more than as convenient, especially if they must be at home to receive the package. Users said that they go to the supermarket anyway so there is not an obvious advantage. Moreover, its ecological positive impact is not clear and the price is expected to be higher than their current options. HOMIE users reported to be more likely to use it but depending on the price and ecological impact.

On the other hand, users report to be highly likely to use smart grid as shown in the scale 6 (See Figure 58).

How are the strategies for sustainable behavior impacting users' decision making?

As mentioned before, the washing machine interface and app has been designed with a strong sustainable behavior strategies rationale, therefore an understanding of the effectiveness of these strategies is relevant for the evaluation of the design.

Eco-feedback:

The representation of energy as light bulbs and water as bottles in both washing machine and app had opposing opinions, while some users found it easily understood and relevant, other users found it not quickly graspable. Accordingly, it can be said that personal previous experiences and concerns affect how users react to eco-feedback. Some suggestions to improve it included to translate consumption into price to make it more personal, or to translate in more personal daily activities (e.g charge the cellphone) or even in environmental terms as Co2 foot print. Despite these criticisms, some interesting reactions to this feedback were caused that could indicate some level of awareness creation.

"oh, that is a lot of water, I am sensitive to water consumption"
User 2

"480 light bulbs seem like a lot"
User 5

"Nice translation! I have now a reason to care about consumption"
User 6

Eco index was not noticed by all the users but when noticed it transmitted a clear message about environmental friendliness of the selected program. Its calculation and considerations as well as its max and min were not apparent. It is therefore suggested to increase its prominence and provide deeper explanation of its functioning.

"If the eco-index is low I would feel guilty and I will change the cycle next time"
User 1

"It is nice to have an overview of how sustainable is the cycle"
User 5

Spur-steer:

The main steering strategy was present in the eco-program suggestion linear menu, which despite its usability flaws was considered as a guiding and certain process. Three of the six users non-HOMIE users opted for this option instead of predefined cycle as the first "click", some argue that they care about sustainability while others did it because its potential relation with low prices. This could indicate a translation of HOMIE environmental friendliness value in the experience of use.

Due to the availability of favorites, some other users opted for what looked like a "pre-set" option, what could indicate users' likelihood of using these as shortcuts. This could be translated into a steer strategy if the cycles in favorites as set up as sustainable options.
Even though, detergent suggestion was not clear when understood, users respond very positively, the same happened with current load suggestions.

"I would use the detergent suggestion because I never know how much to pour"
User 7

"I would put something, the towels or something else to complete the 7kg load"
User 4

Technology control:

As previously mentioned, the fact that the machine decided the most suitable program features was not negatively perceived; just one user mentioned to be willing to change the temperature but still wanted to have an overview of the consequences of this change in energy consumption.

Smart grid was perceived as extremely convenient, especially when it is related with price savings, which immediately relates a sustainable action with a personal benefit. In terms of usability, there are still doubts on the available options for its use and how to make the most of it.

"The eco-program suggestion is nice because it can teach me to wash better, I learn how to wash from my mom and she from my grandma but I guess that is already outdated"
User 6

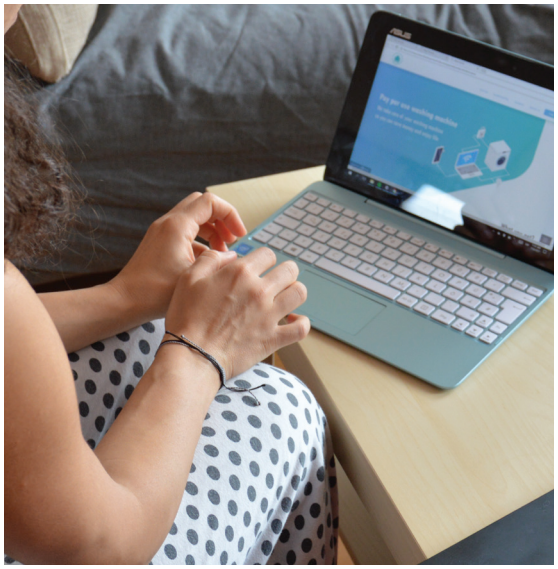
"I would use this menu a couple of times to set my preferences and then would use favorites"
User 8

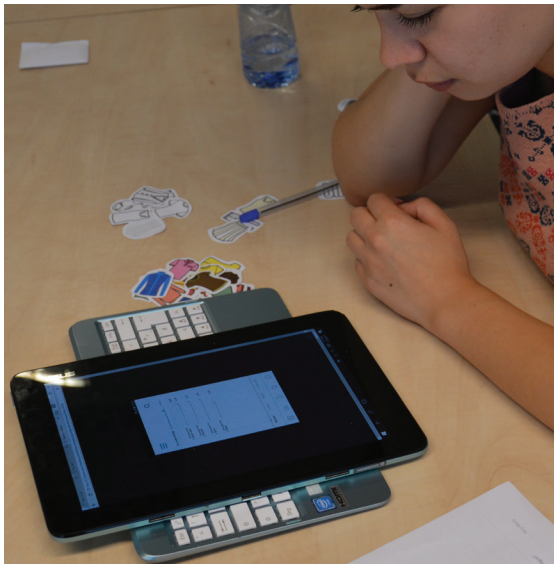
7.3.1.Discussion

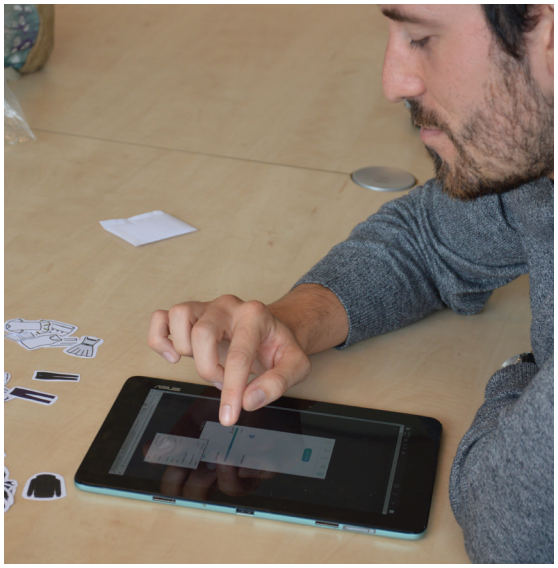
Given that the interview to HOMIE users was remotely performed, the collected data was limited. Moreover, they are early adopters and in some cases not a representative sample of the target group, which could mislead the findings. Regarding non-HOMIE users, even though the sample represented green millennials profile, mostly students were selected, what could had affected the test results, especially in detergent delivery likelihood of use.
Each user has a different perception of the importance and measurement of water and energy based on their personal previous experiences and personal concerns, therefore some users might be more susceptible to the proposed feedback than others. Furthermore, it should be considered that eco-feedback can be presented in different levels of impact and that some persons might be more receptive to deeper layers as for example, dying trees or bears saved. However, translating water and energy in laundry to those levels requires a deeper environmental assessment that is not part of this project.

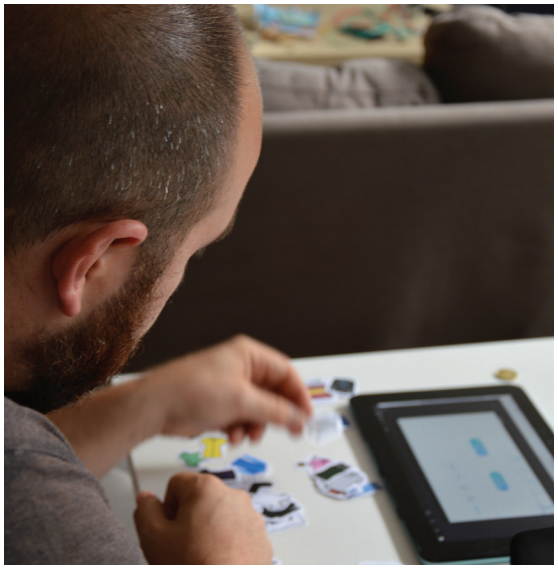
Some users asked to receive explicit feedback in terms of good and bad actions. Nevertheless, program features and consequently consumption highly depends on specific personal needs as for example: having kids or washing special items in special occasions. Therefore, the interface should balance those personal needs with the environmental needs, otherwise it might be in risk of becoming annoying.

Finally, some details of the experience of use were not considered during the test as the specific context of use which could influence the results, especially in the washing machine due to the cumbersome potential locations and interactions that the context could create.










CURRENT WASH
Delicate
Finishes
5:20pm
25 min
Notifications
DELAY FINISH

8.FINAL DESIGN, SMART PSS

Based on the results of the user test, the service features along with all the interfaces were redesigned. This chapter, therefore, elaborates on the final design. First, the service components and its features are explained in an eco-system map, followed by interaction scenarios in a touchpoint matrix and the interfaces embodiment with their design rationale. The latter shows how sustainable behavior strategies and UX improvements have been considered in the interface to convey HOMIE values, particularly environmental friendliness. Finally, an analysis of how this design would potentially increase HOMIE sustainable behavior through connectivity is presented.

8.1.SMART PSSS DESIGN

The proposed HOMIE Pay-per-Use Smart PSS integrates three components: webpage, washing machine interface and app, that are together built on circularity, smartness and sustainable behavior. Defining green millennials as the target group the design improves the UX while fostering more sustainable practices and motivating the service adoption.

Each component is a service touchpoint that responds to the three opportunities identified during the company analysis (See chapter 3). The webpage intervenes the service steps exploration and contact, the washing machine the use phase when doing the laundry and the app the use phase during the follow up (See Figure 61). The current follow up step has been, therefore, replaced by the app that allows more explorative interactions.

8.2.ECO-SYSTEM MAP

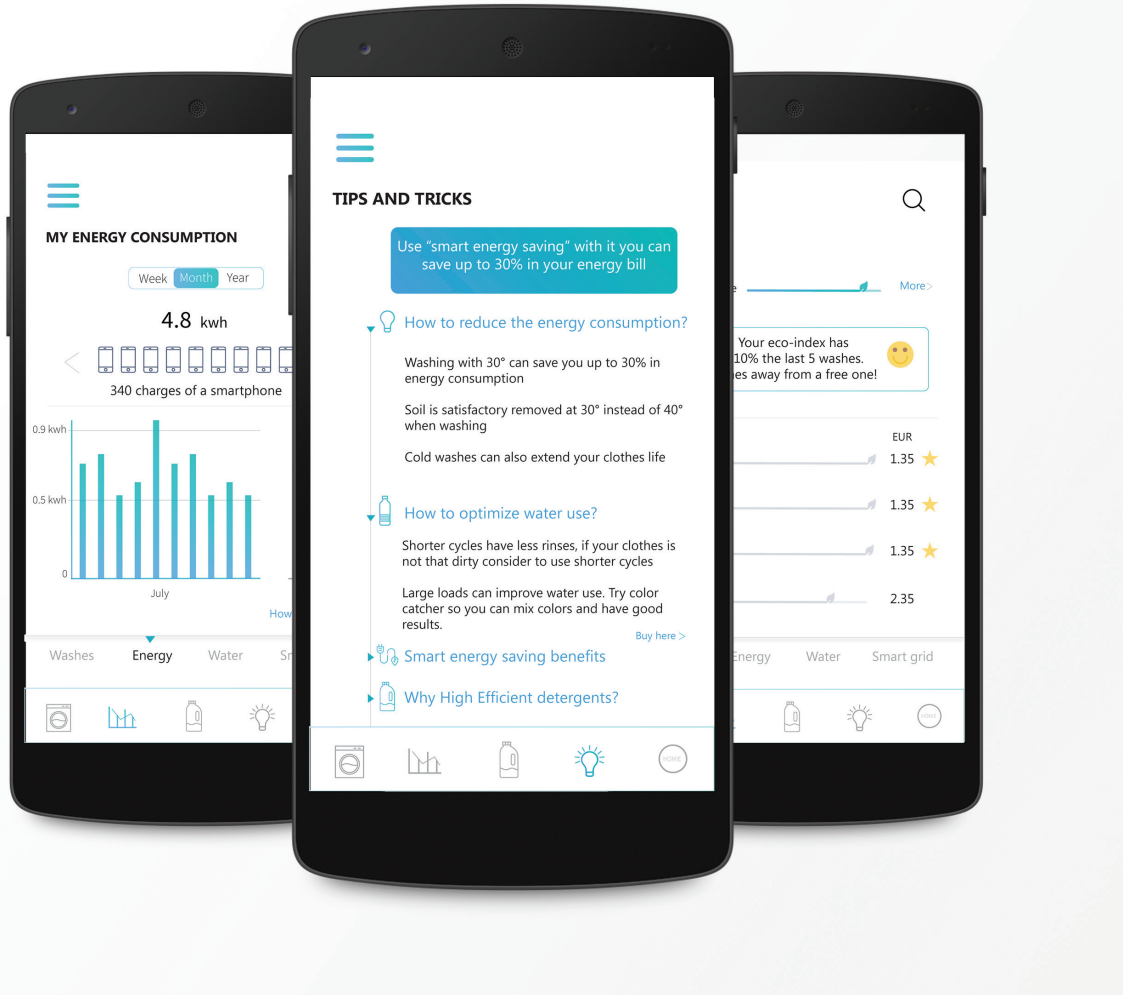
As considered in the design brief, the service must balance users' needs with environmental goals to achieve a true impact in users' behavior. So, each eco-system component has a specific goal in terms of sustainability and fulfill users' needs in each step of the service experience. Accordingly, each one is equipped with different features (See Figure 62).

As the main touchpoint for new users, the webpage has as its main purpose to raise service adoption by allowing users to know and easily obtain the service. This is done by clearly communicating the service value proposition, advantages and practical matters that are relevant for the users' decision-making process. Considering that green millennials prefer digital communication, the webpage has an order-online feature to ease the process.

The washing machine interface aims to reduce temperature use, ensure a full load and support decisions on detergent doses, which are according to the literature research the three principal actions that, if taken by users, could reduce washing machine's use phase impact.

Figure 61. Eco-system components relation with service steps


Pay per use washing machine
We take care of your washing machine so you can save money and enjoy life
What do you get?
MY ENERGY CONSUMPTION
Week Month Year
4.8 kwh
340 charges of a smartphone
Washes Energy Water Smart energy saving


MY ENERGY CONSUMPTION
Week Month Year
4.8 kwh
340 charges of a smartphone
0.9 kwh
0.5 kwh
0
July
Washes Energy Water
TIPS AND TRICKS
Use "smart energy saving" with it you can save up to 30% in your energy bill
How to reduce the energy consumption?
Washing with 30° can save you up to 30% in energy consumption
Soil is satisfactory removed at 30° instead of 40° when washing
Cold washes can also extend your clothes life
How to optimize water use?
Shorter cycles have less rinses, if your clothes is not that dirty consider to use shorter cycles
Large loads can improve water use. Try color catcher so you can mix colors and have good results.
Buy here >
Smart energy saving benefits
Why High Efficient detergents?
More >
Your eco-index has
10% the last 5 washes.
es away from a free one!
EUR
1.35
1.35
1.35
2.35
Energy Water Smart grid

Regarding the added value for users, it is embodied in the certainty and guidance offered during the cycle selection process by providing clear and relevant feedback, as well as the delay and smart energy saving features. Also, as found in the user research, the feeling of being sustainable adds positively to the experience of use.

Finally, the app focuses on strengthening environmental awareness by presenting feedback on water and energy consumption. In this touchpoint, the added value for users lies in the features of real-time monitoring, notifications and data-driven suggestions. It also provides a centralized device for managing the household account and configure automatic debit.

The detergent inclusion into the service was one of the main challenges in this design phase, due to the low interest reported in the user test. Because of the complex and personal decision making about detergent selection observed in the user research, and the constraints that including the detergent into the service would bring to the experience of use, it was finally decided to provide two options for using detergent suggestions. It is possible either to buy it through the machine interface or the app, or to configure its features for an accurate dose recommendation.

Other important change was the update of smart grid to smart energy saving, as users reported to not clearly understand the proposed smart grid functioning.

8.3.TOUCHPOINT MATRIX

Since all the eco-system components have different or complementary features, a touchpoint matrix was developed to depict the expected interactions in multiple scenarios of use. Thus, it becomes apparent which features will be used in which activities (See figure 63).

For example, a first-time use will start with the setup of a multiple users account in the app or washing machine. The cycle will be selected in the resource-efficient cycle menu, which works as a steering strategy. In this navigation flow, users receive feedback on water and energy consumption, load and eco-index. And finally, they will have notifications when the cycle starts and when it finishes. Importantly, every time the app is opened there is a day tip or tailored suggestion.

Other scenario is expected when favorites have already been built. As found in the literature research, users only use three or four types of cycle, so once those have been defined then the favorites feature is expected to

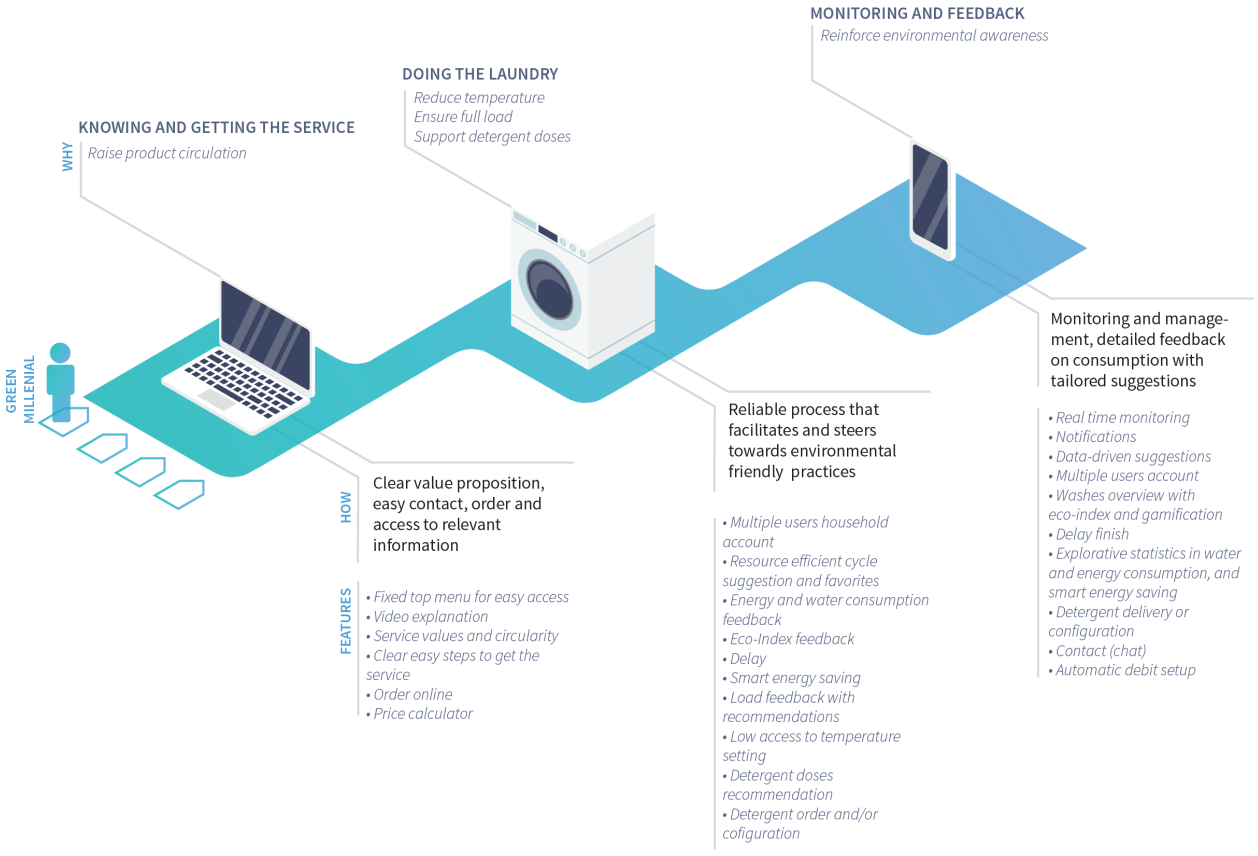


Figure 62. Eco-system map

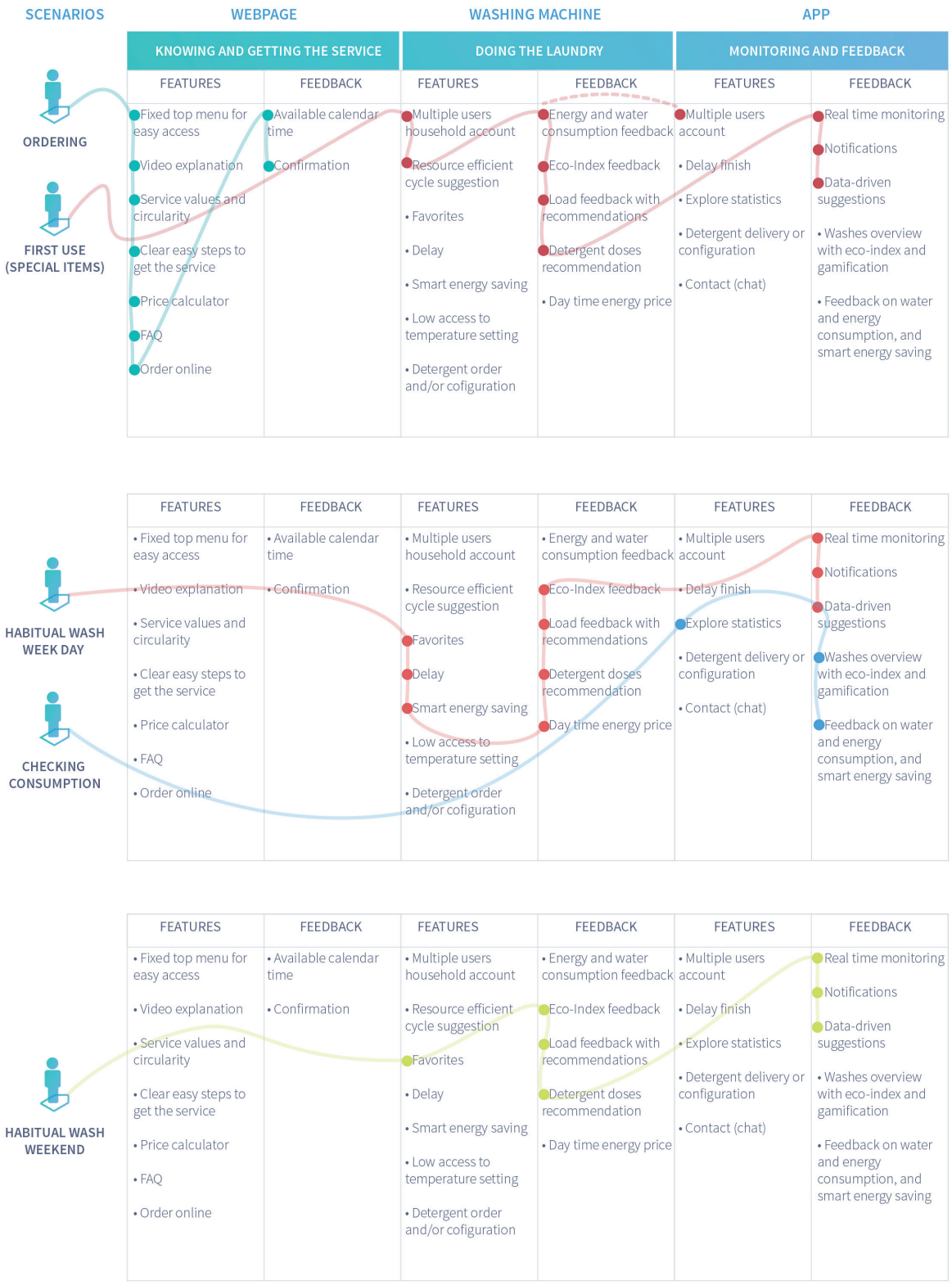


Figure 63. Touchpoint matrix

be used as a shortcut. In this scenario, users will still receive feedback on cycle impact as eco-index, load and detergent recommendations.

Based on the results of the user research, it is predicted that the laundry process will differ between weekdays and weekends since available time varies. This could be strengthened by the delay and smart energy saving features, that facilitate the washing process during weekdays, so, these will be less likely to be used in weekends.

8.4.USER INTERFACE EMBODIMENT

User Interfaces are designed to be consistent yet pragmatic all over the service. The visual design has been carefully selected to convey trustworthiness and positiveness. The blue color and the use of gradients has the intention of representing a mix between water and sustainability in a clean and stylish layout, what was proven successful during the user test. Even though each component has different options, all the icons, features' names and descriptions, and tab menus have a homogeneous style and feedback. In response to HOMIE's will of conveying a more sustainable message in their service, sustainability appears in different ways throughout all the touchpoints. Finally, the language tries to be personalized and informal to achieve a more personal experience (See Figure 64).

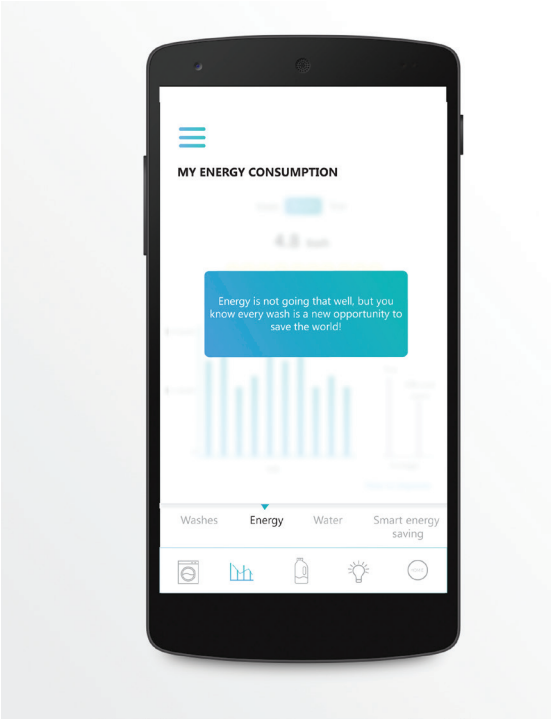


Figure 64. App message example

Given that the washing machine interface and app are use-phase touchpoints, its design rationale is highly related with sustainable behavior strategies and IoT capabilities.

Webpage

Essentially, the webpage tells users how this is not only a sustainable and innovative service but also highly convenient and cheap one that they should not let go. It also tries to solve common doubts, ease the process of getting the service and make sustainability an added value, which is important for the target group.

The main user testing findings regarding navigation issues and lack of payment information are solved by redesigning the top menu tabs and providing more detailed information about payment and terms and conditions in the FAQ section. Sustainability is now proposed as an independent tab where the washing machine circularity is visually presented, and other strategies for reducing personal footprint are suggested. Eleven main aspects tell the design rationale, some of which also respond to improvements after the user testing. These are all gathered in Table 6, tje numeration is related with the ones presented in the figure 65.

Washing machine interface

In the interaction with the washing machine, users decide the program and its settings, thus this is the step of the use phase where the most environmental impact is created. Consequently, this interface implements multiple behavior strategies to influence users' decision making. These strategies are balanced with details that enhance the experience of use, as the feeling of control, guidance and being sustainable. As presented in the user research the current interaction with washing machines is characterized by a lack of feedback on things that matter to the user, like load, detergent and which is the most suitable cycle, then creating an overall confusing experience. These aspects are tackled by the design of the interface to provide a more positive experience that could be described as not only easygoing and understandable but also sustainable.

The main changes implemented after the user testing included the elimination of the pre-defined cycles since the suggestions menu was preferred for its sense of control and guidance. Also, the moment where the detergent dose suggestion is done was adjusted to fit the current workflow, and the smart energy-saving setup was improved to give users control on their preferred time of the day. Finally, as previously mentioned, detergent

configuration was added as a second possibility. The design rationale is presented in the table 8 and figure 66, there the ideas are linked with the sustainable behavior strategy or UX idea to which it responds.

App

Skepticism towards the use of the app was identified during the user research, for what a significant added value must be incorporated to drive users to downloading it and using it, and this way being able to reinforce awareness. This added value lies in remote monitoring, delay and the gamification of the eco-index, which consists of a reward of a free wash for every ten full eco-index washes (See table 9 and figure 67, 68).

No	Design rationale
1	The main top menu is fixed in all windows and during scroll for easy access, it includes: Service, product, sustainability and about us along with order here and log in.
2	The landing page presents a clear description of the service advantages with value proposition
3	A video is displayed to clearly explain service circularity and Pay-per-Use
4	Easy and practical steps to acquire the service.
5	Multiple fast access to “order” and view more are located through the main scroll to facilitate the access in any point of the exploration
6	Frequently asked questions (FAQ) with a focus on payment process is provided to provide answers and certainty about the service.
7	User reviews are displayed to promote trust.
8	Product tab provides an overview of the product functionalities along with the app connectivity.
9	A slider is located in price section to communicate price variability. Additionally, a simple cost calculator is available to facilitate user’s calculation and therefore decision making.
10	Sustainability tab shows a visual message of the service circularity and user’s opportunity of reducing their footprint.
11	An online-ordering feature is included to facilitate and simplify the delivery service what is essential to increase adoption. Also, it conveys a hassle-free experience.

Table 6. Webpage design rationale

No	Design rationale	
1	The welcome screen provides a warm and personalized start along with a tip.	UX
2	The main screen during washing displays the monitoring function. Th shows the most relevant information and is the most appreciated feature of the app. It depicts the current cycle with the finish time and time left. Users reported to be more interested in the finish time, hence this one is more prominent.	UX
3	Delay finish is explained in an overlay and could be activated at any time of the cycle before the first rinse, so users are able to adapt the washing to their schedule if something comes up.	UX
4	Both detergent delivery and configure detergent options are available, this way users are not forced to buy a specific detergent to be able to measure the doses. Detergent delivery also has a feature to follow the order	Steering
5	Suggestions are provided to optimize resources consumption	Steering
6	The statistics of washes are displayed with an overview of the eco-index average. Eco-index is accompanied with a gamified extrinsic motivator in which one free wash is given per each full eco-index washes. This is also a way to promote interest in the feedback in long term	Eco-feedback and steering
7	Due to the low understanding of water and energy consumption found in the user test, both energy and water consumption feedback are translated in terms of various easy to grasp daily products, fun facts and money price that users can explore to have a clearer idea of how much is indeed consumed.	Eco-feedback
8	User’s average consumption is compared with high efficient users, which is made as social comparison to steer behavior.	Steering
9	All the statistics can be filtered by week, month or year so users can visualize progress throughout time.	Eco-feedback
10	When tapped, each bar displays more detailed information of the corresponding cycle. If tapped again it will lead to the complete cycle overview in washing statistics. This navigation flow enables a more detailed explanation and exploration of the consumption data	Eco-feedback
11	Notifications when the cycle finishes and is delayed are provided as well. This considers easy access actions as snooze notifications and delay cycle.	UX

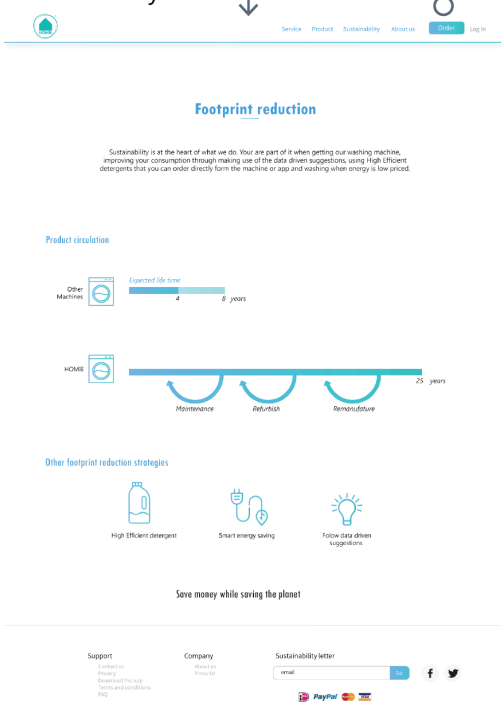
Table 7. App design rationale

No	Design rationale	
1	If a multiple household account is set, the home screens ask who is washing, so that only that single person receives notifications on the wash	UX
2	The “resource-efficient suggested cycle” is a linear menu that allows the machine to choose the most suitable settings according to users input. It asks the user to define “type of clothes” and “dirty level” instead of a specific setting as temperature or spin, this way providing flexibility according to user’s sorting habits and steering towards less temperature use.	Steering and Technology control UX
3	The “type of clothes” options were defined according to the results of the user research.	UX
4	Current load feedback with suggestion is automatically displayed after the “type of clothes” and “dirty level” to catch user’s attention.	Eco-feedback and Steering
5	Detergent recommendation is provided for the use of High Efficient detergents. Due to the low interest in detergent delivery reported in the user test, the detergent tab therefore also allows users to configure their own detergent features for an accurate suggestion.	Steering
6	Delay function works with smart energy saving as default. It can be set with the finish time for a better experience. Its easiness of use could also lead to more often washing during weekdays than weekends.	Steering UX
7	Eco-feedback is provided on water and energy consumption. This is translated into easily graspable daily products, fun facts and money price. The feedback form can be personalized according to user preferences and in consistency with the app.	Eco-feedback
8	The eco-index provides a fast and easy way to evaluate the cycle’s environmental friendliness.	Eco-feedback
9	Temperature setting is hidden in a low hierarchy menu. If the user is willing to increase temperature, the change must be deliberately done and will include feedback on the energy consumption related with temperature increase.	Steering and eco-feedback
10	Smart energy saving relates the use of low priced energy with the personal benefit of saving. This feature also responds to the found trend towards smart grid and green energy at home. The machine can automatically select the most suitable time or users can schedule it and delay the finish until a preferred time; this way the feature is integrated with daily habits.	Technology control and steering
11	To facilitate the use of smart energy saving feature, it can be activated through either its tab or the cycle overview.	UX
12	It is possible to order detergent, microfiber catching bags or color catcher directly from the machine, this with the purpose of steering users towards the use of High Efficient detergents and ecological products.	Steering
13	Using “Favorites” provides a simple cycle overview instead of the complete one to facilitate the use. There is still feedback on eco-index, load and detergent.	UX

Table 8. Washing machine interface design rationale

Figure 65. Final webpage visual design rationale

Sustainability



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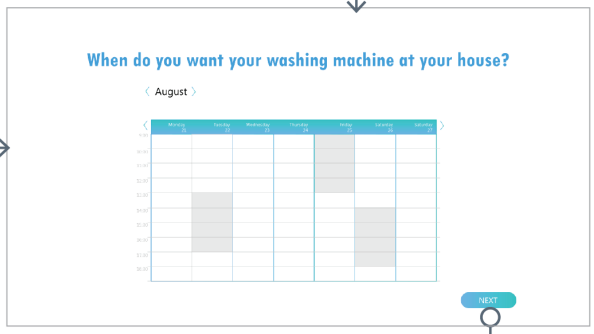
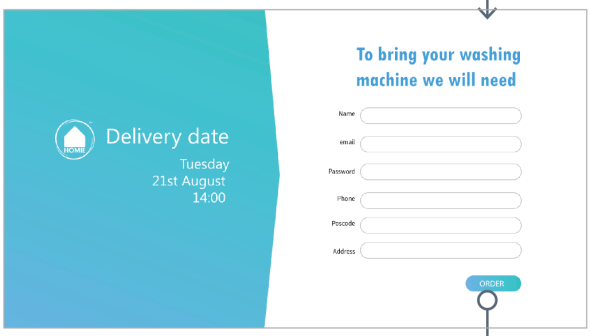
Order calendar

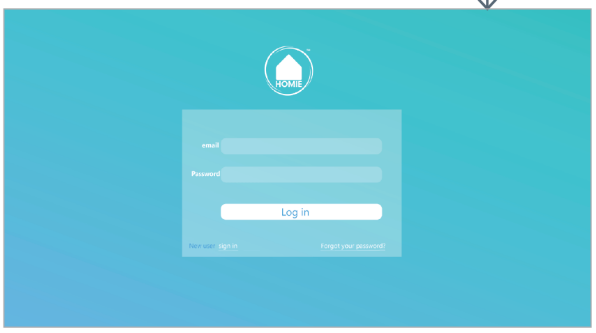


Order, user's information



Confirmation

Log in



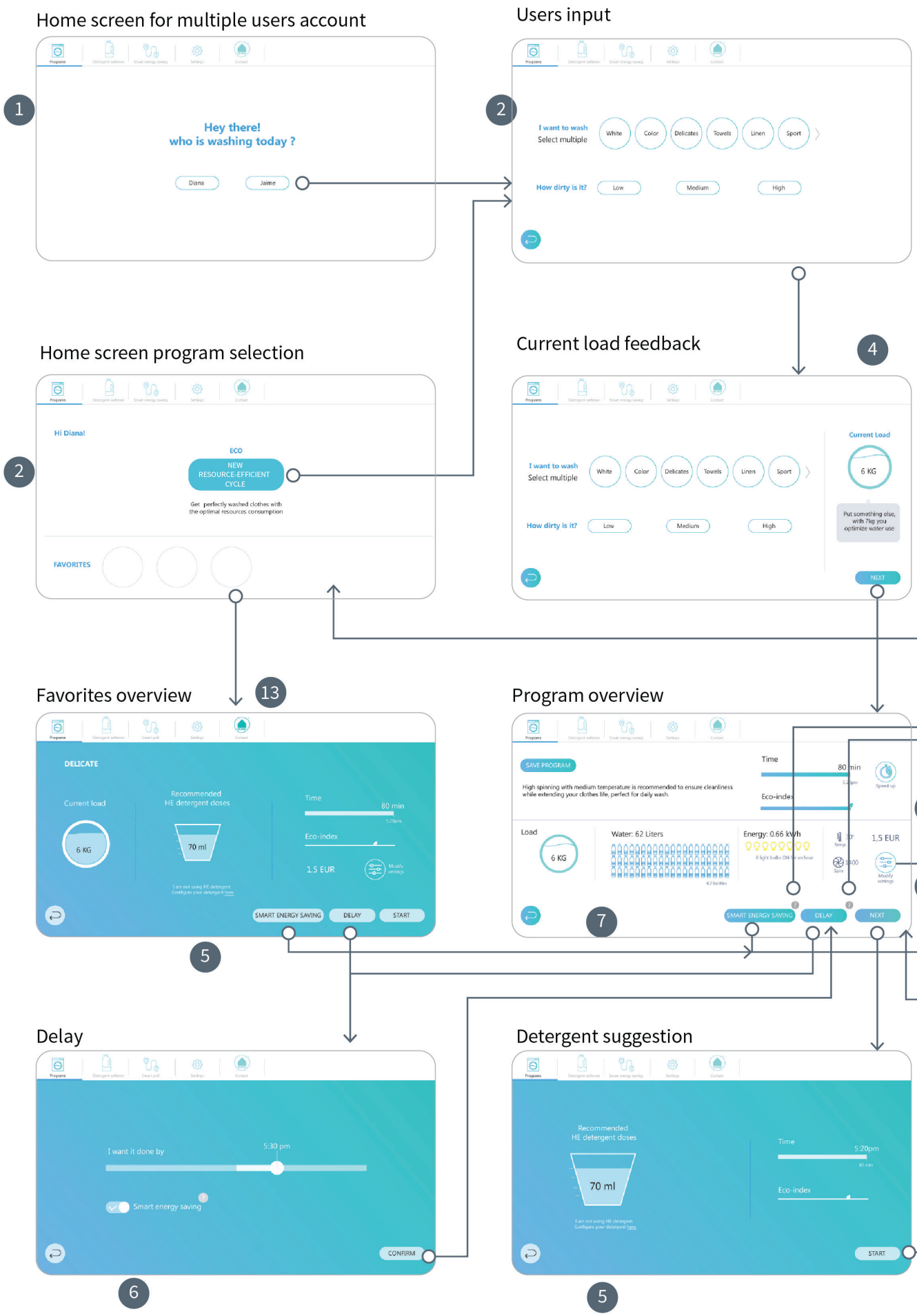
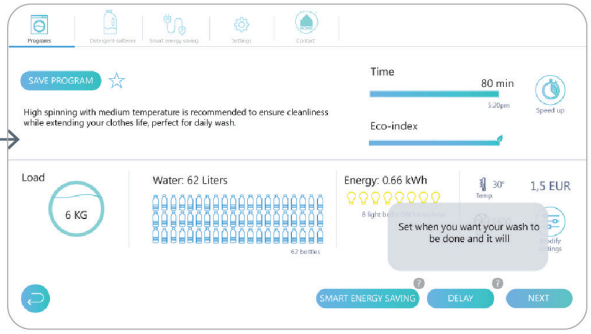
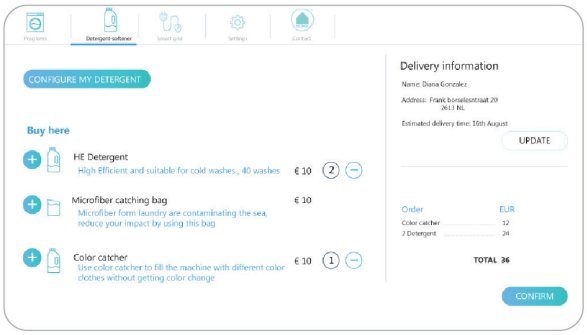


Figure 66. Final washing machine interface visual design rationale

Delay overlay

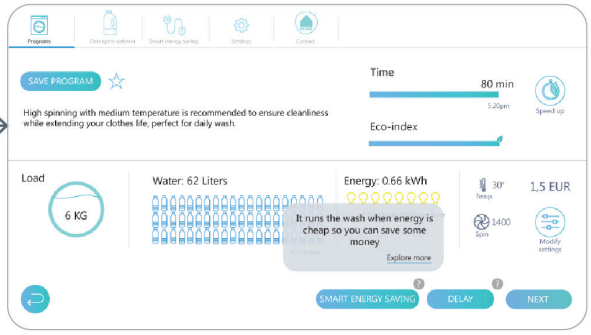


Detergent order / configuration

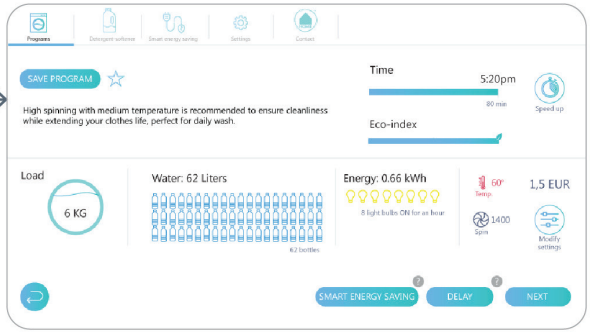


5 12

Smart energy saving overlay



Feedback with high temperature use

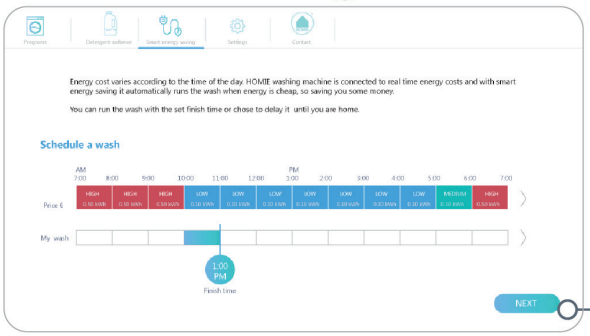


Modify settings, temperature

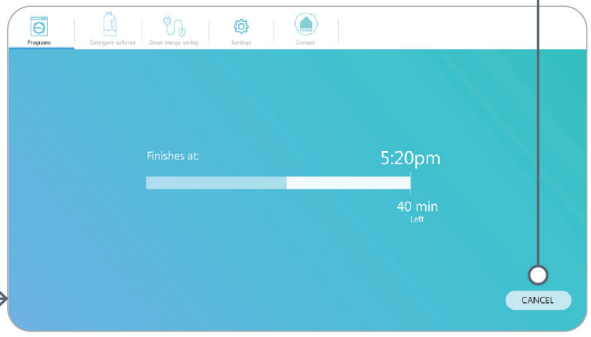
9

Smart energy saving tab

10



Final screen



Smart energy saving setting

11

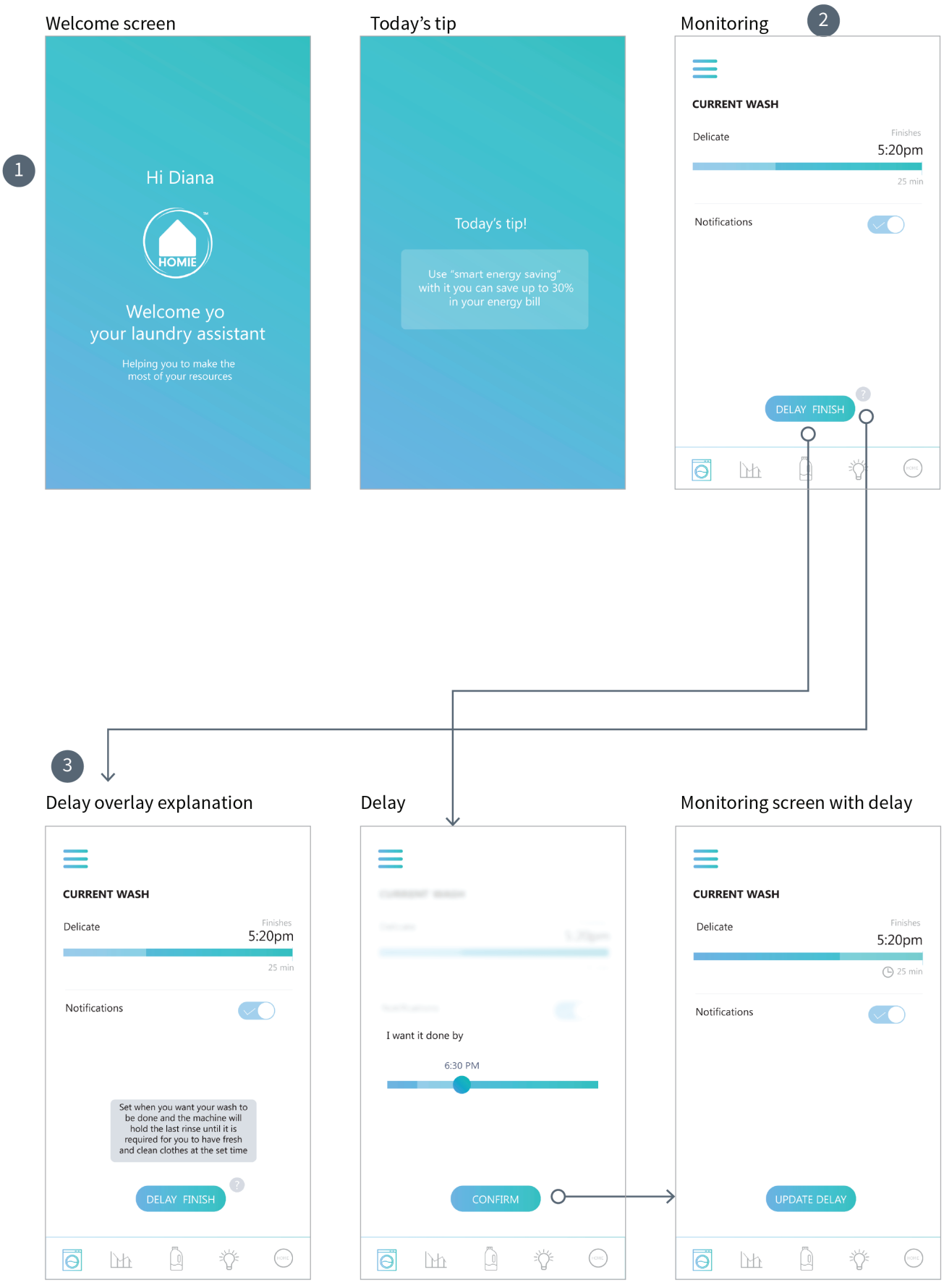
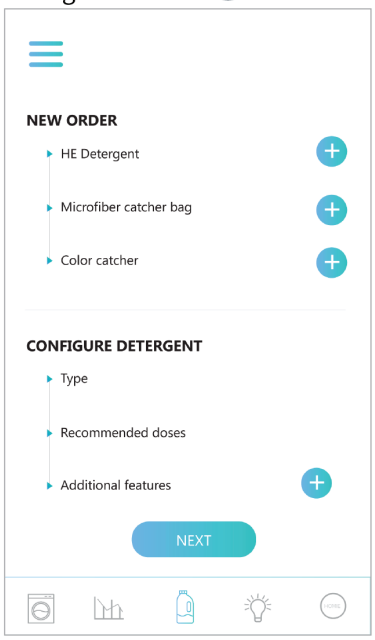
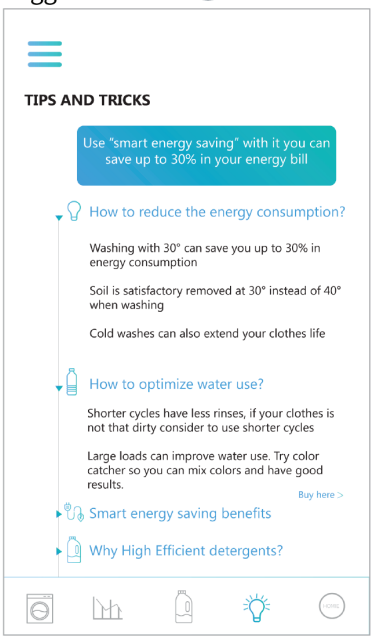


Figure 67. Final app visual design rationale, part 1

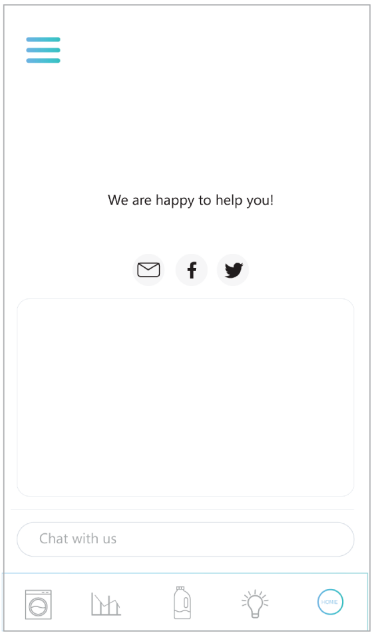
Detergent 4



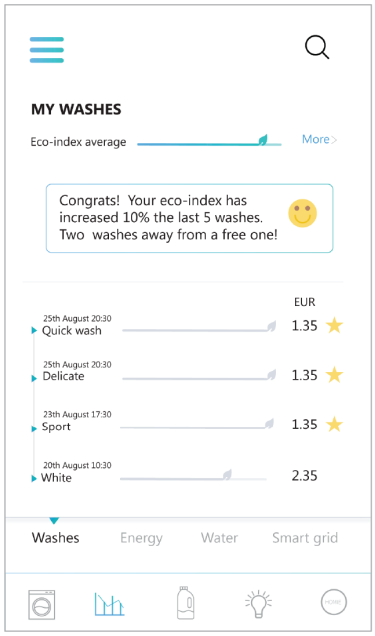
Suggestions 5



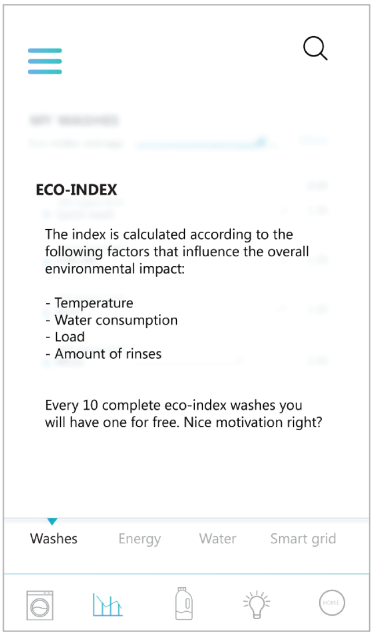
Contact



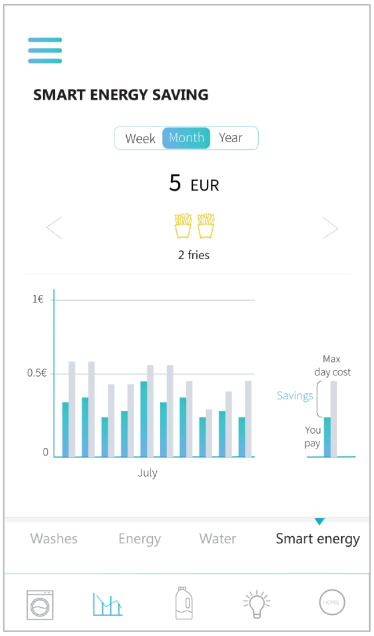
Statistics, washes 6

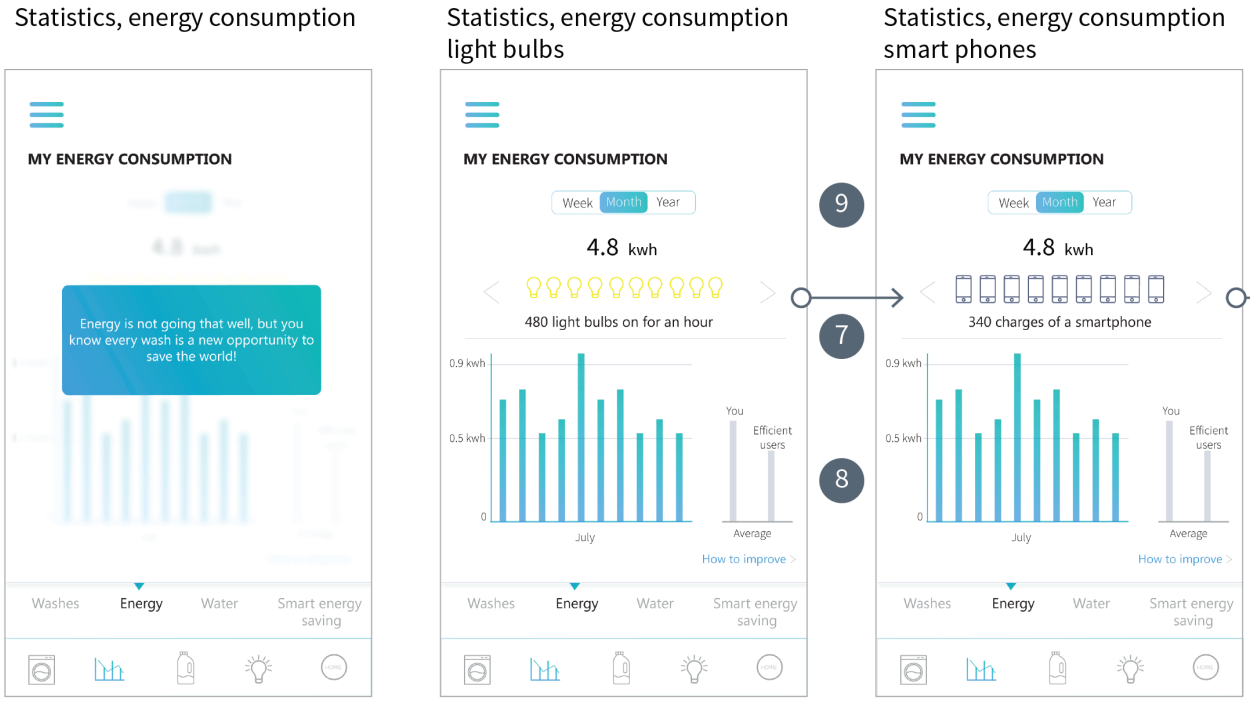


Eco-index overlay explanation



Statistics, Smart energy saving





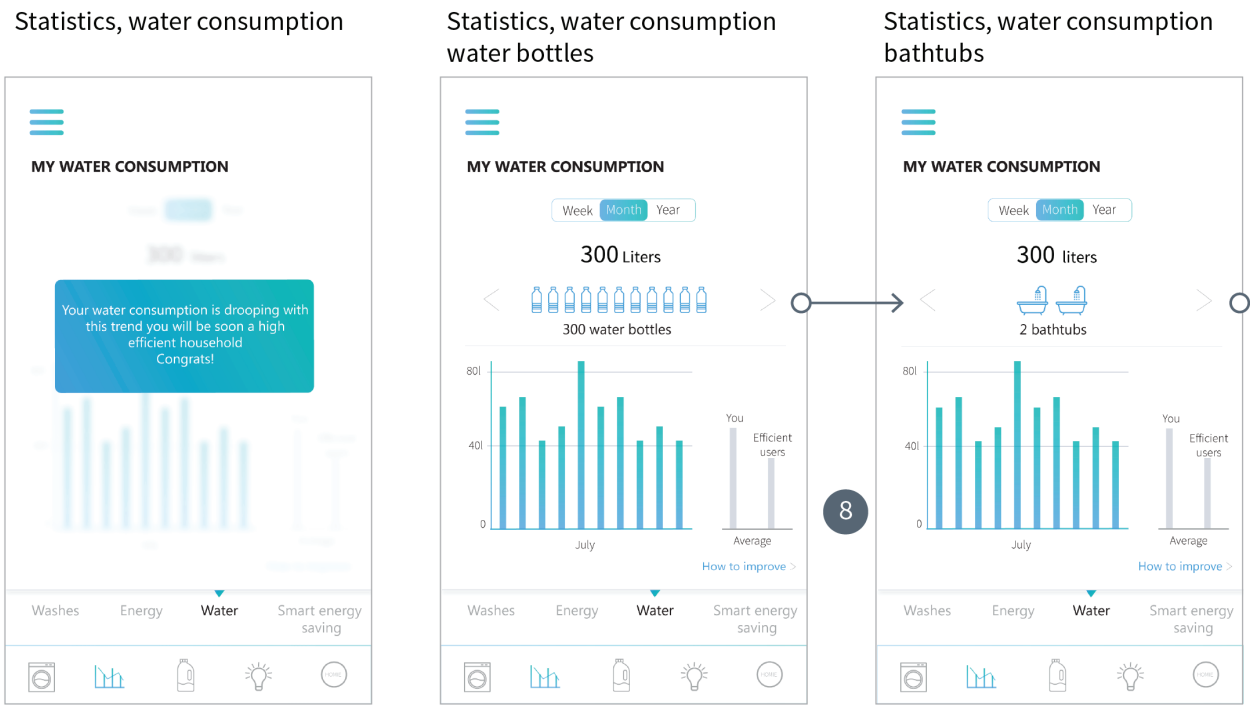
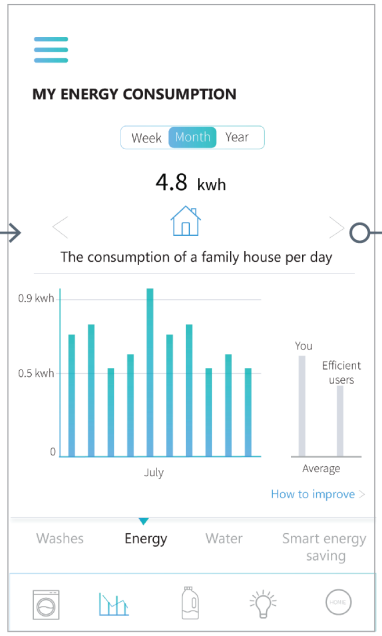


Figure 68. Final app visual design rationale, part 2

Statistics, energy consumption fun facts



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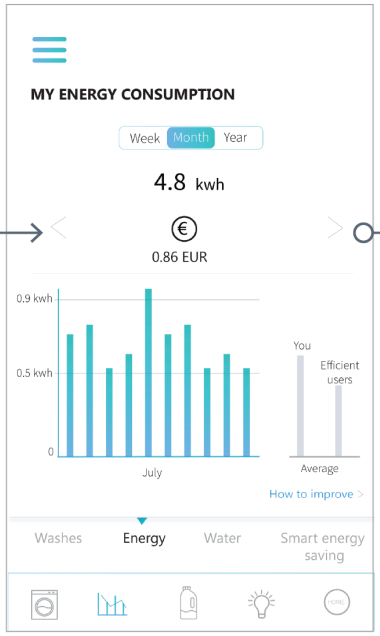
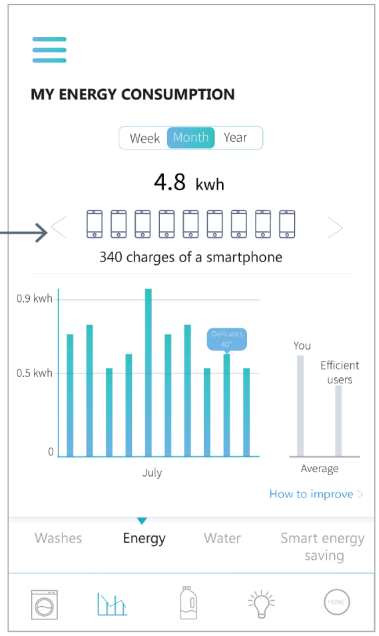
Statistics, energy consumption price



7

Statistics, energy consumption detail wash

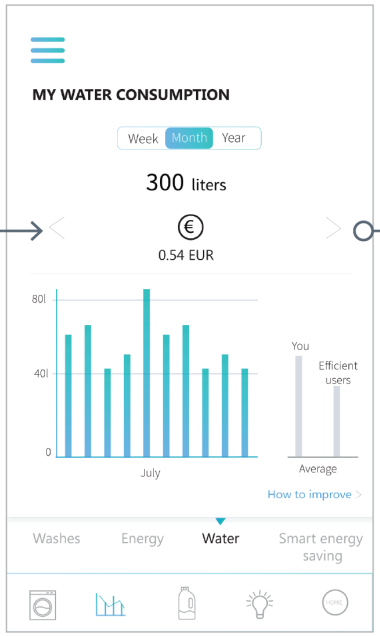


10

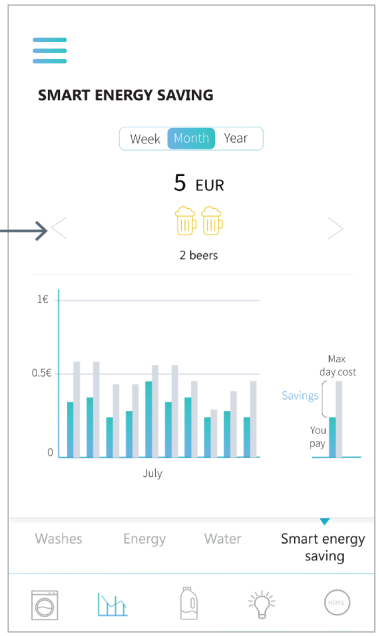
Wash details appear when the bar is tapped

Statistics, water consumption fun facts

Statistics, energy consumption price



Statistics, Smart saving energy beers



8.5.IOT AND SUSTAINABLE BEHAVIOR EVALUATION

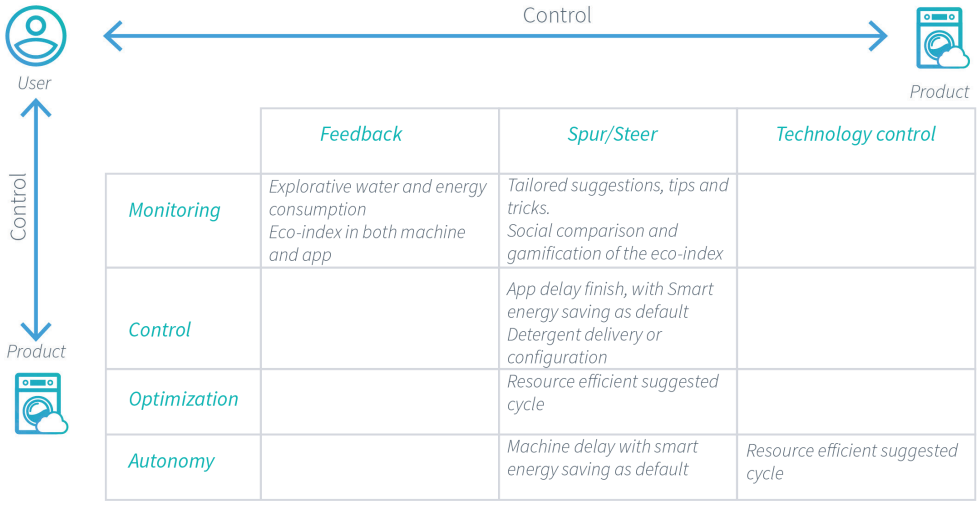
To measure how the proposed design will impact HOMIE's interventions in sustainable behavior through connectivity, the design is analyzed using the framework of sustainable behavior and IoT (See figure XX). Evidently, the strategies cover all the spectrum in both aspects. Especially, spur/steer strategies have been developed due to its rather easy implementation in comparison with technology control. This also supports the hypothesis brought up during the benchmarking study, that stated that Circular Business Models sustainable behavior fostering could be favored by the use of smart products.

8.6.CONCLUSIONS

The design process started with the research question: Considering the outcome of the analysis phase, how can current HOMIE's service UX be shaped by using connectivity to both increase adoption and foster sustainable behavior while fulfilling user needs? This is finally answered in this chapter with the Smart PSSs design.

The design proposes to shape HOMIE's user experience by re-designing their webpage and washing machine interface, and including an app. With these improvements, the service is expected to provide an experience that not only fits into users' daily life but that also adds to it through connectivity. This is achieved with functions like smart energy saving, delay and remote monitoring, which together make the laundry process easygoing, certain and sustainable.

The use of sustainable behavior strategies along with an iterative approach is expected to influence the user's decision making when filling the machine, selecting the cycle and pouring detergent. All the touchpoints have been designed to give sustainability an important position in the experience of use. And this is not addressed only by raising environmental awareness but by facilitating sustainable actions such as: specific cycle recommendation that adapt to users' variable sorting habits and an easy use of the smart energy saving feature.



	Feedback	Spur/Steer	Technology control
Monitoring	Explorative water and energy consumption Eco-index in both machine and app	Tailored suggestions, tips and tricks. Social comparison and gamification of the eco-index	
Control		App delay finish, with Smart energy saving as default Detergent delivery or configuration	
Optimization		Resource efficient suggested cycle	
Autonomy		Machine delay with smart energy saving as default	Resource efficient suggested cycle

Figure 69. Final design IoT - sustainable behaviour framework

CONCLUSIONS

The goal of this project was to explore how product connectivity on a Pay-per-Use model can support Circular Economy. This, with the purpose of reducing the environmental impact of products, specifically when offering products as services in a Pay-per-use model. The latter could help service providers to fulfill user needs with less environmental impact since the product is their main asset, thus they are motivated to extend products' life by means of maintenance, refurbishing or recycling. To support the exploration and to develop an example on how that collaboration between IoT and Circular Economy could be built, HOMIE washing machine Pay-per-Use was taken as case of study.

Furthermore, during the analysis process a gap in Circular Economy's proposition for product environmental impact was found. Its proposal does not consider the impact of the use phase, which can be the most polluting in some products, like washing machines. Therefore, the use phase is included in the project as a complementary strategy to Circular Economy by considering sustainable behavior design strategies. These strategies are generally divided in 3 levels according to users' control, starting with eco-feedback that focuses on awareness creation, then spur-and-steer strategies that subtly guide users towards certain practices by applying affordances and constraints, and finally technology control where the product makes some decisions on behalf of the user. Although eco-feedback is the most common approach, research has found that it's not enough to drive a long term behavior change.

To start the topic exploration, the current state of the art of both connected products and circular PSSs was studied. It was found that even though Circular PSSs promote more sustainable practices there is not a clear intention of conveying an environmental message and consequently eco-feedback is not provided in any case. Additionally, a relation of correspondence between IoT capabilities (i.e. monitoring, control, optimization and autonomy) and sustainable behavior strategies (i.e. eco-interactions, spur/steer and technology control) was encountered, in which a specific IoT capability enable a sustainable behavior strategy. The latter is outlined in a proposed theoretical framework, which is used in multiple stages of the design process. Finally, it was concluded that possibly circular PSSs could be favored when using connected products to promote more sustainable practices.

On the other hand, the user research pointed out to a current experience with the washing machine characterized by uncertainty, due to the lack of feedback from the machine, lack of knowledge of users regarding the washing programs features and a mismatch between users' sorting habits and machine programs offer. Additionally, it was found that laundry practices are performed as habits, a reason why multiple actions performed by the user are not rationalized and could be harmful for the environment, such as: not filling the washing machine, use of unnecessarily high temperature and incorrect detergent amount.

The main user concern is to have clean and well-maintained clothes, and this overrules any other concerns, including environmental ones. However, the research showed that users are willing to engage in more environmental practices, but only if that does not step into their personal interests. The latter constituted one of the biggest challenges of the design process: how to take care of users' personal concerns while promoting more sustainable practices. This is not currently included into most washing machines design since they do not allow users to reflect on resources consumption or translate their concerns about it into practices.

The findings obtained above were shaped into HOMIE service with the purpose of presenting a case of study in which the project goal could reflect. Due to the start-up state a User Experience approach was relevant. Green millennials were chosen as the target group. Three main points of intervention in HOMIE service were defined for the design that could positively impact the user experience, and that are key for the promotion of more sustainable practices. These steps were: first, service exploration phase where users can be motivated to adopt the service and therefore rise product circulation. Second, doing the laundry phase that framed the user-washing machine interaction and where it is possible to steer users' habits and improve the experience in terms of certainty while allowing them to take more sustainable decisions. And finally, the follow up phase where consumption awareness is the focus. These three points were translated into service touchpoints that could be re-

designed. Then, the exploration is done on the webpage, doing the laundry is done by interacting with the washing machine and finally the the follow up of the consumption is made in the app.

Through an iterative approach, the interactive design of the eco-system was developed. First, the interaction design was defined in terms of touchpoint features, and then translated into the user interface with wireframing. In this preliminary state, a first iteration was performed by means of a paper prototype, what later led to the design of more detailed screens used in a digital prototype. With this, an user test was performed with multiple users to evaluate the user experience and usability. The insights obtained from the test were used in the final design iteration.

The final improved design is a Smart PSSs eco-system integrated by 3 devices: the webpage, the washing machine interface and an app. All together aim to improve the experience of use of HOMIE's Pay-per-Use service while fostering more sustainable practices and motivating adoption. The outcome of this thesis shows a clear example of how connectivity can be used to improve a circular business model, and therefore how to reduce the environmental impact of products.

REFLECTION

Human Centered Design matters distinctively in sustainability

During the project, it constantly popped up how essential it is to fulfill user needs and to balance them with sustainable goals, as it is done by human centered design with business and feasibility. As shown in the user research, users are willing to engage in more sustainable practices as long as that does not step in their personal goals. Thus, design through a human centered approach is undoubtedly pertinent to drive and foster sustainable practices. This project proposes to do so in different levels such as: conveying desired service values that solve user needs while trying to modify the user's notion of sustainability as personal benefit rather than sacrifice. In a use level, design adds to service by defining how service values are translated in the experience of use, as service features, usability and visual design. So, the key is then not only to be sustainable but to transform sustainability in a desired and meaningful value of the service and the experience.

Circular Economyis missing something

Although Circular Economyhas the potential of reducing environmental impact of products through circulation, the use phase impact is missing in its proposition. Use phase can be the most polluting in certain products, as washing machines. These high-resource demanding products can certainly reduce its overall environmental impact if more attention is paid to this part of the product lifespan. Furthermore, interventions in the use phase are facilitated when products are offered as services, which immediately creates a stronger company-customer relationship, so it seems that conditions are perfect for PSSs to add a layer into its design and promote more sustainable behavior in all its levels. So far, the state of the art is not very encouraging in this matter though. As presented in the benchmarking, even though circular PSSs promote more sustainable practices through, for example, shared economy services, there is not a clear intention of creating environmental awareness.

Eco-interactions, the forthcoming for Smart PSSs

IoT's expected growth is massive and as an enabler of CBM will create opportunities for the design of eco-interactions. Users are clearly aware and interested in sustainability and in the future this trend is likely to increase. However, products don't always allow them to translate their concerns about the environment in daily life actions. This linked with the fact that feedback is not enough to drive behavior change, rise a challenge for design. But with IoT in the map, eco-feedback, spur/steer and technology control technologies are more feasible than ever before through the design of Smart PSSs. For this aim, the framework developed in this project could help designers to explore how sustainable behavior strategies can be related and enabled by product levels of connectivity. So, we can say that hopefully in the future design will appropriate IoT as an eco-interactions enabler in Smart PSSs.

Sustainable behavior strategies are complementary

Even though literature recommended certain sustainable behavior strategies for certain steps of the new practices adoption process, the design showed how multiple strategies can be successfully complemented by taking advantage of the Pay-per-Use service.

It is hard to define good or bad actions

Washing is not only about bad and good actions, it is more a complex combination of multiple factors that respond to specific user needs, I can guess that there are various similar scenarios in which a specific human behavior is related with consumption without a clear wrong or good answer. So, it is important to be critical about those situations and from a design perspective to be aware of this and being able to translate that complexity in an easy understandable way for customers.

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RECOMMENDATIONS

Long term testing

The sustainable behavior strategies implemented in the design have shown to be in certain extent effective in the user test. However, long term use should be considered since it is common to lose engagement after some time. This might not be always negative, though, especially if a certain level of sustainable behavior has been appropriated in users' habits. Additionally, how the proposed features will be adapted by users in daily routines is unknown. This is crucial to consider, specifically to prevent rebound effects.

Eco-Index and program suggestion development

Both eco-index and program suggestions are crucial components of the proposed design. The former facilitates user evaluation of program sustainability to reduce cognitive load while the latter decide the most suitable ecological features for the cycle to facilitate eco choices. Both features require an algorithm to be implemented.

Detergent delivery customer acceptance evaluation

The result of the customer likelihood of using detergent delivery service were rather fuzzy since it could had been affected by the participants profile and the undeveloped stage of the feature. Therefore, it is recommended to perform a more detailed study of the potential use of this service, which could have a high impact in the adoption of High Efficiency detergents.

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