CHALMERS

Design and Development of Greenwash

A WATER AND ENERGY EFFICIENT WASHING SYSTEM

Bachelor's thesis in Product Design Engineering

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CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2015

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Cover:
[Front view of the Greenwash washing machine, part of the final concept.]

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Preface

This bachelors thesis, spanning 15 credits, was achieved at Chalmers University of Technology and more precisely during the Product Design Engineer programme, spanning 180 credits.

The mission was administered, through the Home Energy Management work package, as a part of the BTA (Building Technology Accelerator). BTA is the flagship of the Climate KIC; an initiative from the European Institution of Innovation and Technology. It was assigned to us through the Department of Product and Production Development, Division Design & Human Factors at Chalmers University of Technology.

We would like to give special thanks to our examiner, Prof. Ulrike Rahe, as well as our supervisor, PhD candidate Anneli Selvefors, for their support during the project, both working at the Division Design & Human Factors. We would also like to thank Fredrik Hallgren at IVL- Swedish Environmental Research Institute and Anne-Charlotte Hanning at Swerea IVF whom both contributed with information about the S'Wash, Sustainable Domestic Washing, project and allowed us to use their technology in our final concept. Lastly, we would like to give thanks to our opponent, Julia Arell, whom contributed with insightful reflections on our report.

Abstract

Reporting on the background and result behind a washing machine concept proposal; designed from the ground up to be a more environmentally friendly solution, compared to what is on the market today, whilst having better ergonomics and procedural advantages as well. This effort was made in the hopes of achieving a great result that eases the transition to a more sustainable washing behavior.

The initial research methods used were literature studies and user studies that expressed their result, except as a frame of reference, as an ergonomic evaluation, a customer journey map, a map of textile demands, an evaluation of concepts and technologies as well as a trend report.

This was followed by an exhaustive concept generation phase, trying to solve the need of washing in new ways while pleasing several influencing factors as well as avoiding the issues of todays solutions. Brainstorming, sketching and sketch modeling for evaluation were critical during this stage.

A second research, on the ideas and directions that were found to be useful in the concept generating stage, was necessary to make the final concept grounded in reality.
The discovery of a conceptual essence was the result, which were then digitally visualized in two different embodiments. These embodiments were evaluated, a winner was appointed and thereafter refined, into the final concept, through surface design.

The final concept was Greenwash; an integrated system that; improves the laundry experience for the user by combining interfacing and sorting; and; improves water and energy efficiency by combining a water reuse system with a correct order of washing.

Table of Contents

1. Introduction

This chapter aims to give an overview of the basis for this Bachelor's Thesis Project. This is done; by presenting the project's background, goal, purpose, delimitations and questions at issue. In addition to this, it also contains a description of the structure of the report.

1.1 Background

Since the invention of clothing, there has always been a need for getting them clean after use. Even to this day our clothes need to be cleaned since most of them do not stay clean by themselves. The process of washing has changed a lot and improved significantly, both in level of convenience and quality, during it's journey from when washing by hand in natural watercourses was the most effective course of action, to today's situation where washing machines have been developed. Despite these dramatical differences, a consequent theme in the history of washing has always been the use of chemicals (primarily water and later detergent) and energy (thermal and mechanical).

In today's washing machines there are environmental issues linked to each of these components. They exist in the form of, for example; water shortage (because of water usage), water pollution (because of detergents) and air pollution (because of energy production).

So far, work towards environmental improvements have been focusing on developing energy efficient technologies, but many researchers have now acknowledged the importance of taking environmental impact caused by user behavior into consideration. Because of this, the research field of "Design for Sustainable Behavior", which is about using design as a tool to a achieve a more sustainable user behavior, have emerged.

As a result of both the environmental worries and the growing field of Design for Sustainable Behavior, Climate KIC together with Chalmers University of Technology carried out a design investigation aiming to assess the potential for energy conservation in home washing activities.

1.2 Goal

The goal, which was specified in the assignment proposal, was "to assess the potential for energy conservation during the use-phase through designing an exemplary appliance for energy efficient use".

1.3 Purpose

The purpose of this project was to investigate the field of laundry and, based on the findings, create a conceptual washing solution for home use. The focus was on environmental aspects in the use-phase but since it was stated in the goal that the project should result in an "exemplary appliance", other relevant aspects were also to be investigated.

1.4 Delimitations

As a starting point for this project, it was determined that the studied situation should include the process, stretching from the moment when the textiles are considered as dirty until they are clean. Further, it should neither address the capability of textiles staying clean nor question the need for getting them clean.

The concept developed in this project shall also be based on existing technology but no detailed research about, or development of, technical solutions will be performed. In addition, economical aspects will only be considered in an overarching manner.

Lastly; the concept is limited to a specific target group which is defined as families with at least two members.

1.5 Questions at Issue

The main problem to be solved was formulated as: "Dirty textiles can not be used until they are cleaned". The questions below have been formulated with the intention to achieve both a solution to this problem as well as an answer to the project's purpose.

- What are the preconditions for change in the washing machine industry?
- Which activities and functions play a key role in today's laundry process?
- Which technologies are used by the pioneers on the market of home washing appliances?
- How do people interact with the appliance during washing activities in the everyday life?
- When designing the interface, which factors are important to support an energy efficient use?
- What combination of function, usability and eco-friendliness would result in a better washing solution?

1.6 Disposition of the Report

This report consists of nine chapters. It begins with the *Introduction*, where the basis for the project is described. After that follows the *Theoretical Frame of Reference* where fundamental information about the currently investigated area is presented. The third chapter *(Method and Process)* describes the work process and the different methods that were used throughout the project.

Chapter 4 *(Pre-study)* presents the results from the pre-study. The purpose with this chapter is to provide complementary information about aspects that were not described in the Theoretical Frame of Reference. The conclusions drawn, and the insights gained, in these two chapters are thereafter compiled in chapter 5 *(Basis for Concept Development)* which aims to define the groundwork for the concept development.

In chapter 6 *(Concept Development)*, ideas and part concepts generated, during the different stages of the concept development process, is described and evaluated. The chapter describes this in a chronological order and therefore it is recommended to read it sequentially.

The final concept is presented in chapter 7 *(Final Concept)* and aims to describe how the concept works, both regarding the user interaction and the underlying technology.

Chapter 8 *(Discussion)* discusses the methods used in the project and also the final result. Lastly, chapter 9 *(Conclusion)* ties together the report by reconnecting to the purpose and questions at issue stated in the introductory chapter.

2. Theoretical Frame of Reference

The theoretical framework, on which the investigation and result were based, is presented in this chapter. Here, relevant design theories, an introduction to the laundry discipline, a technological overview and washing machines environmental impact is presented.

2.1 Design Theories

Design for Sustainable Behavior

As a reaction to recent environmental worries and to fill in the missing gap where not as much research has been done; new theories for how to design for a more sustainable behavior during the use phase has started to emerge. The discipline of designing for sustainable behavior means the use of different strategies when conceiving a design that will make the user act in a certain, more environmentally friendly way. The report: How to Design for Sustainable Behavior? by Lidman and Renström (2011) describes as well as reviews such strategies; summed up into five different categories which are shown in figure 2.1 and listed below:

- **Enlighten:** the user gets aware of the consequences of certain choices
- **Spur:** the user gets encouraged to a certain behavior
- **Steer:** the user is implied to behave in a certain way
- **Force:** the user has no other choice but to behave the right way
- **Match:** the product is adapted to the usual behavior of the user

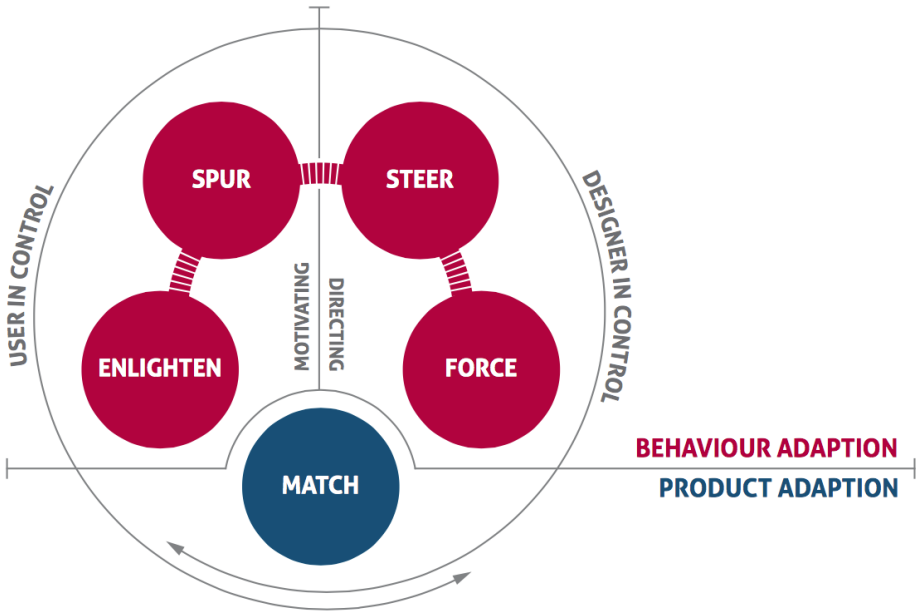

Figure 2.1, Visual presentation of the five strategies for how to design for sustainable behavior.

2.2 The Laundry Discipline

The definition of laundry and washing

According to the Oxford English Dictionary (2015), the definition of laundry is: ”The action or process of washing” where the definition of washing, from the same source, is defined as: "The action or an act of cleansing by water, or of laving or bathing with water or other liquid" and refers, in the case of laundry, to cleansing of dirt from textile items.

The Washing Process

To get clothes or other fabrics clean, dirty laundry needs to be processed in something called the washing process. The fundamentals of the washing process is, to mechanically process laundry, together with detergent and eventually heat (Conradsson, 2015) and as the theory of Sinner's circle states, the result of the process is dependent on four parameters: chemicals, mechanical action, heat and time.

The washing process is achieved both domestically, in laundromats, at dry cleaners, in businesses and large laundry service companies, but, both according to Mozes, Cornelissen, Hirs and Boom (1998) as well as the theory of Sinner's Circle, the underlying processes behind laundry and washing remains the same.

When observed in a system diagram, as seen in figure. 2.2, the washing process receives detergent, electricity and tap water to achieve the process of cleaning the dirty laundry. After a certain period of time; the two resulting outputs are clean laundry and waste water.

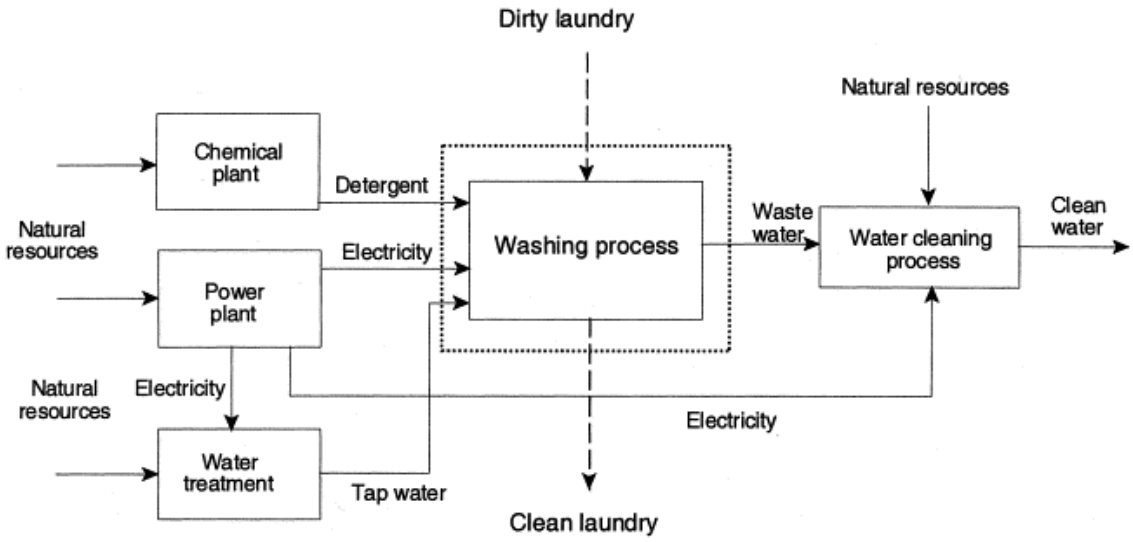

Figure 2.2, System diagram of the washing process.
Original image: Mozes, Cornelissen, Hirs and Boom (1998)

Sinner's Circle

The sinner's circle (see figure 2.3) is a broadly recognized theory by Dr Herbert Sinner, a former chemical engineer at Henkel KGaA, stating that the washing performance is a result of four different factors: mechanical action, expenditure of time, chemical energy and thermal energy. All of these are needed to some degree but are interdependent, meaning; if one of the factors is reduced, at least one of the other factors needs to be increased to achieve the same result (Beringer & Kurz, 2011).

Figure 2.3, Visual presentation of The sinner's circle.

2.3 Technology Overview

Technological principles

Washing machines for home-use are usually based on three different technological principles (Åsnes, 2015). All of them consists of a cylindrical drum in which the laundry is loaded. They also have in common that they use water and detergent to dissolve the dirt and to transport it away after pressing it out of the textiles. The differences, which are presented below, lies in how they are achieving the mechanical action (which is the factor that causes the water to penetrate the textiles).

CENTRIFUGAL WASHING MACHINES

Machines in this category generates the mechanical action through rotation of the drum itself. As the drum rotates, the centrifugal forces presses the water and the detergent through the clothes.

AGITATOR WASHING MACHINES

These machines generates the mechanical action by using an agitator, which can be described as a screw with fins, that rotates to create currents in the water. The agitator is placed in the middle of the base of the drum.

PULSATOR WASHING MACHINES

Machines built on the pulsator principle works similar to the agitator machines, but instead of using an agitator, a rotating disk with fins are used. This disk is also placed in the middle of the base of the drum.

Configurations

There are three main types of washing machines for domestic use on today's market, regarding the overall characteristics. These types are described below.

FRONT LOADER

Front loaders consists of a horizontal axis drum placed in, or close to, the middle of the machine. The drum is opened from the front via a circular lid placed on one of the flat sides. This type of washing machine is based on the centrifugal washing machine principle.

TOP LOADER

In top loaders, the drum is instead placed vertically and the laundry is loaded into the top of the machine. Here, the drum is opened from the top via two, or sometimes three, lids. The mechanical processing in this type of machine is achieved through either the agitator- or the pulsator principle.

EUROPEAN TOP LOADER

European top loaders can be described as a combination of the two first mentioned. They are based on a horizontal axis drum and work with the same principle as front loaders, but, are loaded from above like top loaders. Since the drum is horizontally orientated, the opening is placed on the rounded side of the drum and is, most often, opened through the unbuttoning of two lids.

Other configurations

TUNNEL WASHERS

A technical solution, that can be seen in many situations, where high capacity washing is necessary, is tunnel washers. This solution is based on a long pipe that consists of several sections that each perform different moments of the washing process. The laundry is then moved through these sections by a screw in the middle of the pipe, pursuant to the Archimedes helix principle (European Union, 2007). In several cases, the solution is combined with conveyor belts that, for example, transport or fold the laundry.

DRY CLEANING

Dry cleaning is a method where chemicals are used as a substitute, or in some cases complement, to a small amount of water. The method enables cleaning of garments that can not be washed in water. A negative aspect of dry cleaning is that some of the chemicals used are harmful to both health and environment. The machines have to be equipped with filters but nevertheless they are leaving harmful residues (Åsnes, 2015).

WET CLEANING

Wet cleaning is a method similar to dry cleaning. The biggest difference is that it uses water together with biodegradable detergent instead of chemicals. A disadvantage with this technology is that is can not handle that many types of garment. At best, it could handle as much as traditional dry cleaners can (United States Environmental Protection Agency, 1997).

WASHER DRYER COMBINATION

Some washing machines are so called "washer dryers" which means they include both; a drum capable of centrifuging, and, a fan capable of drying the clothes. This means, when there is not enough space for both a washing machine and tumble dryer, this could do the job instead.

2.4 Environmental Impact

The system

Washing machines generally consumes electricity, water and detergent during the use phase and can therefore be classified as active products. According to LG's sustainability report, the use phase of washing machines is clearly the most critical when it comes to sustainability (LG Electronics ltd., 2014).

THE IMPACT OF WATER USE

Freshwater have a key role for life on earth. At the same time it is a scarce resource in large parts of the world. Therefore it is important to use it in a sustainable manner:

There are a couple of important environmental aspects when it comes to washing machines' use of water. The general problems are that the machines consume a significant amount of water and the fact that the water is being polluted during the washing process. This pollution is caused both by the detergents used and by, for example, chemicals as well as textile particles which are released from the clothes (Donner, Eriksson, Scholes & Revitt, 2008).

A consequence of using fresh water in washing machines is that energy is required to produce and transport it. According to the European Union (2012), pumping and treating freshwater into drinking water consumes about 0.6 kWh/m3. If the drinking water instead is produced out of sea water, the process consumes about 4.6 kWh/m3.

THE IMPACT OF ELECTRICITY USE

In today's society, ca. 67% of the electricity is produced from fossil fuels in the form of coal, natural gas and oil. 15% comes from nuclear power and only 18% comes from renewable resources (consisting of 16% hydro power and 2% bio mass-, solar- and wind power combined) (Gröndahl & Svanström, 2011). Because of this, electricity consuming appliances indirectly causes CO_2 emissions.

To improve this situation, actions are being taken at several levels. Goals and regulations set by governments and similar organizations play an important role in reducing CO_2 emissions. For example, the EU have a goal to increase the energy efficiency with 20% until 2020 (European Union, 2010). Decisions made by these actors have also resulted in laws about environmental labeling which, thereby, spurs companies to reduce their environmental impact and to develop more efficient products. The labeling has also increased the customers' awareness about the products' environmental impact, which has increased the demand for more efficient products.

THE IMPACT OF DETERGENT USE

In contact with nature, detergent is toxic to aquatic organisms and algae. Regarding people, long exposures to detergents with the skin can induce health problems and, in the worst case, cause cancer disease (Pedrazzania, 2012). As it pollutes the wastewater of households, water treatment plants needs to put extra energy energy and effort into the eradication of the toxic substances in the water. When it does come in contact with nature, through the groundwater and alike, its persistence in the environment can also lead to the eutrophication of lakes and waterways. This is much due to the included phosphates in some detergents (Ansari, 2011), however, phosphates in washing machine detergent is banned in the EU since 2013 (European Union, 2007)

During use, overdosing of detergent is one prominent cause to the environmental impact from detergent. The arrival of self-dosing washing machines, however, means the correct dosing of detergent is achieved more frequently (Krozer, 2011).

THE IMPACT OF DRYING

The drying methods influences the environmental impact of the laundry process significantly. According to Swedish Energy Agency (2014) a tumble dryer consumes between two and four times as much energy as the washing machine itself.

Technology

The environmental performance of a washing machine is highly dependent on the technology on which it is based.

The energy efficiency is generally higher in machines with a horizontal axis drum than in machines with a vertical axis drum (Bansal, Vineyard and Abdelaziz, 2011). Based on the washing machine types of today, this means that Front loaders and European top loaders are generally more efficient than Top loaders.

Regarding washer dryer combinations, the compromises of trying to achieve both washing and drying in the same drum means they are less environmentally friendly. As washing and drying put different demands on the design of the inside of the drum, for instance, the highest efficiency, when doing both, can not be achieved. Also; as a washer dryer combination is supposed to dry the clothes, it also has to dry the wet inside of the drum.

Behavior

Technological development have lead to significant improvements regarding the environmental impact of washing machines (Pakula & Stamminger, 2010), but, the environmental impact is also heavily influenced by users' laundry- habits and behavior (Laitala, 2014; Schmitz & Stamminger, 2014). In this section, these behavioral aspects will be presented.

There are several studies about washing behavior investigating, for example, washing frequency, laundry load size and washing temperature. One of them is: "Usage behavior and related energy consumption of European consumers for washing and drying" performed by Schmitz & Stamminger (2014). This report compiles statistics about laundry-behavior and habits based on surveys reaching 2000 households in ten different european countries. In the report, the washing frequency is considered as the most relevant when it comes to resource consumption in the use phase. Washing temperature is presented as the second most important factor. The performed study shows that there is a significant difference in the average temperature used, when washing, in different European countries. This indicates that there is no clearly defined correct, or incorrect, way to wash regarding washing temperature.

Another report, named "Clothing consumption - An interdisciplinary approach to design for environmental improvement" by Laitala (2014), gives a detailed description, of the environmental impact of clothes, from a larger perspective. The report claims that laundry behavior is an important area to consider and therefore several, user-influenced aspects are presented. Today's high washing frequency is one of the most prominent. According to several sources cited in the report, this is, among other things, a result of today's norms about freshness and negativity against body odors. In addition to this, it is also claimed that overdosing of detergent is an important aspect to consider. To exemplify this, Laitala mentions that a lot of informants, in one of her earlier investigations, describe how they use to dose the detergent without measuring it.

Norms and thoughts about freshness are also investigated in a report by Fagrell (2013). The investigational part of this report, based on interviews combined with earlier research, aims to answer questions about laundry behavior and energy conservation. The result from the interviews show that habits and routines are important for the outcome of the laundry process, therefore, several of these factors are discussed. One of them is the opinion about when washing is necessary, which is connected to the cleanliness of the clothes. A common opinion among a majority of the participants were that, if there is not any stains or odor, garments could be worn several times before they needed washing. Many informants stated that they wash their laundry, out of habit, in the same way regardless of the degree of soiling (for example, on a particular day or at a certain temperature). Others described that they sometimes washed clothes which, necessarily, did not needed washing, just to fill the machine. Both of these behaviors lead to unnecessary washing. The fact that the laundry can be sorted into a large number of categories, regarding for example colour and material, is presented as a problem since it makes it harder for the user to fill the machine to a sufficient level. Lastly, airing or refreshing of the clothes, which reduces the need for washing, is presented as a rarely used technique in general.

Materials

EXTRACTION

According to Ashby (2012), the total mass of a front loaded washing machine comprises about two-thirds metal and one third concrete. The remaining parts mostly consists of glass (found in the window of the hatch) and rubber (found in the seals).

Extracting and processing metals impact the environment in several ways. First of all, the resources have to be extracted from the earth, which causes a dramatical change in the local environment. Then, it has to be refined and processed to gain wanted qualities. This is generally a very energy-intensive process which is polluting air and water. Water is mostly used in cooling systems. It can either be used for direct cooling, which pollutes the water, or as a heat exchanger, which only impacts the water by raising it's temperature. (Jernkontoret, 2015).

In the case of air pollutions, CO_2 emissions are one important factor. According to Bosch and Kuenen (2009) the production of one kg of steel releases between 0,5 and 2,7 kg CO_2, depending on what technologies the specific plant uses. Except CO_2, the process also causes pollution consisting of, for example, nitrogen oxide, sulfur dioxide, dust and some organic compounds (Jernkontoret, 2015).

REPAIR OF WASHING MACHINES

The need for the ability to repair the washing machines is derived from the materials used. In common washing machines, the steel, for instance, can hold up for thousands of years but the combination of many moving parts, that makes up the machine, only lasts for about 10. Also, the life expectancy for washing machines is high, the rate of obsolescence is low and they are usually not replaced before they stop working completely (White, St. Pierre & Belletire, 2013). The parts that most frequently breaks in washing machines are the pump, the plumbing and the motor (Ellen MacArthur Foundation, 2012).

According to White, St. Pierre and Belletire (2013); less than a fourth of all washing machines are thrown out before they started to show degradation in functionality and only about 20 percent are thrown out because they are not functioning properly. This means over half of all washing machines, of which are disposed, are not functioning at all; a very good statistic in comparison to computers where about 90 percent, of all disposed, are still functioning (White, St. Pierre & Belletire, 2013).

RECYCLING

In Europe, the European Commission has a set of regulations under the name of the WEEE directive or Waste Electrical and Electronic equipment directive of which, for instance, LG's take-back program has been a part of since 2005 (LG Electronics ltd., 2015b). The Directive means a way for the consumers to dispose of their washing machine for free and by doing so increase the recycling or reuse of these kinds of products (European Union, 2015).

As the product doesn't, in and of itself, communicate how to be recycled; the loss of packaging, instruction manual or a lack of knowledge could result in the washing machine not making it back into the hands of the manufacturer. Hopefully, the washing machine would then end up at a recycling plant such as Stena Recycling in Northern Europe and according to Flink (2015) large items containing many different parts usually go to the shredder. In relation to the number of parts and overall volume, most washing machines consists of a small number of different materials where most of the mass is steel. Parts like the motherboard, the motor and the concrete slab would contaminate this process, and, since most Washing machines are fairly easy to be taken apart, these would be taken out before hand.

The washing machine is recycled by going through a shredder. Shredding, in and of it self, is a toxic and "dusty" process where a lot of particles are stirred up into the air. The process has special requirements where, when not met by the design of the appliance, there is a high likeliness of contamination and down-cycling of the materials. When done right, however, the materials are clean and doesn't compromise on the quality of following products. When it comes to the composition of washing machines, the plastic materials are also considered as bad for the shredding process (White, St. Pierre & Belletire, 2013)

3. Method and Process

This project was performed in two main phases. First, a pre-study was carried out to gather and analyze information from a broad range of subjects. Secondly, an iterative concept development process, based on the previously gathered information and insights, was undertaken. This chapter describes the work process as well as presents the methods and activities performed during the two phases respectively.

3.1 Process overview

The purpose with the pre-study was to collect and map as many factors as possible that could be important to take into consideration in the concept development process. With this starting point in mind, it was realized that the design had several target-audiences; not just the customer of the product but also the clothes that it cleans as well as the physical room in which it operates. The solution were also going to be constructed or built by technological solutions. The design thereby had to exist in the intersection between laundry, contextual, technological and human factors. Figure 3.1 illustrates this intersection and the areas that were, thereby, needed to be investigated in the pre-study.

The concept development process was based on the information and insights gathered in the literature and user studies. With this information in mind, an iterative ideation and evaluation phase begun. During this process, based on their potential to be realized, some ideas were sorted out and others were chosen to be researched further. The Result of the process was a final concept, where the most suitable ideas had been implemented. Figure 3.2 illustrates the iterative process on which the concept development phase was based.

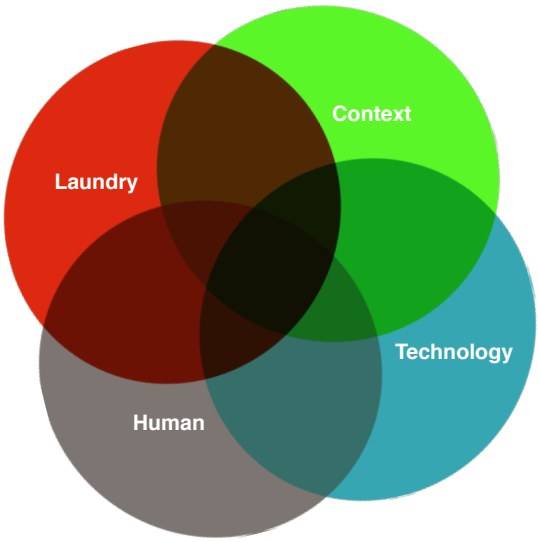

Figure 3.1, Venn-diagram of the investigated areas.

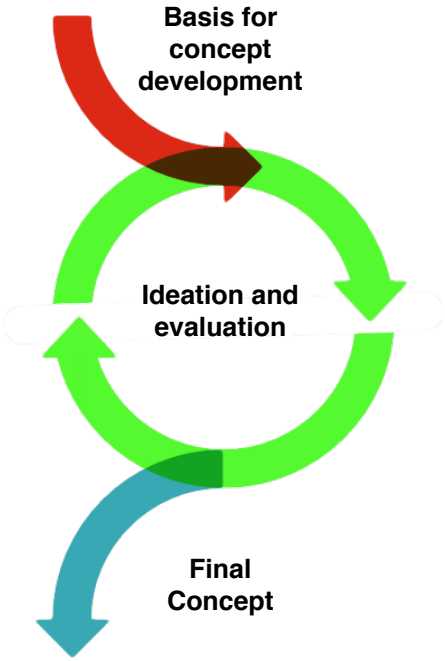

Figure 3.2, Visual presentation of the iterative process.

3.2 Methods used in the pre-study

LITERATURE STUDIES

Many of the methods in the pre-study was based on a thorough literature study. The purpose was to investigate and map the laundry related factors suspected to have an influence on the design.

USER STUDIES

In addition to the literature study, where mostly quantitative data were collected, interviews were performed to gather qualitative data. The interviews aimed to complement the literature study and were primarily focused on laundry behavior and attitudes about environmentally impacting factors.

The interviews were performed with participants from the three different target groups: one-person households, family households and senior households and covered about 30 minutes each. To keep a structured interview; a template, shown in appendix 1, were used as support.

CUSTOMER JOURNEY MAPPING

Customer journey mapping was used as a tool to investigate and illustrate the activities included in the laundry process. The investigation stretched from the point where the user experiences the need to get an item washed, all the way until it is cleaned and dried. For each of these activities, problematic aspects were listed. In addition to this, emotions considered as likely to occur were graded and thereafter illustrated. The basis for the customer journey mapping was the information collected in the interviews.

ERGONOMIC EVALUATION

To investigate the ergonomic performance of the washing machines on today's market, the RULA, Rapid Upper Limb Assessment, method was used. This was done by using Siemens Jack where different body postures, performed by simulated manikins with different anthropometrics, were evaluated. Also, the ergonomic evaluation included a market analysis where information was gained both by comparing different models and by visiting resellers.

SWOT ANALYSIS

The strengths, weaknesses, opportunities and threats, regarding a general washing machines, were listed in a SWOT analysis. This was done to further the understanding of where the final design could improve upon today’s washing machines.

KANO MODEL

The functions and stages, of a regular wash process, were mapped to their respective impact on the customer experience by using the Kano-model. By doing so, the final concept could be compared to the result and, thereby, make sure it include all the features that are deemed to be very important.

3.3 Methods used in the concept development process

BRAINSTORMING

One method, primarily used in an early stage of the idea generating process, was brainstorming. By using it, a large number of initial ideas were generated. The ideas created during the brainstorming sessions were primarily illustrated in the form of sketches. These sketches also acted as a good basis for discussions, which led to even more ideas being created.

SKETCH MODELING

To get an impression of the design possibilities for the final concept, cardboard models, representing some of the most space-requiring parts, were made. These models were very simple, but they gave an important insight regarding several significant factors. Except for having been a rough representation of the required dimensions, it also gave a feeling for the level of user-friendliness and the ergonomic capabilities.

EVALUATION

The ideas and concepts were evaluated continuously during the concept generation phase. Some of the most important criteria for this evaluation were; the level of realism, the user-friendliness and how direct the idea solved the current problem.

A more structured evaluation was performed when the ideas had been developed further and thereafter combined into fewer, but more concrete, concepts. This was done, partly by weighing advantages and disadvantages of each concept but also via a Pugh-matrix. The criteria listed in the matrix were weighted and thereafter summarized to support the concept selection. In addition to this, the examiner and supervisor contributed with good input during the whole process.

SECOND RESEARCH

As mentioned in section 1.4, the concept were limited to be based on existing technology. Therefore, a necessary step in the concept development process was to perform more research regarding the technologies that were found to be of interest. In this part of the project, conversations with industry representatives, from Swerea IVF and IVL Swedish Environmental Research Institute, took place.

REFINING OF THE CONCEPT

The final design was determined through an iterative process, primarily consisting of sketching, sketch modeling, discussions and computer modeling. Most of the modeling were performed in Autodesk Alias AutoStudio 2015, where the final concept was later created. Siemens Jack was also used to give an ergonomic input.

DIGITAL VISUALIZATION

Most of the visualization was made in Autodesk Showcase, in which the Alias model was imported. Some of the sketches were also edited and rendered using Adobe Photoshop.

4. Pre-study

Except for gathering the information that can be read about in chapter 2, Theoretical frame of reference, the Pre-study included several new investigations that were achieved to fill in the gaps where no previous information could be found. The results of these investigations are presented in this chapter

4.1 Ergonomic investigation

The ergonomic investigation resulted in several important insights regarding the washing machines of today.

Insights from field trips

During the visits at resellers; several problems, regarding the ergonomic aspects, were identified. One of the most prominent was that it was far more complicated to open the drum in top loaders than in front loaders. The most significant reason to this was that all the observed front loaders had only one lid, while most of the top loaders had two or sometimes three lids that had to be opened separately. This is also described by the Swedish Energy Agency (2009).

Another insight was that when using a top loader, the user needs to bend the back, more than expected, to reach the laundry in the drum. Despite this, they were experienced as more comfortable to use than front loaders. The reason to this, which is also described by Busch (2006), is that top loaders enables the user to stand relatively upright in comparison to front loaders.

When comparing different washing machine models; it was found that almost all of them had a height of about 85 cm. In front loaders, this means that the loading height lies around 30-65 cm from the floor since the drum is placed close to the middle of the machine. This is far too low according to the recommendations from the Swedish Work Environment Authority which states that elbow level when standing is generally a good work height. This is translated to a height of 90-100 cm being recommended when working at a fixed workbench (Swedish Work Environment Authority, 2015). The use of front loaded washing machines while, at the same time, sorting laundry on a workbench or on the floor, therefore, leads to many uncomfortable postures when loading and unloading (Busch, 2006). Another consequence of this low placement is that the field of view, into the drum, is interrupted which, according to Busch (2006), results in an over-complicated unloading moment.

Results from the RULA (Rapid Upper Limb Assessment)

Figure 4.1 to 4.3 shows three typical loading/ unloading postures that were evaluated. According to the RULA; none of these postures are recommended. In the rating, of seven grades where seven means the highest risk, the posture in figure 4.1 is rated as class 4 which means that further investigation is needed. The Posture in figure 4.2 is rated as class 7, which means that investigation and changes are required immediately. Lastly, the posture in figure 4.3 was rated as class 5 which means that investigation and changes are required soon.

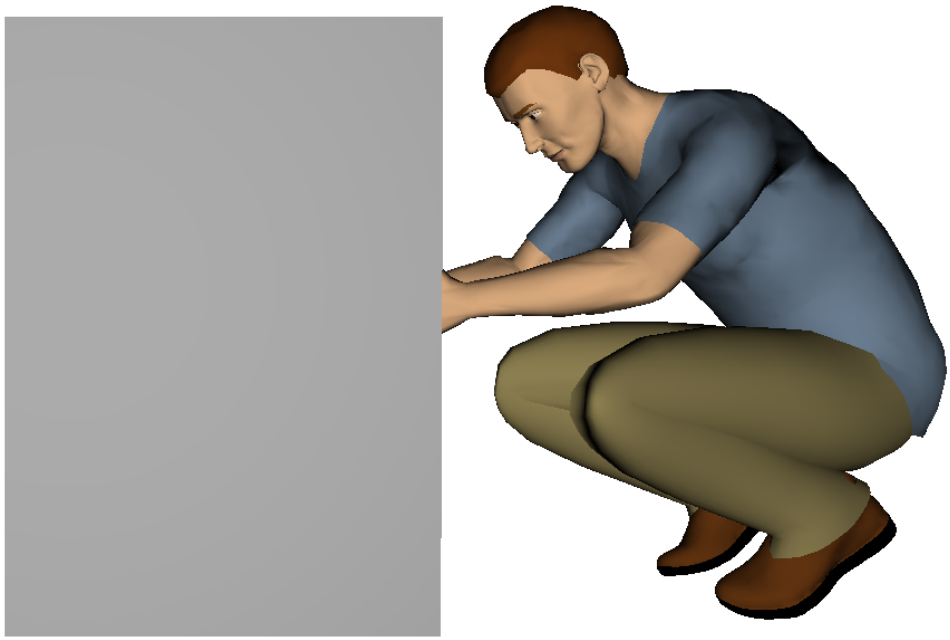

Figure 4.1, Typical loading/ unloading posture, when using a front loader, with bent knees.

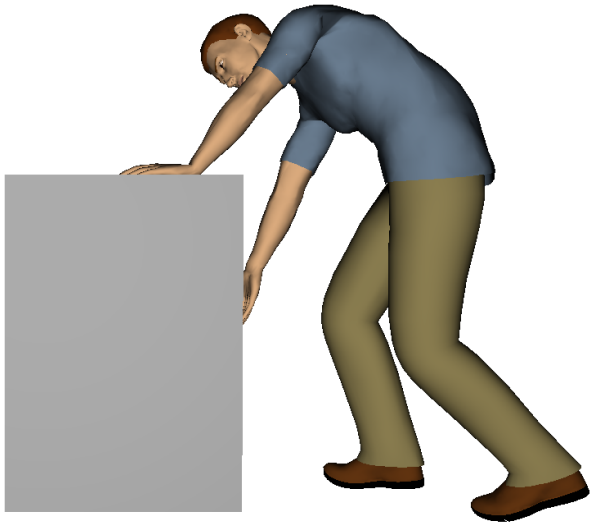

Figure 4.2, Typical loading/ unloading posture, when using a front loader, with bent back.

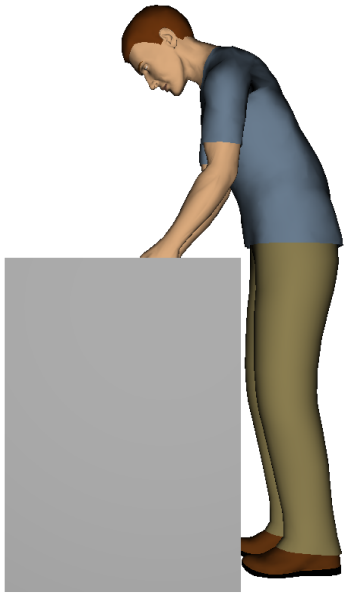

Figure 4.3, Typical loading/ unloading posture, when using a top loader.

4.2 User Studies

The following is solely based upon the user studies performed in this project where a customer journey has been derived from observations of- and quotes from- users whom all uses front-loaded washing machines on a regular basis.

The customer journey

As seen in Appendix 4: Customer Journey Mapping: in a family there are 2 different users of a laundry system. User 1 could be any member in the home who starts the customer journey as he or she realizes their clothes need washing and intends to store it somewhere to be taken care of later. This user does not, necessarily, know how to wash as is the case for most children. The place, the first user most commonly stores the clothes, is in the form of one or more laundry baskets. To some, the choice of washing an item or not could be a very conscious choice where unnecessary washing is preferred to be avoided. One of the informants had a pretty clear picture of when to wash an item and when not to: -"*I consider that garments should be washed if there are stains, if they have an unwanted smell or if they have been used for about two days.*"

User 2 is one or more people in the family who knows how to wash and does most of the laundry in the home. This user usually takes by, in the customer journey, as he or she realizes the laundry starts stacking up and ”filled” washing machine needs to be started. To some informants, this happened sporadically throughout the week: -"*I wash irregularly, whenever I got time*".

After the second user has decided to fill the washing machine, there needs to be a moment of sorting involved and users have several different ways of going about doing so. The categories, into which laundry were sorted, differed slightly between the interviewees: The quotes: -"*I sort the laundry in three categories; lights, darks and coloured.*" and -"*I sort the laundry by whites, lights and darks*" shows a difference where the category of "Light" items are replaced by "Coloured" items. Some also referred to using a category of "Red" items when being uneasy about the potential for bleeding. A common behavior, however, that came up in the interviews, were displayed in the following quote from one of the informants: -"*If there is much laundry; I use to sort it on the floor*”.

When the laundry is sorted; the drum needs to be loaded and whilst some of the informants were concerned wether they would fill the machine: -"*Sometimes lightly soiled clothes are washed to fill the machine*”, -"*I can't say I'm really sure about how much I can fill the machine*"; others were more concerned with the ergonomics: -"*I would really appreciate to be able to stand up during the entire wash process and would really be interested to test a top-loaded washing machine*".

As the washing machine is about to be turned on; detergent needs to be refilled, unless it has an automatic dispensing feature as described in section 2.4, and program chosen. At this stage, some of the interviewees had very separate opinions of the experience; as one informant claimed: -"*I'd like a better structure and more granular control of the wash-programs*" another said: -"*I think I understand my washing machine rather well and don't wish for much to be different*". Regarding the refilling of detergent, quotes like: -"*I'm missing a measuring cup for detergent*" and: -"*I believe that I have somewhat of an understanding about how much detergent needs to be filled but can't say for sure*"

strengthens the point of overdosing detergent as a potential problem regarding the environment.

When all of these, aforementioned, stages are walked through; a moment of waiting is to be expected, as the machine starts washing the clothes, until the user will have to intervene again. The waiting were, for most of the informants, not seen as a very big issue, but rather, a perfect time to do other things like cleaning the clothes that does not work in the washing machine and needs to be washed by other methods such as hand washing. One specifically interesting piece of information was brought to light here by one of the informants: -"*I'm hand washing in a special order just to be able to use the same water for more than one colour; starting with light coloured items, followed by darks and than reds*".

As the waiting is over and the laundry is taken out of the washing machine; drying, and sometimes ironing and folding, comes next. When it comes to the drying of the clothes, there are several options for doing so; except for tumble drying, hang drying and in drying in drying cabinets are also common alternatives. One user, who did not have a dry tumbler available to him but a drying cabinet instead, did not see this as an issue: -"*it is very good that there are drying cabinets, both because it does not wear on the clothes as much and I don't need to iron them afterwards*". Ironing the clothes were not achieved by all of the interviewees and those who did iron their clothes ironed far from every item. The reason for this was voiced by two of the informants: -"*I only Iron maybe once a year; off course the result it is not as smooth as it could be but its a good compromise to save time.*" , -"*It takes too much time*".

As the clothes are deemed finished by the second user, the first user could be responsible for the pick up of their own clean clothes, or in other cases; often when the family consist of young children, the second user does this as well.

Other insights

As questions, not directly linked to the customer journey, were also posed to the interviewees; other interesting tidbits came up as well:

- Some negative opinions about top-loaders and softener, from his experience of the North American market, were voiced by one informant: -"*In Canada, I used a top-loader but it was awful. we didn't have warm water either so it did not feel like the result came out clean.*" -"*Also when in the United States, I used softener which still make my clothes smell of perfume*".
- One interviewee stated what many others deluded to: -"*It is boring, mainly to sort the laundry and to fold it afterwards*"
- An interesting, and unexpected, piece of insight came up during an interview -"*The laundry items are usually much darker in the winter and lighter in the summer due to our choice of clothing*"
- Some people interviewed had opinions about the functionality of today's washing machines: -"*I miss the ability to be able to wash carpets like i used too*"
- Whilst others had very specific demands when choosing a washing machine: -"*I like to be able to adjust the spin speed to really be able to get the water out of the clothes and have chosen a washing machine which could spin at higher speeds than normal*"

4.3 Mapping of Textile Demands

As seen in appendix 2; the clothing materials and fabric types varies allot within several different factors; first of all, the user must know whether to regularly wash it at all or to use dry cleaning or hand washing instead. If several items can be washed at home, this results in several sorting operations just to accommodate these demands. To really undermine the importance of these aspects, it is stated in the report: Potential for environmental improvements in laundering (Laitala, Boks and Grimstad, 2011), that: "When it comes to laundry, both the cleanliness and textiles longevity are important goals".

FABRICS

The first demand comes in the form of different fabrics needing different wash-temperatures and sorts into Cellulose-, Synthetic- and Protein-fibers. Clothing items can be either pure or or a mixture of these fibers. Some fibers fall under the name of delicates meaning they can only be machine washed at low temperatures and with gentle spin speeds. Some fabrics are lint producers while others are lint collectors meaning they can not be washed together. There is also materials that will show signs of shrinkage when washed to hot, for instance, and all items are extra prone to all of these demands when new.

COLOUR

Next there is colour. There are clothes dyed in every part of the colour spectrum and needs to be sorted into whites, lights, darks and sometimes even reds. Uncertainty can definitely arise here as there are also clothes with several different colours. If these demands are not taken into consideration, bleeding of colour from one item onto another will occur.

SOILING

The last, big aspect is soiling which refers to both clothes getting really dirty from stains, and, items which are usually in contact with bodily fluids like underwear and bed sheets. In the first case, the level of soiling usually determines mainly how many items can be washed together for the initial wash-water to really flush out all dirt. In the second case, high temperatures are required to make sure the result is completely clean.

OTHER ASPECTS

- **Items in pockets**
  This always needs to be removed before washing since it can seriously damage the drum.

- **Ownership**
  Different laundry items usually belong to different people and as the items will be stored in a mutual wash pile; a moment of sorting, by ownership, is required.

- **Drying**
  When all of the previously mentioned requirements are considered and the items are washed, they need to be dried and far from all clothes can be tumble dried.

- **Storing**
  When laundry is stored for long periods of time in the drum, after the cycle is finished, it can start to produce odors and when stored for long periods of time in the tumble dryer, the laundry could get really wrinkled.

4.4 Evaluation of Concepts and Technologies

This section presents the results from the evaluation of concepts and technologies by describing them, one by one, and thereafter displaying a conclusion of their advantages and disadvantages.

Description of the concepts

CONCEPTS FOCUSING ON ERGONOMIC IMPROVEMENTS

One common theme, among the different experimental machines and concepts out there, were to make them as small as possible; even to the extent of making them hangable on the wall. This enables the regular front-loaded drum to be placed in the perfect height for the user as well as taking up a very limited amount of space:

- **Electrolux Shine:**
  One such device is the very realistic Electrolux Shine concept, seen in figure 4.4, which confines the drum into a small box with accent lights (Electrolux, 2010).

Figure 4.4, The Electrolux Shine concept

In order of achieving a greater user experience, some concepts tries to combine the washing machine and the laundry basket into one integrated solution.

- **Baguni:**
  The Baguni concept is a small machine in which the laundry basket is a bucket you can carry to the washing machine and put inside the actual drum (Jung, 2009).
- **Orbital:**
  The Orbital concept is quite similar to the Baguni concept as the drum is a sphere that works as a laundry basket while outside of the machine, but, can also be glided into the machine and mechanically rotated to wash the clothes (Roddis, 2008).
- **iBasket:**
  The iBasket concept, however, takes a different approach where the laundry basket and the washing machine is one and the same device allowing for the storing of dirty clothes to be directly inside the machine (Guopeng, 2008). This would reduce the user interaction needed to achieve the same result compared to a regular washing machine.

CONCEPTS FOCUSING ON ENVIRONMENTAL IMPROVEMENTS

As referred to in section 6.3 Environmental aspects, reducing the water usage is a critical part of a more environmentally friendly washing machine. To maximize the washing potential of water, many concepts looks towards a water reuse system:

- **Washit:**
  The Washit reuses the humidity from the shower by integrating the shower and the washing machine into one, isolated cabinet that stores and filters the shower water to be reused in the washing machine (Ilhan, 2012).

- **Humiwash:**
  The Humiwash concept also reuses the humidity from the shower: Intended to be installed in the bathroom and to absorb the humidity in the air to than transform it into steam for washing (Söjtöry, 2013).

- **Cactus:**
  The Cactus concept combines the washing machine with a sink to be able to reuse water from hand washing in the washing process (Gadzhieva, 2014).

- **S'wash:**
  The bigger S'wash project; a collaboration between IMEGO, Akzo Nobel, Swerea IVF, Chalmers, Asko, Unilever and Electrolux and funded by Mistra; all leading companies and research organizations in Sweden; has tried implementing sensors and water tanks into a washing machine to reuse water. The S'wash prototype achieved great, environmentally friendly results by utilizing three tanks to store rinse water from 3 different rinse cycles and than reuse the water in the next wash (Krozer, 2011). The S'wash wash cycle with water reuse can be seen in figure 4.5.

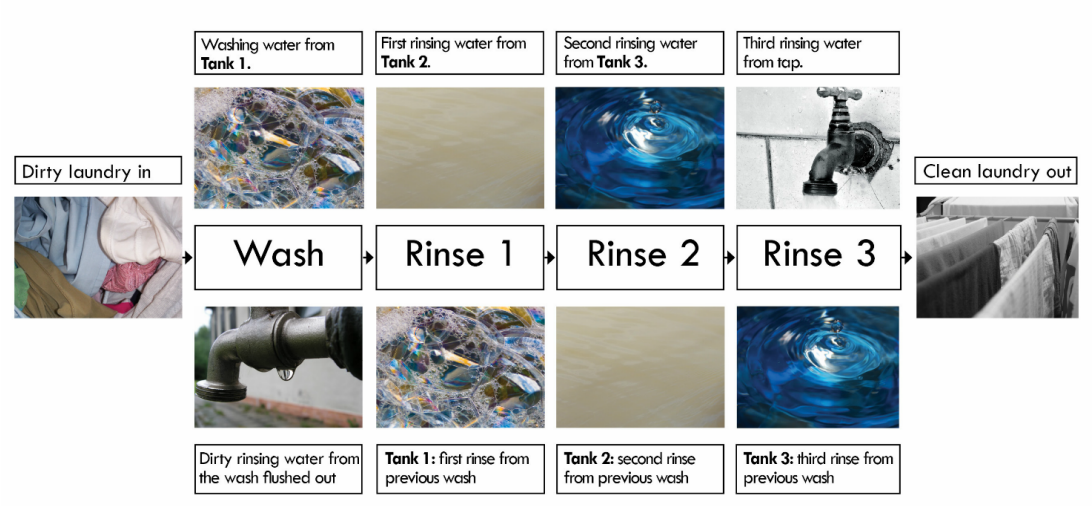

Figure 4.5, The S'wash wash cycle where the water from a previous cycle is stored in the three tanks and reused in different stages.
Original image: Krozer, 2011

As another way to stop the overconsumption of water, some companies has been looking in to replacing the water with other mediums:

- **Xeros:**
  Xeros ltd. is a company that has developed a technology where the water is replaced with millions of polymer beads. These beads can be reused hundreds of times and are fully recyclable. In addition to this, the technology needs less detergent and works in lower temperatures than common washing machines. The technology is so far used in commercial applications but the the company claims to be working on prototypes for domestic use as well (Xeros Ltd., 2015).

A more direct way of going about the problem is making sure not as many wash cycles are performed each year and, therefore, solutions for refreshening clothes, a couple of times before washing them, has become increasingly more popular.

- **Swash:**
  The Swash system, not to be confused with the S'wash project, is a one- or two-item cabinet which refreshes the clothes by steam (Swash, 2015).

- **LG Styler:**
  The LG Styler, as seen in figure 4.6, is a complete locker for hanging a couple of items on racks. These racks shakes the clothes from side to side to refresh them in a steam filled environment (LG Electronics ltd., 2015a).

Figure 4.6, the LG Styler

Less cycles can also be achieved by making sure full loads are washed more often than not. Therefore, several attempts has been made, on a conceptual level, to divide the laundry into segments so that different coloured loads and loads of different temperatures can be washed at the same time.

- **Individual Washer:**
  The Individual Washer concept achieves this by sectioning of a vertical axis drum into three compartments. An agitator runs through all of the compartments to stir the clothes at the same time (Dai, 2010).

- **Dual Wash:**
  The Dual Wash concept makes the divide by putting a smaller drum inside the center axis of a bigger drum, both running on the same power train (Song, 2013).

Conclusion

As concluded and shown in the table below (table 4.1), some of the concepts and technologies were deemed to be more appropriate, for further investigation, than others. As also shown by the numbers; concepts like the Dual Wash, for instance, were not viewed to be a feasible solution as the water from the inner drum would not have any where to go during centrifuging. Technologies like the one in the S'wash project, however, scored high and was seen as very relevant to this project.

Table 4.1, Conclusion of the

Concept	**A**	**B**	**C**	**D**	**E**	**F**	**Total**
Electrolux Shine	4	4	3	5	1	5	22
Baguni	3	3	3	4	3	4	20
Orbital	2	2	2	3	3	3	15
iBasket	2	5	4	5	2	5	23
Washit	3	4	3	2	4	4	20
Humiwash	2	2	2	3	3	3	15
Cactus	2	3	3	3	2	4	17
S'wash	5	4	5	3	4	4	25
Xeros	4	5	3	2	3	3	20
Swash	5	3	3	4	2	5	22
LG Styler	5	4	4	4	3	5	25
Individual Washer	3	4	4	3	4	4	22
Dual Wash	1	3	2	3	4	4	17

A = The concept's level of realism and distance to market

B = The concept's effectiveness at achieving it's main purpose

C = The concept's relevance to this project

D = The probable level of acceptance, from users, regarding the concept

E = The lack of compromises on other aspects than main purpose

F = The level of simplicity in the main idea behind the concept

1 = Low level

5 = High level

4.5 Trend Report

There were distinct trends that were important to the outcome of the project, both directly connected to the field of laundry, including those spotted in the branch, as well as trends influencing the project more indirectly, mainly seen in the evolution of the modern home.

Washing performance

Regarding the theory of sinner's circle, the impact on washing performance from the different factors has changed over the years. In the past; water, time, detergent and mechanical action had a very even ratio between them. Today, that relation has changed where smarter detergent now has the single biggest impact on the cleaning result. In total, all the factors has decreased; shorter washing cycles, lower temperatures, less mechanics and lower detergent dosages can be observed today. This can be attributed to advancements in all areas where the effectiveness has increased regarding all the included parameters (Müller-Kirschbaum, 2009).

The technology of self dosing detergent, based on the weight of the laundry, is a refined functionality that has been limited to more expensive machines and, as described in section 2.4; has been shown to have clear environmental advantages. This technology has started to reach more of the base line washing machines and is a relatively big addition since manufacturers have been focusing on energy saving technologies. Samsung Eco Bubble and Miele Power Wash are two such technologies which are also heavily utilized as marketing material. Except for the addition of self dosing detergent, the market will most likely continue to focus on this.

Connected, smart and learning

The rise of smartphones and apps have led to the incorporation of functions like NFC chips, Near Field Communication, into products to be able to communicate with your phone. The phenomenon, created by the combination of this rapid development of small chips for communication and the new use for the internet as a pipeline between them, has been dubbed the Internet of Things and fuel's the dream of the smart/ connected home.

One company on the verge of this trend is Nest Inc. Their focus lies on just this market and the Nest thermostat, seen in figure 4.7, and Nest Protect fire alarm, their first two products, connects to the internet and learns from your behavior to both save energy and to deliver a greater user experience (Nest, 2015).

Figure 4.7, The Nest thermostat

5. Basis for Concept Development

This chapter will present the groundwork for the concept development by first summarizing the most important insights from the pre-study and thereafter by clarifying the intention with the concept development. By doing so; a good basis for creating a complete design solution, which solves the main problem (which was defined as "Dirty textiles can not be used until they are cleaned") without regenerating the problems found in todays washing machines, could be laid out.

5.1 Most Important Insights

IDENTIFIED PROBLEMS

The behavioral studies resulted in the identification of several problems in today's washing activities. Many of these reoccurred in both the literature and the user studies which indicated that they were important to consider. The table below (table 5.1) shows a compilation of these problems, combined with factors that was identified as influential for each problem.

Table 5.1, Conclusion of the identified problems and underlying influential factors

Identified problems	Influential factors
High washing frequency	• Norms about freshness and body odors • Routines and habits • Hard to define soiling level of the garments • Airing, which reduces the need for washing, is generally a rarely used technique
Washing without filling the drum	• Hard to collect enough laundry of one sort (because of the large number of laundry categories) • Sometimes the user needs one specific piece of clothing at a specific occasion.
High washing temperature	• Routines and habits • Fear for that laundry, washed in low temperature, will not be clean enough. • No clear rights or wrongs regarding the washing temperature (which is indicated by the average European washing temperature)
Overdosing of detergent	• Unclear amount needed
Complicated sorting	• No integrated solution for sorting • Different requirements for different types of textiles • Many wash programs

INFLUENTIAL FACTORS

In the pre-study, a lot of information about influential laundry factors were investigated. To give an overview of the most important ones, a compilation of them are shown in figure 5.1 below. The aspects are categorized in the same way as in the process overview (section 3.1), with main categories in the form of Laundry, Human, Contextual and Technological factors.

Figure 5.1, Overview of the most important influential laundry factors.

5.2 First intention

To further define and develop the intention of the development stage, based on the goal from section 1.2; the key lessons, for how to reach that goal, were the following:

- The norms and standards associated with washing needs to be questioned to be able to find a solution that differs from the washing machines of today.
- Further research, of the possibility to include refreshing in the final solution, needs to be achieved since most clothes simply doesn't need washing.
- Washing needs to be a more fun and emotional experience. This should be researched further.
- Except for the environmental issues, the ergonomics of washing is the second most important factor to attend to.
- The fact that washing machines are usually not at work during night time and when people are not at home, to instead need constant reloading and overseeing, seems like a key area to improve upon.
- The low usage of the environmental options are a waste of potential in many washing machines and should not be repeated.

5.3 Target Audience

When having a larger understanding of the problem at hand, exactly for whom the design was intended for, were pinned down. The target audience was defined as families of more than two members; usually consisting of two adults and one or more child. This target group were to be the foundation behind many of the later design choices.

Regarding the customer journey, this target audience stands out in many ways: When the children are of a young age, the wash loads are generally larger. Also, at this stage the identified first user, as presented in section 4.2: is basically exactly the same as the second user due to the incapability of most small children to take care of their own clothes. As the children of the family gets older, however, and they start to be able to decide by them selves wether to wash their clothes or not and deliver them for washing, the two users gets more pronounced. When the children turn into teenagers and eventually young adults, they start to learn how to do the laundry by themselves and the two different sorts of users become one again.

Also, regarding anthropometrics, this target audience can vary in pretty much the entire spectrum. The parents could be very tall, for example, while the teenagers, using the same device, could be only half the height. These sorts of scenarios were very important to keep in mind in the development stage.

While this target audience would be the ”early adopters” of the intended solution and the solution were to be focused on this group, it was not supposed to make it unusable for any other demographic: Once the young adults move out of the house, for instance, the owners of the device would fall out of the target audience and the device should work just as well for them then.

6. Concept Development

This chapter will make the case for the final concept by describing the procedure that was used- and the argumentation that was made- to achieve it. First, some of the best ideas ,that were derived from several different points-of-view, are laid out to show upon the breadth of the investigation. This is followed by an argumentation, about why some ideas were followed upon and why some were not, to then be summarized into an conceptual essence. Lastly, the refinement of the winning solution is described to show upon the depth of the investigation.

6.1 Ideas Derived from Fundamental Rethinking

Process

By going back to the main problem as well as being open minded; an idea generation, that were unaffected by earlier influences, became possible. As a result; completely new ideas of how to fulfill the need of washing, were generated. The ideas started by trying to solve, at the predetermined boundaries of the project and with the main problem in mind, a scenario where the user decided an item needed to be cleaned and immediately gets it washed, dried, ironed and folded; thereby ending up clean and ready for use in the hands of the user again, without any work done. This pursuit was further divided into the following approaches:

AUTOMATIC
This meant looking at the kinds of solutions that would be as automated as possible; reducing the amount of interaction needed with the device, reducing the time and energy spent by the user as well as ruling out user error as much as possible.

FULLY INTEGRATED
An all-in-one solution was also sought out as this is usually an advantage to the user and makes for a more simple and graspable machine whilst simplifying or even eliminating the transfer of clothing. The Idea was to create a machine that had every moment from sorting to folding integrated into one and and the same device.

MORE DIRECT
Lastly, early ideas were also supposed to be more direct than what exists on the market today, regarding the customer journey, where steps would be merged or avoided. According to the Oxford English Dictionary (2015), more direct means: "Proceeding from antecedent to consequent, from cause to effect, etc.; uninterrupted, immediate."

While this sort of thinking is very important and paves the way for later, user-centered ideas that are actually realizable while at the same time pushes the envelope, to really achieve advantages, regarding environmental -aspects and others, there also needed to be ideas from other points of view, as described in the following four sections.

AUTOMATION

- **Revolver Machine:**
  Some ideas achieved by this kind of thinking were about the machine being able to self-load; one idea were to do this by sorting into a revolver-kind-of functionality, as seen in figure 6.1, where the loads would drop down one-by-one into the drum.

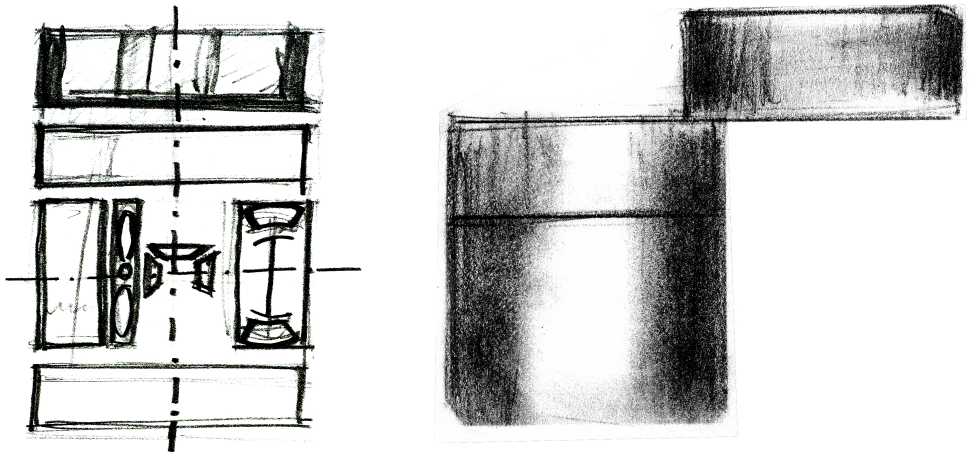

Figure 6.1, The revolver washing machine

- **NFC:**
  To take this a step further, the small NFC-chip trend, as mentioned in section 4.5, inspired to ideas of machines that would not even need a sorting moment but instead would read from NFC tags embedded into the clothes (see figure 6.2). This idea is also discussed by Busch (2006).

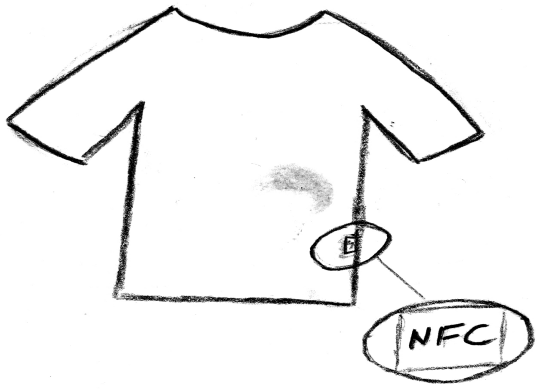

Figure 6.2, A clothing item with an embedded NFC-chip.

FULL INTEGRATION AND MORE DIRECT

- **Separated Drum:**
  The idea of a separated drum (figure 6.3) meant sorting could be, partially, achieved directly into the drum. This meant sorting would be integrated and not outside of the system boundary of the final solution.

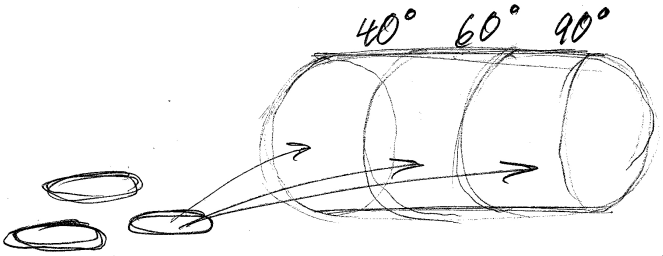

Figure 6.3, A separated drum into which clothes can be directly sorted.

- **Walking Laundry:**
  One more direct idea idea, compared to the solutions of today, was of a walking laundry, as seen in figure 6.4; a combination of a walking closet and a laundry room which would centralize the clothes and washing to the same place. This would enable and generate advantages where the user could, for instance, hang the clothes to refresh at the same place as they get dressed; thereby making refreshing solutions accessible to everyone in the family.

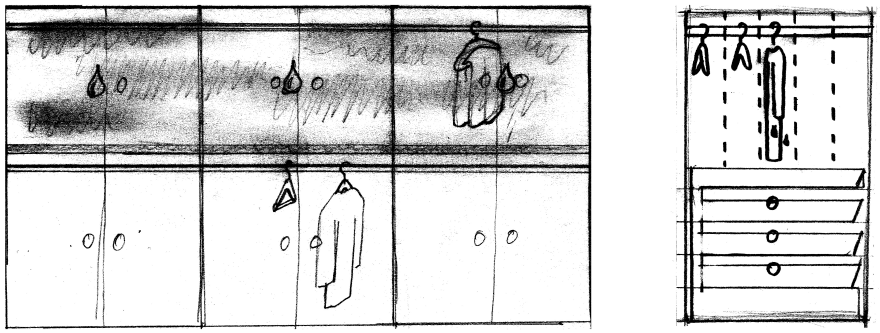

Figure 6.4, Different wardrobes that could make out a walking laundry.

- **Soft Hangers:**
  This thinking also resulted in ideas like soft hangers (figure 6.5), being able to be put directly into the drum without damaging both the drum and itself, therefore making hang drying much less of a hassle.

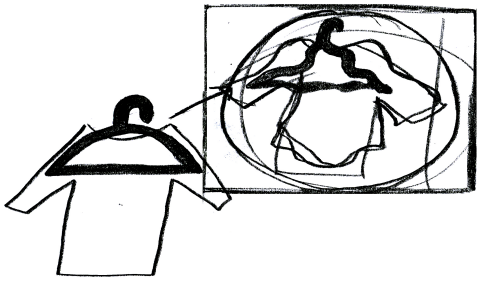

Figure 6.5, A soft hanger together with a clothing item being washed.

6.2 Ideas derived from environmental adaption

Process

By looking at the current environmental situation and all the problems described in section 2.4: The following areas were pursued as a direct answer:

WATER AND ENERGY REUSE
In order for the machine to operate as normal but save a lot more water in the process, a water reuse system was researched. Energy saving solutions was also sought after by ideas of reusing the mechanical and thermal energy within the system

COMFORTABLE SOLUTIONS
The idea was to solve the main problem from an environmental point-of-view by not adding more hassle in and of itself, neither environmentally nor physically. This reasoning is also argued by Laitala, Boks and Klepp as cited "It will be easier to argue for change when the consideration for the environment is not in conflict with other values" (Laitala, Boks & Klepp, 2011).

Results

- **Water filtration:**
  A water filtering system (figure 6.6) was imagined and combined with a self-loading detergent mechanism; all of this would be incorporated into a Washer-dryer combination. If including a subscription- and deposit- system; the water-filter, the detergent-container and the lint filter could all be combined into a single item to buy and deposit, thereby taking full advantage of filter and container reuse.

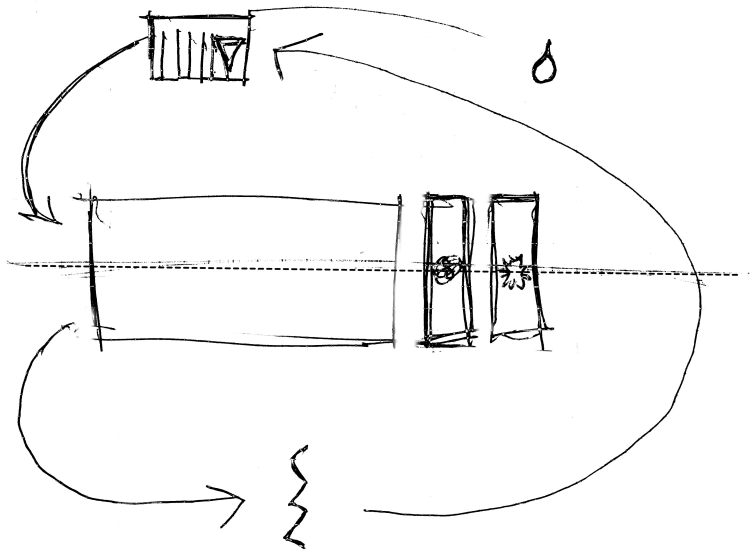

Figure 6.6, A water filtering system together with a detergent and filter deposit system.

- **Right order of washing:**
  The idea was to use a correct order of washing based on hand washing principles (figure 6.7): In hand washing, to be able to make use of the same water for light and dark colours of clothing, the light coloured items are washed before the dark ones since there will occur no bleeding this way. This principle could also be used in a washing machine and mean water reuse would no longer be limited to similarly coloured loads.

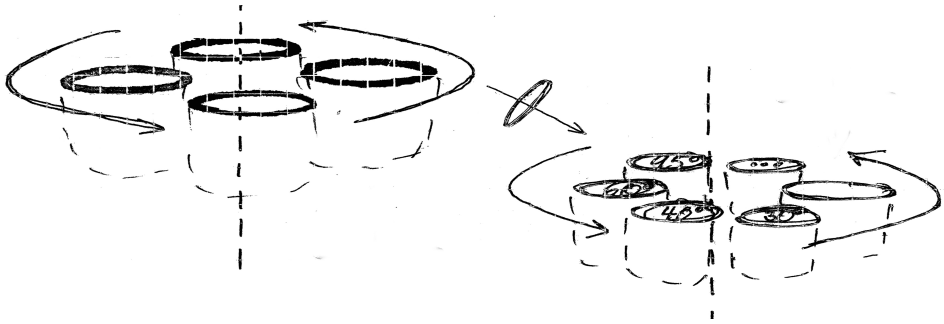

Figure 6.7, An imagined system that could load laundry in a correct order.

- **Separated drum:**
  Once again, as it was also mentioned in section 6.1, the idea of having two drums for the sake of one came up. This time, the idea referred to running both on the same power train and thereby saving energy as two loads of different colours could be run at the same time (figure 6.6).

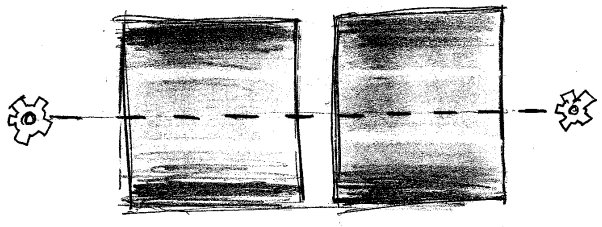

Figure 6.8, Two drums running on the same power train.

- **Thermally isolated:**
  By making the entire machine thermally isolated (figure 6.9), the amount of lost energy in the system could be significantly reduced.

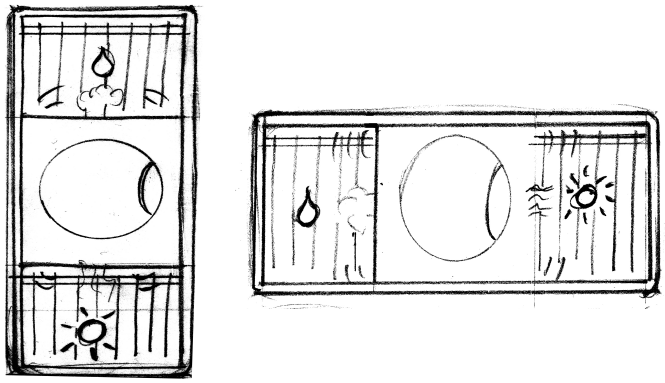

Figure 6.9, An isolated locker which maximizes both water and energy reuse.

6.3 Ideas Derived from behavioral adaption

Process

By looking at how the behavior, when washing clothes, influenced both usability and the environmental impact of washing; a machine were imagined, functioning similar to what is on the market today, but where the design is adapted to the most common behavior achieved by users while using washing machines. Also, Inspired by the trend of smart and learning technology as described in section 5.2, a machine that usually operates when people are not at home or sleeping was researched and meant counteracting the feeling of not being able to leave it running due to safety risks.

Results

- **Connected laundry baskets:**
  ideas of using probability to fill the washing machine in tandem with connected laundry baskets (figure 6.10), aware of their degree of filling, could result in less washing cycles achieved per year. This could work together with the use of notifications on your smartphone, telling you which colour there is time to wash.

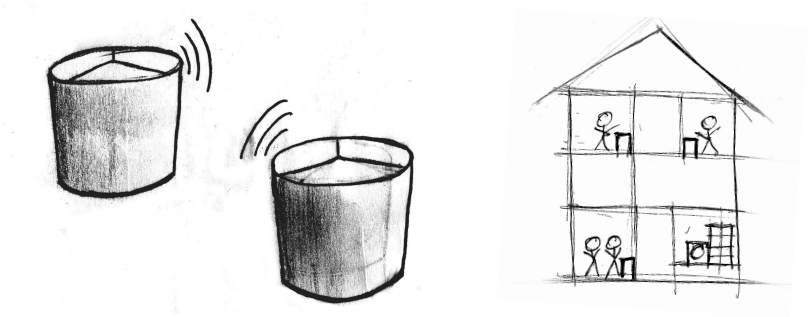

Figure 6.10, Connected laundry baskets which could be placed throughout the house.

- **Levels of interaction:**
  One idea was to adapt to the two different users identified, presented in section 4.2, by using the choice of the first user as well as design for the two different understandings of washing. Thereby, a more direct and automatic solution without moving parts were created. This idea was imagined in a guiding locker as seen in figure 6.11.

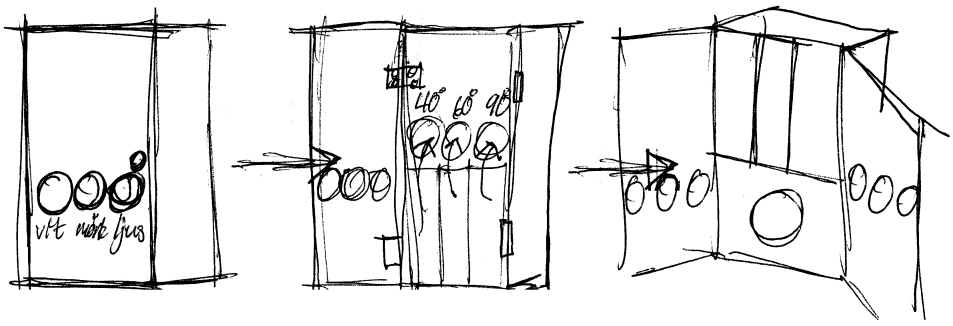

Figure 6.11, A guiding locker.

6.4 Ideas Derived from ergonomic adaption

Process

As mentioned in section 4.1, the ergonomics of current washing machine are bad. As a response to this; ideas, mainly looking at drum based washing but also just regarding optimal working height, were generated to solve this. Many different drum-opening variations where the result as well as ideas for procedural advantages as well.

Results

- **Different lid variants:**
  Some interesting lid variants that were imagined were the following: the drawer lid, pulling out the drum like it was a drawer; the grill lid, lifting a lid exposing the drum much like in a grill; and the visor lid, sliding up the lid, in much the same way as a helmet visor, to get access into the drum; all seen in figure 6.12.

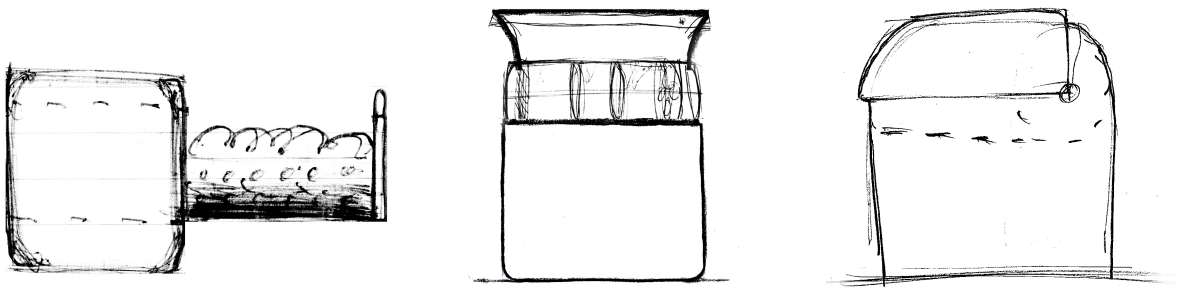

Figure 6.12, The drawer lid, the grill lid and the visor lid.

- **Laundry-dispenser:**
  The idea of having a spring inside the laundry basket much like in a plate-dispenser would bring the clothes up to the users level instead of having to bend down (figure 6.13).

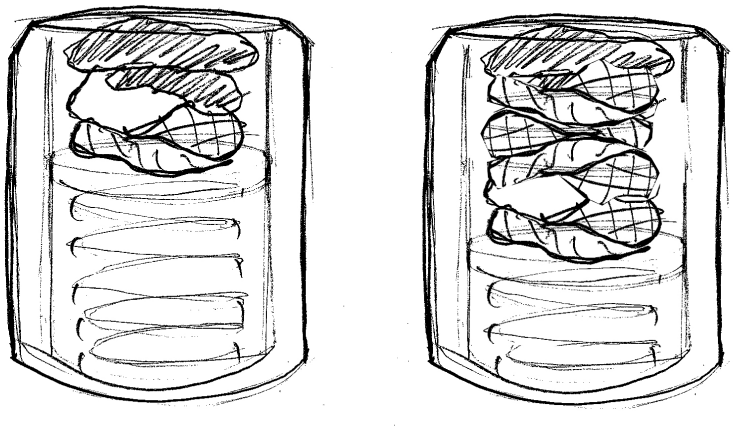

Figure 6.13, The Laundry dispenser loaded to different degrees.

6.5 Ideas Derived from reverse engineering

Process

By dissecting and trying to reverse engineer the washing machines of today; a large amount of ideas for structural improvements were the result. These ideas were mainly focused on improving the environmental aspects.

Results

- **Integrated Euro Pallet:**
  The large amount of free space in the washing machines standard 60 by 60 by 85 cuboid left space for the integration of a Euro Pallet (figure 6.14). An improvement which, if realized, would mean a large saving of space and effort during the transportation process.

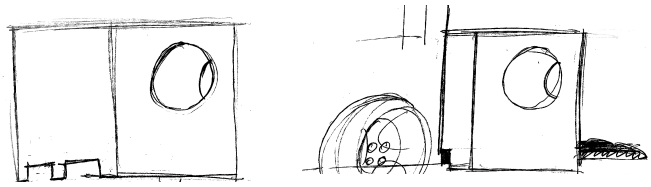

Figure 6.14, A washing machine with an integrated Euro Pallet.

- **Concrete Supplement:**
  As a reaction to the heavy, polluting and banal concrete slab; the incorporation of a water tank, much like in a parasol stand, where the tank would be emptied during transportation and end-of-life stages, would give much benefit to the environment (figure 6.15).

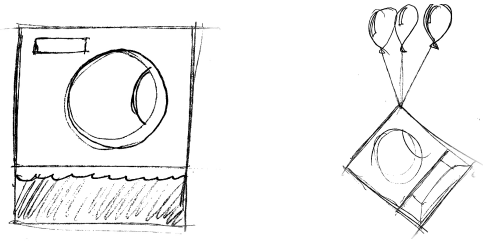

Figure 6.15, A washing machine with a water tank instead of the concrete weight.

- **Module based:**
  Based on the normal life-span of washing machines, as referred to in section 6.3, in contrast to the life span of the incorporated materials; a modular platform would make sense to incorporate where the different parts could easily be switched out (figure 6.16).

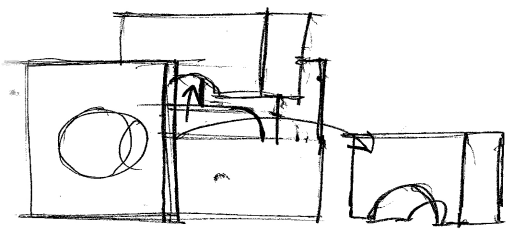

Figure 6.16, A washing machine with easily interchangeable parts.

6.6 Insights from Seeking Feasible Solutions

Process

Since there is no machine that has ever been created with no human interaction; an Iteration towards realism, that could result in more real ideas where the user is more involved, were critical.

REALIZATIONS

From there, the solutions quickly iterated towards what kinds of technology existed on the market. The design then needed to supply a great interaction experience with as supported steps as possible. Also; designing the interaction that were unavoidable with the theories of Design for Sustainable behavior, as mentioned in section 2.1, in mind was crucial and were of special importance when solving a problem as complex as laundry.

SEEKING THE TECHNOLOGY

As the idea of a water tank imbedded into the solution started making sense; the search for such a technology commenced. This search led to the discovery of the Swash-Sustainable Domestic Washing concept, as first described in section 4.5. The S'wash project; had researched and proven the idea to be possible by their prototype. From there, interaction was made with both Fredrik Hallgren at IVL Svenska Miljöinstitutet and Anne-Charlotte Hanning at Swerea IVF to further research what demands this technology would place on a design based upon it.

Results

- **Delimitation to solely focus on drum-solutions:**
  Firstly, when it comes to the actual washing functionality; the realization, that a drum washing solution was the way to go, appeared at this point. This choice of going with a drum-solution were mainly made to make sure the concept was realizable in a not-to-distant future.

LESS AUTOMATIC

- **Not to go with a washer dryer combination:**
  Regarding the integration of a washing drum and tumble dryer; some of this technology is displayed in a washer dryer combination but where the drawbacks of such a device, as stated in section 2.4, makes it far from optimal from an environmental point-of-view.

- **More Interaction from the user is needed:**
  Also; the extreme variety of different clothes, as stated in section 4.3 and seen in appendix 2, needed attention and is supported by most commercial-market products; focusing on being able too clean a smaller variety of textiles would make an automated sorting process much easier to achieve. This drawback, of not supporting by far as many different clothing types for the sake of automatization, though, would be very hard to pitch to consumers. Therefore input from a user was needed.

- **Going for more direct solutions:**
  As the machine would be less automatic and make use of more human interaction; it made sense to make use of the very direct solutions that had been generated since they would have, to a certain degree, the same effect as mechanical automatization.

SHAPE AND SIZE

- **Going for washing only:**
  As stated in section 4.4, space is, in many parts of the world, a scarce resource. As a washer-dryer combination was out of the question; integrating one drum for washing and one drum for drying in the same machine was considered to simply be too large.

- **To question stack-ability:**
  Going with one drum solely made for washing instead means drying had to be considered as a standalone device. As seen in section 5.1, normal tumble drying is not good for the environment. The question is then, if chosen not to incorporate a tumble dryer into the machine, wether the customer will go out and buy a tumble dryer anyway. If that is the case, having not designed for ”stack-ability” will result in the two machines taking up double the floor area after all. As normal washing machines and tumble dryers are, both, made to be able to stack on-top of each other and to have a work-surface for sorting of clothes; they are required to have a flat surface on at least one of the two machines. If the machine is going to be designed in unison with a tumble dryer and the choice would be up for the user to choose weather to stack the machines, place them side by side or separate from each other; The centered, front-loading drum is about the only way for placement. This meant if the intention were to design a product that is better than todays washing machines, from an ergonomic point-of-view, this sort of stack-ability and work-surface functionality needed to be questioned.

- **To design for sorting:**
  Then having designed for integrated sorting, as the ideas of an integrated laundry basket applies, means the workbench is not needed to the same extent. In the same way, like with the laundry basket, there were also possibilities for an integrated laundry drying stand.

- **To pursue horizontal axis drums:**
  Further, this drove the discussion for front-loaders versus top-loaders, where the preferred design would be having the environmental advantages of front loaders whilst having even better ergonomics than top loaders, as described in section 4.1. As there is no clear disadvantages of top loaders with horizontal axis drums however, except for stack-ability, this was the technology that was pursued.

S'WASH-SUSTAINABLE DOMESTIC WASHING CONCEPT

- **To address the issues of the S'wash concept:**
  The S'wash project expressed two significant problem areas: the storage of water in the tanks for more than 24 hours resulted in fast bacterial growth, only solved by the use of biocides; and; the saving of energy based on the lowering of washing temperature, thereby risking the resulting level of cleanliness.

- **Water filtering does not work:**
  Further, the ideas of water cleaning and filtering was also researched but the technology seemed to be to large and complicated for the implementation of such a technology in domestic washing machines as of this point; this is also argued by the S'wash project (Krozer, 2011).

6.7 Direction of Further Development

Process

Based on the previous results and discussion, the ideas that were deemed most feasible, and worked extremely well together with others, were combined. This combination then turned into a conceptual direction where the whole was deemed larger than the sum of its parts. This supposed to be the very essence of the design, and thereby ending up as a list of criteria which the embodiment of the design were supposed to fulfill. The essence could not be anything other than a machine that made for a seamless, and almost automatic, experience for the user, while having clear environmental pros. The big focus of the conceptual direction were the reuse of as much water and energy as possible.

Results

FUNDAMENTAL IDEAS AND IDEALS TO FULFILL:

- **Water and Energy Reuse Technology:**
  The final solution were to be based on the swash technology, an internal system that combined the 3 water tanks with the idea of using a divided drum. this would resolve the problem of the swash-prototype were the water needs to be reused as soon as possible. By instead "locking-up" as much clothes in the machine as possible and running the two drums asynchronous from each other means the second drum can reuse the water from the first. This could also be used to save energy as the heat can instantly .

- **The correct order of washing:**
  The idea of using a right order of washing, as first mentioned in section 6.2, meant much more water could be reused as well as make sure the time between washes, that makes use of the stored water in the tanks, were reduced to avoid bacterial growth.

- **Levels of interaction:**
  When having identified the two users; as seen in Appendix 4, It was clear that the washing device needed to accommodate the two different behaviors. Therefore, levels of interaction were developed much like the ones seen on many tv-remotes. User 1 will be met by the laundry basket while User 2 would be able to transform the device into a great station for washing clothes.

- **The merger of sorting and interfacing:**
  The opinion were that the best interface is as little interface as possible and there should be no difference between the interface and the machine itself. Therefore the idea here was to make use of the sorting, where the choices for temperature, colour and program were already made instead of most of the interfacing; this would thereby mean the user would not make any unnecessary interactions with the machine.

- **Maximizing the chance:**
  The behavior, that the design wishes to inaugurate, shall not be forced upon the user but the user shall be merely encouraged and guided to it. This will over time achieve a rhythm where the baskets are filled and emptied in the order as preferred by the machine. The machine also learns and gets better much like the very successful Nest thermostat, as mentioned in section 4.4. All of these aspects together, maximizes the chance of the user washing in a more environmentally friendly way.

EMOTIONS TO EVOKE:

As seen in appendix 5 and derived from the aforementioned starting points; the emotions that was sought to be evoked by the design were the following:

- **The feeling of being Enabled:**
  The design should provide the user the sense of being enabled, supported and in control of the washing while still keeping the sense of clarity and simplicity in the task ahead. This is expressed, in the mood-board, by pictures of a helicopter cockpit, a stovetop and a radio tuner.

- **The Feeling of True Freshness:**
  As seen in the images of bubbles, clean water, and vibrant-coloured clothing in the mood-board; the design should evoke feelings of freshness, effectiveness and efficiency. The user should feel that he or she is using a sophisticated, environmentally friendly machine that takes good care of the clothes that it washes.

- **The Feeling of True Craftsmanship:**
  The physical embodiment should breathe craftsmanship, elemental form, state of the art technology and design. This is expressed, in the mood-board, by pictures of green technology, sophisticated patterns, stainless steel details and the raw process for making them.

PHYSICAL PARTS TO INCLUDE:

- **3 tanks:**
  The three water tanks, specified by the S'wash technology, were to be imagined and calculated for into the embodiment. With a volume of 15 liters each, these were key for the solution to be more environmentally friendly.

- **Laundry Basket:**
  As argued in the report "Fit for Washing: Human Factors and Human Factors of Washing Machines" (Busch, 2006); if designing a washing machine with the placement of the drum at the most ergonomically optimal position possible, the ergonomic advantages are all lost if the laundry basket is placed on the floor and makes the user bend all the way down to make high lifts. Another reason to make an integrated laundry basket was to really take advantage of the choice that is made by User 1 when dumping the dirty clothes for washing.

- **The divided drum:**
  The case for the divided drum includes both advantages to users as well as the environmental performance of the machine. From a users point-of-view, it extends- and gives support for- the moment of sorting where the user can sort directly into the drum and not on the floor, as shown in section 4.2, to be a recurring behavior. The second user would be able to sort one of the colour-sorted piles in the laundry basket, by what works together regarding other parameters, directly into the drums. This would all be possible if the the drum and wash baskets are of the same volume. This would also mean the user does not need to sort any clothing outside of this system.

This integration of laundry basket and divided drum, where it is first the dividing into colours and then by secondary parameters directly into the machine, that makes the merger of sorting and interfacing as well as the correct order of washing all possible.

6.8 The Two Concept Embodiments

Process

After defining the direction of further development, conceptual solutions for how to embody all of the ideas were sought out. The result of this search were two different interpretations which lived up to the criteria, of section 6.4, in different ways. Both of these concepts left out the drying for further investigation. These two concept were then pitted against each other, as seen in Appendix 6, and a winning, final concept were appointed. These embodiments were the following:

Results

- **The Cabinet:**
  The most integrated embodiment of the essence were a collection of all the functions into one, single device (Figure 6.17). To make the case for the larger size, this meant it would have to come in two variants: a smaller version intended for the bathrooms of homes where space was very limited; it would include just the needed components including the incorporation of a washbasin and thereby taking the place of the wash locker in the bathroom. The second combination was bigger an intended for homes with a laundry room. This bigger version included a work surface and a rough sink instead of the basin. Also, both of these versions would come with customizable aesthetics matching the decor.

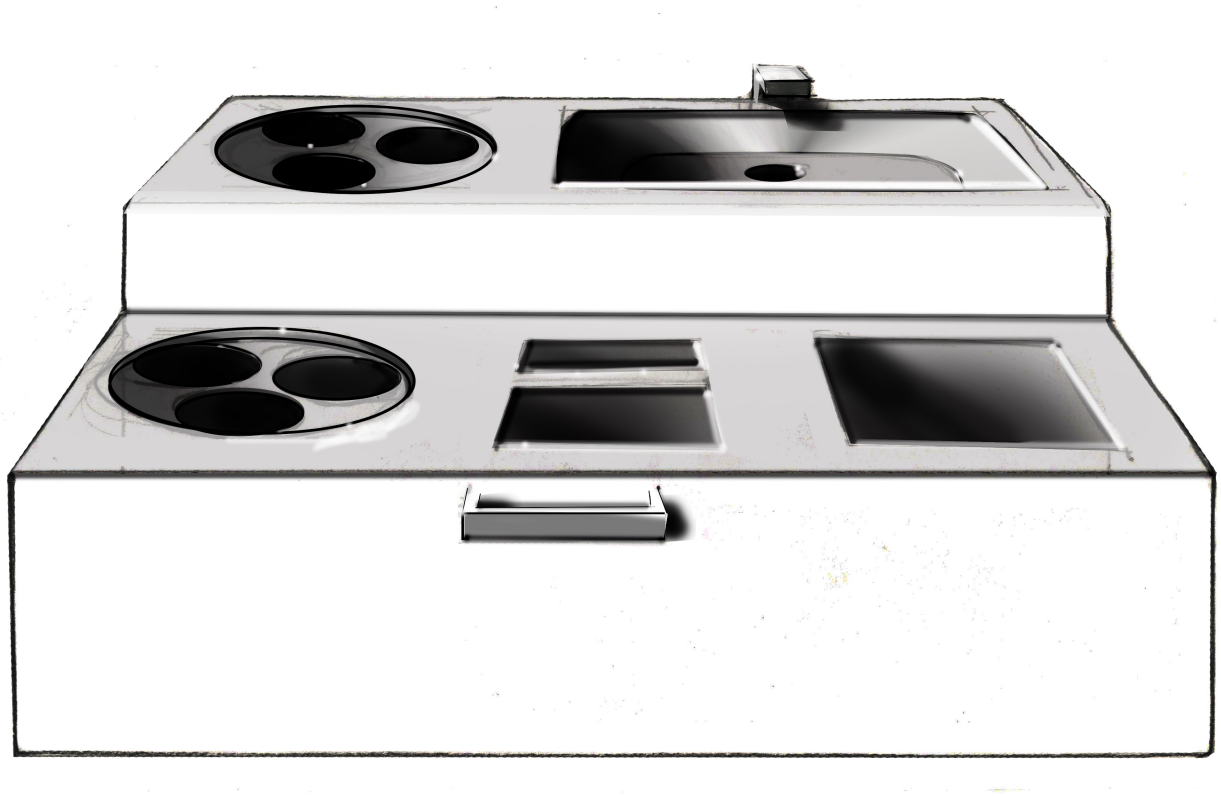

Figure 6.17, The Cabinet concept with the drawer extended exposing the drum and UI.

- **The System:**
  For the sake of space-saving, a divided, module-system, living up to the criteria in section 6.4, by two separate devices: a laundry basket on wheels and a stationary washing machine were imagined (Figure 6.18). The washing machine puts the drum in an optimal position for the user while the laundry basket gives support to the whole process. The laundry basket can be rolled to the optimal position for off-loading clothes and then be rolled back a place where it is not in the way.

Figure 6.18, The System concept with the laundry basket on the left and the washing machine on the right.

6.9 Concept Refinements

Process

While having announced the System concept as the winner of the two embodiments, further perfection of this concept was made. By further evaluating form and function of the concept through physical modeling, the overall shape and size could be determined. Through surface design, the details and more exact dimensions of the concept were pinned down to achieve the final concept, as described in the following chapter.

Results

DIMENSIONS

- **A rounded top:**
  What the conceptual washing machine were, was a drum, open on the side and positioned in just the right height, while the rest of the machinery were logically placed below. This shape meant the top would be rounded of for the user to have a direct access to the drum from his or her point of view.
- **Higher and more shallow:**
  The concept were designed with dimensions that improved the ergonomic situation compared to today's washing machines. A higher and more shallow device were the result of the final iteration. The shape and posture, seen in figure 6.19, were evaluated, by using the RULA method in Siemens Jack, and resulted in a class 2 rating: "Posture acceptable if not maintained or repeated for long periods."

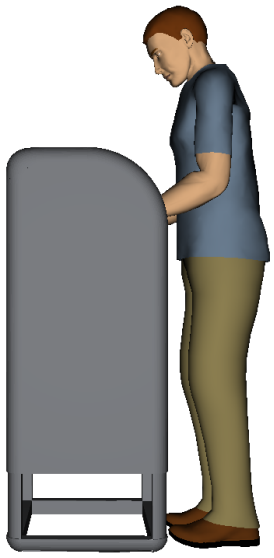

Figure 6.19, The intended outline of the machine and posture of the user to be used in the final concept.

LEGS

- **Adjustable legs were needed:**
  The integration of adjustable legs would make sure most users could use the machine at the right hight as well as make the machine reusable by different people with different needs. Legs were thereby incorporated into the concept and meant the height to the middle of the drum was adjustable by 20 cm.

- **Cage configuration, with rounded corners, for legs:**
  To let the legs continue the shape of the device simply and seamlessly in a cage-like configuration, the silhouette or outline of the device is thereby retained. At the same time, it is a very stable solution as feet.

LID

- **A visor for lid:**
  The concept were chosen to be opened through a Visor lid, an idea mentioned in section 6.4. This was refined to a solution where the outer tub was opened and closed via a sliding hatch, covering the drum, and the drum would slide open, in the same movement, via a sliding hatch as well.

- **A recessed handle:**
  The handle, which were supposed to help open the hatch, was designed to blend in with the entirety of the machine and was therefore recessed into the lid.

INTERFACE

- **Low placement of the Play/ Pause button:**
  The fact that the interface is placed on a curved surface enables a feature. By placing the play/pause button in the lowest position, where the surface is closest to being vertical, it could easily be seen from a distance.

- **Visible Play/ Pause button and hidden UI:**
  As the lid is closed, only the play/ pause button, showing the duration of the running wash program, is visible of the UI. This is meant to create the two levels of interaction as the first user is only met by a closed lid and a laundry basket. When the lid is opened the drum and the interaction panel are revealed. The idea with this was also to give the user the sense of being enabled, which was one of the desired emotions mentioned in section 6.7.

- **The UI in the middle:**
  A good viewing angle, when close to the machine, is achieved by placing the UI in the middle of the curved surface. As the machine is height adjustable through its legs, this position will remain the same for any user.

7. Final Concept

The concept development process resulted in Greenwash; a concept built on the fundamental idea that the design should give advantages for both the user and the environment. This is achieved by a combination of technological and user-centered ideas that together form an integrated system. This combination benefits the user to wash in the right way while also simplifying the laundry process. By designing for sustainable behavior in this way; the concept maximizes the chance for the user to behave in a way that is most beneficial for the environment.

7.1 Concept Overview

The main idea is built around a system, including a washing machine with an innovative new design, together with a custom made laundry basket which is integrated into the laundry process. Figure 10.1 shows the two devices and gives an overview of their most important functions. A more detailed description of the system will be presented in the rest of this chapter.

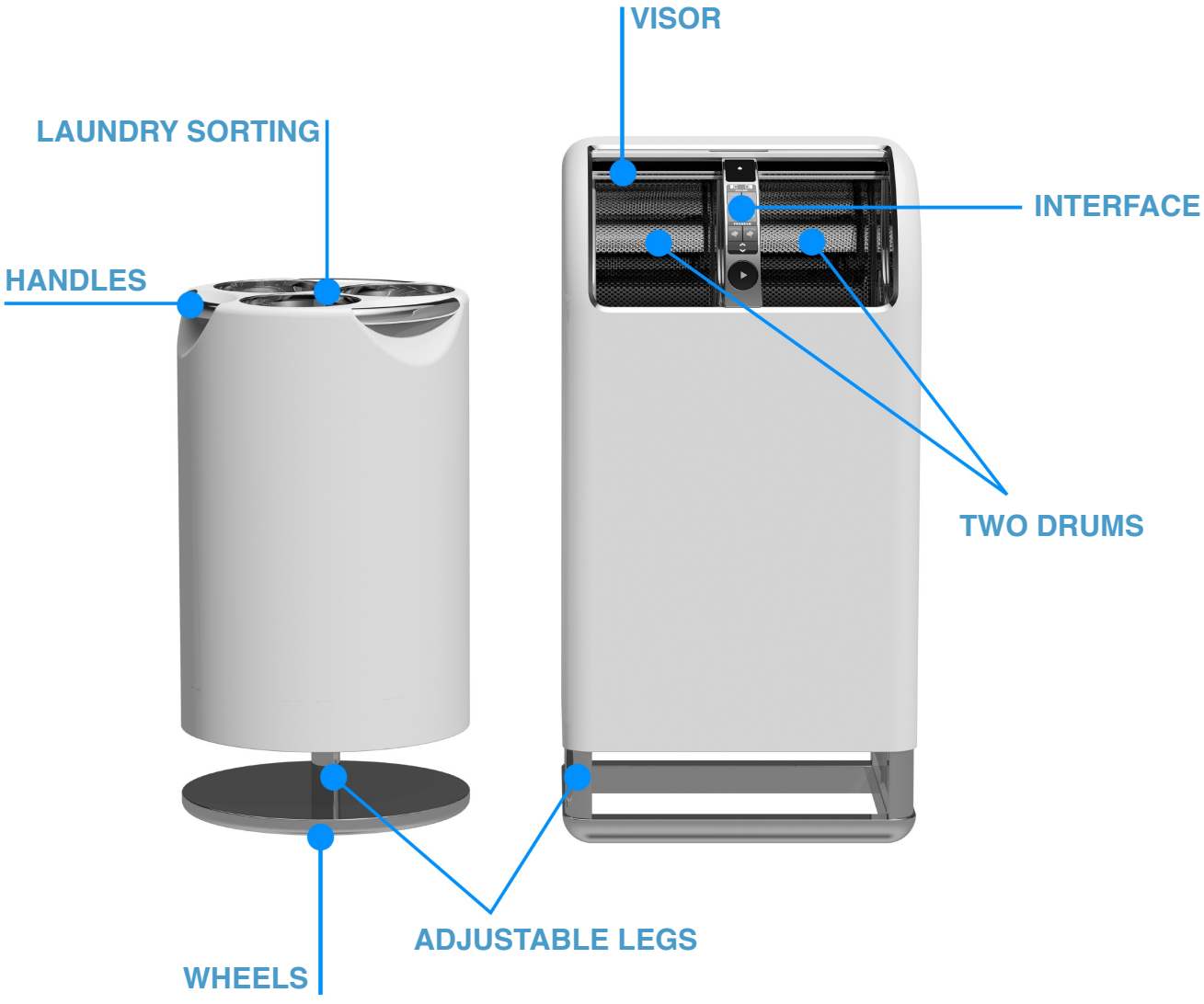

Figure 7.1, Overview of the Greenwash washing machine.

7.2 User Experience

Two loads, one cycle

A key feature of the Greenwash washing machine is that it has two drums (see figure 7.2). Because of this, it is capable of handling two different laundry loads at the same time; even if the colour, the temperature requirements or the soiling level of the laundry differs.

The advantages with this can easily be explained by comparing Greenwash to a common washing machine. This is done in the following two paragraphs.

First of all the wash capacity can, with higher probability, be utilized in a more efficient way in the Greenwash washing machine. The reason to this is that common washing machines require one single type of laundry to fill the machine but with Greenwash two different loads can be combined to fill it.

Another advantage can be found in a scenario where the user has two different laundry loads that he or she wants to wash, but none of them is large enough to fill the drum. By using Greenwash, these two loads can be washed simultaneously which both saves time and also reduces the need for interaction with the device. The reduced interaction is achieved because only one loading/unloading procedure is needed when using Greenwash (instead of two, which would be needed if the same result should be achieved on a common washing machine).

Figure 7.2, The two drums and interface of the Greenwash washing machine.

Simplified sorting

One of the most significant reasons for the improved ergonomics of Greenwash is its dimensions. It is higher than common washing machines and it also includes adjustable legs, as seen in figure 7.3. The combination of these two aspects, enables a broad range of users to use the machine at the perfect working height.

The laundry basket ,seen in figure 7.4, can be height adjusted to match the height of the washing machine. Its job is to store and, at the same time, make sure the laundry, that the first user chooses to put in, is separated into the colours that can be washed together without bleeding. This takes away one step from the second user when its time to sort the laundry. The laundry basket also includes large springs, like in a plate dispenser, to always keep the garments at the most desired level.

The two drums, seen in figure 7.5, also have a key role regarding the sorting since it enables the user to sort most of the laundry, already separated by colour in the laundry basket, directly into the machine instead of sorting it on the floor. Another big improvement has to do with the design of the drum and the hatch. The combination of the high placement and the wide opening angle, results in improved loading and unloading activities: First of all, it makes it easier for the user to reach garments in the drum and secondly it ensures the garments and user interface are within a good viewing angle.

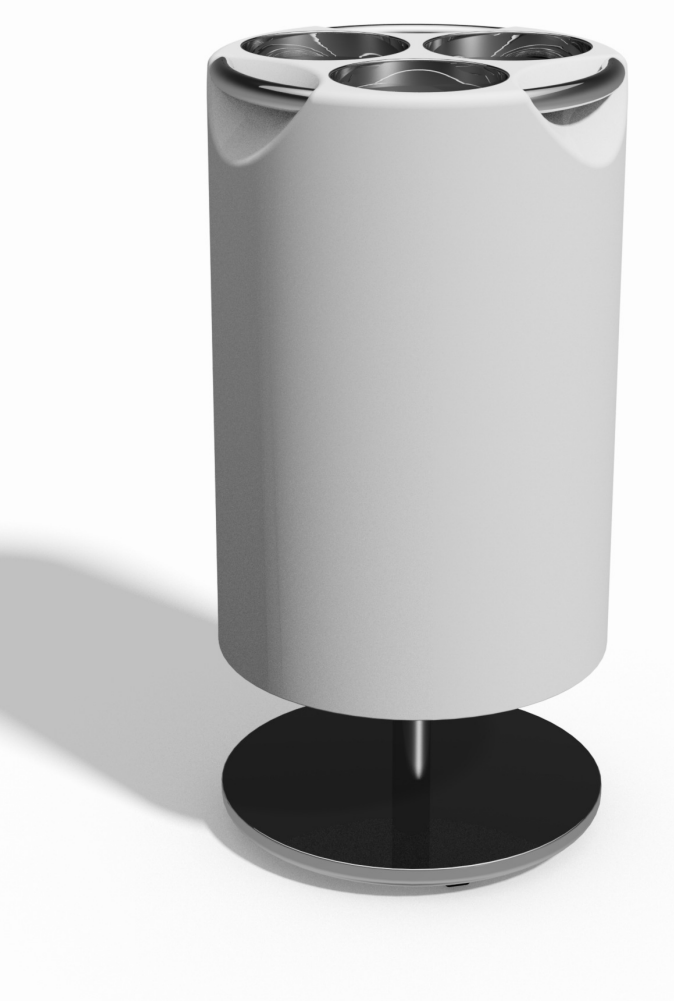

Figure 7.4, Laundry Basket

Figure 7.5 The two drums

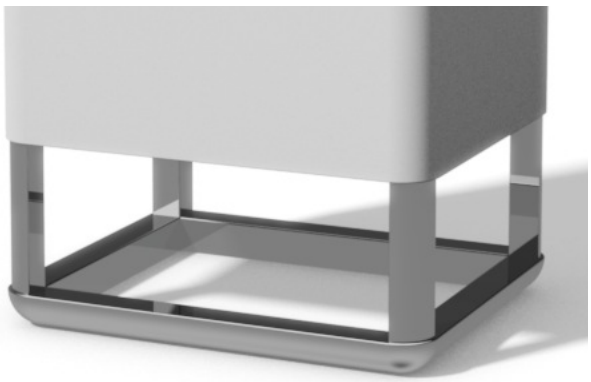

Figure 7.3, The adjustable legs.

Less interaction

The Greenwash system aims to reduce the user interaction, but at the same time it will not make the user feel limited. The reduced interaction is achieved by letting the machine pre-set a wash program based on the correct order of washing and what the user is most likely to wash next. This means, as the user opens the lid of the washing machine, the colour and temperature combination that he or she, most likely, intends to wash with is already pre-set and the user can directly start sorting the laundry into the drums. As this is done, the user only has to close the lid and press play.

To support this; the play/pause button is equipped with a small screen. This screen have two important functions: when the machine is not operating but ready to be started, it shows a play symbol (see figure 7.6). While operating, the button instead displays a Pause symbol and around it shows the remaining time of the currently operating wash program (see figure 7.7).

As the machine does not, in any way, force the predetermined settings on the user, the parameters can easily be changed. The current settings are always displayed in the interface as shown in figure 7.8. To change a setting, the user only has to go through two steps. First the desired washing parameter has to be selected, which is done by pressing the corresponding button. The edges of this button are then lit to mark that it is selected. Thereafter the "up and down arrows" are used to browse and select a new setting. While browsing, the previously selected button acts as a screen where the new parameter is shown.

Figure 7.6, View of the Play/ Paus button while the washing machine is not operating

Figure 7.7, Close-up of the play/ Pause button while the machine is operating

Figure 7.8, The User Interface as exposed when the lid is pulled up.

7.3 Underlying Technologies

Water reuse system

From a technological point of view, the two drums enables a water- and energy saving technology, based on the S'wash concept (presented in section 5.3), to be used. The idea is, like with the S'wash concept, to reuse water by using three water tanks, but Greenwash differs since it does not have to store the water during particularly long periods of time. Instead, the idea is to let the two drums drive asynchronous, which enables the rinse water from the first drum to be used directly in the second drum, solving the bacterial growth problem described in section 6.6.

THE WASH PROCESS

Figure 7.9 shows a schematic explanation of how the water resusal system works. The squares to the left represent the wash cycle stages for the left drum and the squares to the right represents the corresponding stages for the right drum. The squares in the middle, numbered 1-3, represent the three water tanks. The water flow through the system is illustrated by the horizontal lines that connects the drums and the tanks.

- A wash cycle starts with drum A being filled with water. This water is used to wash the laundry in this drum and is thereafter emptied (since the quality of water, that has been used for washing, is too poor).
- Thereafter, the same drum is filled with "new" water. This water is used in rinse A1 and is thereafter carried to drum B where it is used for washing.
- Thereafter, drum A is filled with "new" water again (for rinse A2), which is then carried to be used in rinse B1.
- Thereafter, drum 1 is filled with "new" water one last time (for rinse A3), and then the water is carried to be used in rinse B2.
- Lastly, the wash cycle ends with drum B being filled with new water for rinse B3.

Throughout the entire washing process, the rinse water that is emptied from drum B is always stored in the three tanks (water from B1 is stored in tank 1, water from B2 is stored in tank 2 and water from B3 is stored in tank 3). The reason for this, is that; if a new wash cycle, following the right washing order, is performed, the stored water can be reused in this cycle too. The "new" can therefor refer to either this stored water, but also to fresh tap water (if the stored water can not be used).

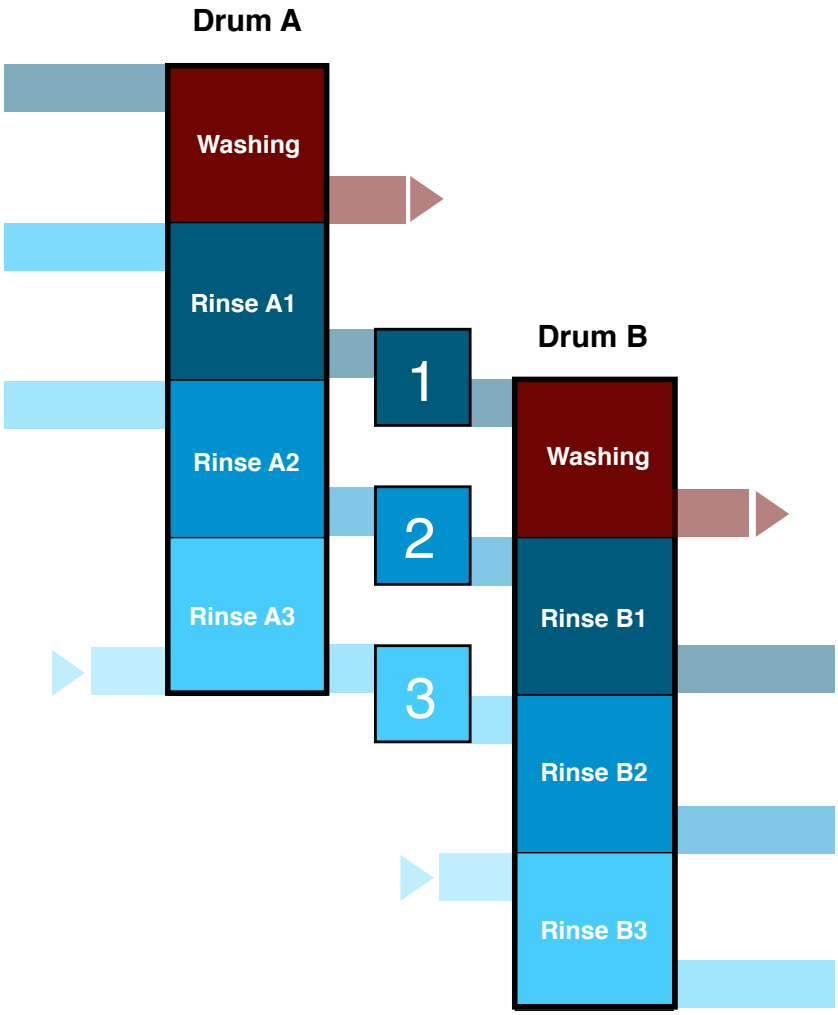

Figure 7.9: The internal water reuse system of the Greenwash concept.

THE RESULTS

The concept achieves reduced water consumption at even higher levels than the S'wash project, as reported to be 79%, by making it attractive for the user to wash in a more environmentally friendly way. This in the form of a correct order of washing where water reuse can be achieved on a higher level. Reduced energy consumption is also a result, not by reducing temperature levels as is how the S'wash concept achieves their energy saving, but through reusing the energy stored in the water. The direct reuse of water in the two drums means energy is not lost between the washes and if the water is reused from a wash of a higher temperature to a wash of a lower temperature; the small losses of thermal energy could be synced with the differences in temperature between the two washes. Lastly, a reduced use of detergent is integrated into the solution where a system of automatic detergent dosing prevents overdosing from happening.

Materials

The concept means to be better during the transportation-, installation- and end of life-stage as the concrete, usually found in today's washing machines, is non existent in this case. The weight, to keep the machine from vibrating during centrifuging, is instead achieved by the water tanks when filled with water. This is better during transportation of the machine since the tanks will be empty and the machine a lot lighter. The tanks will not be filled during installation either which means putting the machine in place will be a lot less of a hassle. The tanks also means a better end of life stage where the absence of concrete means the shredding process will get a lot less contaminated.

As the housing, the frame, the drums and much of the motor is made of steel; the water tanks and the legs are made of steel as well to maximize the potential for material recycling.

Interface

The area between the drums, shown in figure 7.10, are used, both to show, and to select washing parameters. The UI consists of nine physical buttons. Seven of them, including the washing parameter buttons and the play/pause button, are equipped with a small OLED-display each. This technology already exists in some computer keyboards made by, for example, Razor (Razor inc., 2015) and Art Lebedev (Art Lebedev Studio, 2015) where the individual keys are reprogrammable to match what is being displayed on the screen.

The pre-determined setting, that the washing machine suggests to the user before each wash, is based on two things: The choice of colour is based on what colour was washed the cycle before since this makes the washing machine able to reuse the water to a larger extent. The choice of temperature is based upon the machine having learnt, from previous washes, what combination of temperature is most likely to be washed.

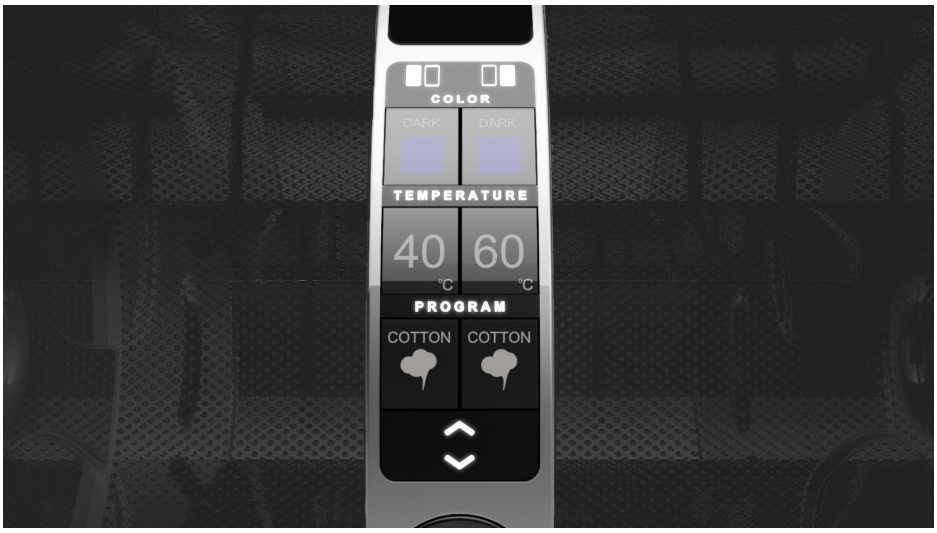

Figure 7.10, The two drums and the interface of the Greenwash washing machine.

8. Discussion

8.1 Methods and Process

Because of the project's wide scope, and since the field of washing was found to be very complex, we realized that the pre-study had to cover a lot of different fields to give us the entire picture of the situation. This, together with the fact that the project were only spanning 15 credits, impacted the course of the pre-study.

In the beginning of the pre-study we decided to perform literature studies since it was considered to be a very efficient method to gather information from such a broad range of fields. The study turned out to answer a lot of important questions and because of this we choose to build the pre-study around it and focus less on performing own user studies and the user studies we performed were therefore only seen as a complement to the literature study.

The goal with the user studies was to collect qualitative data since the literature study resulted in a large amount of quantitative data. Because of this, we decided to perform interviews and to skip questionnaires. We are aware of that more interviews could have improved the pre-study, but even if only nine interviews were performed, we found them to be valuable since they both gave us new insights and also supported some of the information found in the literature study.

When it comes to the concept development process, we think that the methods used were suitable and that they fulfilled their purposes. The fact that we built physical models was very rewarding since it gave a good input, primarily regarding the overall experience of the final concept during refinement.

Another factor that impacted the concept development process in a good way was the fact that we evaluated our ideas iteratively during the whole process. By doing so the design direction got more and more clearly defined until only two concepts remained. The fact that these two had a lot of similarities, despite the large number of different ideas, indicated that we had found a thought-out entirety.

Lastly, regarding the final concept, with which we are very pleased, there were no time left for building a full scale model, for presentational purposes, as first intended. Also, the concept shows upon strengths in many different areas which means if some part of it turns out to not be feasible after all, there are still many aspects left which still improve upon the washing machines of today.

8.2 Further Investigation

To bring the concept closer to reality there are several important factors that have to be investigated further:

First of all, the washing order is a very important aspect that needs further investigation. The order, in which the colour needs to be washed, is fairly defined, but, more research regarding the order of washing temperature and how this order can be achieved by the user, needs to be carried out.

The design of the interaction panel is another important area to further develop. As mentioned earlier in the report, it's current design is the most minimal UI to fulfill the essence of the design, and since no detailed investigation about it was carried out during the design process, it is not necessarily the most optimal layout. Also, more features could be added to really make the user get the feeling of being enabled, such as more granular controls.

Regarding engineering, a more detailed design of the opening/closing mechanism is also needed as this visor-kind of opening is not used by any washing machines on the market today. As the inner drum is meant to close in tandem with the lid, clothes could get tangled up in the parting lines of such a mechanism. Clever engineering is therefore needed here to really make this lid a reality. Also, since this project did not take the design of internal components into account, this is another important aspect to investigate further. The machine could be unstable, for instance, due to the high placement of the drum. This could maybe be solved by placing the water tanks at the bottom of the device and, instead, make the mid section of the machine into the hight-adjustable part. Further, the circular laundry basket is maybe not the best space saving shape and no distinctive investigation has gone into determine the best shape of the device. However, as there is three sections of the laundry basket, It would not work together with a square geometry, which in this case is probably the best space-saving geometry. This means other, more unusual geometries needs to be investigated.

Even though drying of the clothes has been taken into consideration throughout the entire development process, it is not included in the final concept. It was fundamentally believed that to make better ergonomics possible; the importance of stack-ability and building codes for laundry rooms needed to be questioned. Also, to incorporate tumble-drying or a drying cabinet into an environmentally friendly washing solution was not considered to be a good idea due to its clear environmental drawbacks. To not leave this unanswered, drying was imagined as a drying rack which, in the same way as the laundry basket, would roll on wheels, be adjustable to match the height of the washing machine and could be tucked away when not used. The shape of such a device and wether it is enough for the user to hang dry or if they will go out and buy a tumble dryer anyway, needs to be investigated

Even more comfortable solutions (such as a smart laundry bag that gives input to the washing machine/ sends notifications to the user) could be implemented but would probably result in a, considerably, more expensive machine. There is also a lot more potential to draw from the smart and learning trend where the finished product could learn more from the user and provide even more features.

9. Conclusion

The result has answered the goal and purpose of the project by having designed a washing machine that is both more environmentally friendly as well as ergonomically beneficial compared to today's machines.

This was achieved by:

- having analyzed the current state of the industry, where several influencing factors were found towards solving the need of getting laundry washed in a more environmentally friendly way.
- having narrowed down the issues of todays washing machines and thereby made it possible to create a solution that manages to avoid the main problems recognized.
- having assessed the potential of, not-only energy conservation during the use-phase, but water and detergent conservation as well as overall environmental impact. Thereby, the groundwork for development was laid out.
- generating ideas based on the fundamental need to wash clothes and having sought after solutions for an exemplary appliance that is more efficient and more comfortable to use, solutions, which all pointed towards the final concept to be built as a integrated system, was the result.
- Iterating on the aforementioned ideas, generating a conceptual solution for home-use, where the focus were on sustainable behavior, including a washing machine with an innovative new design, together with a custom made laundry basket which is integrated into the laundry process.

This concept development process resulted in Greenwash; a concept built on the fundamental idea that the design should give advantages for both the user and the environment. This is achieved by a combination of technological and user-centered ideas that together form a system that benefits the user to wash in a way that reduces the environmental impact.

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Appendices

Appendix 1: Interview questions

Before washing

- *How often do you wash?*
- *How are you distributing your washing? (Day, week, irregularly?)*
- *When do you consider that the clothes have to be washed?*
- *What kind of system do you have for laundry sorting?*
  - *How do you sort your clothes?*
  - *Do you use one or more laundry baskets?*
- *Do you use any other product than detergent?*
- *Do you wash some clothes different than others?*
- *Do you have an extra amounts of a certain colour?*
- *Do you have an extra amount of a special material?*
- *Do yo have any garments that require special procedures?*
- *What is your opinion about the time spent on sorting laundry?*

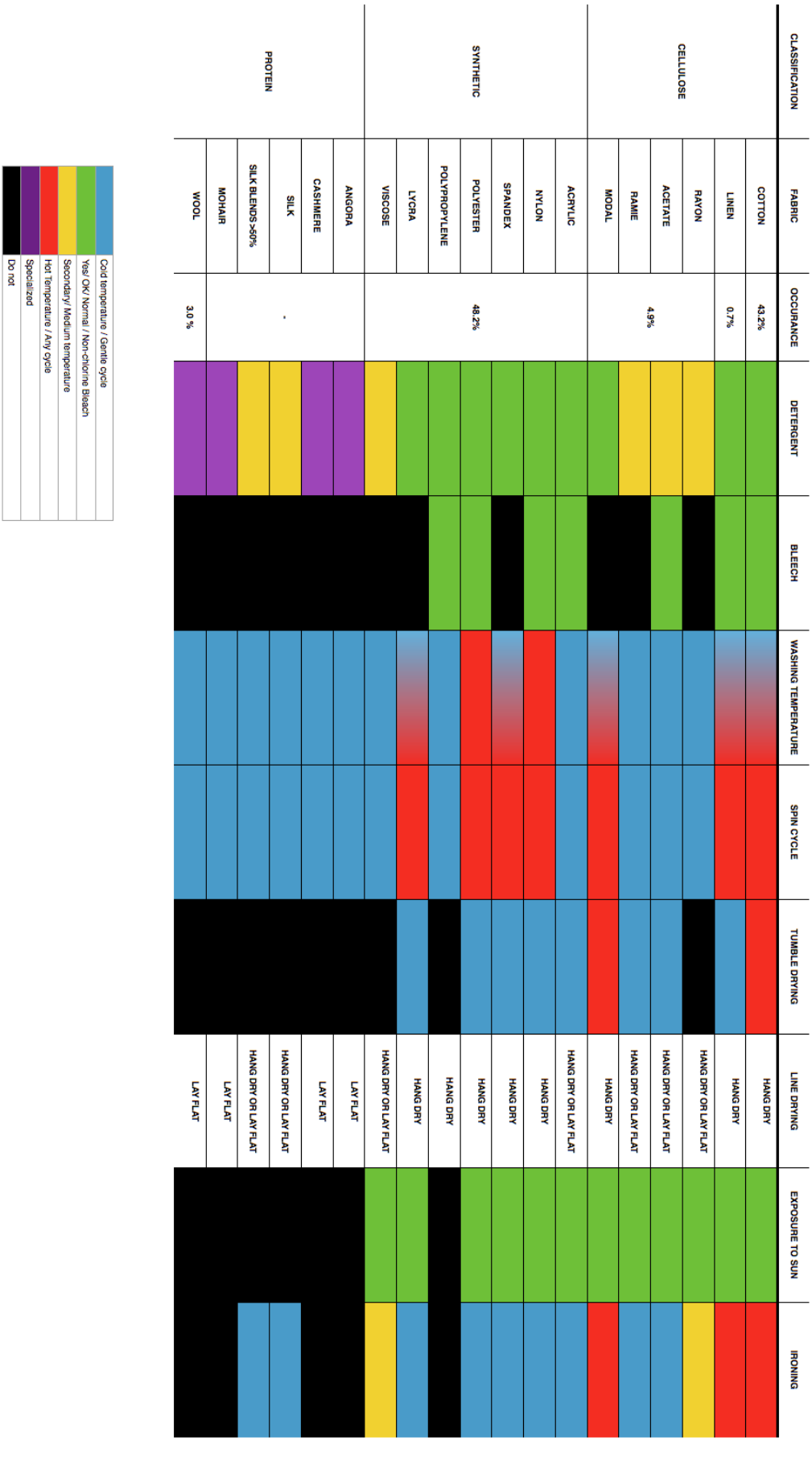
During washing

- *What kinds of washing utensils do you use?*
  - *Are you missing something you deem necessary?*
  - *Do you wish for something that is not necessarily required to wash?*
  - *Have you used a washing machine with better / worse features?*
- *Routines*
  - *Describe your distinctive washing routines?*
  - *Do you have any laundry tips?*
  - *To what extent do you utilize the programs on your washing machine?*
  - *Do you feel certain regarding the amount of laundry and detergent to be applied?*
  - *Do you usually fill the machine?*
  - *Do you find it difficult to wash?*
  - *Do you think any laundry steps are physically straining?*
  - *Do you think your washing machine is easy to understand?*
- *Environment*
  - *Do you use the environmental wash program?*
  - *Do you keep the environmental impact in mind when washing*
  - *Are you aware of your washing machine's Eco-labeling?*
  - *Do you know your washing bait the various impacts on the environment?*
  - *can you imagine a worse performer washer for nature's / user's sake?*

After washing

- *How do you dry your laundry?*
- *Do you Iron your clothes frequently?*
- *Is it tiresome to take care of the finished wash?*
- *Are you satisfied with the results after washing?*
- *Can you describe your entire washing process, from beginning to end, as accurately as you can?*

Appendix 2: Washing demands of textiles



Appendix 3: Specification of requirements

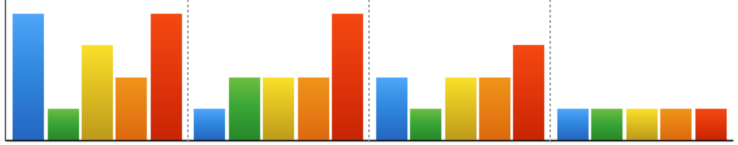
Nr	Description	Type	Value
1	Regulations		
1.1	Include protection if there is risk that children might access the machine (BFS 2006:12).	R	
1.2	Only aloud to reach a maximum of 62 dB during washing (Konkurrensverket, 2015).	R	
1.3	Only aloud to reach a maximum 78 dB during centrifuging (Konkurrensverket, 2015).	R	
2	Size and shape		
2.1	Higher and more shallow than the regular measurements for washing machines are 60x60x85	R	
2.2	To incorporate legs	R	
2.2.1	To design the legs as a cage configuration with rounded corners	D	3
2.3	Incorporation of 3 tanks and a water and energy reuse system	R	
2.4	Integrated laundry basket	D	4
2.5	Include a divided drum	R	
2.5.1	Direct access to the drums	D	4
2.5.2	The UI in the middle	D	3
2.5.3	A low placement of the Play/ Pause button	D	2
2.6	A visor for lid	D	5
2.6.1	A recessed handle	D	3
3	Interface		
3.1	Induce a correct order of washing	R	
3.2	Be designed with levels of interaction	D	5
3.2.1	visible Play/ Pause button and hidden UI	D	4
3.3	Design a merger of sorting and interfacing	D	5
4	Emotions to Evoke		
4.1	Evoke the feeling of being Enabled	D	4
4.2	Evoke the Feeling of True Freshness	D	4
4.3	Evoke the Feeling of True Craftsmanship	D	3

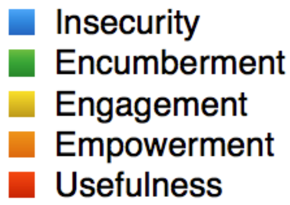
R = Requirement
D = Desired

Appendix 4: Customer Journey mapping

User 1

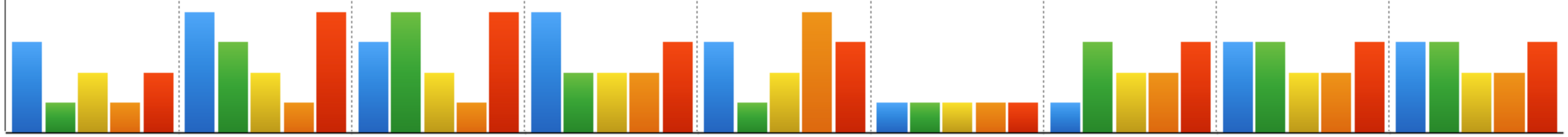
	Decides to wash apparel	Gets clothes to laundry basket	Puts the clothing in the laundry basket	Await cleaned clothing
Problems	• Unclear level of soiling • Social insecurity • Smell • Visible spots • Habit	• Demand for physical movement	• Choice of basket by color	• Time-consuming
Emotions				



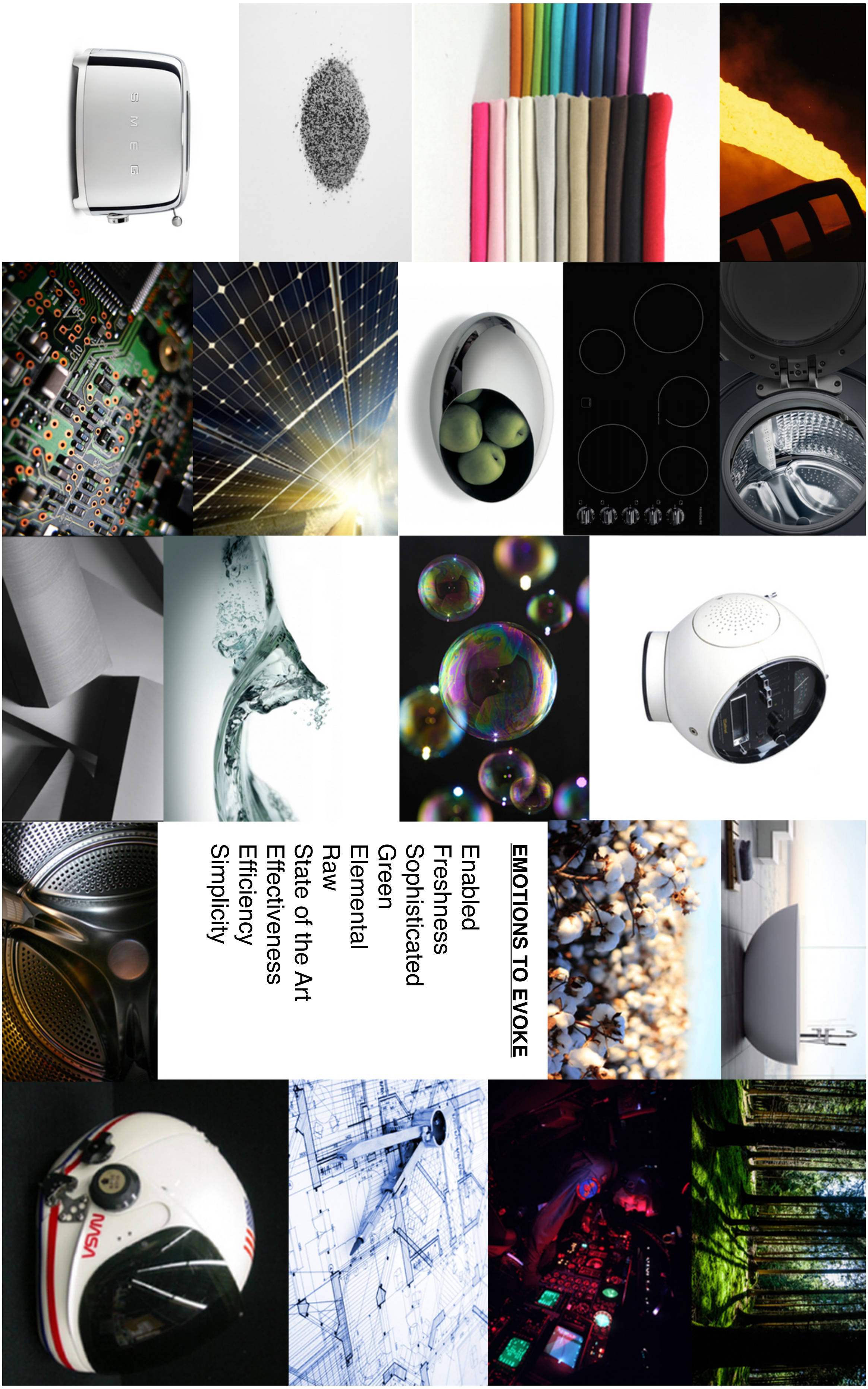


User 2

	Awaits large enough amount to wash	Sorts and controls the laundry	Loading the Washing Machine	Dosing detergent	Choosing wash-program and starts the machine	Awaits laundry to be washed	Unloading the Washing Machine	Making use of appropriate method for drying and post-treatment	Folding of the laundry and return to its propper storage
Problems	• Unclear when enough • The urge for washing despite low amount of laundry • Difficulty for planning	• Time consuming • Difficult • Big variety • Scrap in pockets	• Unergonomic • Heavy • Demand for reloading • Unclear amount to be loaded	• Unclear load to detergent ratio • Forgettable • Unclear which department is correct	• Unclear which program is the right one • little or no help • Not dynamic • Not environmental option as standard	• Difficulty for planning • Bad Notifications • Noise • Vibrations	• Unergonomic • Wet laundry • Requirement of post treatment • Bad integration with post-treatment	• Different requirements • Time consuming process •	• Laundry by ownership is mixed • Socks come in pairs • Requires movement • Heavy
Emotions									



Appendix 5: Moodboard



Appendix 6: Pugh matrix

Criteria	Importance	Reference product	The cabinet	The system
Ergonomics	4	0	0	+
Easy sorting	4	0	+	+
Easy loading/unloading	4	0	+	+
Easy interaction	4	0	+	+
Easy to fit in	3	0	-	0
Energy savings	5	0	+	+
Water savings	5	0	+	+
Sum of positives		0	22	26
Sum of negatives		0	3	0
Total		0	19	26

Appendix 7: SWOT

This SWOT analysis is based on the most common strengths, weaknesses, opportunities and threats of a general, modern, washing machine for home use. The analysis was done to be better prepared for shifting market trends as well as to better utilize existing knowledge about washing machines.

STRENGTHS
- Washing quality meets the requirements
- Many washing machines have programs with a reduced environmental impact
- Many washing machines are dosing detergent automatically (to ensure the right amount)A large part of the washing machine is composed of few different materials

WEAKNESSES
- Consumes and pollutes water
- Consumes energy
- Uses primary resources from the earth's crust
- There are many small components made of different materialsWashed laundry requires post treatment (such as ironing and drying, which requires energy)

OPPORTUNITIES
- Technological development (regarding washing performance and environmental factors)
- There is a potential for design- and user focused solutions, as a complement to technological factors.
- Customers are being more conscious about making environmentally friendly choices
- There is a huge potential market

THREATS
- Increasing requirements for recycling
- Legislations for water- and energy efficient products
- The price for raw materials, water and electricity might fluctuate or increase.