CHALMERS

Development of a Sustainable Dishwasher for Compact Living

Master of Science Thesis in the Master Degree Programs, Industrial Design Engineering and Product Development

SOFIE ANDERSSON

JOHAN HAGEJÄRD

CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2016

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JOHAN HAGEJÄRD

SUPERVISOR: JOHAN HEINERUD

EXAMINER: ULRIKE RAHE

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Chalmers University of Technology
SE-412 96 Goteborg, Sweden
Telefon +46(0) 31-772 1000

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Abstract

Urbanisation and climate change will bring challenges to the way we design our future homes. Since the middle of 2009, more people are living in cities than in rural areas. A decline has been seen both in the average household size and floor area per person. With more people living in less area per person, there will be a growing need for more space efficient as well as energy efficient solutions. A dishwasher can save both energy and water compared to manual dishwashing. Still, many small households are without a dishwasher due to limited space.

This master's thesis project has been carried out in collaboration with Electrolux and has had the aim to develop a space efficient dishwasher concept that meets the needs and requirements of small households, while minimising the energy and water consumption related to the dishwashing process. Findings from user studies, literature studies and benchmarking indicate that there is a lack of dishwashers on the market that are adapted for smaller kitchens and households. A dishwasher designed for this segment should focus on making the most out of the already limited workspace and storage found in compact kitchens. Another finding was that user behaviour greatly affect the environmental impact of the dishwasher. This concerns for instance pre-rinsing of dishes before placing them in the dishwasher, the extent to which the dishwasher is loaded and the selection of washing program.

To evaluate the possibilities of saving water and energy related to the dishwashing process, the total water consumption of the kitchen was considered. A conclusion drawn was that there is a lack of system thinking over the kitchen's water consumption. Used tap water of relatively high quality and energy content is not taken advantage of. The final concept is a solution that handles all washing and waste management of the kitchen in one unit, where the sink unit and the dishwasher are designed to support each other. A great focus lies on flexibility of use to support the various tasks handled in the kitchen.

Preface

This is a report for a master's thesis project of 30 ECTS in the Department of Product and Production Development at Chalmers University of Technology. The project has been carried out in collaboration with Electrolux, beginning in January 2016 and running until June 2016. The project idea was an initiative by the project team and the scope and content was then initiated and formulated together with the examiner.

Supervisor at Electrolux

Adam Szczepanowski, Global Product Line Leader – DishCare, Senior Design Manager, Major Appliances EMEA, Electrolux Group Design

Examiner

Ulrike Rahe, Professor, division of Design & Human Factors, Department of Product and Production Development, Chalmers University of Technology

Supervisor

Johan Heinerud, Lecturer, division of Design & Human Factors, Department of Product and Production Development, Chalmers University of Technology

Project Team

Sofie Andersson, Master's student at Industrial Design Engineering, Chalmers University of Technology

Johan Hagejärd, Master's student at Product Development, Chalmers University of Technology

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In this master's thesis project there have been many people who have provided knowledge as well as support to the project team. Without them, this project would not have been possible.

First of all, we would like to thank Adam Szczepanowski, our supervisor at Electrolux, who has guided us and given us valuable inputs throughout the whole project. Thank you for believing in our concept and for inspiring us with your positive spirit. We also want to thank Anna Delin at Advanced Development at Electrolux for providing us with knowledge about dishwashers and for discussing the feasibility of the concept. We would also like to thank the other employees who attended our final presentation at Electrolux in Stockholm and showed interest for our solution by asking relevant questions.

Johan Heinerud, who has been our supervisor at Chalmers, deserves a great thanks for his support in this project. Our discussions about different ideas have been inspiring for our work. Finally, we want to thank our examiner Ulrike Rahe for making this project possible by establishing contact with Electrolux and communicate the idea of a project dealing with the development of a sustainable dishwasher for compact living.

Contents

1

Introduction

This chapter introduces the master's thesis project by describing the background and aim as well as the delimitations of the project. It also gives an overview of the report outline and ends with a brief introduction of the company Electrolux.

1.1. Background

The world has gone through a major demographic shift with more people living in urban areas than in rural areas since the middle of 2009 (United Nations, 2010). Urbanisation is expected to continue and United Nations (2010) predicts that by 2050, the world urban population will increase to 6.3 billion, which is about the same size as the world's total population was in 2004.

Urbanisation brings both challenges and opportunities. Developed countries have historically increased the average amount of floor space available per person but today, this number is beginning to decline. With more people living in less area per person, our future homes will need to provide more flexible, smart and sustainable solutions. As living space becomes smaller, design will play an important role in developing pleasant and convenient solutions that can utilise space more efficiently. Multi-purpose functionality of products is becoming increasingly important, as well as enhanced customisation (Electrolux, 2015).

Apart from the shift to urbanisation, there has also been a shift to smaller household sizes. According to Dol and Haffner (2010), European households have become smaller as a result of more older people, fewer children and more young single-person households. In 2012, single-person households accounted for more than 38% of all households in Sweden, Norway, Denmark and Germany (Euromonitor, 2013). In Sweden, the share of single-person households increased from 33% to 44% between 1981 and 2008 (Dol and Haffner, 2010). Single-person households require the same amount of household appliances as larger households, which makes it an important group to consider in the development of home appliances. It is also important to develop products that facilitate the social change while at the same time considering the environment (Electrolux, 2015).

1.1.1. Problem Description

By using a dishwasher instead of washing by hand, you save not only time but also energy and water. Still, many households are without a dishwasher because of limited space in their kitchens.

Most of the dishwashers that exist on the market today are suited for larger kitchens and households. The smaller variants that exist are often in the category of benchtop dishwashers. These are in many cases too bulky to fit into kitchens with limited workspace, which is typical for the compact

kitchen. At the same time, they can only handle limited variants of dishes and do not fully replace the standard sized machines.

Therefore, there is an opportunity to explore the needs and requirements related to dishwashing in small households and develop a dishwashing machine to meet those needs. This is also an opportunity for Electrolux to explore a new market of dishwashers and promote a more sustainable way of handling dishes.

1.1.2. Project aim

The aim of this project is to develop a dishwasher for small households with limited living space. The final concept should be compatible with standard measures used in kitchen modules and should also fit into Electrolux's product portfolio. The aim is also to reduce the environmental impact of dishwashing compared to washing dishes by hand.

1.1.3. Questions posed

The questions posed in this master's thesis project is:

- How should a dishwasher be designed in order to meet the needs and requirements related to compact living?
- How should a dishwasher be designed in order to minimise the environmental impact of the dishwashing process?
- How should such a dishwasher be designed in order to fit into Electrolux's product portfolio?

1.1.4. Delimitations

The final concept of this project is targeted to the European market, mainly focusing on Sweden. The user study have included people living in Sweden and the development work has focused on dimensions found in Swedish kitchens. This does not limit the concept from being able to reach a global market as well. The concept focuses on compact living and a sustainable use of water and energy in the kitchen, which are contributing factors to making it interesting on a global market due to the trends of urbanisation, climate change and limited resources.

The target users for this project are people living in urban areas with compact living space. They have dynamic lifestyles and find chores such as dishwashing too time consuming. This target group includes a wide range of ages, from adolescents living in cramped student apartments to senior citizens who want to make the most out of their living space. The target users are living in apartments and households of one up to two people. The main focus will be people in their mid-twenties to mid-thirties who are working and spending little time at home.

The final concept should be feasible to be realised within five years. The concept has therefore been based on technologies already existing on the market today. Every detail of the concept has not yet been defined and will need further development.

The aim of minimising the environmental impact of the concept is mainly focused on the use phase. Materials selections, production methods and the end of life phase have therefore not been included in the scope of the project. Interior layout and interface of the concept have been considered, but not in focus of the development process.

1.1.5. Deliverables

The main deliverable for this project is an academic report describing the work process, main findings from the study and the resulting concept. The project will finally be presented at Chalmers University of Technology and at Electrolux in Stockholm.

The presentations will include visualizations of the final concept through illustrations and CAD renderings.

1.1.6. Report outline

This report consists of fourteen chapters, each starting with a short introduction to its contents. After this first chapter that introduces the background and aim of the project together with a short description of the company Electrolux, follows a theory chapter that presents information from different areas relevant for this project. Chapter 3 describes the different methods used and Chapter 4 presents findings and results from the initial research that was made in this project. Thereafter follows a chapter covering the setup and findings of the user study. Chapter 6 is a summation of the main findings from both the initial research and the user study. This chapter functions as a bridge between the study and the concept development, which is presented in Chapter 7. Chapter 8 explains the further research and development of the concept, followed by a list of requirements in Chapter 9. The final concept of this project is presented in Chapter 10 and evaluated in Chapter 11. The final three chapters includes a discussion about the methods and result of this project, the conclusions and recommendations for further work with the concept.

If the reader is mainly interested in the final result of the project, this is presented in Chapter 10. To better understand the final outcome, the reader should also go through Chapter 6 until 9. Complementary material can be found in the appendices.

1.2. About Electrolux

1.2.1. The Electrolux Group

Electrolux is a global leader in home appliances and bases their product development on deep consumer insight and close collaboration with professional users. They offer products such as dishwashers, refrigerators, vacuum cleaners, washing machines, cookers, air conditioners and small domestic appliances. Every year, more than 50 million of their products are sold in more than 150 markets. About 50 percent of the sales are in America, 30 percent in Europe and 20 percent in other markets.

Electrolux Group consists of eight strategic brands including AEG, Electrolux, Eureka, Frigidaire, Grand Cuisine, Molteni, Westinghouse and Zanussi. The Group offer solutions to both consumers and professionals, reaching luxury, premium as well as mass markets (Electrolux, 2016a).

1.2.1. The Electrolux brand

Electrolux has an impressive heritage stretching back to 1919, when it was founded by an agreement between AB Lux and Svenska Elektron AB. Since then, they have developed a variety of successful products based on their philosophy of being convenient, easy and enjoyable to use at home. A few examples of their innovative creations are the world's first vacuum cleaner with metal runners and the world's first benchtop dishwasher (Electrolux, 2016b).

Figure 1.1 – The Electrolux logo

2

Theory

This chapter presents the theory relevant for this project. This includes theory about the dishwashing process and the dishwasher itself. The chapter also covers theory about water treatment and storage as well as theory about design for sustainable behaviour.

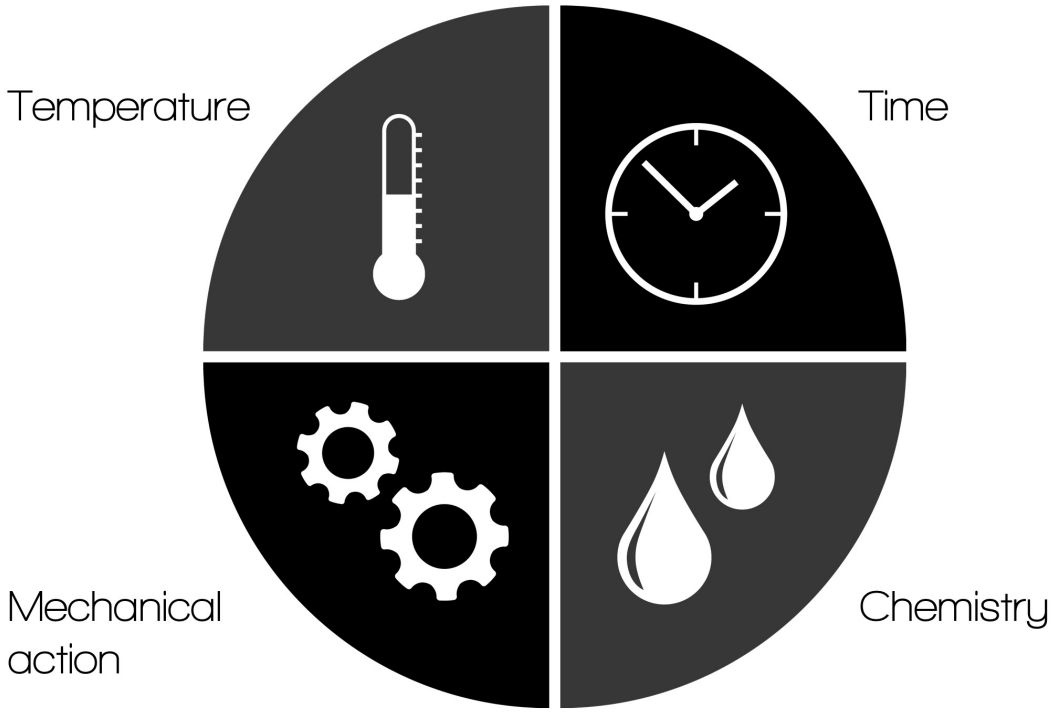

Figure 2.1 – Sinner's circle describing the different factors that affects the cleaning performance of the dishwashing process

2.1. The dishwashing process

2.1.1. Factors affecting the cleaning performance

Sinner's circle (Figure 2.1) is a theory widely used to describe the washing performance for laundry as well as dishwashing processes. It was founded by Dr Herbert Sinner, who between 1932 and 1966 was employed by Henkel & Cie and worked with textile washing procedures and improving the washing result of mechanical washing devices. His theory states that the cleaning performance is determined by four individual factors: temperature, time, chemistry and mechanical action. These

factors operate together and if one of them is reduced, at least one other factor has to be increased to achieve the same washing result (Beringer and Kurz, 2011).

2.1.2. The dishwasher cycle

The washing cycle of a dishwasher can be divided into several steps. A normal washing cycle includes at least a pre-wash, a main wash and a rinse. Water temperature, duration and how many iterations the dishwasher will perform depends on what dishwashing program the dishwasher is running. If an auto program is used, the cycle will adapt its temperature and duration to the amount of soil on the dishes. The dishwasher cycle is designed to give a good cleaning result while minimizing water and energy use. As cleaning performance is determined by temperature, time, chemistry and mechanical action, this means that an eco-program will consume less water and energy, but at the cost of a longer wash cycle (Szczepanowski and Delin, 2016).

Pre-wash

The pre-wash prepares dishes for the main wash phase. The purpose of the pre-wash is to soak dishes and to remove loose particles which are drained at the end of this phase. By removing loose particles, less particles will be available to dissolve and soil the water during the main wash. The pre-wash is normally performed without heating or detergent.

Main wash

The main wash is done to remove soil that did not dissolve during the pre-wash phase. At this stage heat and detergent are added to increase the cleaning performance. The water is then drained before the rinse phase.

Rinse

Rinsing is done to remove soiled water remaining from the main wash phase that include food particles and detergent. The rinsing often consists of two steps. During the first rinse, no heat is added. During the final rinse, water is heated and rinse-aid added to prepare for the drying process.

Drying

As the water is heated and rinse aid added during the last rinse this will not only speed up the drying process but also have a positive effect on the cleaning result. By doing so, the risk of having lime deposits on the dishes when water evaporates is reduced. Water that evaporates will either condensate on the dishwasher walls and then be collected in the sump at the bottom of the dishwasher, or be exchanged with the surroundings by venting the dishwasher. There are mainly two ways to do this, either by opening the dishwasher door or by the use of a vent fan inside the dishwasher (Szczepanowski and Delin, 2016).

2.2. The Dishwasher

2.2.1. Technical principle and construction

The typical consumer dishwasher has a water circulation and filtration system to remove and collect food particles from dishes. In addition to this, heat and additives are used to increase the cleaning performance and to speed up the drying action. As described in Section 2.1.1., the cleaning performance is determined by four factors including temperature, time, chemistry and mechanical action. The different parameters may differ between different models, brands and program used but the technical principle are similar for most consumer dishwashers.

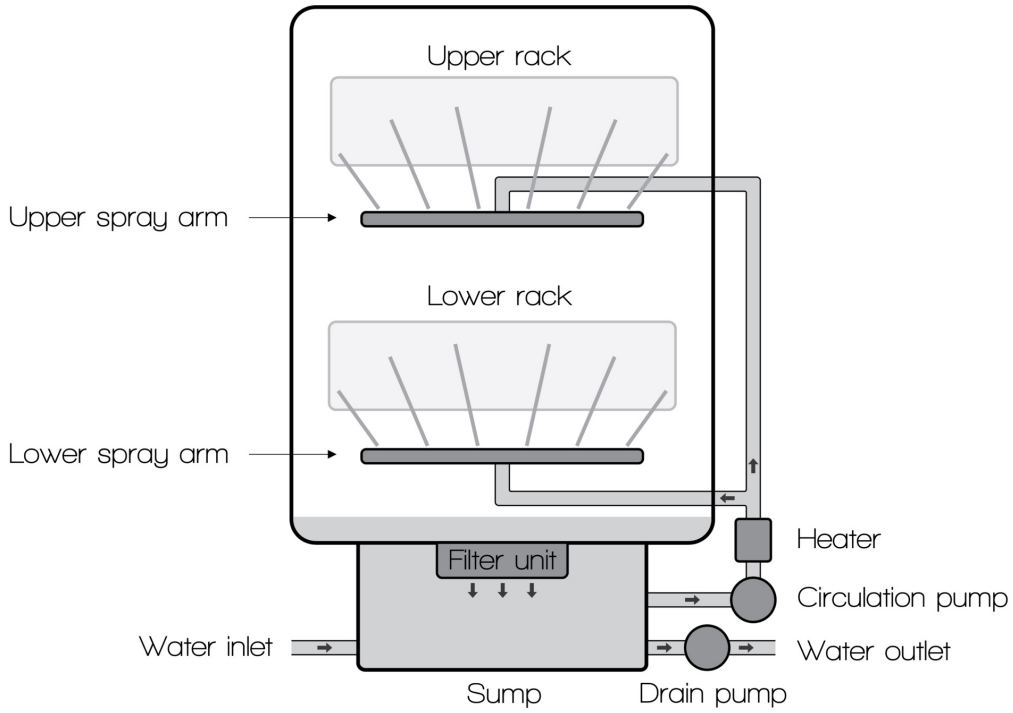

Figure 2.2 – Technical principle of the dishwasher

The dishwasher can be described as a hydraulic system. The hydraulic system alters between working as an open or as a closed system depending on which operation the machine performs. When the dishwasher acts as a closed system, water is circulated in the machine. The main components involved at this stage includes a circulation pump, a filter unit, a heater and at least one water distributer, called spray arm. The spray arm rotates as it sprays water on the dishes that are placed in the racks. The circulation of water and the motion of the spray arm are all driven by the pressure from the circulation pump. At this stage, food particles are removed from the dishes and collected within the filter unit. As the water circulates within the dishwasher, it is heated up by the heater component. The walls of the dishwasher are insulated to maintain heat within the system.

When the dishwasher acts as an open system, water is instead passing into the dishwasher and out through the drain. The water passes into the machine via an inlet valve. This allows for clean water to enter the dishwasher. After the water has circulated a number of times in the closed system, water can then be drained by the drain pump. At this stage, food particles are removed from the filter and flushed out through the drain. An overview of the different components is shown in Figure 2.2.

The spray arm

The standard sized and the narrow dishwashers typically uses two spray arms since they both have a two storey configuration. One spray arm is placed underneath the upper rack and the other is placed on the floor on the dishwasher. There are also models with a third spray arm mounted on the ceiling to increase water distribution on dishes in the upper rack. The benchtop or compact dishwasher typically have a one storey configuration and therefore uses one spray arm.

In order to distribute the water a number of jet holes can be found on the spray arm. The circulation pump forces water into the spray arm and out through the water jet holes. The

nozzles on the water jet holes have a small angle so that the reaction force from the water jets causes the spray arm to rotate, this to distribute the water as much as possible over the dishes.

The dishes that are convex like glasses and bowls are placed upside down to prevent collection of water. The upper spray arm sprays water upwards to clean dishes in the upper rack and downward to clean dishes in the lower rack. The lower spray arm sprays water upwards to clean dishes in the lower basket and downwards to transport soil to the drain which also helps to clean the filter unit. If the dishwasher is equipped with a third spray arm in the ceiling, the water jets sprays water downwards.

The spray arm comes in different configurations with the intent to optimise the cleaning result. There are also spray arm configurations with an additional rotating part to increase the distribution of water even further. Electrolux for example uses a rotating sprinkler device called satellite in some of their dishwashers (Szczepanowski and Delin, 2016).

The filter unit

The main function of the filter unit is to collect food particles that are mixed with the process water. This prevents loose food particles from being repositioned on the dishes. When the particles are separated from the water they can then easily be flushed away when water is drained.

Another function of the filter unit is to prevent larger particles from blocking the system and to protect the pumps from damages. If the system is blocked, the circulation will be restricted and the dishwasher will not work properly. Larger particles might clog the water jet holes on the spray arms and prevent water from reaching the dishes.

The filter unit plays an important role in order for the circulation to work, which allows cleaning dishes with less water than a system without circulation would. In order to have a high filter efficiency while maintaining a high flow rate, the filter is divided into two sections: one fine and one coarse filter. The filtration is done in parallel which allows the main flow to go through the coarse filter. The coarse filter allows for a higher flow rate than the fine filter but can on the other hand not collect as fine particles as the fine filter. Correspondingly the fine filter have a lower flow rate but collects finer particles. As the water circulates several times, it will eventually pass through the fine filter as well. With a continuous flow through the fine filter, particles can gradually build up and stay in the fine section. By using two parallel filters water can pass through the filter unit with sufficient flow rate to supply the spray arms continuously.

To prevent the filter from clogging, which will decrease or even stop the flow, the filter must be cleaned during the washing cycle. The coarse filter is cleaned by a water jet from the lower spray arm that rinses the particles in the direction towards the sump. The sump is where water is collected and diverted to the circulation pump. The finer filter that is placed in the sump is cleaned by back flushing water during the drain phase.

Sensors

In order for the dishwasher to be able to operate and to control different parameters it is equipped with a number of sensors. Type and number of sensors may vary between different dishwashers.

A water level sensor makes sure that the dishwasher has enough water to run the circulation pump. A floater ensures that the dishwasher does not overfill with water. There are also sensors measuring the temperature of the process water circulating within the machine.

With a turbidity sensor, also called soil sensor, included in the dishwasher, the wash cycle can be adapted to the soil level of the dishes. This means that instead of running a fixed wash cycle, the dishwasher will adjust the cycle to get the dishes clean by using minimum amount of water and energy (Delin, 2016). The turbidity sensor estimates the amount of particles in the process water by using infrared light. Compared to having to run an extra wash cycle because of a poor washing result, a prolonged wash cycle determined by the sensor will save both time and water. However, the dishwasher has to be cleaned regularly for the turbidity sensor to work. Otherwise, it will continue to sense particles in the water and prolong the cycles more than necessary, leading to a higher energy and water use in the end (Parkinson, 2016).

Commercial dishwashers

Dishwashers that are used in commercial kitchens are effective and fast but use much more energy and water than consumer dishwashers (Szczepanowski, 2016). These types of machines are often designed specifically to handle a certain type of dishware. Except for the additives used in consumer dishwashers, some types of commercial machines also use pellets to increase the mechanical action.

2.2.2. Energy classification

Household dishwashers sold in the European Union are required to bear an energy label declaring the energy efficiency of the product (European Commission, 2010a). The energy efficiency is rated on a scale from A+++ to D, with A+++ being the most efficient and D the least efficient rating. When the energy labelling was first introduced, its energy efficiency scale ranged from A down to G. As dishwashers have become more efficient, the scale has been extended up to A+++, removing the lower efficiency classes of E down to G.

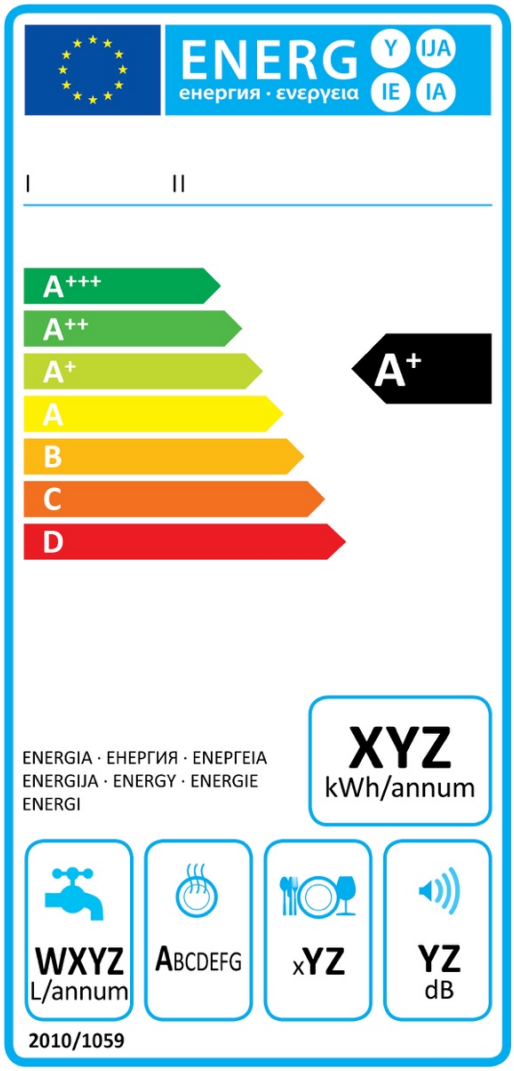

Figure 2.3 – The standard energy label of a household dishwasher (European Commission, 2016)

Apart from the energy efficiency rating, the label includes information on the annual energy and water consumption of the dishwasher. The capacity of the dishwasher is measured by the number of place settings that it can hold, which is a defined set of tableware used by one person for a three course meal. Additionally, the label presents a rating on the dishwasher's drying efficiency and its noise emissions (European Commission, 2010a).

The energy efficiency rating is based on an index that takes several factors into account, including the capacity of the dishwasher, power consumption in 'standby' and 'off' mode, program time and energy

consumption. The index is calculated by comparing the annual energy consumption of the dishwasher with a reference value of a standard annual energy consumption of a dishwasher that is used 280 times a year (European Commission, 2010a).

Since the implementation of the European energy labelling for dishwashers in 1999, dishwashers have become considerably more efficient. Between 1999 and 2005, the average energy consumption per cycle was reduced by almost 30 %, from 1.43 kWh to 1.035 kWh. In 1999, approximately one third of the dishwashers had a worse energy rating than class C and only about 9 % had a class A energy efficiency. In 2005, the share of class A dishwashers had increased to 90 % with no dishwashers being worse than class C (Stamminger, 2007). Since December 2013, the lowest approved rating of a household dishwasher with a capacity of 11 place settings or more is A+ (European Commission, 2010b).

In 2010, The European Commission identified the best available household dishwashers in terms of the parameters included in the energy label for different dishwasher capacities. In the category of 12 place settings dishwashers, the best one had an energy consumption of 0.95 kWh/cycle and a water consumption of 9 litres/cycle. In the 6 place settings category, the best model had an energy consumption of 0.63 kWh/cycle and a water consumption of 7 litres/cycle (European Commission, 2010b).

Heating is by far the most energy consuming factor in the dishwashing process. Energy is not only needed for heating the process water, but also for heating the dishware and the interior of the machine, which constitutes a large part of the total mass that needs to be heated in order to reach the desired temperature. In relation to heating, the work performed by the circulation pump demands significantly less energy and constitutes only a fraction of the total energy consumption (Szczepanowski and Delin, 2016).

2.3. Design for Sustainable Behaviour

When designing for sustainability, it is important to look into every phase of a product's lifecycle, from raw materials and manufacturing to end of life. For electronic products, it is often in the use phase where the greatest environmental impact occurs and this phase offers a great potential for improvements. When making efforts in reducing the environmental impact of the use phase, this is often done by making the product more energy efficient, with little attention paid to the user's involvement. But the environmental impact during use is strongly affected by the way that users interact with the product (Strategic Direction, 2008). Changing user behaviour into a more sustainable way is therefore of high value. This, however, is not an easy task. Consumers are slow to adopt more sustainable behaviours (DeVries, 2006; Siegle, 2006) and even when they do so, these changes are often short-lived (Scott, 2004).

Several authors have come up with different approaches on how to influence users to a more sustainable behaviour. In 1997, Jelsma applied the concept of *scripting* as a way of reducing environmental impact by influencing how users interact with products. He describes a script as "a kind of user manual inscribed into an artefact" (Jelsma, 1997). The design of the product should guide the way it should be used by making unsustainable behaviour difficult or impossible, while sustainable behaviour is made easy or even automatic (Jelsma and Knot, 2002).

Lilley et al. (2005) made a first attempt to capture several approaches in one

framework, referred to as *product-led interventions*. The product-led interventions consist of the three following strategies:

- *Scripts and behaviour steering* – products or systems that contain scripts for the intended use by the designer
- *Eco-feedback* – products or systems which inform users of the impact of their behaviour in an attempt to persuade them into a more sustainable behaviour
- *'Intelligent' products and systems* – avoiding rebound effects by ceding the decision making to the product or system in order to control or block inappropriate user behaviour

Bhamra et al. (2008) developed the product-led interventions framework by Lilley et al. (2005) further by splitting it up into seven design intervention strategies:

- *Eco-information* – provides information to the users by making consumables visible, understandable and accessible in order to inspire them to reflect upon their use of resources
- *Eco-choice* – provides options to encourage the users to take responsibility of their actions
- *Eco-feedback* – offering real-time feedback and informs the users about the consequences of their behaviour
- *Eco-spur* – inspiring users to a more sustainable behaviour through rewordings for good behaviour and penalties for unsustainable usage
- *Eco-steer* – makes intended behaviour easier and unintended behaviour more difficult by embedding affordances and constraints in the product design
- *Eco-technical intervention* – restrains unintended behaviour and makes intended behaviour automatic through advanced technology
- *Clever design* – automatically acts environmentally without raising awareness or changing user behaviour through innovative design

Wever et al. (2008) distinguish two options for reducing environmental impacts during use. Either you can adapt the product better to the actual use and thereby minimise negative side effects, or you can influence the user behaviour through design. Matching the products' functionality to the actual use is the least intrusive of all the strategies but probably also leads to the least improvement in environmental impact. When influencing user behaviour through design, the more the product is in control, the more the intrusiveness increases, and the more effective it gets in making a sustainability improvement (Wever et al., 2008).

Lidman and Renström (2011) have created a model based on previous work in the area that includes five categories of design strategies for sustainable behaviour: *Enlighten, Spur, Steer, Force* and *Match* (see Figure 2.4). The first four categories requires the user to change his or her behaviour and are ordered according to the degree of the user being in control versus the designer being in control of the behavioural change. The fifth category, *Match*, differs from the previous categories in the way that it requires none or little user adaptation. The categories can be described as follows:

- *Enlighten* - motivates the user to change behaviour through information, feedback or means of reflection. Raises the user's awareness of their behaviour and its consequences.
- *Spur* - encourages the user to change behaviour by focusing on positive consequences or aspects apart from the environmentally related ones, through for instance incentives or competition.
- *Steer* - guides the user through for instance constraints and affordances to

make the most sustainable behaviour the evident choice.

- *Force* - restrains the undesired behaviour or limits functionality to force the user into the desired behaviour.
- *Match* - instead of changing the user's behaviour, the product is adapted to the current behaviour or intention of the user. At the same time it minimises its environmental impact (Lidman and Renström, 2011).

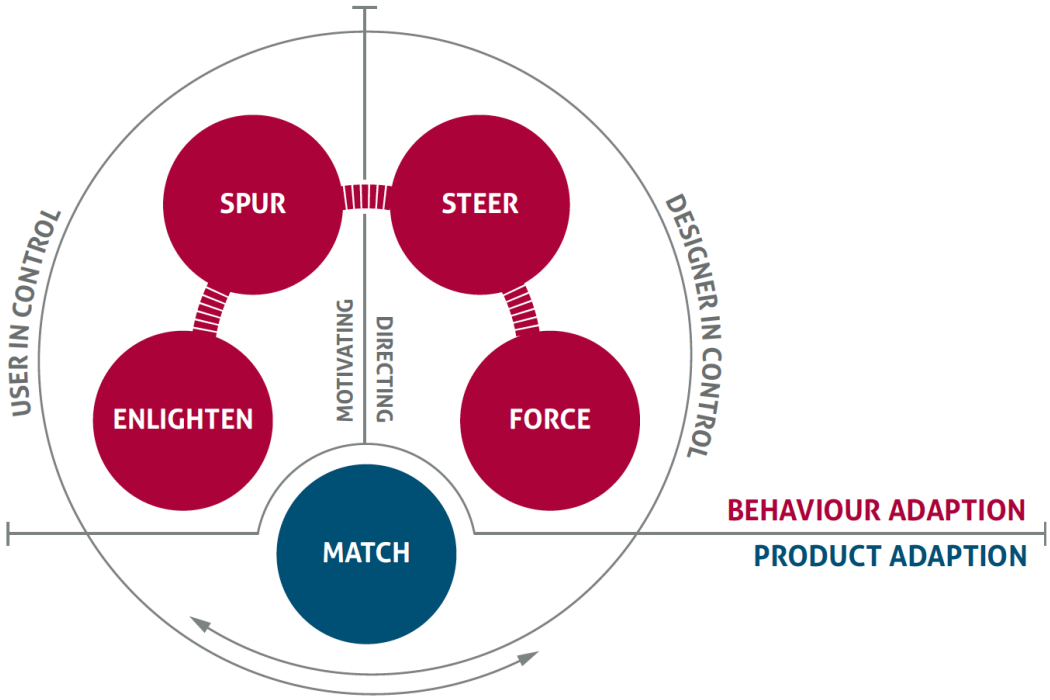

Figure 2.4 – Design strategies for sustainable behaviour (Lidman and Renström, 2011)

2.4. Water treatment

The process in a water treatment plant includes a series of individual processes that are effective in separating different contaminants from the water. Each individual process will be described below in the typical order they usually have in the overall water treatment process.

2.4.1. Coagulation and flocculation

The purpose of *coagulation* is to condition the dissolved and dispersed matter of the water that do not sink to the bottom of the water container. This is done by adding chemical coagulants such as alum and iron salts or organic polymers. The coagulation process destabilised particles which means that it reduces the surface charge of particles. It also adsorbs dissolved matter into particles and forms flocculent precipitates that catch dissolved matter as it settles to the bottom. The following *flocculation* process aggregates the destabilised particles into larger particles that can later be removed by the subsequent processes of gravity sedimentation or filtration. The flocculation process takes around 20 to 40 minutes in general (Crittenden et al., 2012).

2.4.2. Sedimentation

Sedimentation is the process where large enough particles sink to the bottom by

gravitational forces. This can be done by letting the water flow in a calm pace through a large basin. This gives the particles time to settle and form a sludge layer on the bottom, which can then be removed by mechanical scrapers (Crittenden et al., 2012).

2.4.3. Filtration

In the *filtration* process, water passes through a porous medium that removes particles physically that are too large to pass. The porous medium can either be a thick bed of granular material such as sand, or a membrane which is a very thin synthetic material with tiny holes in it through which the water can pass. Rapid filtration is the most common granular filtration technology, which has a high filtration rate due to processing of the granular media into a more uniform size than what is typically found in nature. Membrane filtration is a much newer technology that rely on straining instead of depth filtration, which means that it does not require coagulation, flocculation and sedimentation for effective particle removal. Even though a membrane filtration plant demands 100 times the filter area of rapid granular filtration plant, the membrane filtration plants are often smaller due to their high packing density (Crittenden et al., 2012).

Filtration membranes are classified as microfiltration or ultrafiltration membranes. Microfiltration membranes have a pore size of 0.1- µm, which captures particles, sediment, algae, protozoa and bacteria. Nanofiltration membranes has a pore size of 0.01- µm, which also captures small colloids and viruses. Both types of filtration mediums needs to be periodically cleaned from particles through a backwash cycle (Crittenden et al., 2012).

2.4.4. Reverse osmosis

Another membrane treatment process is *reverse osmosis*, which is a pressurised system that lets water pass through the membrane while solutes are rejected. Reverse osmosis is used for desalinating seawater and brackish groundwater. It is also used for softening of water, disinfection by-product control, specific contaminant removal and advanced treatment for drinkable water reuse (Crittenden et al., 2012).

2.4.5. Adsorption and ion exchange

In the processes of *adsorption* and *ion exchange*, dissolved constituents are transferred to the surface of a solid and thereby removed from the water. In drinking water treatment, the most common adsorbent material is activated carbon. The adsorption processes are used to remove synthetic organic chemicals, taste- and odour-causing organics, colour forming organics and disinfection by-product precursors (Crittenden et al., 2012).

2.4.6. Air stripping and aeration

In the processes of *air stripping* and *aeration*, water and air is brought into close contact so that volatile substances like hydrogen sulphide or volatile organic compounds can be transferred from the water into the air. Likewise, substances can be transferred from the air to the water like for instance oxygen and carbon dioxide (Crittenden et al., 2012).

2.3.7. Advanced oxidation

Unlike previously described water treatment processes where contaminants are removed from water, the *oxidation* process instead chemically transform compounds so their undesirable properties are eliminated. During the oxidation process, electrons are transferred from one reactant to another (Crittenden et al., 2012).

2.4.8. Disinfection

Disinfection is an essential part of the process of making water safe to drink. Five different disinfection agents are common to use in the drinking water treatment: free chlorine, chlorine combined with ammonia, chlorine dioxide, ozone and ultraviolet (UV) light. The use of UV light involves the use of electromagnetic radiation while the other four are chemical oxidants. The use of chlorine is most common while the use of ozone has increased lately due to its stronger disinfecting properties and its control of taste and odour compounds. The use of UV light is not yet very common but it is expected to increase in the future because of its lack of generation of by-products and its effectiveness against protozoa (Crittenden et al., 2012).

2.5. Water storage

Water stored for longer periods of time may be subjected to growth of *Legionella* bacteria. Legionella bacteria may cause illnesses of varied severity, from a mild febrile illness called Pontiac fever, to a potentially fatal form of pneumonia called Legionnaires' disease (World Health Organisation, 2007).

Legionella bacteria are commonly occurring in both natural and artificial water environments but its growth may be encouraged by the conditions of the storage tank. Temperature is one of the influential factors as the bacteria can multiply at temperatures between 20° C and 45° C (Health and Safety Executive, 2014). Below 20° C, there is little or no increase in numbers of legionella bacteria. At temperatures of 50° C, they are able to withstand for several hours while at temperatures above 70° C, they are destroyed almost instantly. Another factor influencing the bacterial growth is the presence of other microorganisms as they allow legionella bacteria to increase in numbers (World Health Organisation, 2007).

3

Methodology

This chapter describes the methods and tools used in this project, divided into the areas of planning, data collection, analysis, concept development and evaluation.

3.1. Planning

3.1.1. Gantt chart

A Gantt chart is useful in getting an overview of the time plan for a project. It illustrates the relationships between different activities and time. Each activity is listed on the vertical axis and illustrated by a horizontal bar in the chart. The length and positioning of the bars in relation to a horizontal axis show the start and end date as well as the duration of each activity. Gantt charts are easy to understand and communicate to others (Maylor, 2010)

3.2. Data collection

3.2.1. Literature studies

The purpose of literature studies is to gain more knowledge and insight about specific areas relevant for the study. Relevant information can be found in various publications, including physical books as well as online sources (Bohgard et al., 2010). Information was collected throughout the whole span of the project and included material about dishwashing, water and energy consumption, compact living, water treatment and different technical principles. The material was retrieved from sources like e-journals, web pages and company reports (see References).

3.2.2. Benchmarking

Benchmarking is a method used to investigate market trends and differences within a specific segment. It can be used to analyse the strengths and weaknesses of existing products, as an understanding of competitive products is critical to successful positioning of a new product (Ulrich and Eppinger, 2012). Benchmarking was performed at several stages of the project to gain knowledge about existing products, features and configurations.

3.2.3. Survey

Surveys are useful when the aim is to collect data from a large amount of people during a short period of time or from people that are difficult to reach. They can also be used to validate the result from interviews. Surveys mainly collect quantitative data and should contain clearly formulated questions (Bohgard et al., 2010). An online survey was sent out at an early stage of the project as an explorative method to gain knowledge related to dishwashing from a varied group of people.

3.2.4. Interviews

For gathering information about people's thoughts and opinions, the most fundamental method to use is interviews.

Depending on the structure of the interview, the data that is being collected can be either qualitative or quantitative. In a structured interview, the interviewee is asked predetermined questions that can be answered either freely or by choosing between predetermined alternatives, providing quantitative data that can be easily analysed. In an unstructured interview, only open-ended questions are asked and the interviewee can steer the discussion into areas they find important, providing qualitative data. A semi-structured interview is a combination between the two, which allows for probing (Bohgard et al., 2010).

The interviews performed in this project was of a semi-structured character, with open discussions about areas that was found interesting during the interviews.

3.3. Analysis

3.3.1. Function analysis

To perform a function analysis means to translate fundamental system requirements into detailed specifications for subsystems and functions (Bohgard et al., 2010). There are several ways to perform a function analysis. The method used in this project is based on an approach by Cross (2000), which includes the following steps: First, the general function of the system is expressed as a conversion from input to output. Second, the general function is split into central sub functions. Third, the interactions between the sub functions are drawn in a block diagram. Fourth, the sub functions are allocated to components.

The function analysis was performed in order to describe what is being achieved in current dishwasher systems by analysing the flow of material, energy and information as well as relations between the different sub functions.

3.3.2. KJ-analysis

KJ-analysis is a method used for structuring large amounts of collected data in order to get a better overview. Quotes and comments from the study are written down on one post-it paper each. These are then placed together with related post-it's on a board, creating several categories which can be used later as a guide when formulating requirements for the concept (Karlsson, 2007).

3.3.3. Fishbone/Ishikawa diagram

A fishbone diagram, also called Ishikawa diagram, is used to structure the main and part reasons to a defined problem. This is in order to simplify the finding of a solution to the problem. The procedure starts by defining the problem. Problem categories are then identified through brainstorming and part reasons are listed. Finally, the reasons are ranked according to their importance (Bohgard et al., 2010).

3.3.4. Design Format Analysis (DFA)

The purpose of a Design Format Analysis (DFA) is to identify characteristic visual elements of a brand, also known as explicit design cues. The visual elements can be found in shapes, proportions, colours, materials, textures, graphics etc. How characteristic each of the identified elements is can then be assessed by comparing them with each other and by comparing different products from the brand's product range (Warrell, 2006).

3.3.5. List of requirements

A list of requirements is a document that, based on findings from the study, formulate in detail what a product has to fulfil. It does not, however, give any solutions to how customer needs should be met or how

problems should be solved (Bohgard et al., 2010; Ulrich and Eppinger, 2012). The list of requirements is often not completed at one single occasion. It can be continuously updated throughout the product development process as the solutions go into more and more detailed levels (Bohgard et al., 2010). This was also the case in this project, where a very general list of requirements was created at first to allow for various solutions. As a more specific direction of the solution was chosen, more requirements were added, focusing on different parts of the concept.

3.3.6. Persona

An effective way of communicating the attitudes, desires and needs of the target user it to create a persona. A persona is a fictive character who could be a possible user of the product. In order to cover a variety of users in the target group, several personas can be created (Österlin, 2010). Three different personas was created in this project. Different personalities, habits and living situations were assigned to the personas, all representing possible members of the target group.

3.3.7. Scenarios

Scenarios were used to analyse and communicate different use situations and for specifying requirements of the concept.

3.4. Concept development

3.4.1. Brainstorming

Brainstorming is a widely used method for idea generation. It is performed in groups during sessions with the aim of producing as many ideas as possible. Criticism is not allowed during the brainstorming session, as it has a negative effect on the creativity. All ideas are noted down and evaluation of the ideas is performed after the session (Bohgard et al., 2010). Brainstorming was performed at several stages of the concept development phase, in the beginning focusing more on general problems found in the study while the later brainstorming sessions focused on finding solutions to specific aspects of the chosen concept.

3.4.2. Sketching

Sketching is an effective method for exploring, analysing as well as communicating different ideas. It can be used at different stages of a project with varied level of detail depending on what the purpose is. At the concept generation stage, sketches are made fast and simple in order to express different ideas. At the stage of further refinement and concept selection, the sketches often include more information showing design details and features (Ulrich and Eppinger, 2012). Sketching was used intensively in this project for generating ideas, evaluating different design alternatives and for communicating different possibilities both within the group and with supervisors.

3.4.3. Physical models

Building physical models in foam board is a quick method that allows concepts to be expressed in three dimensions and often in full scale. These models are generally made quite rough, but provide the possibility of better evaluating concepts and making design modifications (Ulrich and Eppinger, 2012). Physical models was used mainly to evaluate the dimensions of the concept at the concept refinement stage.

3.4.4. CAD-modelling

Computer aided design (CAD) tools are used to generate three-dimensional models of concepts, that can be rapidly modified and visualised as realistic images. The CAD software can also be used to generate

drawings and models that can be directly transferred to mechanical systems (Ulrich and Eppinger, 2012). The CAD-software that was used in this project to generate the concept model was CATIA V5.

3.5. Evaluation

3.5.1. Kesselring matrix

The purpose of a Kesselring matrix is to evaluate different concepts from a number of defined criteria. The criteria are given a weight indicating their importance and the concepts a score on how well they meet each criteria. The scores and weights are then multiplied to generate total scores that can be compared between the different concepts (Johannesson et al., 2004).

4

Initial Research and Analysis

In this chapter, the results from the initial research and analysis performed in the project are presented. The results come from literature studies, benchmarking and different tools including a function analysis and a design format analysis.

4.1. Literature studies

4.1.1. Water consumption in households

According to Vattenfall (2016), the average water consumption per person and day in Sweden is 160 litres. Of these, about 30 litres are used for dishes and 10 litres for cooking and drinking. Hot water stands for about 40% of a household's total water use and 20% of the total energy consumption. About 40% of the hot water is consumed in the kitchen (Vattenfall, 2016).

As part of a study on dishwashing habits conducted by the University of Bonn, data was provided from measurements of water consumption through the kitchen tap in 81 households from Germany, Italy, Sweden and the UK. The total result showed an average consumption through the kitchen tap of almost 19 litres per person and day. However, the result differed a lot between the countries with the lowest consumption in Germany, of just 11 litres compared to 21 in Sweden and almost 24 in Italy. The activity that was found to contribute the most to the kitchen tap's water consumption was dishwashing with an average share of 58%. This percentage includes the water used for manual dishwashing but also the water used for pre-rinsing the dishes in households with dishwasher. The pre-rinsing stood for between 14% and 25% on average of the dishwashing category of water consumption in households with a dishwasher (Richter and Stamminger, 2012).

The second most tap water consuming activity in the kitchen was found to be cleaning, including activities such as rinsing out the cloth or sponge, cleaning the sink and rinsing packages to prepare them for recycling. The rinsing of packages was especially common in Sweden and the UK among the four countries.

Cooking activities ended up on a third place in the study with more than half of the category's total amount of water being used to wash vegetables, fruit or meat. The category also included filling water into a pot, rinsing pasta, plunging eggs into cold water, unfreezing and making ice cubes (Richter and Stamminger, 2012).

Richter and Stamminger (2012) found a varying consumption of tap water used for the drinking category. In Sweden, the participants often left the tap running before filling up the glass or bottle so that more water than necessary was used for the actual drinking. In Germany, the participants showed the opposite behaviour as in a

majority of the cases, water was filled directly into the glass or bottle.

Another important finding that Richter and Stamminger (2012) made was that single-person households consume around twice as much water per person as a person in a five-person household. The difference in water consumption per person between single-person and two-person households, however, was quite small with only 10% less for two-person households. Comparing single- and three-person households the reduction was as much as 40% less per person for the three-person households (Richter and Stamminger, 2012). This makes it extra important to consider small households in developing projects concerning kitchen water use.

4.1.2. Comparison between manual dishwashing and use of dishwasher

Stamminger et al. (2010) performed an investigation on the environmental effects of manual dishwashing compared to dishwashing machines by letting 113 persons from seven European countries wash 12 place settings (equalling 140 individual pieces) of dishes manually. They then compared the results to two modern A labelled dishwashers running under equal conditions. They found that in average, the test persons used 103 litres of water and 2.5 kWh of energy to wash the 12 place settings of dishes. In comparison, the dishwashers used 15 litres of water and between 1 kWh for a 'normal' program and 2 kWh for an 'intensive' program. The test persons took in average 79 minutes time to finish the dishes compared to the operating time of typically between 80 and 160 minutes for the dishwashers. However, considering instead the total working time of around 15 minutes for loading and unloading the dishwasher, the user can save at least one hour's work per load by using a dishwasher. Regarding the wash result, it was found that the dishwashers were able to reach at least the same performance as the test persons, but with significant less amount of water (Stamminger et al., 2010).

Another consumer study on dishwashing was performed by Richter (2010) including 200 households with and without dishwasher from Germany, Italy, Sweden and the UK. The households were interviewed and kept diaries recording every dishwashing process for two weeks, with 82 of them participating in deeper observations including webcam recordings and resource consumption measurements. From the study, it was found that the households with dishwasher on average used 50% less water and 33% less energy per cleaned item compared to the households without dishwasher. However, the study also showed that even with the ownership of a dishwasher, a large proportion of the dishes still get washed by hand (Richter, 2010).

4.1.3. Consumer behaviour affecting the environmental impact of dishwashers

Although a dishwasher has the potential to lower a household's water and energy consumption, its environmental impact is greatly affected by consumer behaviour. In the study performed by Richter (2010) it was found that pre-rinsing of dishes was a common consumer habit especially in Sweden and Italy. This activity caused an average additional water consumption of 11 litres per dishwasher cycle in the Swedish households and 20 litres in the Italian households participating in the study. Dishwasher manufacturers recommend consumers to scrape or wipe food leftovers from the dishes before placing them in the dishwasher. If consumers do not perceive the dishes to get clean from the wash cycle without pre-rinsing them, a less water

consuming option is to use the dishwasher's 'rinse and hold' program.

Another factor affecting the energy consumption of the dishwasher is the program selection. Richter's study showed that the majority of the participants chose the same program all the time and that in half of the wash cycles, a temperature of 65°C or higher was selected. In the Swedish households, the most commonly chosen program temperature was 50/55°C followed by 65°C. Very few of the Swedish households selected programs of either 35/45°C or 70/75°C.

The extent to which the dishwasher's total loading capacity is used also affects the water and energy consumed per item. In Richter's study, less than 40% of all dishwasher loads were filled to the full capacity. The Swedish households, however, had the lowest proportion of only slightly filled baskets among the four countries in the study.

Comparing different household sizes, Richter (2010) found that the frequency of dishwasher use and manual dishwashing is higher per person in single-person households than in bigger households. This tends to lead to higher water and energy use per item for the single-person households. Concerning the dishwasher capacity, a lower capacity did not seem to increase the dishwashing frequency in the study. Single-person households with a standard sized dishwasher was found to run their machines almost as frequently as single-person households with countertop dishwashers (Richter, 2010).

4.2. Benchmarking

4.2.1. Dishwasher configurations

From the benchmarking, the project team was able to identify six different dishwasher configurations found on the market today, which are presented below and summarised in Table 4.1.

Standard dishwasher 60 cm

A dishwasher of standard width (60 cm) gives the highest capacity and can normally take between 12 and 15 place settings, where one place setting equals about the amount of dishes that one person generates from a three course dinner. This type can either be fully integrated with a front panel matching the rest of the kitchen, or semi-integrated, leaving the control panel to the dishwasher visible. They can also, of course, be installed without any integration, leaving the whole machine visible.

The interior of a standard dishwasher commonly includes two level racks with the lower meant for large dishes like plates and sauce pans but also includes a basket for cutlery. The upper rack leaves less height above itself and is intended for smaller dishes like glasses and cups. There are also variants including three level racks, where the third and uppermost rack holds cutlery, replacing the cutlery basket from the first level rack.

Narrow dishwasher 45 cm

A narrow dishwasher of 45 cm has a similar layout to the standard machines but has a lower capacity of normally nine place settings, which equals about two thirds of the capacity of the standard dishwashers. Like the standard ones, this type also has the possibility to be integrated with front panels.

Compact/benchtop dishwasher

A compact dishwasher, also called benchtop dishwasher, are for those who do not have the possibility to install a standard or narrow dishwasher in their kitchens, or for those who only generate a small amount of dishes. A compact dishwasher is typically 55 cm wide and has the capacity of six place

settings, or about half the capacity of a standard dishwasher. There are a few models also from this category that can be integrated in the kitchen with a front panel.

Drawer dishwasher

This category of dishwashers is relatively new and was launched first by Fisher&Paykel in 1997 with their DishDrawer™ (Architecture & Design, 2008). This type of dishwasher has only very recently started to appear on the Swedish market.

The DishDrawer from Fisher&Paykel comes in several configurations with either double or single drawers. The double drawers have the same outer measurements as a standard dishwasher, with the capacity of six place settings in each drawer. The separate drawers allow you to run smaller loads more frequently. The single drawers are also available in extra tall or extra wide models. Just like the above presented categories of dishwashers, the DishDrawers can be integrated as well.

Sink dishwasher

The principle of a sink dishwasher is to replace the sink with a combined sink and dishwasher to avoid taking up storage or workspace in the smallest kitchens. However, the sink dishwasher extends downwards and takes up more space from the sink cabinet than an ordinary sink does. A few years ago, KitchenAid launched its in-sink model Briva, with a capacity of up to five place settings and a top lid that could be used as extra workspace when closed. At the moment, sink dishwashers are not available on the Swedish market.

Portable dishwasher

Portable dishwashers on wheels are an option for people who do not have the possibility to install a dishwasher in their kitchens but have enough space to store a dishwasher somewhere else. When used, the dishwasher is placed beside the sink and connected to the faucet. Portable dishwashers exists in the sizes of standard (60 cm) or narrow (45 cm), but are not available on the Swedish market at this moment.

	 Standard dishwasher	 Narrow dishwasher	 Compact/ benchtop dishwasher	 Drawer dishwasher (single drawer)	 Sink dishwasher	 Portable dishwasher
Width (cm)	60	45	55	60/90	-	45 - 60
Height (cm)	80 - 90	80 - 90	44 - 45	41/48	-	92 - 98
Capacity (place settings)	12 - 15	9	6	6/9	5	9 - 12
Price range (SEK)	2500 - 25000	2500 - 15000	1500 - 5500	8000 - 9500	-	-
Available on Swedish market	Yes	Yes	Yes	Yes	No	No

Table 4.1 – Benchmarking of dishwasher configurations

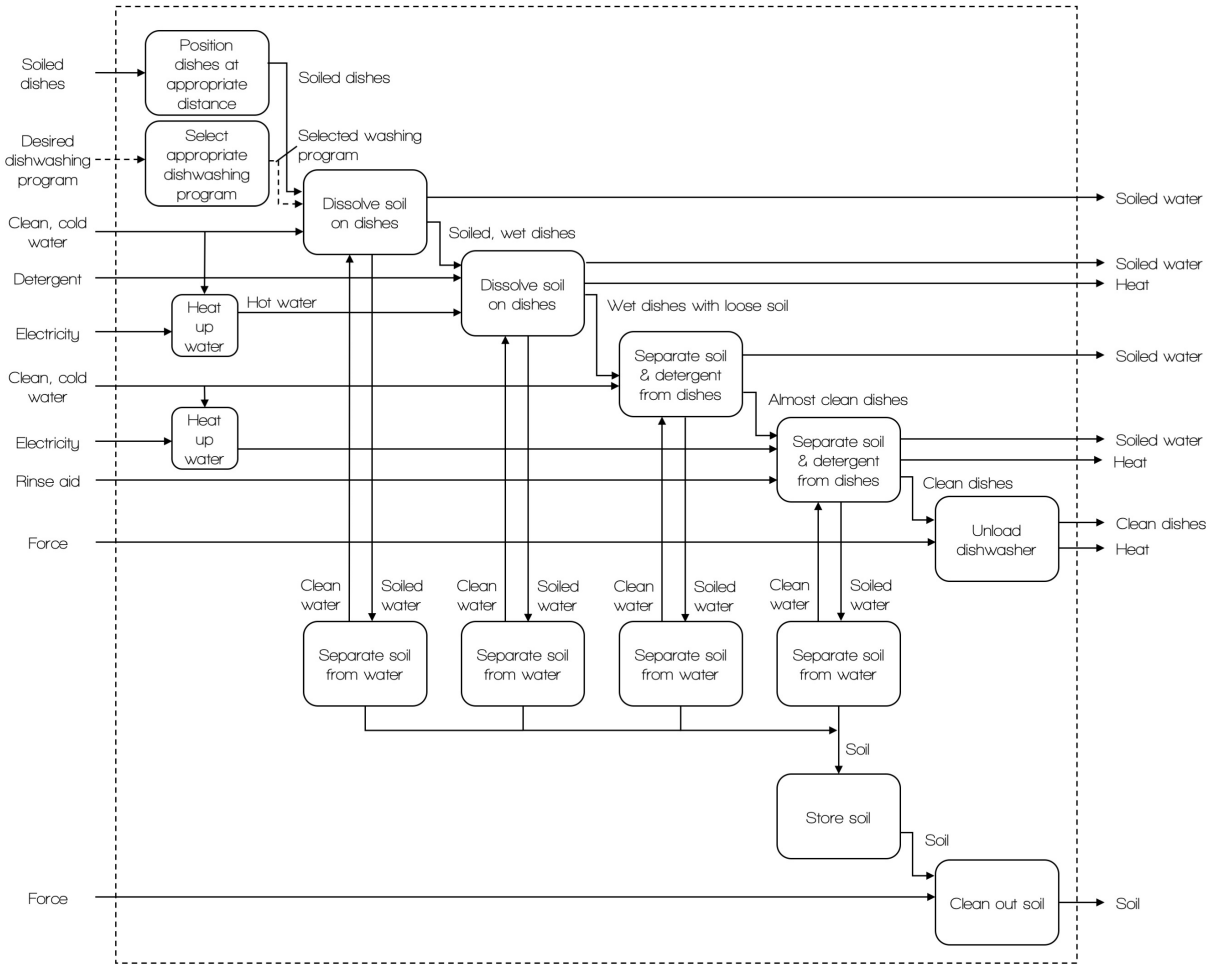

Figure 4.1 – Function analysis of the dishwasher

4.3. Function analysis

A function analysis as seen in Figure 4.1 was performed to analyse and map up the flows of material, energy and information during a normal wash cycle of the dishwasher. The information flow is marked by a dashed arrow while the material and energy flows are marked by continuous line arrows.

4.4. Analysis of Electrolux's visual brand identity

According to Karjalainen (2007), a brand's character can be mediated through a product by using explicit and implicit design cues. The explicit values of a brand can be immediately perceived and recognised through design features embedded in the product while implicit values are more related to the overall reputation and image of the brand.

4.4.1. Design Cues

To identify the explicit design cues that expresses Electrolux's visual brand identity, several existing Electrolux products were analysed according to a Design Format Analysis (DFA). The DFA can be found in Appendix II. The identified design cues are summarised below and by Figure 4.2.

- Distinct flow line (1) that balances strong angles with a little bit of smoothness. It is often symmetrical on a central axis but can also be part of other directional lines in the product.

- Angled surfaces and flow lines showing direction.
- Sharp contrasts between surface finishes, materials and colours (2).
- Common materials are shiny plastics, glass and stainless steel. The stainless steel can have both brushed and shiny surface finish.
- The logotype is often in a central position on the central axis of the product (3). The logotype consists of a symbol and text, which are often placed together with the symbol above the text. A bit less common is to place the symbol and text at separate places, or with the symbol to the left of the text.
- The colour of the logotype depends on the colour of the surface it is placed on. If placed on stainless steel it is often black/dark grey while if placed on a dark surface it commonly has a light silver tone. When placed on a white surface, the logotype can either have a darker silver or grey tone
- Besides the logotype, silver can be found in other small details as well such as text or buttons (6)
- Chamfered edges (4) together with slightly arched and angled surfaces give the products a compact, strong and robust appearance. This expression is further enhanced by the distinct split lines (5) and sharp transitions between different surfaces.

Figure 4.2 – Identified design cues exemplified in the Electrolux Ultraone vacuum cleaner

5

User Study

The setup and findings of the user study are described in this chapter. The user study deals with the use of dishwashers but also manual dishwashing, cooking habits and kitchens in general.

5.1. User study setup

A user study was performed early in the project and aimed to get an understanding for habits, attitudes and thoughts as well as problems related to dishwashing. The study included both people who own a dishwasher and people who wash the dishes by hand as the two groups were believed to contribute with different perspectives on the dishwashing matter. The user study started off with a survey to provide quantitative and general information about dishwashing. Thereafter followed semi-structured interviews with people who were considered to be within the target group. These interviews aimed at getting deeper knowledge about the target users' wants and needs related to dishwashing as well as to cooking and the kitchen in general.

To get more information about customer demands when purchasing a dishwasher, a semi-structured interview was performed with the store manager of an Electrolux Home store in Gothenburg. Another interview with the administrator for rented apartments at HSB Gothenburg discussed kitchen layouts and the possibilities of installing a dishwasher in different types of rented apartments. Lastly, one short interview was carried out with the master chef in a commercial kitchen at Chalmers University of Technology for taking inspiration from the effectiveness and efficiency of a workplace kitchen handling a large amount of dishes each day.

5.1.1. Survey

The survey was spread as an online version via Facebook and email. It consisted mainly of multiple choice questions that would be quick to answer but also had a few open ended questions were more information was sought for. The survey consisted of six sections where the first handled general questions about age and housing. The second part dealt with the kitchen and cooking behaviour while the third part was about environmental impact and washing effectiveness of dishwashers in relation to hand washing of dishes. After section three the respondents were sent further to two different sections depending on their answer to the question "Does your kitchen have a dishwasher?". Finally, all respondents finished the survey with a section about dishwasher purchase.

In total, the survey generated 97 responses with age distribution and type of housing shown in Figure 5.1 and 5.2. The living space of the respondents varied from less than 20 m^2 to more than 100 m^2 and the number of

people per household from one person to more than four. This diversity of respondents was desired in some of the questions, while in other questions it was more interesting to look only at what people living more compact answered, which is why a filter was added to screen out respondents living in 50 m² or larger in some questions. This left 40 responses, of which 20 were single households, 17 households of two people, one household of three people and two households of four or more people. The last two stated to be living in student apartments of less than 20 m², which in this case would probably mean a rented room with shared kitchen. It will be specified in the text as well as the diagrams whenever the filter is used for a result.

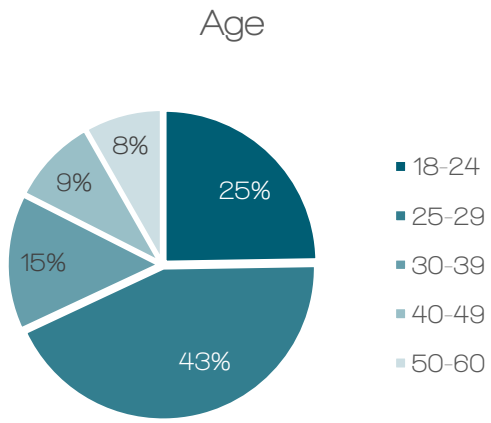

Figure 5.1 – Age distribution of survey respondents

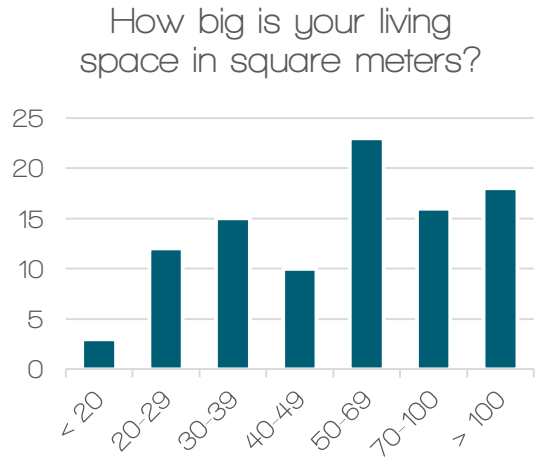

Figure 5.2 – Living space distribution of survey respondents

5.1.2. Interviews

Eight interviews were held with twelve persons from ten different households. This means that in half of the cases the participants were interviewed one by one and in the other half of the interviews there were two participants, who were encouraged to discuss with each other for generating deeper information. All interviews were of a semi-structured character meaning that some prepared questions were posed but whenever needed, the interviewees were given supplementary questions to explain more. The interviews ended with a task where the participants were asked to place the dishwasher in relation to other kitchen appliances on a diagram measuring utility versus status, and encouraged to explain their thoughts while they were doing so. After the interviews, the participants were also asked to photograph their kitchens and send the pictures to the project team.

The complementary interviews with Electrolux Home and HSB Gothenburg were both held via phone while the interview with the master chef was held in the commercial kitchen at Chalmers University of Technology for being able to observe the flow and different operations handling the dishes.

5.2. User study findings

5.2.1. Cooking habits

The cooking habits were found to be highly individual among the participants in the user study. In the survey, the respondents were asked how often they buy lunch and dinner during a normal week excluding the weekend. Buying lunch was in general more frequent (mean value 2.3) than buying dinner (mean value 0.9). Adding the filter of living space less than 50 m² was found to have little effect on the result. Among those respondents, the mean values were 2 for buying lunch and 0.9 for buying dinner. Among the interviewees, the cooking

frequency varied between three times a day to about once a week, not meaning that the persons would buy food for all other meals but rather that more simple meals was prepared or that they had ready meals or lunch boxes available.

What turned out to be most appreciated in terms of cooking among the interviewees was either related to social aspects or to creativity and accomplishment. Some preferred cooking together while some preferred cooking alone and serving food to others. Many of the interviewees mentioned that the most boring part of cooking was to cook only for themselves and then eat alone but also to take care of the dishes afterwards. The way of handling mess caused by cooking also varied greatly. One interviewee mentioned that she would not sit down and eat before the countertop was clean while some others would usually leave the mess to be taken care of later, or another day when they would have to deal with it for being able to cook again.

Some of the interviewees mentioned that they always tried to make food that would be suitable for lunch boxes while others explained that the cooking varied between weekdays and weekend, being more varied and enjoyable on the weekends. What was found to be common for the interviewees was to have a basic set of tableware they would use very frequently but that other utensils varied a lot depending on the type of cooking.

5.2.2. The kitchen

Out of the survey respondents living in less than 50 m², 40% had a separate kitchen, 42% an open plan kitchen and 18% a kitchenette. To the question “Do you feel that the kitchen is big enough for your needs?”, 22% from the same respondent group answered that it is way too small, 40% that it could have been a little bigger and 38% answered that it is adequate.

From the interview with Joakim Edman, administrator of rented apartments at HSB Gothenburg, it was learned that the kitchen often take up quite a small part of the total living space, and that new apartments often are built with open plan kitchens. Also, kitchens in newly built rental apartments often have the possibility to install a standard sized dishwasher as there is usually one 60 cm cabinet that can be exchanged and a faucet adapted for standard dishwashers. However, it is the tenants themselves who are responsible for purchasing the dishwasher and making sure that it is correctly installed. Edman emphasised the importance of having a valid insurance as there is a risk of water leakage from the dishwasher. Unfortunately, water damages are not uncommon but the cause is typically carelessness, either during installation or during usage if the user leaves home while the dishwasher is running.

In older kitchens, it may be more problematic to install a dishwasher due to different dimensions. Kitchens that were built until the sixties sometimes have an empty space beneath the countertop that is usually 50 cm wide, and originally meant for placing a stool. This space is too narrow for a standard dishwasher of 60 cm but can be used for a narrow dishwasher of 45 cm. Another alternative for older kitchens is to use a benchtop dishwasher. However, benchtop dishwashers today are generally wider (500-580 mm) than older ones (450 mm). As kitchens from the fifties, sixties and seventies have draining boards adapted for dish racks that are maximum 50 cm wide, part of today’s benchtop dishwashers may hang out over the sink. Another problem with benchtop dishwashers is that if the hose is connected directly to the tap, there is a risk either of the hose to come loose or, if the water is led back to through the water system, a risk of legionella bacteria. Therefore, using a benchtop dishwasher demands a special faucet adapted to this

kind of dishwasher. Installation of a new faucet could cost around 3000-4000 SEK, including both a new faucet and charge for approximately one hour installation work, according to Edman.

HSB Gothenburg owns and administrates 1600 rented apartments. The smallest ones are in the size of 20-30 m², which are very few and viewed mainly as short term accommodations. 30-40 m² apartments are more common and viewed as standard one room apartments. According to Edman, there is almost always two sinks in the kitchen for the ability to do manual washing of dishes. HSB Gothenburg uses no kitchenettes for safety reasons as kitchenettes with integrated stove in the draining board poses a risk of short circuit or of electricity moving from stove to the water leading system as well as a risk of fire.

From the user study, it was possible to identify four different types of kitchens: Standard kitchens, compact kitchens, older or special kitchens and kitchenettes. The standard kitchen is based on modules of 20, 40, 60 or 80 cm, with 60 being the most common dimension. It has, besides the sink unit (which is generally 80 or 60 cm), room for at least three 60 cm units including both a dishwasher, oven and cabinet/drawers. A compact kitchen is also based on standard sized modules but has, compared to the standard kitchen, only room for two 60 cm units beside the sink unit, with one of them being the oven. Those who want to install a dishwasher therefore have to sacrifice the only 60 cm unit left and thereby lose important storage. The older or special kitchens are only partly compatible with today's standard units and often include special units with different width and height. The kitchenette has no exchangeable units and is not compatible with any of the existing dishwashers on the market. This type of kitchen exists mainly in student apartments or temporary apartments.

From the interviews with the different households, it appeared that the ones living in rental apartments did not want to invest much money in their kitchens, which was in some cases one important reason for not installing a dishwasher. People who own their apartments of course have greater freedom in the way they can build their kitchens and a larger variation can therefore be found in the design of those kitchens.

It was also evident from the interviews that workspace is highly valued and essential both for being able to be creative in cooking as well as for being able to socialise in the kitchen. When asked what their dream kitchen would look like, almost all interviewees answered that they would like to have a large, bright kitchen with a kitchen island in the middle providing a lot of workspace and room for several people. There should also be lots of storage and easy access to items needed when cooking.

The future of kitchens was also discussed with the interviewees. Some believed that the kitchen will always be important for determining the value of an apartment and that this may be one reason for people to invest money in their kitchens, even though they may not spend much time cooking in them. It was also discussed that socializing in the kitchen may become even more important with open plan kitchens that are part of the living space. Another thought was that smaller kitchens may have to be tolerated in the future due to a lot of people moving into the cities and that the need for smaller products that can do the same job as larger kitchen appliances will then increase. The need for more energy efficient, user friendly products and better waste handling in the kitchen was also discussed.

Of all the respondents to the survey, 54% had a dishwasher in their kitchen (Figure 5.3). However, of the 40 respondents living in less

than 50 m², only 15% stated to have a dishwasher (Figure 5.4).

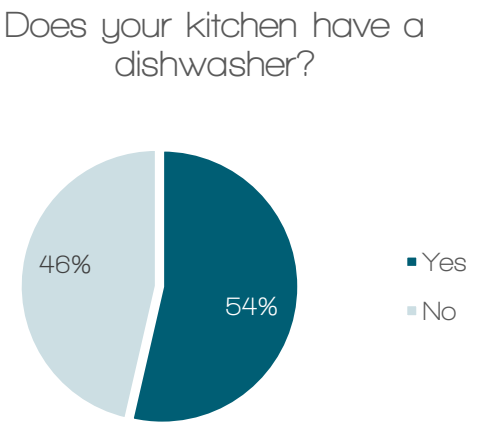

Figure 5.3 – Ownership of dishwasher among survey respondents

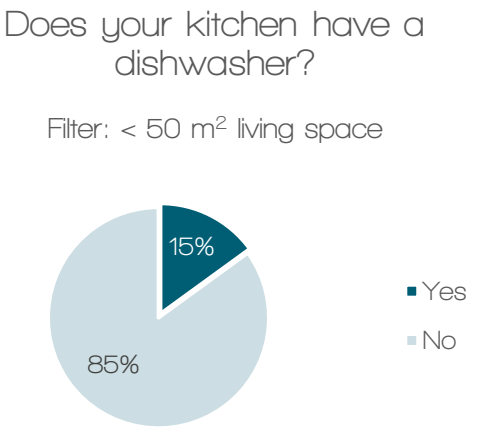

Figure 5.4 – Ownership of dishwasher among survey respondents living in less than 50 m²

5.2.3. Dishwashing frequency

The frequency of which people do the dishes turned out to be quite similar for people with and without dishwasher in the survey. Most common was to do the dishes once a day followed by every other day. The main difference between the two groups was a higher number of respondents doing the dishes several times a day from the group without dishwasher and a higher number of respondents doing the dishes every third day or one to two times a week from the group with dishwasher.

The participants with dishwashers were also asked how often they wash dishes by hand. It turned out that as much as 40% actually washed some dishes by hand every day. Only 4% stated to never wash any dishes by hand.

From the interviews it was found that benchtop dishwashers mainly can contain a basic set of tableware and therefore needs to be run often to avoid piles of dishes on the countertop or in the sink. However, despite the larger capacity of standard dishwashers, they may need to be run almost as often since the tableware and utensils may be needed soon again. Users who have a relatively small set of tableware and utensils may therefore run the dishwasher when it is only half full. One interviewee explained that when she lived in a place where she shared kitchen with others, the dishwasher acted more as a storage for dirty dishes than an actual dishwasher as it never got full and items were taken from the dishwasher to be hand washed when they were needed. In the survey, however, only 6% stated to usually have room for more dishes when they run their dishwasher, with the rest stating that it is usually full. What people perceive to be a 'full' dishwasher may of course vary.

It was also found in the interviews that the frequency of doing the dishes is highly individual and depends on personality as well as cooking habits. Some users cannot stand to see the dirty dishes while others leave them standing for days, or even a whole week.

5.2.4. Cleaning result

When asked in the survey which option they thought provides the most effective cleaning of dishes, 19% of the respondents answered washing the dishes by hand, 58% using a dishwasher and 23% that both alternatives

are equally effective in cleaning the dishes. However, when asked if they perceived the dishes to get clean from using a dishwasher and washing by hand, only 17% of the dishwasher owners answered "yes, always" compared to 35% of the users without dishwasher. On the other hand, only 4% of the dishwasher owners answered "no, usually there is some dirt/spots left on the dishes compared to 7% of the users without dishwasher. 50% of the dishwasher owners stated that the dishes are usually dry when the washing cycle is finished.

The interviewees who owned dishwashers were in general satisfied with the washing result of their dishwasher even though the dishes did not always get completely clean and not always completely dry. They seemed to have accepted the dishwasher's limitations and appreciated the time it saves them compared to washing the dishes by hand. To ensure clean dishes, most participants usually pre-rinsed their dishes and did not rely completely on the dishwasher to do the job.

5.2.5. Environmental impact of dishwashing

In order to investigate people's perception about the environmental impact of dishwashers in relation to washing the dishes by hand, the survey respondents were asked which of the two options they believed to be most environmentally friendly. 22% answered washing by hand, 69% using a dishwasher and 9% that both options are equally environmentally friendly. However, since the survey was answered also by employees at Electrolux, it was believed that their knowledge about dishwashers may have affected the outcome of this question. Since those people answered the study later than the rest of the respondents, it was possible to screen out the answers from the particular date when the survey was sent to them. This cancelled out 31 responses. Out of the remaining 66 respondents, 29% answered that it is more environmentally friendly to wash the dishes by hand, 61% using a dishwasher and 10% that both options are equally environmentally friendly. This shows that the result indeed was slightly affected by the employees' participation and that there exists some confusion about how to handle the dishes in the most sustainable way. This was also the impression from the interviews, where several participants mentioned that they had low awareness of how much water and energy a dishwasher uses and did not know which the most sustainable option would be. One aspect that made some of them hesitate to use a dishwasher was the stronger detergents that are used for the dishwasher compared to the detergents used for hand washing.

The survey respondents were also asked to what extent they thought that dishwashing contributes to a household's total environmental impact, with a scale from one to five with one being small contribution and five large contribution. Of all the responses, the mean value was calculated to 2.73, which is almost in the middle of the interval.

5.2.6. Problematic items to wash

There are a few items that are difficult to wash, both manually and with dishwashers. Among the users without dishwasher, the most frequent complaint were about the plastic lunch boxes. These were explained to be very difficult to get clean from all the grease sticking to them. One of the interviewees explained that she had accidentally left used lunch boxes with their lid on for several days and then found them with mould inside. The dishwashers seemed to have no problem with getting the plastic lunch boxes clean but their light weight and large area could sometimes cause the lunch boxes to flip around from the water jet in the

dishwasher, leaving them with the bottom down preventing them from getting clean and also getting filled with water. The same problem exists for other light items such as measuring cups, which are also small enough to fall down through the bars and end up in the sump.

Another problematic item is the baking tray, which is too large to fit both in the dishwasher and in the sink. When washing it by hand, you easily splash water all over the countertop or yourself. Other large items such as oven ware, frying pans and sauce pans can be difficult to handle as well and when placed in the dishwasher, they may block the water jet from reaching other items. If they also have dried food residues left on them, they may pose a challenge to both manual washing and the dishwasher.

Tall glasses and carafes can be particularly difficult to place in the dishwasher as they are often too high for the upper rack while the lower rack often lacks a secure way of placing those items. As the lower rack is meant for larger items, some interviewees explained that they hesitated to place the delicate glasses there as they felt that they could either fall or get crashed by the larger, heavier items. However, tall and narrow glasses could also pose a problem for manual washing if they are too narrow to be able to reach with a brush or a sponge. Another category of problematic items for both groups are items with small holes in them, such as the cheese grater or the garlic press.

There are in particular a few categories of items and materials that the dishwasher cannot handle and need to be hand washed to avoid destroying them. These are for instance items made of cast iron like pots and pans, wooden items like cutting boards and utensils, knives and fine crystal. One of the interviewees described how she had put a brand new wooden cutting board in her dishwasher and after the program was finished, it had cracked in half.

To conclude, the dishwasher cannot, as it looks today, completely replace the need for washing the dishes by hand. Nevertheless, it facilitates the dishwashing process greatly and is highly appreciated by its users.

5.2.7. Use of dishwasher

Of all the respondents in the survey who had a dishwasher, 79% owned a standard dishwasher (60 cm), 11% a narrow dishwasher (45 cm) and 8% a benchtop dishwasher. The 2% that chose the option ‘other’, which equals one person, specified that it was a 60 cm dishwasher in a raised position. One to three years was the most common age of the dishwashers with 35% of the total responses, followed by four to six years (27%), seven to ten years (23%) and less than one year (11%). Only 4% had a dishwasher older than ten years.

Programmes and duration

The survey participants were asked which dishwasher programs they use frequently in a multiple choice question where several choices could be made. As can be seen in Figure 5.5, ‘Main/normal’ scored highest, followed by ‘eco’, ‘auto/sensor’, ‘quick wash’, ‘delicate/glass’ and finally ‘intensive’. Nobody selected the options ‘half-load program’ and ‘rinse and hold’. In general, it appeared that users often stick to the same program.

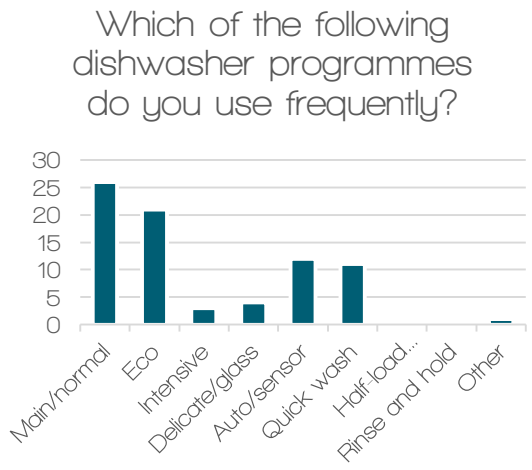

Figure 5.5 – Program selection among survey respondents

There seemed to be a general lack of understanding why eco-programs often are significantly longer than the normal programs. Some participants felt that it was contradicting and thought that a longer program should instead consume more energy and water. The long cycle time of the eco program was frequently mentioned as the main reason for not choosing it. One interviewee had a dishwasher that took four hours to finish with the eco-program and in order to avoid having to wait for it to finish, she usually ran it at night.

There also seemed to be a general lack of understanding in what distinguishes the different programs and what the different symbols indicating those means.

Feedback

Depending on the interface, different dishwashers give different amounts of feedback to the users. Where feedback is lacking, users can be unsure of if the dishwasher has finished or not, how much time that is left of a cycle and what is actually going on in the machine. Some dishwashers beep when they finish while others indicate the change with lamps. Some have displays while others do not.

One of the interviewees that owned a benchtop dishwasher explained how she could tell from the humming sound of the dishwasher when it needed water from the tap to which the hose was attached, and when it was 'safe' to disconnect the hose for short periods of time if she needed the tap for other purposes. Another interviewee was unsure of what was going on in the dishwasher during the last two hours of the cycle since it then went quiet. Therefore, she would sometimes open it to let the dishes dry faster.

Cleaning and maintenance

Cleaning of the dishwasher was not an appreciated task among the interviewees. Especially cleaning the filter was described as very unpleasant as it gets greasy and can be difficult to reach. Some were even unaware of the need to clean the dishwasher once in a while. Others were unaware of the need to use rinse aid or salt in the machine. The frequency of cleaning the machine seemed to depend partly on the dishwashers and their self-cleaning effectiveness and partly on the users as they have different knowledge and care, but also treat their dishes differently concerning the degree to which they pre-rinse their dishes.

Interior layout

Regarding the inside of the dishwasher, there seemed to be highly individual needs among the users depending on their type of dishes and cooking habits. In general, flexibility and ability to customise the interior was highly appreciated. A few examples are the plate holders that can be folded down for the sake of other dishes, cutlery baskets that can be moved to different positions and second level racks that can be adjusted in height.

What kind of dishes that was supposed to be placed in certain areas was not always clear and some participants explained that there

could occur some minor disputes within the household about how the dishes should be placed. The two different variants of placing cutlery in the dishwasher, namely either in a basket or in a third rack, was mentioned frequently among the participants with some preferring the first alternative while others the second. Placing the cutlery in the third rack can be a little more time consuming than just throwing them into the basket but the rack also holds the cutlery in place while in the basket they may stand too close to each other or fall down through the bars and thereby stop the spray arm from rotating.

In general, it seemed to be height rather than width of the dishwasher that was the limiting factor for what dishes that could be washed and how they should be placed.

Pre-rinsing of dishes

Out of all the survey respondents with a dishwasher, only 27% stated that they usually do not rinse the dishes before placing them in the dishwasher. 37% stated to pre-rinse their dishes with cold water and 36% with hot water (Figure 5.6). Pre-rinsing of dishes has a significant impact on the total amount of water and energy used for the dishwashing process and is a waste that to a large extent is out of the control of the dishwasher producers.

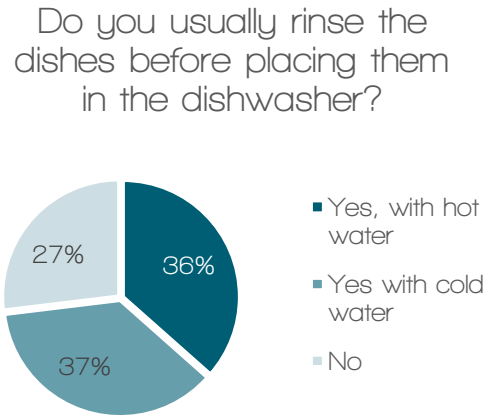

Figure 5.6 – Pre-rinsing of dishes among survey respondents owning a dishwasher

Desired improvements

The participants of this user study had a few requests on desired improvements of the dishwasher. Faster washing cycles was frequently mentioned since the dishware are inaccessible during the washing cycle and may be needed for preparing food again. Another reason for having shorter programs is for the users to not feel hindered to leave home for long periods of time while the program is running.

The participants also wanted a better self-cleaning function, more effective drying of the dishes and easier unloading of the dishwasher. An extra program for half-loaded dishwasher was mentioned by some participants who felt that they normally could not fill up a whole machine. Due to the different needs and types of dishes, some participants requested the ability to customise the interior even more. One interviewee gave the suggestion that different interiors could be purchased separately to be combined with different dishwasher models to enable customers to choose more freely. Other ideas from the same interviewee was a dishwasher that would evaluate its result and highlight items that may not have become properly washed to help the user detect those items before loading them into the cabinet and also to be more forgiving against the dishwasher's shortcomings. Moreover, by enabling users to login to the dishwasher before unloading it, the dishwasher could store information about how many times each member of the household had taken out the dishes each week, for avoiding disputes about whose turn it is to take care of the dishes. This suggestion will most likely not be appreciated by everyone.

5.2.8. Manual dishwashing

Of all the 45 survey respondents without dishwashers, 93% answered that they would like to have a dishwasher (see Figure 5.7).

When asked which kitchen space they would be willing to sacrifice to make room for a dishwasher, 31% answered 'none'. Of the rest, 33% would sacrifice a cabinet, 18% a drawer unit, 7% the dining area and 2% the sink. None of the respondents would be willing to sacrifice worktop area. Of the 9% selecting the alternative 'other', one commented 'almost anything', and the rest that they needed all the space they had.

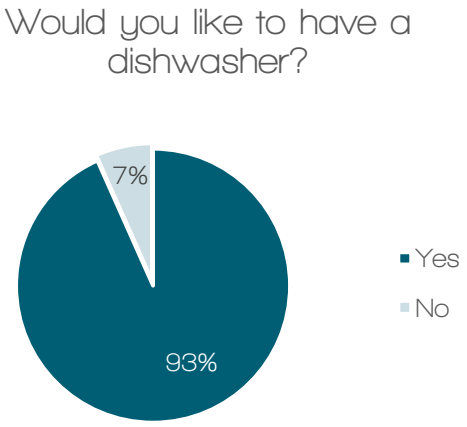

Figure 5.7 – Share of respondents without dishwasher wanting to have one

Reasons for not having a dishwasher

The main reason for not having a dishwasher was lack of space with 65% of the responses, as seen in Figure 5.8. 13% answered that it is too expensive and the rest 22% chose the alternative 'other'. Those who chose 'other' specified either that they were not allowed to install one in their rented apartments, that their contract only was temporary or that it was too difficult and costly to install one.

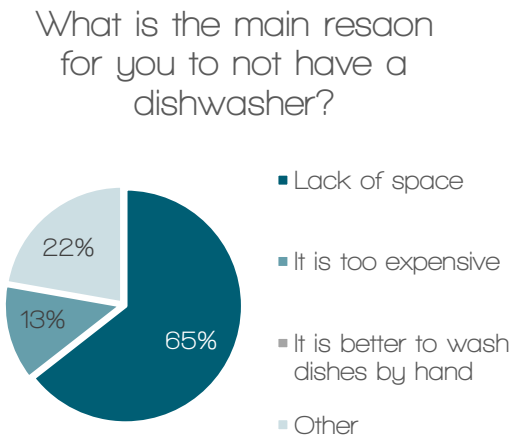

Figure 5.8 – Reasons for not having a dishwasher

In one of the interviews, it was discussed that you may have only occasional use of a dishwasher, like for instance when you have had guests over for dinner. At those occasions, it would be convenient to have access to a room with dishwashers, similar to the ones used for laundry today. Another reason that was discussed was the environmental impact of the dishwasher detergent that some believed to be higher compared to the detergent used for hand washing.

Dishwashing procedure

As shown in Figure 5.9, in answer to the question how they proceed when doing the dishes, only 4% of the respondents without dishwasher stated to wash in the sink and rinse in a tub, which would be the alternative assumed to consume least water. 56% stated to wash in the sink and rinse under running water and 33% to both wash and rinse under running water. The remaining 7%, which corresponds to three persons, chose the alternative 'other'. From the interview, one additional technique for washing the dishes was discovered, namely using a spray bottle with mixed water and detergent, for washing only a few items at a time.

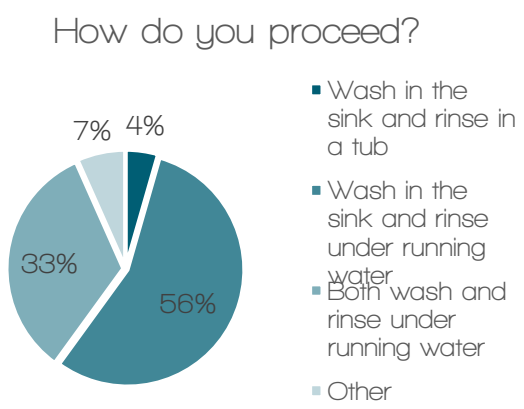

Figure 5.9 – Manual dishwashing procedure among survey respondents

Pre-rinsing the dishes before placing them in the sink seems to be at least as common as pre-rinsing before placing them in the dishwasher. Not pre-rinsing the dishes before placing them in the water filled sink would of course cause the dishwater to get soiled very quickly, which in turn could cause an inferior washing result. Therefore, some of the interviewees described how they have a principle for washing the least dirty dishes first and ending with the worst soiled dishes. Some would also let dishes with dried or burned food residues soak for some time before washing them. A few interviewees mentioned that they felt disgusted by the dishwater and therefore washed the dishes under running water.

The amount of dishes washed each time was found to vary a lot among the hand washing survey participants. 27% of them wait until there as more dishes than the sink can hold, 40% do the dishes as soon as the sink is full and 33% before the sink is full. 58% let the clean dishes dry in a dish rack, 31% uses a dish rack and wipe some of the dishes with a towel and 11% only wipe with a towel.

The temperature used for the water in manual dishwashing was investigated in the survey as well. On a scale from 1 to 5, with 1 being cold and 5 being hot, the mean value of the respondents were calculated to 3.9. The approximate time needed for the tap to be kept open in order for the water to reach the desired temperature varied with 33% selecting the alternative 'less than five seconds' and 33% 'less than 15 seconds'. Of the remaining respondents, 16% answered 'less than 30 seconds', 9% 'less than one minute', 2% 'more than one minute' and 7% that 'the water does not reach the desired temperature'.

The time it normally takes to do the dishes among the hand washer respondents was most commonly 10-20 minutes (49%), followed by less than ten minutes (31%) and 21-40 minutes (18%). None selected the interval 41-60 minutes and only 2% chose the alternative 'more than one hour'.

5.2.9. Purchase of dishwasher

If the respondents to the survey would buy a new dishwasher, the following aspects would be the most important to them by the order they are listed: First energy efficiency, then price and noise level with equal importance, interior layout, aesthetics and design, time, brand, capacity and finally extra features. According to the interviewed store manager of Electrolux Home in Gothenburg, price and noise level are the two most important factors for the customers. Since the energy efficiency of dishwashers are overall very good, this is often not a determining factor for the purchase. The design of the interior was learned to be more important to previous owners of dishwashers than to first time buyers.

From the survey, it was found that a little more than half of the respondents (52%) expected a new dishwasher to last for 5-10 years, 38% 11-15 years, 6% 16-20 years, 3% more than 20 years and 1% less than five years.

5.2.10. Utility vs status of the dishwasher in relation to other kitchen appliances

Figure 5.10 shows the combined results from the final task of the interviews where the participants were asked to place the dishwasher in a utility-status diagram. The dishwasher, marked by dark grey circles, is placed in the right half of the diagram in an area of high utility and very spread status. This area is shared mainly with the microwave, marked by red, but also partly by the refrigerator and the oven, marked by dark blue and yellow, which mainly lies in the upper right quarter and therefore perceived to have a higher status among the interviewees. The light blue circles corresponding to the kettle has, from this diagram, overall a lower utility than the dishwasher and a more narrow spread on the status axis.

On the contrary to the dishwasher, there is the light green dots symbolizing the coffee maker, spread across the whole utility axis but only in the upper half of the status axis. The spread on the utility axis can of course be explained by the interviewees varying coffee drinking habits. Although, no matter how much coffee they drink, they all valued the status of the coffee maker high. Another kitchen appliance with high status was the kitchen machine. The purple circles symbolizing it are quite densely placed in the upper middle of the diagram except for one circle with lower utility and another with both lower utility and status. The toaster (dark green) has both a generally low status and utility and the blender (orange) is spread almost all over the diagram.

From this diagram, it can be assumed that the dishwasher is mainly purchased for its utility rather than for its status and have to rely on a high functionality to convince the customers. According to the interviewed store manager of Electrolux Home, dishwashers that can be fully integrated are the ones that are sold most. These are hidden behind a panel to fit into the rest of the kitchen while the oven, for example, is fully exposed. This leaves little room in the dishwasher design to express any status. Moreover, there can be assumed to be more prestige involved in the cooking activity than in the dishwashing activity.

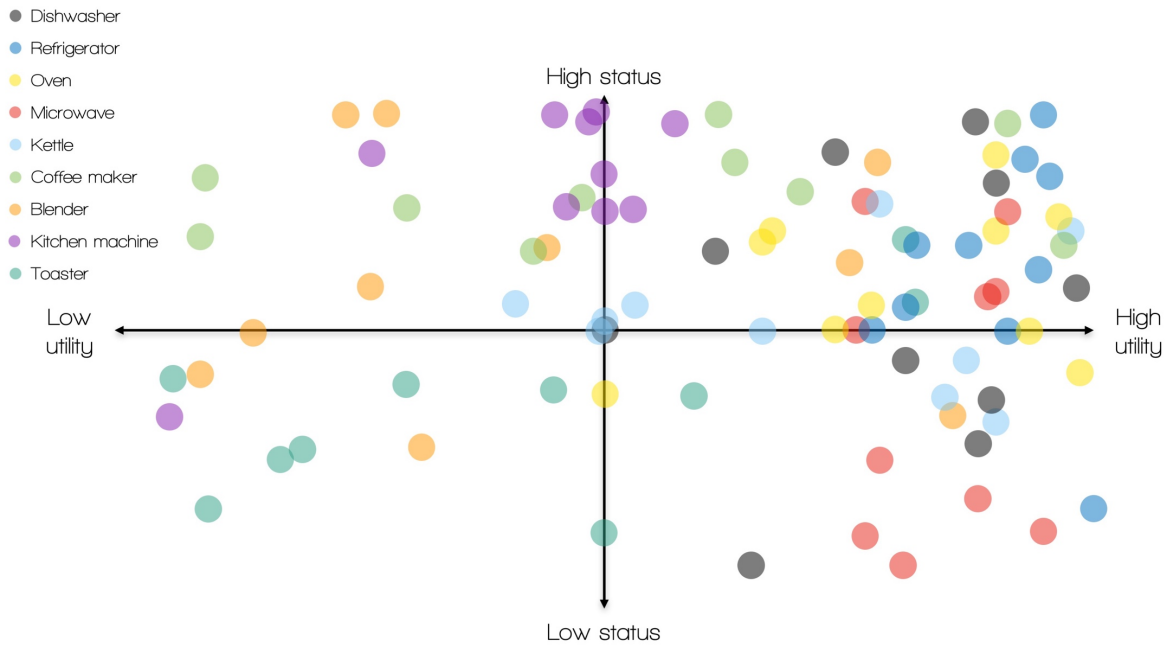

Figure 5.10 – Utility vs. status of the dishwasher in relation to other kitchen appliances

6

Basis for Concept Development

This chapter summarises the main findings from the two previous chapters. It also presents an initial list of requirements, three personas and the expression that is aimed for in the final concept. This chapter therefore functions as a bridge between the performed studies and the concept development in this project.

6.1. Main findings from initial research and user study

6.1.1. Main problems related to manual washing of dishes

- Manual dishwashing generally consumes more water and energy than dishwashers.
- Manual dishwashing generally takes more time from the user compared to the time taken for loading and unloading a dishwasher.
- Manual dishwashing generally uses lower temperatures than the dishwasher.
- Even though all utensils and tableware can be washed manually, there are many items that are difficult and time consuming to wash due to their size, shape or degree of soiling.
- Because of the unstructured placement of dishes in the sink and in the dish rack, items may fall or break each other during the dishwashing process.
- If not performed frequently, the sink or countertop will be filled up with dishes (depending on the user's cooking frequency and eating habits). This gives the kitchen a messy expression.

6.1.2. Main problems related to dishwashers

(This only refers to standard, narrow and benchtop dishwashers as no other models were encountered in the user study).

- Not all kitchen utensils and tableware can be washed in the dishwasher.
- The total water and energy consumption of the dishwasher is greatly affected by user behaviour. This concerns selection of program, amount of pre-rinsing, the extent to which the dishwasher is loaded, detergent dosage as well as cleaning and maintenance of the machine, as summarised in Figure 6.1.
- The wash cycles of newer dishwashers (especially the eco-programs) generally takes a lot of time to save energy. The long duration was found to be the main

Figure 6.1 – The environmental impact of a dishwasher is greatly affected by user behaviour

reason for not choosing the eco-program. A problem with long wash cycles is that it occupies the dishes, which may be needed again by the user before the program has finished.

- Small households who generate small amounts of dishes may have problems with filling up a whole machine. Running the dishwasher fully loaded is a prerequisite for the dishwasher to be as energy and water efficient as possible.
- Some dishwashers provide inadequate communication concerning significance of wash programs, run time and end of wash cycle.
- Dishes are often pre-rinsed more than necessary. This has several reasons, both related to the user and to the dishwasher itself. The user may not trust the dishwasher to be effective enough in cleaning the dishes or may have had a previous experience of a poor dishwashing result. It may also be to avoid smell from the dishwasher as well as the need to clean the filter. Sometimes, it seems to be just out of habit and sometimes there is just a lack of knowledge from the user in how the dishwasher should be used. The dishwasher may not eliminate the need for pre-rinsing the dishes. This may be due to a low cleaning performance, which in turn may be caused by inadequate cleaning and maintenance performed by the user. There is also a limitation in how much food waste the dishwasher can handle and it may not have sufficient self-cleaning in order to provide a good result. It may also be due to the lack of a 'rinse and hold'-program, or a failure to communicate the existence of such a program. Communication may also be lacking concerning how and when maintenance should be performed.

6.1.3. Main problems related to compact kitchens

- Too little workspace and storage.
- Dishwashers are not optimised for compact kitchens. Even though it may be possible to install a dishwasher, it is at the expense of important storage or workspace. Installation can be difficult and costly.
- The modules included in compact kitchens are usually the same as in larger kitchens. Some of the units are oversized and poorly adapted to the compact kitchen.
- The sink takes up a large part of the countertop. Still, it is not optimised for washing large items such as baking trays.
- Lack of space for and poor organisation of recyclables.

6.2. Initial list of requirements

An initial list of requirements is shown in Table 6.1.

Initial list of requirements

No.	Requirement
1.	Have the potential to be more sustainable than manual dishwashing
2.	Not reduce the amount of workspace in the kitchen
3.	Encourage a sustainable handling of dishes
4.	Be applicable in a modular and compact kitchen
5.	Be easy to clean
6.	Be easy to use and to understand
7.	Be a natural part of the workflow in the kitchen

Table 6.1 – Initial list of requirement

6.3. Personas

Three different personas that would be possible users of the final concept were created, based on the target group and the different behaviours and needs found in the user study. The personas are presented in Figure 6.2 – 6.4.

Emma, 29

Emma is 29 years old and lives in Uppsala. She moved there six years ago to study and recently took her first job as a teacher in social sciences. Emma is single and recently moved out of her old student apartment to a two room apartment in the city. The new flat provides more space and Emma has bought a large sofa and a dining table since she enjoys inviting her friends over for dinner. The kitchen, however, takes up a modest share of the apartment and Emma can barely fit in her kitchen appliances and utensils. Emma enjoys cooking and baking and sees it as a relaxing activity in the evenings. Unfortunately, the sink fills up way too quickly with dishes and makes the small kitchen look messy. Emma usually do the dishes several times a day to keep the countertop clean. She would like to buy a dishwasher but neither would she like to sacrifice a cabinet or the tiny workspace that she needs for preparing food.

Figure 6.2 – Description and images representing the persona Emma

Anita, 56, and Lars, 54

Anita, 56, and Lars, 54, have been living in a house in Lindome outside of Gothenburg for the last 20 years. They have three children, of whom the last one moved out three years ago. They have now sold the house and bought an 50 m^2 apartment in town. For the money they saved from selling the house they now like to travel, go to restaurants and cinemas more often and enjoy a simple lifestyle. They buy lunch everyday and generate a small amount of dishes that is generally washed once a day. The apartment has a separate kitchen in which they occasionally like to spend some time to cook something special. Even though a standard sized dishwasher would be able to fit in their kitchen, they feel that they would not be able to fill it up completely with dishes.

Figure 6.3 – Description and images representing the personas Anita and Lars

Figure 6.4 – Description and images representing the personas Isac and Daniel

6.4. Expression

Based on Electrolux's brand values as well as an attempt to improve the status of the dishwasher, the words in Figure 6.5 were chosen to describe the desired expression of the dishwasher concept. These words resulted in the creation of the expression board shown in Figure 6.6.

Figure 6.5 – Words representing the intended expression of the final concept

Figure 6.6 – Expression board

7

Concept Development

This chapter presents the idea generation leading to a first generation of concepts. Those concepts are evaluated before the second phase of the concept development is presented. Further development and research related to the chosen concept will then be described in the next chapter.

7.1. First concept generation

The idea generation for the first round of concept development was performed through several brainstorming sessions focusing on different areas:

- Natural workflow of dishes
- Avoid pre-rinsing
- Simplify unloading of dishwasher
- Communication with user
- Dishwasher combined with storage
- Dishwasher combined with other kitchen appliances
- Flexibility and space efficiency
- Simplified cleaning of dishwasher

7.1.1. Sink dishwasher

The sink dishwasher concept is targeted to users who are not able to install a dishwasher in their kitchens. It utilises the area of the sink, which is already meant for dishes and does therefore not take up any workspace from the countertop. Unlike existing sink dishwashers on the market, it does not demand installation of a new sink, but can be placed inside a sink of the common dimension 34x40 cm. By using a water tank that is filled up before the wash cycle is started, it does not occupy the tap while running. Therefore, this concept constitute both a more flexible and simple solution compared to existing sink and benchtop dishwashers.

This sink dishwasher could either be designed as a closed unit that can be fitted into the sink (see Figure 7.1), or it could utilise the sink as side walls to be complemented with a cover mounted on top of the sink (see Figure 7.2). It would then consist of several components: a water tank, a filter, a circulation pump, a spray arm, a dish rack and a cover. These components can be disassembled and stored inside the cover somewhere else when not used. With a flat top surface of the cover, it may offer extra workspace when mounted over the sink. To take up less space while not holding dishes, the cover could also be collapsible.

Complementary ideas

To facilitate handling of leftover food on the dishes, this concept can be combined with a food grinder placed over the drain in the sink (see Figure 7.3). By grinding the food into small particles, it can be flushed out together

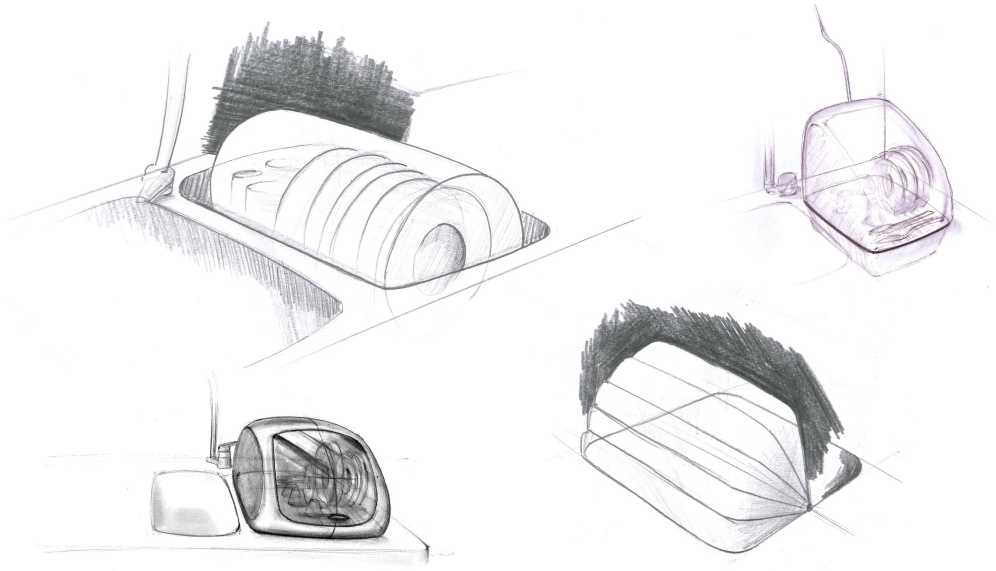

Figure 7.1 – Sketches of the sink dishwasher as a closed unit

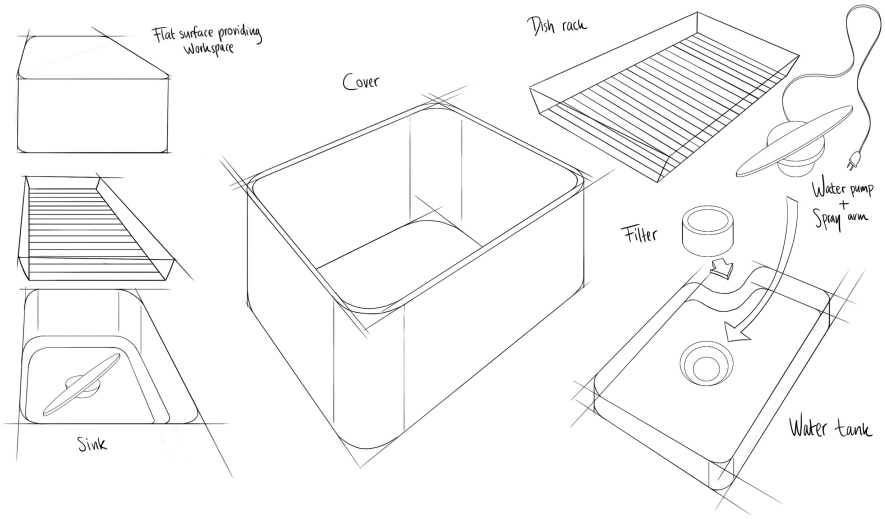

Figure 7.2 – Sketches of the sink dishwasher utilizing the sink walls with components that can be disassembled

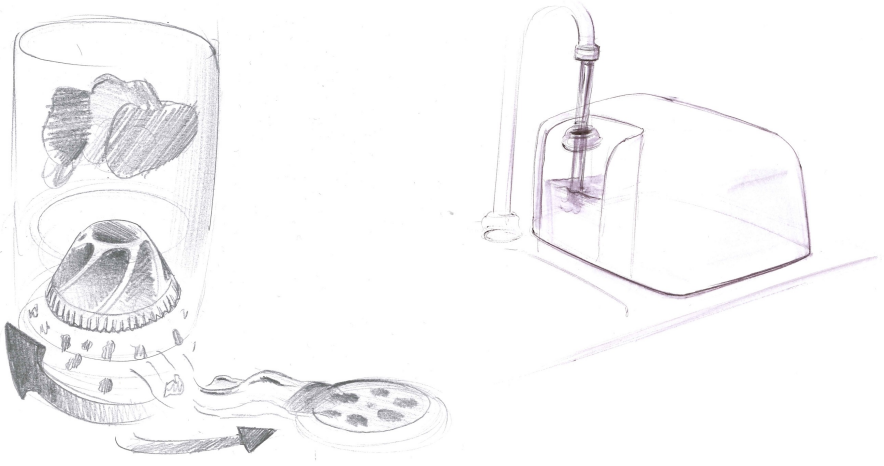

Figure 7.3 – Sketches of complementary ideas to the sink dishwasher

with the water and thereby reduce the need to pre-rinse the dishes

Negative aspects and areas of improvement

The sink dishwasher has a small capacity, which brings both positive and negative aspects. The positive aspects are that it is easily filled up even for users with small amounts of dishes and can be run frequently without occupying large amounts of dishes. However, the small capacity is also limiting the size of the dishes that can be placed in it and also forces users with larger amounts of dishes to run the dishwasher several times a day. However, the wash cycle of this concept is likely to take as much time as of a standard dishwasher. The capacity will be limited further by the water tank which needs to hold a large enough volume of water to be sufficient for the wash cycle.

Unlike the discrete integrated dishwashers that are very popular today, this concept becomes highly visible in the kitchen. The cover may although hide the dishes beneath but dishes that are added while the wash cycle is running have to be placed somewhere else than in the sink that is occupied by the dishwasher.

This concept definitely works best in kitchens with two sinks, which is also by far more common than having only one sink in rented apartments. Although the sink dimension of 34x40 cm is very common, a variety of other dimensions and shapes exist as well and it would be impossible to design a dishwasher that fits all sinks on the market.

If this concept utilises the sink walls rather than being designed as a closed unit, the dishwasher gets very limited insulation which could lead to high noise levels as well as significant heat losses. Some question marks also exist concerning the volume and placement of the water tank but also how the water should be circulated. Other areas that need more investigation are how the electricity supply should be handled safely, how the food grinder should work and how the different parts can be optimised to be as compact as possible. It would also be interesting to investigate if this concept could be used for other purposes than doing the dishes, like for example rinsing of vegetables.

7.1.2. Handheld unit

The handheld unit concept, shown in Figure 7.4, is targeted to the smallest kitchens that cannot even fit in a sink dishwasher. The handheld unit uses steam to help the user to do manual dishwashing more effectively while at the same time using minimal amounts of water. It has different modes for either washing, rinsing or drying that can be accessed by pushing different buttons. The steam provides a gentle handling of the dishes while at the same time reaching higher temperatures than the tap water. It can also be combined with a brush to increase the mechanical action.

This concept encourages the user to wash the dishes frequently by being easily accessible at all times and also gives the user control over the washing process. It is flexible and can handle all types of dishes as well as cleaning recyclable packages or be used for other cleaning purposes in the kitchen.

The handheld unit is connected with a hose to the main unit, including a water tank and a heater, which can be mounted on the wall. It does therefore not require any installation and neither workspace nor storage need to be sacrificed from the kitchen.

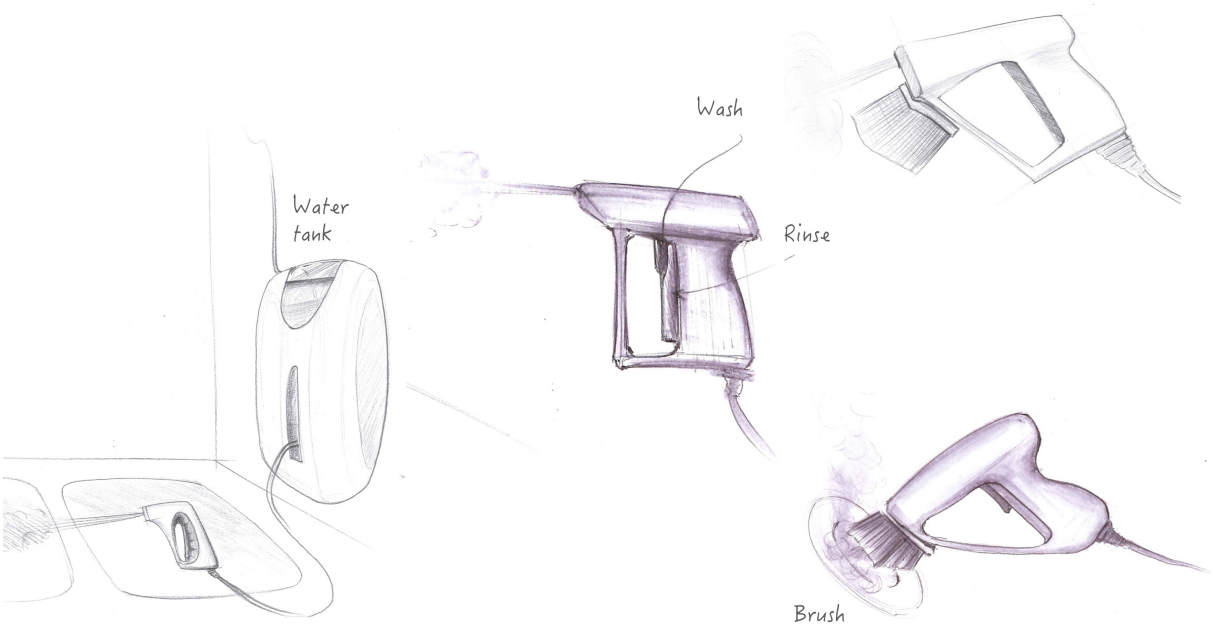

Figure 7.4 – Sketches of the handheld unit concept

Negative aspects and areas of improvement

The most obvious negative aspect of this concept is that it does not handle the dishes automatically, but needs to be operated by the user. Neither does it hide the dishes like a dishwasher does. Due to the high temperature of the steam, there is a risk for the user to get burned while using it. Considerations therefore has to be made concerning how burning injuries can be prevented. Dish gloves may be needed for a safe usage.

Even though the handheld unit may save water compared to conventional manual dishwashing, it has no circulation of water like a dishwasher does. Additionally, it will demand a considerable amount of energy to heat up the water and keep it ready to use at all times. The energy consumption for a product like this therefore needs to be investigated further.

Another interesting area of investigation is how to prevent users from rinsing under the tap instead of using the handheld unit. How large volume that would be needed for the water tank also needs further investigations. Alternatively, the handheld unit could instead be integrated with the faucet.

7.1.3. Toaster dishwasher

The toaster dishwasher concept, shown in Figure 7.5, is another solution for the smallest households that does not require any installation. Similar to the mechanism of a bread toaster, the dishes are placed in slots and lowered into the dishwasher. The toaster dishwasher is compact, can be placed almost anywhere and is easily plugged into a wall socket before use. Like the two previous concepts it contains a water tank that can be detached and filled up under the tap before attaching it to the dishwasher. It is convenient to use and encourages the user to run the most frequently used tableware directly after every meal.

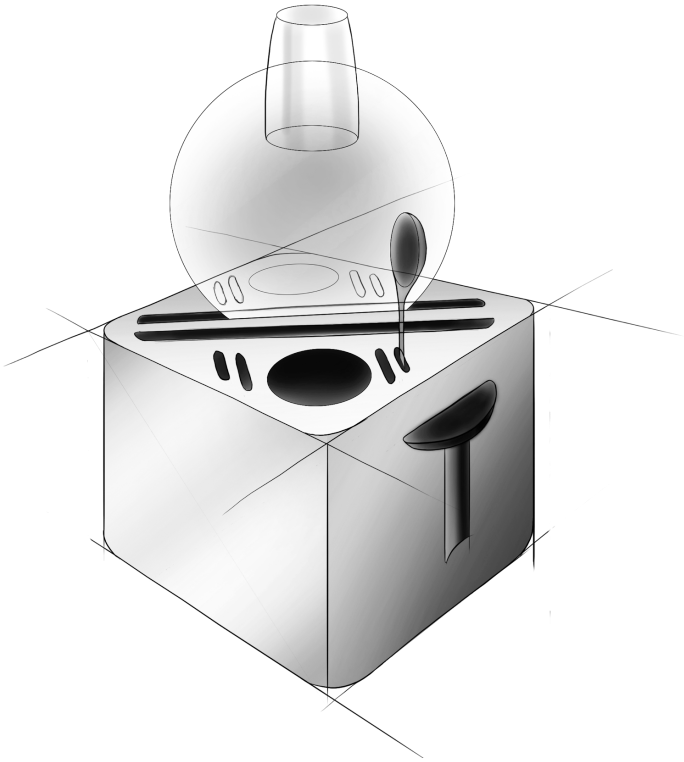

Figure 7.5 – Sketch of the toaster dishwasher concept

Complementary ideas

This concept can be combined with a customised set of tableware sold together with the dishwasher. This set of tableware should be designed to be as compact as possible and should be given a shape and finish that is easy to clean. This set of tableware could come in a variety of designs to attract different customers and be intended for different occasions such as everyday use or formal dinner.

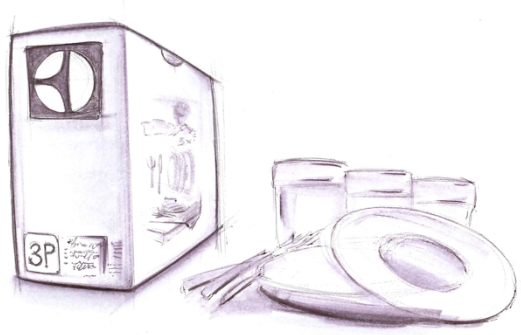

Figure 7.6 – Sketch of the complementary idea of a customised set of tableware to the toaster dishwasher

To provide more flexibility in what type of dishes that can be run in the toaster dishwasher, it could also be sold together with a variety of slot instances to enable users to customise the dishwasher after their own needs.

Negative aspects and areas of improvement

Even though the toaster dishwasher could be varied with different slot instances, it has a limited flexibility. It cannot handle large items such as sauce pans or mixing bowls and if it could, it would become too large and lose its main strength of being compact and easy to move. It can mainly be used for tableware and does not eliminate the need to wash most of the cooking equipment manually. Therefore, this concept is best suited for users who do little cooking, but who often eat easily prepared meals at home.

The capacity of this dishwasher concept is very small and it has to be used frequently to avoid build-up of dish piles. When not used, it will take up either some workspace if placed on the counter, or some storage space if placed in a cabinet or drawer. Some question marks exist concerning how it should handle food waste and how the water tank should be designed.

7.1.4. Combined oven and dishwasher

By sharing the same unit for the dishwasher and the oven, the dishwasher can make use of excess heat from the oven. This heat can be utilised to heat up the water in the dishwasher and thereby save energy. This concept is aimed for users who do not need a full size oven. For those users, the full height of the oven is not utilised. By making the oven more compact height wise, there may be room for a compact dishwasher beneath it and the space would be used more effectively. This concept is shown in Figure 7.7.

This dishwasher concept would be comparable to the size of a benchtop dishwasher or slightly smaller. It can therefore be filled up quickly with dishes and run frequently. Unlike the previous concepts, it also keeps the dishes out of sight.

Negative aspects and areas of improvement

A drawback for this concept is that the oven may not be used as often as the dishwasher. The use of the two appliances may neither be in direct connection to each other, which limits the degree to which the dishwasher actually can utilise the excess heat from the oven. It could be interesting to look at other possibilities of combining the dishwasher with kitchen appliances, like for instance with the refrigerator and freezer. These appliances constitute a more continuous and reliable energy source. On the other hand, the amount of energy that would be possible to extract from the excess heat of a fridge or freezer is assumed to be low.

Another drawback with this concept is that the oven is usually not placed directly beside the sink unit as there is often at least one unit in between that provides workspace. A dishwasher placed beneath the oven will therefore much likely need the water to be transported for a longer distance than a standard dishwasher placed beside the sink unit. The low placement of the dishwasher also provides a poor working height for loading and unloading the dishwasher. Furthermore, this concept demands not only installation but also change of oven. Whether or not the height of a kitchen counter would be sufficient to fit in both an oven and a dishwasher needs to be further investigated.

7.1.5. Narrow dishwasher combined with drawers

40 cm drawers seem to be a quite common unit in kitchens. The drawers are great for storing smaller items such as cutlery and utensils. The question is, however, if all drawers are really necessary? This concept replaces the lower drawers of a 40 cm unit with a dishwasher, and saves the two uppermost drawers for storage, as seen in Figure 7.7. This gives the dishwasher about the same capacity as a benchtop dishwasher but with more narrow and higher dimensions. It can be easily installed by replacing a few drawers instead of the whole unit. Similar to the previous concept, it hides the dishes and the small capacity means that it can be filled up quickly and run frequently.

Negative aspects and areas of improvement

The dimensions of this concept differs from other dishwashers on the market. Therefore, further studies are needed on how the

interior would be designed. Being higher than a benchtop dishwasher but lower than a narrow dishwasher of 45 cm, it is possible that the height dimension is too low for two rack levels and at the same time a bit too generous for only one rack level. The height can of course be varied by changing the number of drawers that are excluded from the unit. Therefore, the relation between dishwasher and storage capacity is an interesting area of investigation.

Another drawback of this concept is, similar to the combined oven and dishwasher concept, the low height for loading and unloading the dishwasher.

7.1.6. Combined storage and dishwasher

The last concept focuses on combining the dishwasher with storage by dividing the dishwasher into sections that can be run independently. The idea is that soiled dishes are placed in an empty section and once it is full, a wash cycle is run in that specific section. The clean dishes can then be taken directly from the clean section, used and placed in another empty section. This means that the dishes are stored in the dishwasher and just moved between the different sections so that clean and soiled dishes are kept separate at all times. The need to unload the dishwasher to place the clean dishes in a cabinet or drawer is eliminated, except for perhaps some reorganisation from time to time.

This concept comes in two different variants, either with a drawer configuration for the lower units or a cabinet configuration for the upper units of the kitchen, as seen in Figure 7.8. Both versions are intended to constitute a natural part of the kitchen and promote a more natural workflow of the dishes in the kitchen. By dividing the dishwasher into several sections, this gives a higher freedom of washing smaller amounts of dishes at a time instead of having to fill up the whole dishwasher.

Even though the concepts seem large, they combine the two purposes of storing and washing dishes into only one unit instead of two and are therefore more compact. The dishwasher sections keep the dishes organised and out of sight. Both variants can be installed by replacing standard kitchen units

Complementary ideas

This concept has a few complementary ideas on how to further ease the workflow of the dishes and to reduce the water and energy consumption of the dishwashing process. One idea is that the dishes get a spray shower the moment they are placed in the dishwasher to avoid leftover food to dry on the dishes and to reduce the need of pre-rinsing. Another idea is that as soon as a section of the dishwasher is full, it automatically starts a predetermined eco-program to ensure that the dishes get washed as soon as possible in the most energy and water saving option available.

To minimise the effort of taking out clean dishes from the machine, the dishes could be moved forward as one piece is taken from the dish rack, similar to the way shampoo bottles are sometimes stacked in the stores to always keep the bottles in the front of the shelf.

Negative aspects and areas of improvement

The main difficulty of this concept is that it cannot completely eliminate the presence of empty spaces, as there always has to be at least one empty section where soiled dishes can be placed. Neither will it be as space efficient as conventional storage since the dishes need space in between them for the water jets to be able to reach every spot. One challenge would be to design the environment inside the dishwasher to be

perceived as clean and tidy as ordinary storage spaces. Also, the two variants of the concept may not individually be the natural storage place for all kinds of dishes as tableware often are stored in upper cabinets while pots and pans often use a lower storage place.

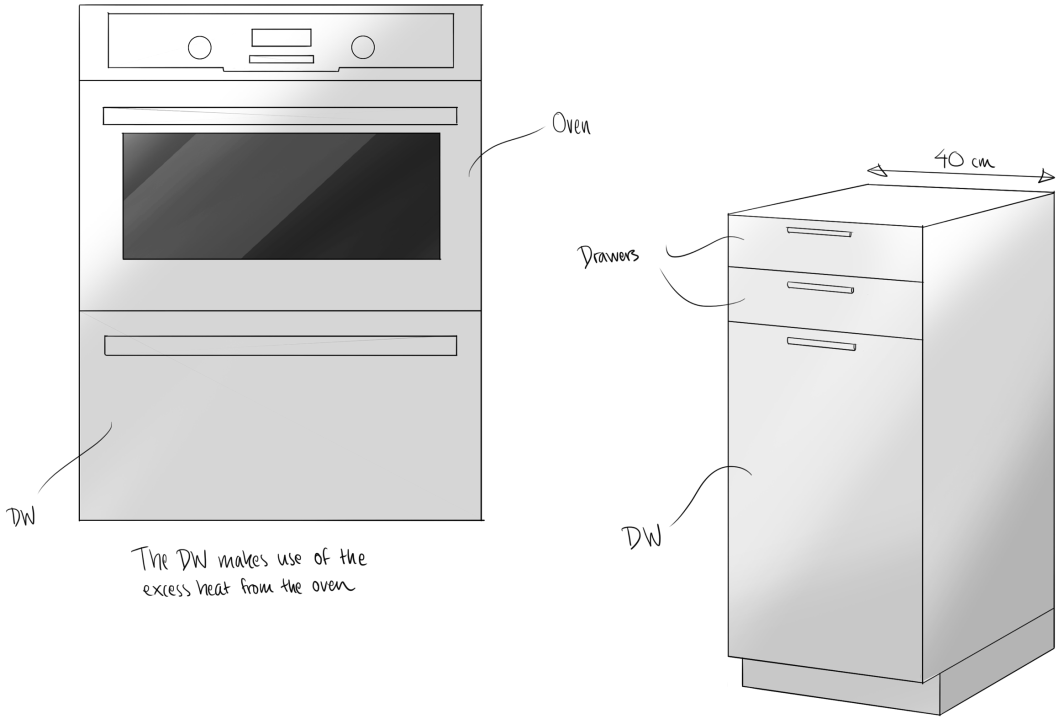

Figure 7.7 – Sketches of the combined oven and dishwasher concept to the left and the concept of a narrow dishwasher combined with drawers to the right

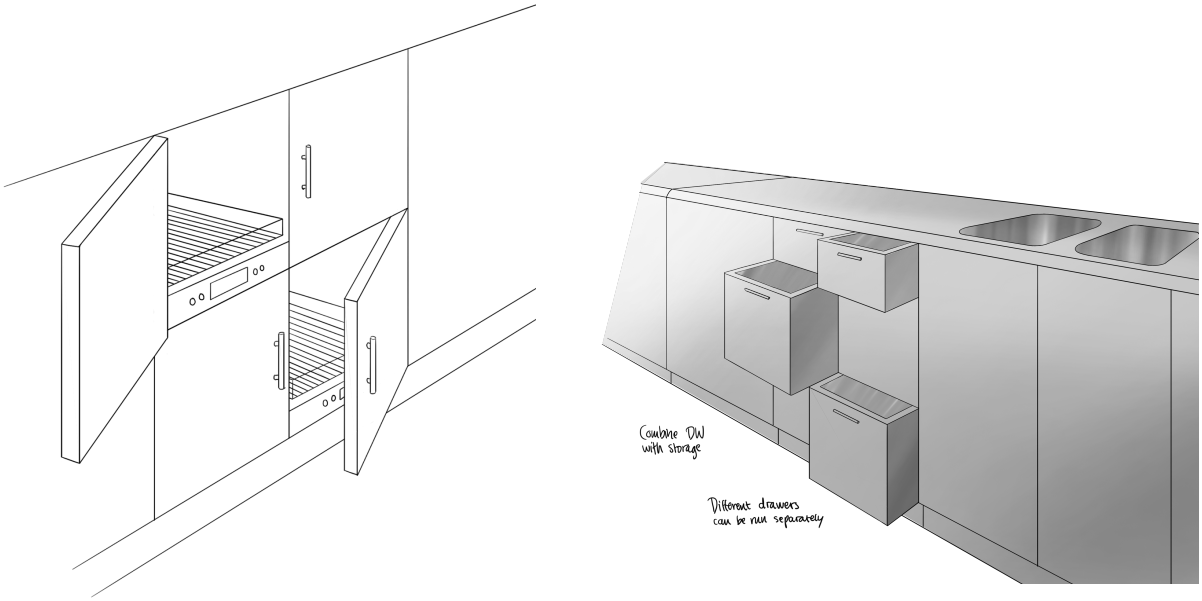

Figure 7.8 – The concept combined storage and dishwasher. The sketch to the left illustrates the concept integrated in an upper cabinet and the sketch to the right illustrates the concept in a drawer unit

7.2. Evaluation of concepts

The above presented six concept ideas focus on different areas of a compact kitchen as well as different users from the target group. They do not individually solve all problems found in the analysis but focus on different areas respectively. The sink dishwasher, the handheld unit and the toaster dishwasher are all concepts that do not require installation and are very compact in size. These concepts are for users with the tiniest kitchens or for users who are not able to install a dishwasher. The focus of these concepts is to wash small amounts of dishes frequently and to save time and effort from the user.

The combined oven and dishwasher and the narrow dishwasher combined with drawers are concepts with a slightly larger capacity but still small enough to be run frequently. They demand installation and focus on utilizing space more efficiently in two different areas. They are aimed for users who do more cooking and who have the possibility to do changes in their kitchens.

The last concept of combined storage and dishwasher focuses on easing the workflow of dishes. The concept demands more space than previous concepts but also has an extra purpose of storing the clean dishes, which justifies its size.

7.3. Second concept generation

Since the first generation of concepts could not individually solve all problems found in the analysis, the project team took a step back to get a more holistic view over the water consumption in the kitchen.

A fishbone diagram was performed to understand the possible reasons to why water and energy is wasted in the kitchen. This diagram can be found in Appendix VI. The main reasons found were ordered into the following categories:

- *People* use more water than actually needed. Waste of water during manual dishwashing can be due to impatience or to distrust in cleanliness, so that items are rinsed a little bit longer just to be sure that no soil or detergent is left on the dishes.
- *The faucet* is difficult to adjust with precision. Although it controls both temperature and pressure of the water flow, the control may be too imprecise due to a low quality or robustness of the faucet. It also demands some effort from the user since the adjustment is placed on a distance from the actual water stream and the mechanism has some resistance in it. Furthermore, there is often a delay of the temperature change after an adjustment has been made due to an unreliable water supply. There is also a lack of flexibility and control over the flow distribution and the possibility to angle and move the stream.
- *Items* are difficult to wash. Large and bulky items, items with complex shapes or items with rough or sticky surfaces may demand extra water during manual dishwashing to get clean.
- *The plumbing system* does not fully utilise heat and water. Used tap water often have a low degree of soiling but is not circulated or utilised for other purposes. Neither is the heat of the water. This means that valuable water and energy is wasted down the sink.

With a dishwasher in the kitchen, the use of the sink unit for dishwashing purposes is diminished, but not eliminated. Additionally, the sink unit handles other important tasks that a dishwasher cannot handle today:

- Washing of dishes that are not suitable for the dishwasher such as large or sensitive items.
- Tapping fresh water for drinking, cooking and cleaning.
- Preparation of food by allowing washing of vegetables, fruit, pasta etc. It also collects waste and separates water from waste.
- Washing of packages before recycling.
- Other cleaning purposes.

Based on this, the project team raised the question of how well the sink unit is designed to support the user in performing the above listed tasks. The impression of the project team was that the sink and faucet unit is mainly designed to tap water and provides little flexibility for performing other tasks. The sink unit was also viewed from the perspective of space efficiency, including the cabinet underneath the sink. This unit constitutes a large volume taking up both a lot of workspace and storage from the kitchen. The project team's impression was that this space may often not be fully utilised and that existing solutions are not well adapted for the compact kitchen.

7.3.1. The kitchen's washing and waste management station

The second concept generation focuses on the sink unit, including the faucet, the sink and the cabinet underneath. It aims to improve this central area of the kitchen to a better utilised washing and waste management station that also includes a dishwasher. This concept is shown in Figure 7.9.

In this concept, the unit is given one single wide and shallow sink. Since the dishwasher will handle most of the dishes, the need to fill up one sink with dishwater and have another sink for rinsing decreases. By using one sink instead of two, it can be given a large area which will make it easier to wash large items such as baking trays and also give a more roomy feeling, resembling a larger kitchen.

The depth of the sink has to be large enough to prevent water splash, which may not require the full depth of today's sinks. By combining this concept with the handheld unit described in section 7.1.2., the need for filling the sink with water to soak dishes is further reduced. A shallow depth of the sink gives more space beneath it which can be shared by both a dishwasher and recycling bins. The dishwasher is placed directly underneath the sink which gives it a comfortable height for loading and unloading of dishes as well as a good overview of its content. The recycling bins are placed in the bottom drawer, which can be opened by a gentle push with the foot. To be able to fit in a dishwasher in the unit, the recycling drawer has to be made quite shallow. This means that the bins have to be emptied quite frequently. However, emptying the waste and recycling material often has the advantage of preventing smell.

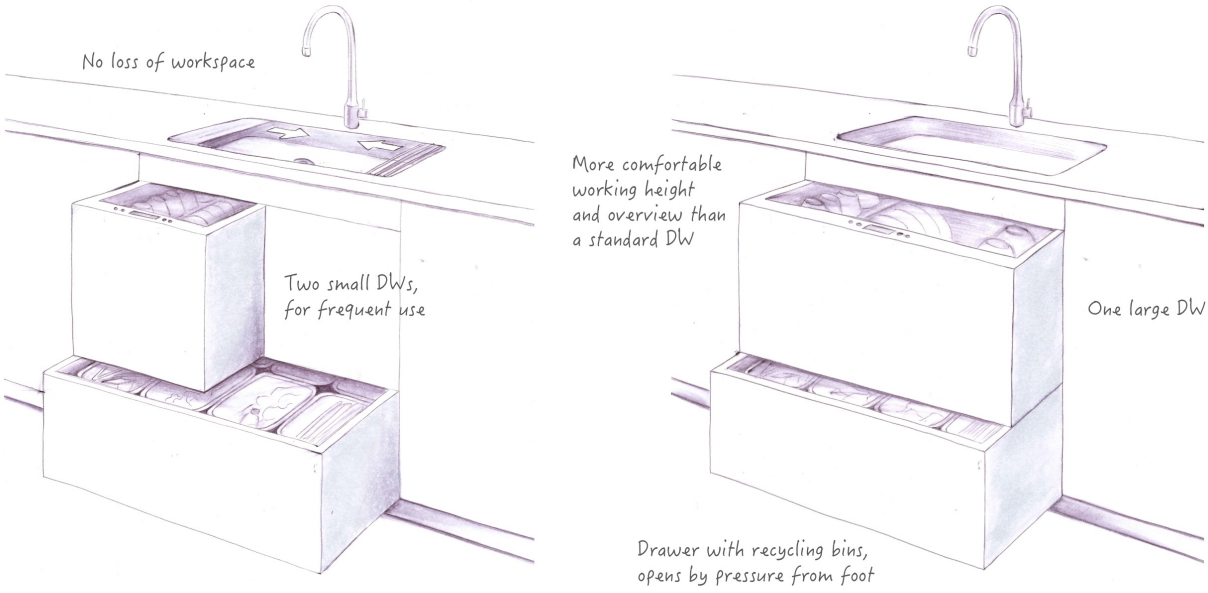

Figure 7.9 – Sketches of the kitchen's washing and waste management station concept

Concept variations

The dishwasher can consist of either one or two sections. One large section gives a good overview of the interior and the possibility of washing larger items. Having two sections, on the other hand, gives the user a higher flexibility of washing small amounts of dishes independently. By washing one section at a time, less dishes are occupied at once which gives a higher tolerance to longer wash cycles. Dishes that are added during the wash cycle can be placed in the other section instead of on the counter or in the sink. The negative aspect of having two sections is that there will be some space loss due to the extra wall in between the sections. Additionally, the cost would increase due to the need of a double set of components.

Another selection to make is whether the sections should have a drawer configuration or a door opening like standard dishwashers have today. The positive aspects of a door opening is that when the dish rack is extended from the dishwasher, you get a high visibility of the dishes and it is possible to reach the dishes from the sides. With a drawer configuration, you get a quicker overview of the content as there is only one step to be able to access the dishes inside instead of two. The walls of the drawer also protect the floor better from spilling water and food from the dishes. Moreover, a drawer configuration of the dishwasher also contribute to a more uniform expression with the recycling drawer beneath it.

The last and perhaps most important choice to make is the size of the unit. Sink units are common as both 60 cm and 80 cm units in compact kitchens today. This makes both options reasonable dimensions for this concept. A 60 cm unit is of course more compact and if the future trend is even smaller kitchens, the 60 cm option is the more relevant option. However, considering that this concept will handle all washing and waste management in the kitchen, including sink, recycling boxes and dishwasher, an 80 cm unit is still space efficient compared to existing sink units. With 80 cm you get a higher capacity of the dishwasher, more space for recycling and the possibility of having a larger sink.

Complementary ideas

To make the sink a more flexible work place, one idea is to provide it with an extendable board and bars (see Figure 7.10). The extendable board will provide extra workspace on top of the sink while the bars can be used either as a dish rack or for rinsing vegetables.

To support manual dishwashing, this concept could, as suggested earlier, be combined with the handheld unit, as seen in Figure 7.10. Another possibility would be to make the faucet itself more flexible in its positioning and more precise in its adjustment. This would avoid adding one extra element to the sink and thereby possibly contribute to a cleaner expression of the product. The faucet could use pre-set temperature and pressure modes for more precise control and LED lights for heat indication to make the user aware of the energy consumption (see Figure 7.11).

As a lot of water is wasted down the sink, the possibility to circulate water to reduce the total consumption of the product would be another interesting area that would demand further research about water purification technologies.

To improve the workflow from clearing the table to placing the dishes in the dishwasher and unloading the dishwasher, one idea is to use dish rack modules. The modules can hold a small amount of dishes, be carried from the table and placed inside the dishwasher. This would lead to simpler handling when loading and unloading the dishwasher, and hold the dishes in a secure way while carrying them. Another idea to allow more secure, flexible and possibly denser positioning of dishes in the dishwasher is to use magnets in the tableware, which can be sold together as a set with the dishwasher (see Figure 7.12).

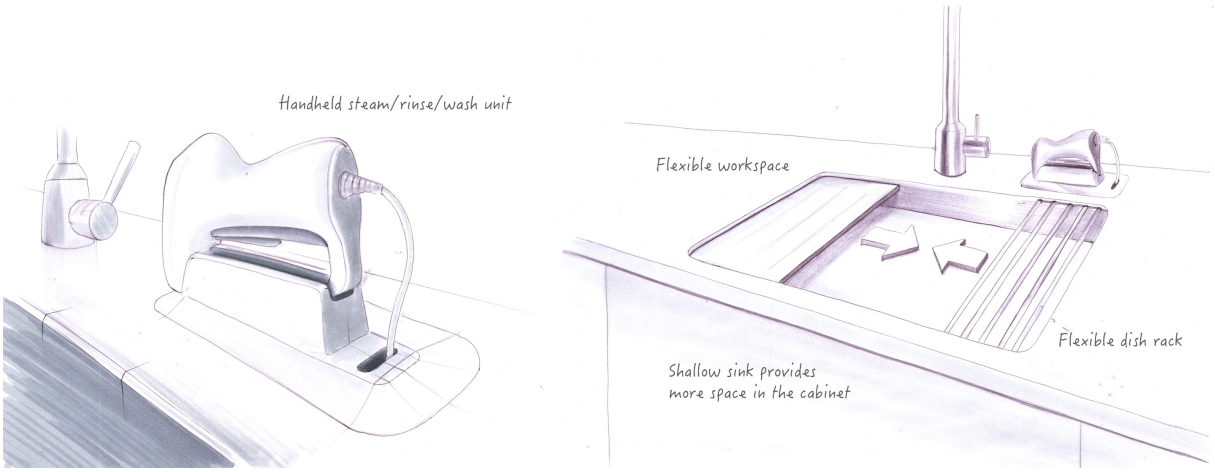

Figure 7.10 – Sketches of the complementary ideas of combining the concept with a handheld unit and extendable board and bars

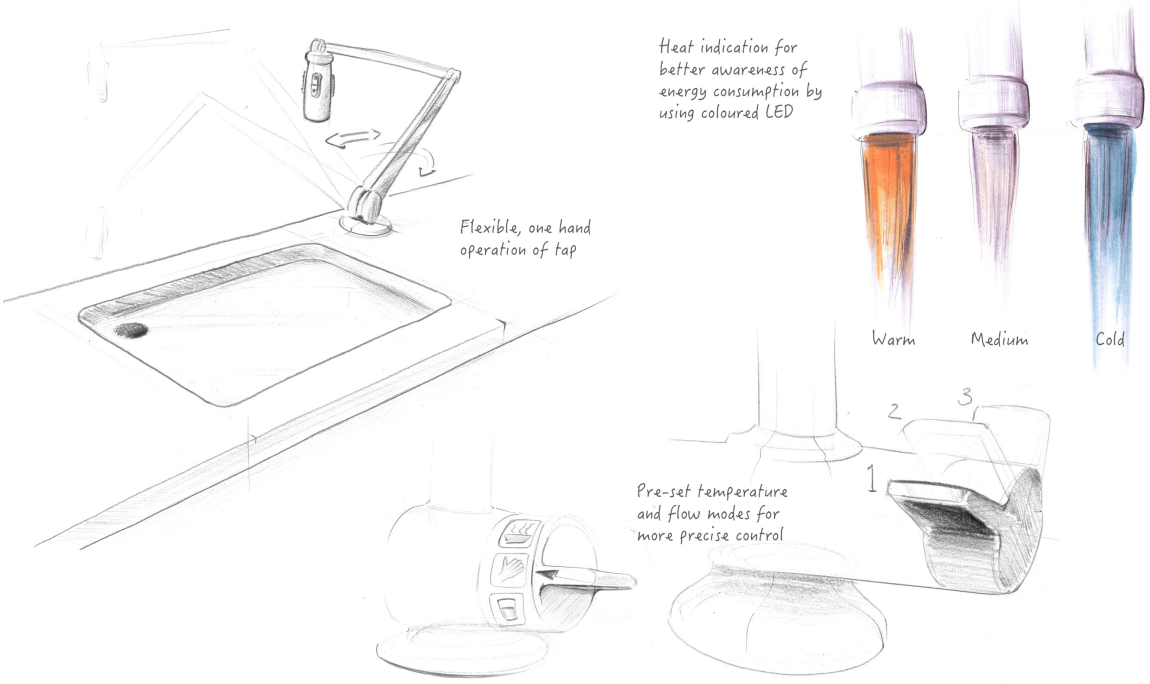

Figure 7.11 – Sketches of the complementary ideas of combining the concept with a more flexible faucet, LED colour indication of water temperature and pre-set temperatures and pressure modes

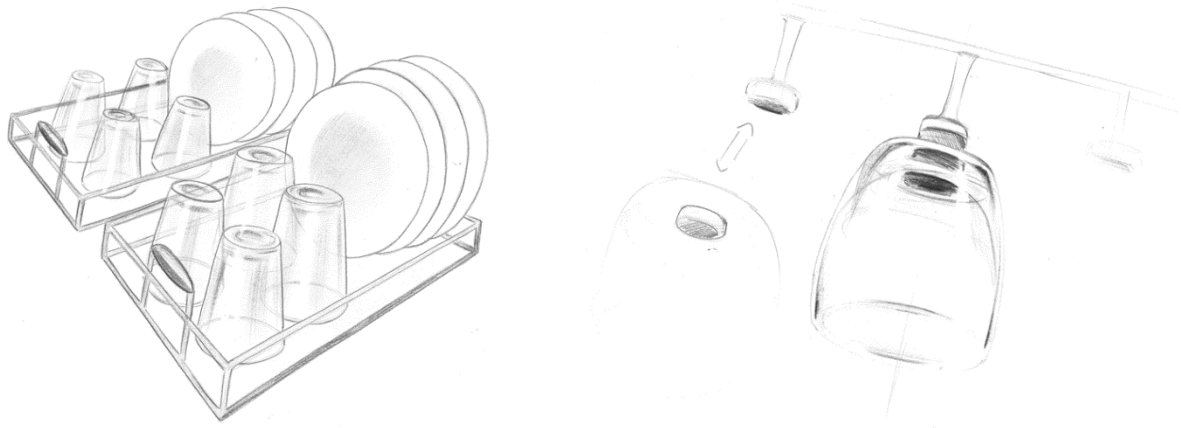

Figure 7.12 – Sketches of the complementary ideas of dish rack modules to the left and to the right, integration of magnets in the tableware for placement in the dishwasher

Negative aspects and areas of improvement

In this concept, the most limiting factor is the height, which has to be taken both from the sink and the recycling bins to be able to squeeze in a dishwasher in between, without changing the total height of the unit in relation to the rest of the kitchen. There will be a trade-off in how much space that will be given to each element. For example, more height to the dishwasher means that it can handle larger plates while more height to the recycling drawer means that it can handle more waste. Due to the low depth of the sink, which is necessary in this concept, the possibility of filling up the sink with water is reduced. It is however expected that the need for filling up the sink is reduced by the existence of the dishwasher. If needed, it is still possible to place a separate tub in the sink to be filled with water.

8

Further Research and Development

This chapter presents the further research and development of the concept. This work includes the interplay between the components of the concept, their dimensions and configurations as well as their form expression.

8.1. The system - interplay between components

From the theory on water treatment and storage, found in section 2.4 and 2.5, it could be concluded that water treatment is a long and complicated process that demands regular maintenance as well as chemicals to provide clean water. It was also found that water stored for longer periods of time may be subjected to bacterial growth. To be able to reuse water in the concept system, the focus therefore lies on taking care of water with high degree of cleanliness and store it for as short as possible.

With large amounts of relatively clean tap water being wasted down the sink and with the dishwasher being placed directly beneath it, the project team saw potential in letting the used tap water be reused directly to pre-rinse the dishes inside the dishwasher. This could give the dishes several rounds of pre-rinsing spread out during the day to prevent food leftovers from drying and getting attached too hard on the dishes, without using any extra amounts of water. The need for the user to pre-rinse the dishes by hand before placing them in the dishwasher would be eliminated. Moreover, by storing information about the number of times that the dishes have been pre-rinsed, the dishwasher could adapt the main wash cycle to save water and energy. By storing the used tap water only for a short period until enough water for a pre-rinse has been collected, the risk of bacterial growth can be controlled. The project team introduced the term 'semi-tank' to describe this container for temporary water storage.

A system overview is shown in Figure 8.1, including a faucet, a sink, a semi-tank that collects the used tap water and a dishwasher that reuses the tap water for pre-rinse. Between the components there will be a flow of water but also other substances of which as much as possible should be removed before entering the dishwasher. This process will be supported by a flow of information between the components.

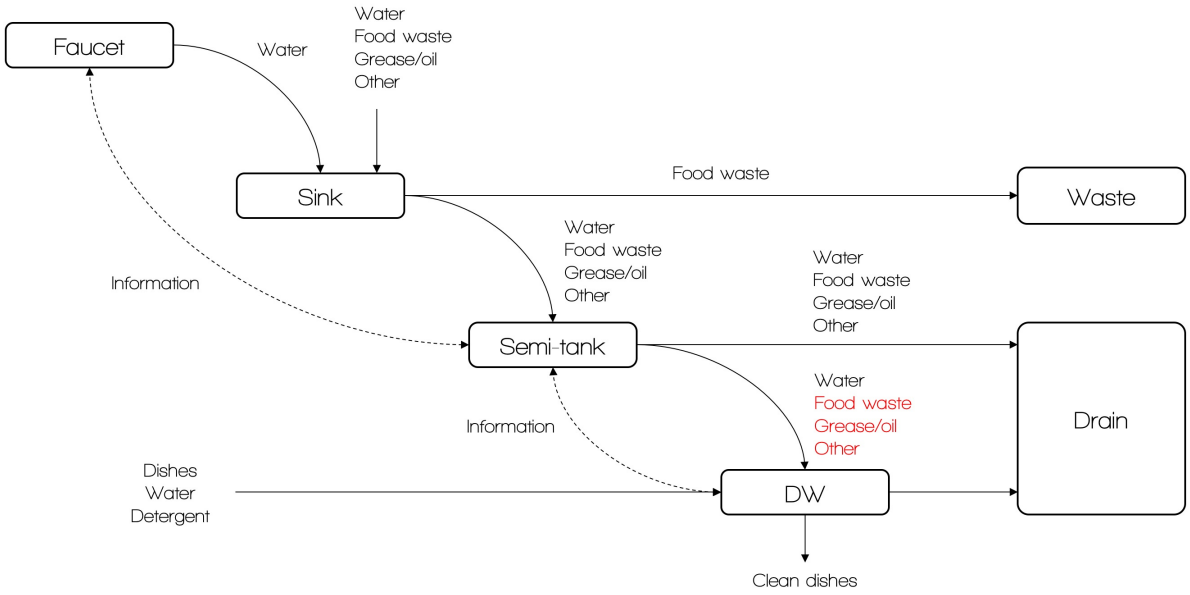

Figure 8.1 – System overview of the interplay between the different components

8.1.1. Controlling the water quality inside the system

The positive aspect of reusing the tap water only for pre-rinsing is that it places lower demands on the quality of the water than if it would be used during the whole wash cycle. However, to avoid an increased need of cleaning the dishwasher, the quality of the used tap water should somehow be evaluated before entering the machine. In many cases, the tap water will probably have been used for activities with a low soiling level such as rinsing vegetables. In a few cases, however, it may contain for instance chicken residues, which could pose a health risk if it enters and circulates through the dishwasher. Another substance that should be prevented from entering the dishwasher is detergents for manual dishwashing as they produce suds that could quickly overflow the dishwasher. There would therefore be a need for non sudsing detergent, such as the detergent used for dishwashers, when manually washing dishes in the sink.

To control the quality of the water, the project group discussed the possibility of using different sensors like the turbidity sensor described in section 2.2.1. The turbidity sensor would be placed beneath the outlet from the sink and prior to the semi-tank that would collect the water before pre-rinse. It would evaluate the water flowing past the sensor and reject water with too high soil level. This solution could be combined with a fine sink filter that already at the outflow from the sink stops most of the food waste from entering the system. The fine sink filter would require a large area to allow a steady outflow and prevent clogging.

It was also discussed that by letting the water be retained inside the semi-tank for a moment before pre-rinsing, the semi-tank could make use of different densities for a second separation of possible food waste from the water. With heavier particles probably ending up at the bottom and light density oil and grease at the top surface of the tank, the upper and lower content of the semi-tank could be rejected, similar to the principle of sedimentation, described in section 2.4.2. To make sure that no unpleasant or hazardous microorganisms enters the dishwasher, it should finally go

through a disinfection treatment stage by using either chlorine, ozone or UV light, as described in section 2.4.8.

Communication between the faucet and the semi-tank could be valuable in order for the semi-tank to determine whether to collect or reject the incoming water from the sink outflow. By sending information from the faucet each time it is used, the semi-tank would know that the fluid that is entering the system comes at least partially from the tap and should therefore have enough high quality to keep. However, if no signal is received from the faucet, the semi-tank will know that any fluid entering the system is coming from another source than the tap and may not have high quality enough to keep. This could for instance be when emptying a bucket of used cleaning water containing both soil and detergents not suitable for the dishwasher.

The information received from the faucet could also concern the temperature of the incoming tap water. As the temperature of the water is one of the factors affecting the cleaning performance, the semi-tank could choose to keep water of higher temperatures only. Another way to control the temperature of the incoming water is to use a temperature sensor in the semi-tank. In either case, the semi-tank should prevent hot water from getting mixed with cold water in order not to lose valuable heat energy. Therefore, it may be necessary to divide the tank into more than one section so that the most recently added water does not get mixed directly with the already existing fluid of the main section. The use of several sections would also be beneficial to ensure that enough time is given for the semi-tank to determine the water quality without creating bottlenecks restricting the flow of water inside the system.

8.1.2. Communication between the dishwasher and the semi-tank

Crucial for this system to work is that the dishwasher is able to communicate to the semi-tank whether it holds clean or soiled dishes. Already clean dishes should under no circumstances get rinsed by the collected tap water. At the same time, the soiled dishes should not miss the opportunity to get as many rounds of pre-rinsing as possible. The simplest way to solve this would be for the user to push a button that resets the dishwasher to the status of 'not clean' each time he or she unloads the dishwasher. However, this would demand attention and action from the user which could be easy to miss or forget. A more reliable system was sought for by listing the possible parameters that the dishwasher could be able to measure in order to determine its status. What was found to be useful parameters for this purpose was: (1) memory of performed operations, that is, wash programs and pre-rinse cycles, (2) time since last operation and (3) weight of dishes before and after a wash program has been performed.

8.1.3. Handling of food waste

Another discussion in the development work was whether or not to include a hard food disposer in the dishwasher to better take care of food waste. The final decision was to exclude it, considering that it would consume more energy, take up valuable space from the dishwasher and possibly cause a higher noise level of the dishwasher, which was one of the aspects being scored as highly important in a dishwasher purchase according to the survey result.

8.1.4. Security against water leakage

With the recycling drawer being placed beneath the dishwasher, it has the potential

to act as a buffer or extra barrier to prevent water leakage from the dishwasher. There should nevertheless be a water level sensor included inside the dishwasher to detect if the water level is too low or high.

8.1.5. Updating the system

By storing and sending information about how the unit is used, the system could over time get updates from Electrolux in order to improve its functionality for the best possible use experience and lowest possible energy and water consumption.

8.2. Dimensions and configurations

As previously discussed in section 7.3.1., the concept has the possibility to be included in either a unit of 60 cm or 80 cm. It also has the possibility of using either one or two dishwasher sections, which in turn can use either a door opening or a drawer configuration. The height of the complete unit has to be divided between the different components in a way that supports the overall functionality of the concept in the best possible way. Additionally, the configuration and dimension of the faucet needed to be evaluated to find a solution that would give the highest flexibility to handle various tasks that the dishwasher would not be able to replace.

To evaluate the different options, simple physical models was built in foam board showing the available volume of the dishwasher interior as well as the volume of the sink. The dimensions of existing benchtop dishwashers as well as the DishDrawer from Fisher & Paykel was also investigated to get an estimation of how much space that would need to be dedicated to wall thickness as well as the bottom thickness where most of the technical components of a dishwasher are positioned. Benchmarking on different sink dimensions as well as recycling boxes and faucets was also made, including visits to Ikea to see different solutions in a kitchen context. Different solutions were also discussed together with supervisors at Electrolux.

8.2.1. The unit

As the concept is targeted to compact kitchens, 60 cm rather than 80 cm width of the unit was perceived by the project team to be the most convincing solution. Assuming that urbanisation will continue in the coming years, resulting in more people living in less area per person, there is a likeliness that urban kitchens of the future may become even more limited in space. 60 cm is a standard width of kitchen units today and even though it poses more of a challenge to fit in the concept, it was decided to continue the development of the 60 cm unit. If succeeding, there would be nothing that stopped the concept from being able to be included in a 80 cm unit as well, which could be a concept targeted for larger kitchens and households.

The height of the unit will be 80 cm, with an additional 8 cm below it in the base and an additional height above it of at least 3 cm constituting the countertop. The unit will be installed using the same countertop as the rest of the kitchen to give a uniform expression. This is also to avoid gaps between the units where water could splash from the sink and run down the sides. The depth of the unit is 60 cm, as in standard kitchen modules. The suggested dimensions are illustrated by Figure 8.2.

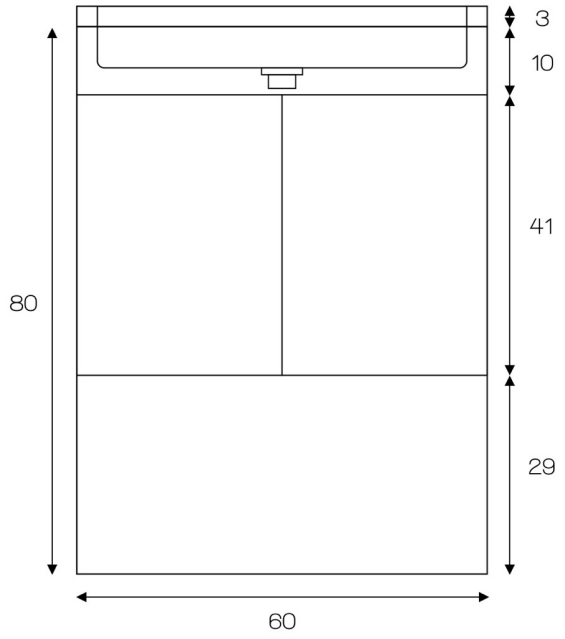

Figure 8.2 – Suggested dimensions of the unit

8.2.2. The dishwasher

After having tried out different sizes of the dishwasher sections with physical models, shown in Figure 8.3, it was concluded that even in a 60 cm unit, there would still be enough space to fit in two sections of the dishwasher instead of just one. However, the bottom area of each dishwasher section would be rectangular with the inside dimension of 26.5 x 36 cm. This dimension is assumed to give enough space for a reasonable wall thickness as well as space behind the drawers for the semi-tank and piping. Had the unit instead been 80 cm wide, the two individual dishwasher sections would have been able to use a square bottom shape which would have been a more beneficial shape in order for the spray arm to reach the dishes as efficiently as possible. Still, the rectangular shape of the bottom area is acceptable considering that its ratio is similar to the bottom area of a narrow (45 cm) dishwasher. The narrow dishwashers on the market use either one single spray arm or two smaller spray arms at its bottom. Both alternatives manage to do the job of cleaning the dishes but has a slightly lower efficiency compared to a square bottom section (Delin, 2016). Concerning the choice of using either a drawer configuration or a door opening, it was decided to continue the development of the drawer configuration due to its uniform expression with the recycling drawer and its simplicity of handling.

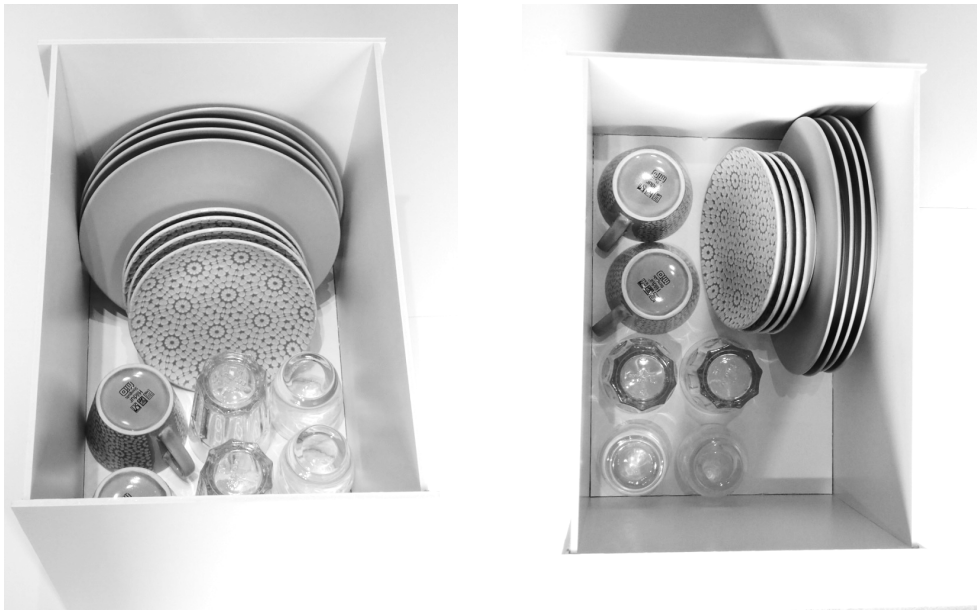

Figure 8.3 – Simple physical models in foam board was built to evaluate different alternatives and the volume of the interior in the dishwasher sections

When deciding on the height of the dishwasher, a trade-off had to be made considering the other components of the unit as well. It could either be prioritised to be able to run large plates in the dishwasher, get more room for the recycling drawer or a deeper sink. Inspiration was taken from the existing DishDrawer from Fisher & Paykel that uses a total height of 41 cm. This height seemed reasonable for being able to run plates of normal size. With some space available behind the dishwasher in the concept it was also discussed that some of the components that are usually placed at the bottom of the dishwasher actually could be moved to the back of the dishwasher to give more height to the interior. It can be assumed that around 10 cm of the bottom would need to be dedicated for water circulation components, leaving around 31 cm of height inside the dishwasher.

8.2.3. The sink

With a large sink, the concept aims at giving a more roomy feeling of the kitchen and a better ability to handle large dishes such as baking trays and ovenware. Therefore, it was decided to maximise its area. The inner width of the sink was set to 54 cm, leaving 3 cm on each side to make the installation possible within the boundaries of the unit. The horizontal depth of the inner sink area was set to 40 cm, which is a common measurement of existing sinks that would give enough room for the faucet behind the sink.

After having built a physical model with these dimensions, shown in Figure 8.4, it was found that the area would be adequate to hold a baking tray of 37.5 x 46.5 cm for a standard 60 cm oven. The size of baking trays varies depending on brand and model of the oven, but after a quick research, the project team did not find any baking tray larger than 38.5 x 46.6 cm on the Swedish market, which would still be able to fit in this sink concept. The large area of the sink will also help prevent water splashes which is extra important given that the sink will be more shallow than conventional sinks.

Figure 8.4 – Simple physical model in foam board of the sink

With the physical model it was possible to evaluate different measurements of the vertical inner sink depth. As the purpose of the sink is not mainly to be filled with water but rather to act as a workspace giving the flexibility of handling many different items, the goal was to find a depth that would be suitable for handling a variety of items and enough to prevent water splashes. It was concluded that a depth of around 9-10 cm would be adequate while going down to as little as 8 cm did not give the feeling of a sink any more but rather an immersed surface. Given the height limitation of the complete unit, it was decided to set the sink depth to 9 cm. With a countertop of at least 3 cm and a distance of 10 cm between the countertop and the dishwasher, there would be 4 cm saved beneath the sink for placement of the water outflow.

To enable placement of large items at the bottom of the sink and save as much of the height as possible, the bottom surface was decided to have only a slight fall of 1.5 cm, leading the water towards the outflow.

8.2.4. The recycling drawer

The remaining height of the unit after the sink and the dishwasher have been subtracted leaves 29 cm for the recycling drawer. Subtracting also the bottom wall thickness of the unit and the drawer leaves about 26.5 cm to the inner height of the recycling drawer. This allows bins of 25 cm in height to be placed in it. The usual height of kitchen recycling bins is commonly slightly above 30 cm, which is suitable to hold compost bags measuring 30 cm in height when unfolded. Therefore, this concept will give a slightly lower height of each bin, requiring the bags to be folded over the edges. It is reasonable, however, to assume that small households generate less waste than larger households and that the bins holding waste should be downsized accordingly to encourage a more frequent emptying of the trash to prevent unpleasant odours.

The inside volume of the recycling drawer, measuring approximately 52 litres, is to be distributed between several bins to sort the different wastes and recyclables. Given the inner area of 55 x 36 cm, it was discussed whether to divide the space between four or six equally sized bins. Alternatively, the space could be distributed unevenly between the different bins, depending on type of waste. The final decision was to use two equally sized bins of 24 x 17 cm in the front row of the drawer for the most common types of waste and three equally sized bins of 17 x 17 cm in the back row of the drawer, all with a height of 25 cm. That leaves enough space between the bins for being able to lift them up and the users can determine themselves which type of waste that should be stored in each bin. Wastes that are generated in small quantities such as lamps and batteries either have to share one bin to get sorted later, or be stored somewhere else. The reason to why some bins were not made even smaller was that the shape would then get a very narrow and deep, which is not very easy to handle.

8.2.5. The faucet

Investigation of technical principle and construction

To get a better understanding of the construction and how the mechanism works, a kitchen faucet of basic model was purchased at Ikea and disassembled. The design and functionality of the product is typical for basic models among other brands but can be seen at other high end models as well. Water pressure and temperature are both regulated by the faucet handle. Temperature is regulated between warm and cold by rotating the handle horizontally at a range of approximately 90 degrees. Water pressure is regulated by lifting the faucet handle vertically. The faucet are turned fully on and off at a range of approximately 30 degrees.

The valve mechanism consists of two ceramic disks that slide against each other to regulate both flow and temperature. By sliding and rotating the two disks, this expose two openings which hot and cold water can flow through. The water is then mixed and by varying the openings and proportion between the two, temperature and flow can be regulated. Water will not flow between the two disks due to the fine surface that form a waterproof sealing. This type of mechanism does not include a thermostatic regulator that could be seen on for example shower mixing unit. If pressure drops in one of the two water supplies, both flow and temperature will be affected.

Evaluation and development of faucet configuration

The purpose of the faucet is to support the dishwasher by handling the tasks that the dishwasher cannot handle. Six different scenarios was created to describe different

use situations placing different demands on the faucet:

- *Washing hands*
  When washing your hands, you would want to have an appropriate temperature from start so that you avoid both getting burned by too hot water and frozen by too cold water. Depending on what activity that has been performed prior to washing the hands, it may be desirable to touch the faucet controls to as small extent as possible to avoid spreading contamination. This would for example be the case after having handled or prepared chicken.
- *Filling a drinking glass with water*
  In this use situation it would be desired to get cold water from the start. It would also be desirable to have a moderate flow rate of the water so that the glass gets filled quickly without splashing water around it. When the glass is filled, the flow should get stopped almost instantly to avoid using too much water.
- *Filling a bucket with water*
  Similar to the situation when a drinking glass is filled, the flow rate from the tap should be high in order to fill up the bucket quickly. The bucket actually allows for an even higher flow rate than the glass due to its high walls preventing splashes. The desired water temperature may vary depending on the purpose of filling the bucket. The nozzle of the tap must be able to be positioned at a high level to make room for the bucket underneath.
- *Washing packages before recycling*
  When washing packages the aim should be to remove as much residues with as little water as possible. Therefore, the flow should have a high pressure while at the same time using a low flow rate. The temperature should be high enough to dissolve the food residues but low enough not to waste too much energy.
- *Washing fruit and vegetables*
  When washing fruit and vegetables, the pressure of the flow does not need to be very high but a low flow rate and a good spread of the water would be desirable in order to wash the food as efficiently as possible. The temperature should be kept low but not too cold for the hands. When performing this task, it is convenient having a workspace or drain board close by where the food can be placed while continuing to wash the rest of the food.
- *Washing a large pot containing dried food residues*
  For this task, a high temperature combined with a high pressure and low flow rate would provide a high cleaning efficiency. For heavy items such as a large pot it would also be convenient to let the object stay placed at the bottom of the sink while the water jet is moved and angled towards different areas of the object, instead of having to lift up and angle the object itself. A heavily soiled pot may have to be left for a while filled up with water in order to loosen the food residues.

From these six scenarios, a list of criteria was created that the faucet should meet in order to provide as high level of flexibility and convenience as possible. Added was also one criteria concerning the visual appearance of the faucet and its potential to fit into Electrolux's product portfolio. Each criterion was valued in relation to each other and given a weight number indicating its importance. The list of criteria is presented in Table 8.1.

Faucet criteria

No.	Criteria	Weight
A	Allow separate adjustment of temperature and pressure	5
B	Allow precise adjustment of temperature and pressure	5
C	Allow opening and closing of the water flow at the nozzle	3
D	Allow horizontal movement of the water stream	4
E	Allow vertical movement of the water stream	4
F	Allow angling of the water stream	4
G	Allow positioning of the water stream	2
H	Have a range that does not exceed the boundaries of the sink	Req.
I	Allow variable spread of the water stream	4
J	Allow ergonomic gripping of the handle	2
K	Have a visual appearance that is consistent with Electrolux's visual brand identity	4

Table 8.1 – Criteria for the faucet

After benchmarking different faucet styles and configurations, sketching was used to produce four different faucet configurations focusing on flexibility of use. These configurations was evaluated together with three already existing faucet configurations on the market using some of the criteria in the list presented above in a Kesselring matrix, found in Appendix VII. Only the criteria that were relevant for the configuration evaluation was used in the matrix. The faucet that got the highest score was the faucet to the left in Figure 8.5.

Based on the complementary research of faucets, it was assumed that the existing mechanism/mixing valve would not be able to handle criteria A, B and C from the list above without the use of electronic controls. The main reasons for this are that the adjustments will need to have a smooth control for the user, which could not be seen in the reference product, but also that the construction itself is not likely to fit in the nozzle due to its size. Another problem is that both temperature and pressure are regulated by one mechanism in the reference product which would need to be separated in the concept for a more precise and easy control.

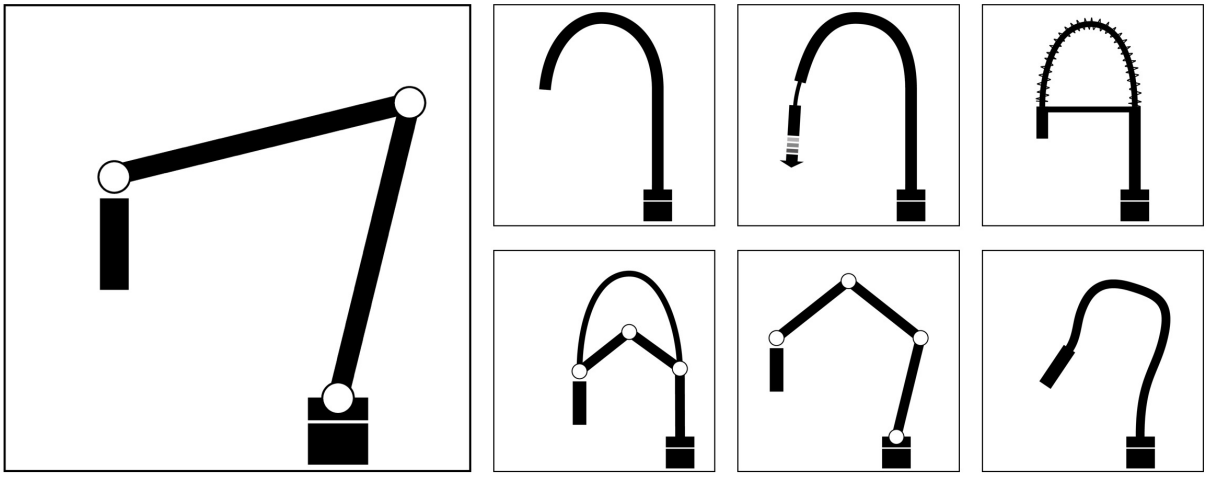

Figure 8.5 – The different faucet configurations evaluated with the criteria presented in Table 8.1. The faucet to the left scored highest.

8.3. Form development

8.3.1. The unit

The unit could either be treated as a separate unit with an individual design, similar to an oven unit, or it could be adapted to as far as possible blend in with the design of the kitchen. As previously mentioned, kitchens with built-in dishwashers using the same front panel as the rest of the kitchen is growing in popularity. For this concept, the two different options were decided to be combined by letting the uppermost panel of the unit be kept visible to contain the interface of the dishwashers, while the three remaining sections, including the two dishwasher drawers and the recycling drawer, have the possibility to get integrated with front panels matching the rest of the kitchen. By keeping the interface visible, there is more freedom in what communication that can be given from the dishwasher to the user.

The front design of the unit, including the shape of the display area in the upper panel and possible handles of the drawers was elaborated by using Adobe Illustrator to vary one parameter of the shape at a time. The design was focused on making a clear distinction between the interface area and the rest of the panel by using colour and material contrasts and the distinctive Electrolux flow line. Inspiration was also taken from the design of Electrolux's existing range of ovens. A few of the variations are shown in Figure 8.6.

Figure 8.6 – A few variations of the front design of the unit

8.3.2. The sink

The shape of the sink was elaborated in a similar manner as the front design, using Adobe Illustrator to vary one parameter at a time. First, a simple top view sketch of the sink was used to vary the radius of the sink corners. The variations of corner radius is shown in Figure 8.7.

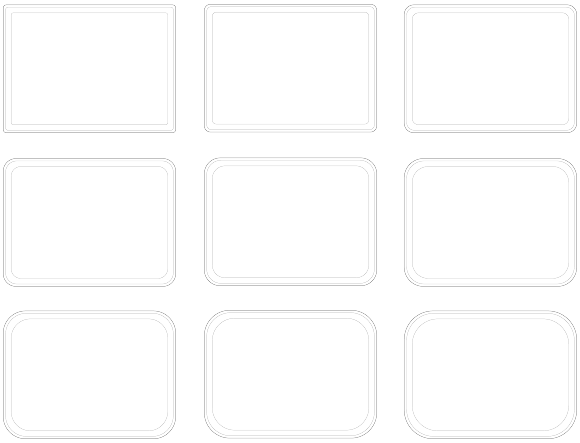

Figure 8.7 – Variations of corner radius in the sink

The different sizes of the corner radius was found to have a great impact on the overall expression of the sink. A small radius was perceived by the group as more precise and modern while a larger radius reminded more of conventional kitchen sinks. As the group aimed for a precise expression and wanted to keep as large bottom area as possible for the sink's ability to hold larger items, it was decided to use one of the smaller radii. The same reason contributed to the selection of a small variation in sink depth as illustrated by the side views of the sink in Figure 8.8.

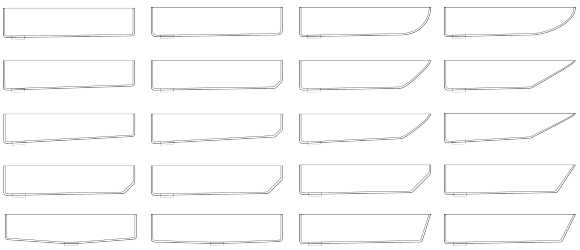

Figure 8.8 – Variations in sink depth viewed from the side

Another variation of the sink design was to include different shape elements connecting to the Electrolux flow line. The variations are shown in Figure 8.9. It was decided to use a central shape element to mark the position of the faucet. The size of the shape element had to be small in order to not lose too much space from the sink.

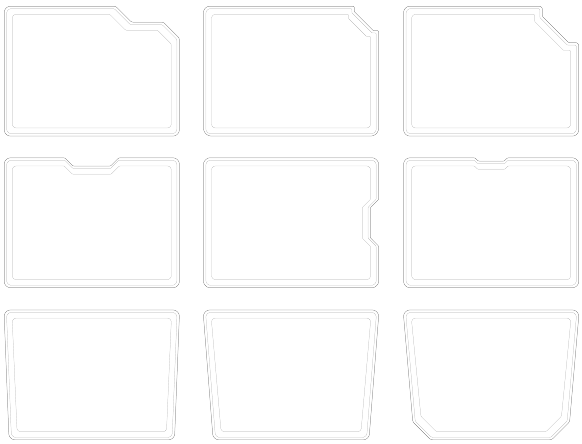

Figure 8.9 – Integration of different shape elements in the sink

Sketches were also made to try out the position of the Electrolux logotype in the form of a flood protection, as seen in Figure 8.10.

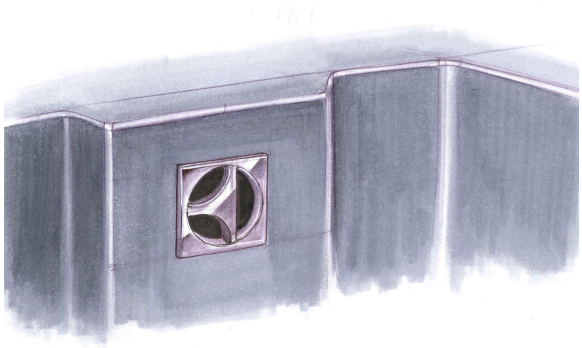

Figure 8.10 – Sketch of the Electrolux logo included as a flood protection in the sink

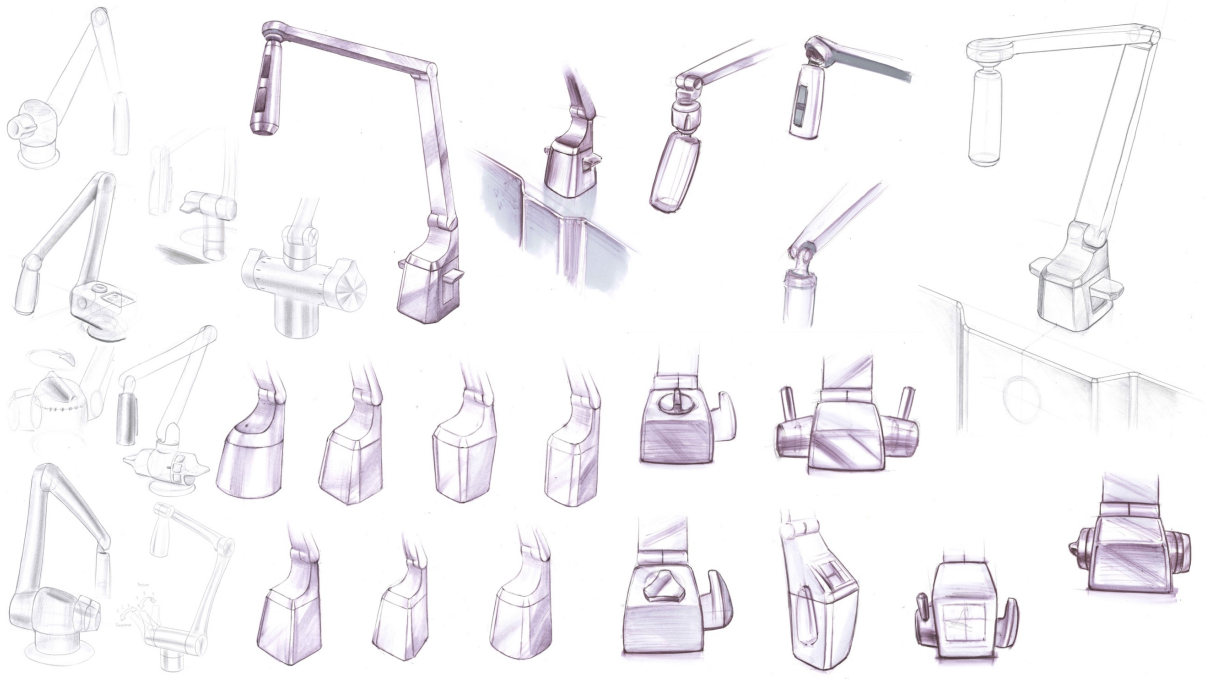

Figure 8.11 – Sketches of the faucet

8.3.3. The faucet

Having decided to continue the development of the left faucet configuration in Figure 8.5, a large amount of sketches were produced to try out different designs of the faucet body, joining elements and nozzle. The aim was to use as simple and clean design as possible. This was, however, found to be quite a challenge given the requirements on a high flexibility of movement including both rotation and bending the different parts in relation to each other. Some of the sketches are shown in Figure 8.11.

8.4. Development of the user interface

To fully utilise the functionality of pre-rinsing the dishes with reused tap water, the dishwasher should adapt its main wash cycle after the number of times that the pre-rinsing has been performed and the soil level of the dishes. Therefore, the main wash cycle of the dishwasher should be an auto/sensor wash program that adjusts the temperature and duration of the wash cycle. Using auto/sensor as the main wash program would eliminate the need of most other wash programs, as the dishwasher itself would adjust the cycle to make sure that the dishes get clean while consuming as little energy and water as possible. One program that could be added as an alternative option would be a quick wash cycle to give the user freedom of accessing the dishes quicker. After discussions with supervisors at Electrolux, it was learned that the dishwasher occasionally needs to run cycles of higher temperature in order to clean out its circulation system. Therefore, it was discussed to let the dishwasher run a higher temperature automatically every fifth cycle.

With only few program options, the interface can be kept simple. In the development of the interface, focus lied on providing feedback concerning remaining time of the wash cycle, information about the available program options and the current status of the machine. Having two dishwasher sections in the concept, it was decided that it would be easier to control each section and get clear feedback if the interface is divided into two different sections as well.

9

List of Requirements

Based on the further research and development described in the previous chapter, the initial list of requirements presented in Chapter 6 was completed. It is here presented as an extensive list divided into different areas of the concept in Table 9.1. The list starts with general requirements of the concept, followed by requirements of the dishwasher, the sink, the faucet, the semi-tank and finally, the recycling drawer.

9.1. General requirements

No.	Requirement
9.1.1	Have the potential to be more sustainable than manual dishwashing
9.1.2	Not reduce the amount of workspace in the kitchen
9.1.3	Encourage a sustainable handling of dishes
9.1.4	Be applicable in a 60 cm unit
9.1.5	Be easy to clean
9.1.6	Be easy to use and to understand
9.1.7	Be a natural part of the workflow in the kitchen
9.1.8	Handle all washing and waste management in the kitchen
9.1.9	Have a visual appearance that is consistent with Electrolux's visual brand identity

9.2. Dishwasher requirements

9.2.1	Be divided into two independent sections of 30 cm width each
9.2.2	Use a drawer configuration
9.2.3	Allow placement of plates of minimum Ø 27 cm
9.2.4	Have a depth of maximum 40 cm

9.2.5	Reuse water from the tap for pre-rinse
9.2.6	Have a total capacity of six place settings
9.2.7	Memorise performed operations
9.2.8	Measure weight of dishes

9.3. Sink requirements

9.3.1	Prevent water splashes
9.3.2	Allow outflow of water
9.3.3	Separate food waste from outflowing water
9.3.4	Allow placement of extra workspace
9.3.5	Have an inner dimension of 54 x 40.5 x 9 cm

9.4. Faucet requirements

9.4.1	Allow separate adjustment of temperature and pressure
9.4.2	Allow precise adjustment of temperature and pressure
9.4.3	Allow opening and closing of the water flow at the nozzle
9.4.4	Allow horizontal movement of the water stream
9.4.5	Allow vertical movement of the water stream
9.4.6	Allow angling of the water stream
9.4.7	Allow positioning of the water stream
9.4.8	Have a range that does not exceed the boundaries of the sink
9.4.9	Allow variable spread of the water stream
9.4.10	Allow ergonomic gripping of the handle

9.5. Semi-tank requirements

9.5.1	Evaluate cleanliness of incoming water
9.5.2	Eliminate health risks by preventing unhealthy substances from entering the system
9.5.3	Prevent odours
9.5.4	Have a volume capacity of 3 litres

9.5.5	Estimate contained volume
9.5.6	Measure temperature of incoming water
9.5.7	Store water for maximum 2 hours
9.6. Recycling drawer requirements	
9.6.1	Provide separate boxes for different wastes
9.6.2	Prevent spreading of smell

Table 9.1 – List of requirements

10

Final Concept

In this chapter the final concept of the project is presented. A description is given of the product, its constituent parts and their functionality. Then the interaction with the interface is explained, followed by a description of the form expression of the concept.

10.1. UNIWA

Uniwa is designed to unite all washing and waste management of the kitchen into one single kitchen module. Its development has been focused on three areas:

- To provide a space efficient solution for compact kitchens
- To minimise water and energy consumption related to the dishwashing process
- To support users in their daily kitchen activities

Uniwa replaces a central unit that is often not fully utilised in today's compact kitchens. It leaves the workspace of the kitchen free, which is a vital element needed to support creativity in cooking as well as the ability to socialise in the kitchen. The space beneath the sink unit is organised and no storage space is taken from neighbouring cabinet units.

By treating the sink unit and the dishwasher as a system, Uniwa takes control over the water consumption in the kitchen. Tap water is normally washed down the sink without taking advantage of the energy and the relatively high quality it may still hold. This concept utilises the potential of the tap water to pre-rinse the dishes inside the dishwasher, possibly reducing the energy and water use of the dishwasher cycle as well as the need for the user to pre-rinse the dishes.

Uniwa is designed for persons who desire a smooth and flexible way of handling dishes that enables them to make the most out of their limited kitchen workspace. It supports the user in handling a variety of tasks as well as a variety of dishes.

10.2. The product and its constituent parts

Uniwa has the dimensions of a standard 60 cm kitchen module and includes a sink, a faucet, two separate dishwasher drawers and one waste and recycling drawer. Different views of Uniwa are shown in Figure 10.1 – 10.3.

10.2.1. The dishwasher drawers

The dishwasher drawers are placed at a height that gives the user a good overview of the content as well as a comfortable height of loading and unloading the dishes. The two sections can either be run independently or simultaneously. This gives the user freedom

Figure 10.1 – Uniwa

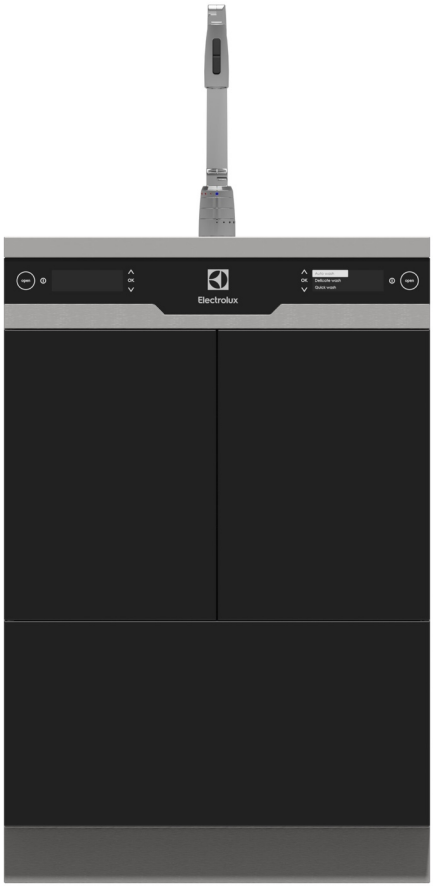

Figure 10.2 – Front view of Uniwa

Figure 10.3 – Top view of Uniwa

of running variable amounts of dishes depending on the dish load of each day. By running one section at a time, only a small amount of dishes is occupied by the dishwasher. While it is running, the user can add new dishes to the other section instead of placing them in the sink or on the counter. This facilitates keeping the kitchen clean and the workspace available for other tasks. It can also give a higher tolerance to longer wash cycles, which is a prerequisite in order to keep the energy and water consumption low. The dishwasher drawers use no physical handles. Instead they are opened by two separate opening buttons positioned in the interface panel, which will be described in section 10.4.

Interior

With an interior area of 26.5 x 36 cm and a height of 31 cm, each dishwasher section can contain approximately up to three place settings. To allow for plates larger than 26.5 cm in diameter, plates are positioned facing the side wall. Cutlery is placed in a basket that can be positioned in one of the front corners. Glasses, cups and bowls share the remaining space, with one extra level along one of the side walls. The extra level can be folded upwards when not used, and adjusted in height to fit various sizes of dishes. Figure 10.4 gives a simplified overview of how dishes can be placed in the dishwasher drawers, but the interior has not been developed in further detail than this.

10.2.2. The recycling drawer

The recycling drawer is positioned at the bottom of the unit (see Figure 10.5). Similar to the two dishwasher drawers, it uses no physical handle. Instead, it is opened by a gentle push from the foot. Unlike the dishwasher, that includes heavy objects in form of dishes, the recycling drawer contains relatively light objects in form of waste that can easily be thrown into the right bin. Therefore, the lower height of the recycling drawer is more acceptable than a low height of the dishwasher. The different categories of waste is sorted into five bins of two different sizes. Some of the bins have lids that can be used in order to prevent odours from food waste.

10.2.3. The sink

Figure 10.6 shows the sink, which takes up most of the top surface of the unit. It has been developed with the aim to support the dishwasher by handling the tasks that cannot be performed by the dishwasher. It also aims at giving the compact kitchen a feeling of a good workplace, more similar to a larger kitchen. The sink provides a spacious area that supports dishwashing of large and bulky items. In order to facilitate preparation of food, the sink area can be combined with extra workspace, in the form of a cutting board and a dish rack.

The inner edge if the sink uses the shape of the Electrolux flow line which creates a natural positioning of the faucet. The depth of the flow line is just 1.5 cm, leaving 39 cm of the total 40.5 cm depth of the sink, which is enough for placing large items such as baking trays inside the sink. At the vertical surface in the centre of the flow line, a flood protection with the shape of the Electrolux logo is positioned. To remove as much food waste as possible while maintaining a good outflow of water, the sink is given a fine filter with large area. It is placed close to the flow line shape at the sink bottom, which has a slight slope towards the filter (see Figure 10.7).

The cutting board, shown in Figure 10.8, is shaped to fit snugly into the shape of the sink. Half the thickness of the cutting board is visible above the sink while the other half is lowered into the sink. This keeps the cutting board in a secure place, preventing it from moving during use. The cutting board is given a wide shape that leaves the inner 15 cm of the sink free. This gives the user a

Figure 10.4 – Simplified overview of the dishwasher drawer interior

Figure 10.5 – Top view of the waste and recycling drawer

Figure 10.6 – The sink and faucet of Uniwa

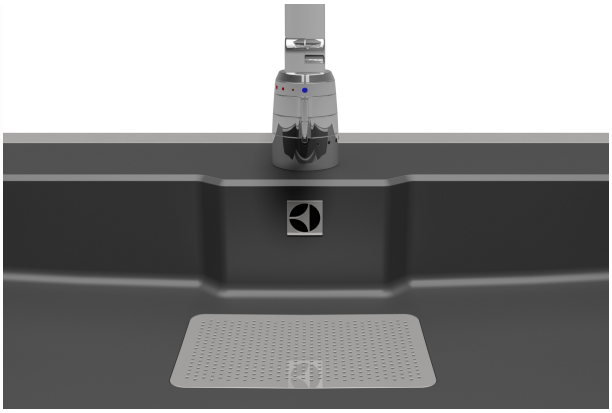

Figure 10.7 – The sink filter and flood protection

Figure 10.8 – Cutting board that gives extra workspace to the sink

Figure 10.9 – Dish rack for preparation of food or placing of dishes

comfortable position while cutting or performing other tasks. The remaining inner space of the sink enables use of the faucet for rinsing various items without having to remove the cutting board. This area also allows food waste to be wiped off the cutting board right into the sink. A groove close to the edges prevents fluids from overflowing the cutting board. The flow line shape of the inner edge form a natural handle for lifting away the cutting board.

The rack can be placed on top of the sink edges, as seen in Figure 10.9. Food or dishes can be placed on it during or after rinse to enable the rinse water to drain from the items. Similar to the cutting board, the rack uses a wide shape that provides a comfortable working position and enables use of the faucet.

10.2.4. The faucet

The faucet is developed with a focus on providing flexibility while at the same time helping users consume less water. It consists of a faucet body, two arm sections and a nozzle. The cylindrical body includes two control handles, one for temperature and one for pressure adjustment. When both control handles are in a central position, this means that the faucet is set to the lowest temperature and pressure. The two handles can then be turned in the opposite direction of each other. This is to prevent confusion and simplify adjustment of one handle at a time without accidentally adjusting the other handle as well. It also makes it easy to see the current setting of the two parameters, as shown in Figure 10.10 and 10.11.

Temperature is adjusted by turning the upper handle to the left for higher temperature, which is consistent with most other faucets on the market. The adjustment is stepwise to provide a precise control over the setting. The steps does not limit the handle from being set in between two steps, but can rather be seen as checkpoints on a scale, giving the user both haptic and visual feedback on how far up the scale that the handle is set. This facilitates setting the desired temperature.

The pressure control is treated in a similar way to the temperature control, but is instead turned to the right for increased pressure. As the convention is that scales often increase in value when moving from the left to the right, the control of the pressure parameter should also be consistent with previous experiences by the users.

Adjusting the temperature and pressure does not start the water flow from the tap. The flow is instead controlled by two buttons at the nozzle, giving two different distributions of the water flow. The lower button starts an even flow with a high flow rate, suited for situations such as when the user wants to fill a drinking glass, bottle or bucket quickly with water. The upper button distributes the water into a shower like flow that maintains a high pressure while using a lower flow rate to save water. This option is suitable for instance when washing hands or various items including both dishes, packages and food.

The water flow is regulated in two steps. By pushing lightly, the button will spring back as soon as it is released. This facilitates using just the amount of water needed for the task. If the button is pushed beyond this first step, it will stay in that position, allowing a continuous water flow in situations when both hands are needed. To cut the water flow, the user simply pushes the other side of the button, similar to the mechanism of a light switch. This gives in total four modes for regulating the water flow: regular - short, regular - constant, shower - short, shower - constant and neutral (off). The different buttons and adjustment handles are regulated by electronic controls. The actual mechanism is located in the faucet body. The

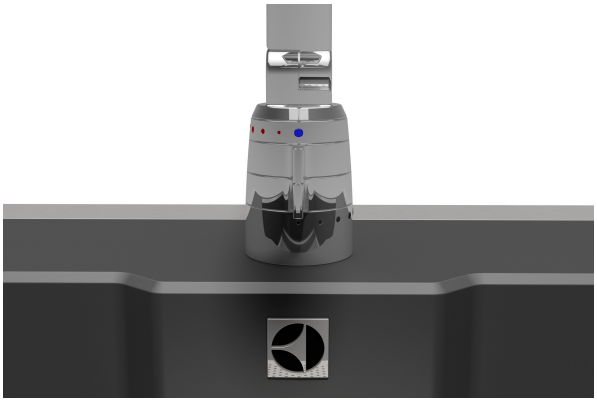

Figure 10.10 – Both control handles are in a central position for the lowest settings

Figure 10.11 – Temperature and pressure has been adjusted

Figure 10.12 – Flow is controlled by two buttons at the nozzle

Figure 10.13 – The faucet is positioned with the nozzle close to the inner sink edge

Figure 10.14 – The faucet in a low position and turned to the left

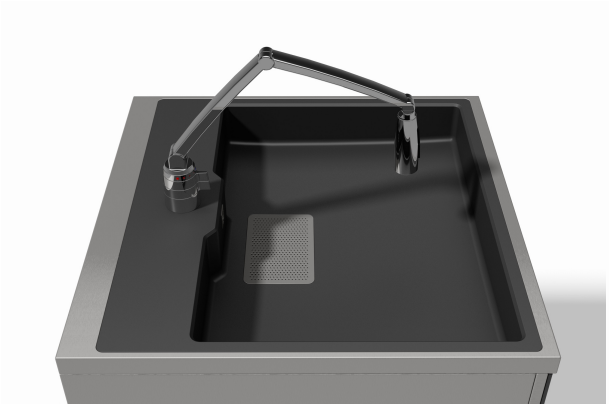

Figure 10.15 – The faucet in a low position close to the front edge of the sink

Figure 10.16 – The faucet in a high position

Figure 10.17 – The space available for the semi-tank and piping of the unit

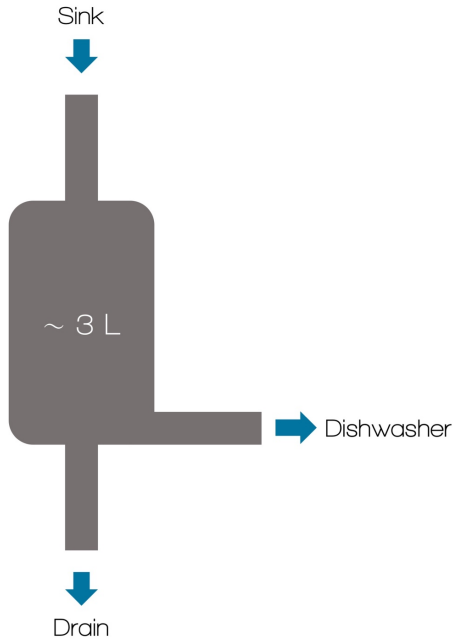

Figure 10.18 – Simple illustration of the semi-tank

Figure 10.19 – The dishwasher drawer is set on 'clean' mode after a finished wash cycle

Figure 10.20 – If a small weight reduction is detected, the mode continues to be set on 'clean'

Figure 10.21 – Detection of a large weight reduction prepares the dishwasher for pre-rinse again

arm sections connect the nozzle with the faucet body through rotational joints. The joints allow the faucet to rotate around the axis of the body, to bend forward or backward and to angle the direction of the nozzle (see Figure 10.13 – 10.16). The arms are given a rounded rectangle cross section that gives a smooth transition to the joints connecting the two arms. The area of the cross section varies from 3 x 1.5 cm just above the faucet body, and 2.5 x 1 cm just before the nozzle joint. This gives a cross section area comparable to other faucets on the market.

10.3. The pre-rinsing system

Used tap water passes through the sink filter, where most of the food waste is removed from the water. It then enters the semi-tank, which evaluates the quality of the water to determine whether the water should be reused for pre-rinsing or not. Water of sufficient quality enters the dishwasher drawers from inlet valves placed in the rear walls. The water is circulated for a few minutes before being emptied by the dishwasher drain pump. Figure 10.17 indicates the space that is available for the semi-tank and piping of the unit. A simple illustration of the semi-tank is shown in Figure 10.18.

Each dishwasher section uses logic to determine whether they hold clean or soiled dishes. This logic is based on previous operations and the weight of the dishes. By measuring the weight of the dishes before a wash cycle is started, the dishwasher can compare this value with the weight of the dishes after the wash cycle is finished. As soon as the wash cycle is finished, the dishwasher sets its status to 'clean'. If the weight remains the same, the dishwasher will know that no dishes have been unloaded and thereby the status will continue to be set on 'clean'. If a small weight reduction is noticed, this means that only a few or one single item has been unloaded from the dishwasher and the remaining weight will still consist of clean dishes, and the dishwasher will retain its status as 'clean'. If, however, the whole weight of the dishes is subtracted from the dishwasher, the user will have unloaded the complete content of clean dishes and the dishwasher will change its status to 'empty'. When weight is added once again, the status is changed to 'not clean'. The dishwasher is once again prepared to pre-rinse dishes. The principle is summarised by Figure 10.19 – 10.21.

10.4. Controlling the dishwasher drawers from the interface panel

The dishwasher sections are controlled from an interface in the upper panel of the unit (see Figure 10.22). This panel includes one opening button for each dishwasher drawer. The opening buttons replace the need of a physical handle. There are two reasons for using opening buttons rather than physical handles. First, it will give the dishwasher time to pause any ongoing operation before it is opened, even though it will only need a short moment for this purpose. Second, the lack of physical handles contributes to a clean expression of the unit that is more likely to be consistent with the rest of the kitchen.

The panel also includes two separate displays with touch buttons. While in standby mode, only the on/off button and the opening button for each section is visible (see Figure 10.23). By pushing one of the on/off buttons, the corresponding display and other touch buttons become visible, including two arrows and one 'OK' button. These buttons are used to toggle between and select different options presented in the display.

Figure 10.22 – The interface panel of Uniwa

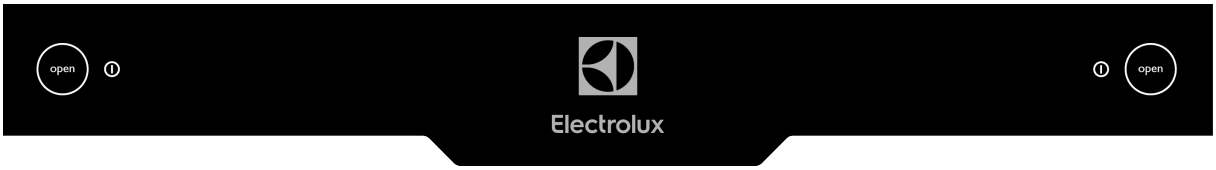

Figure 10.23 – The interface of Uniwa. Both dishwasher sections are in standby mode

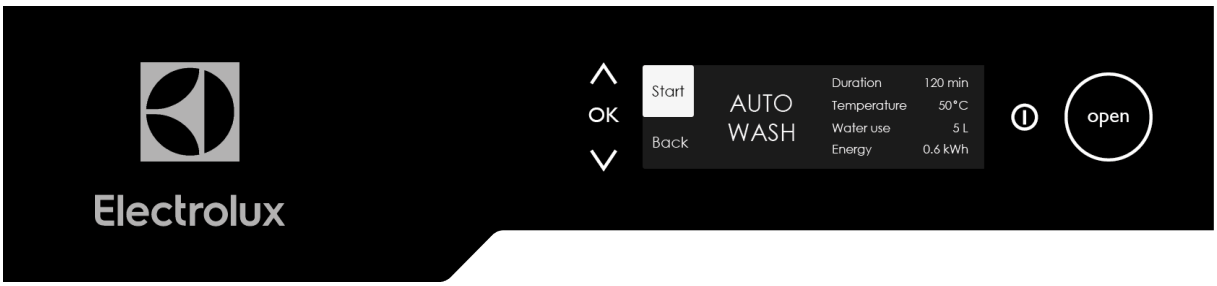

Figure 10.24 – The on/off button to the right has been pushed. The display shows a default auto wash program and information about its duration, temperature, water and energy use. The possible options are either to start the program or go back to the menu

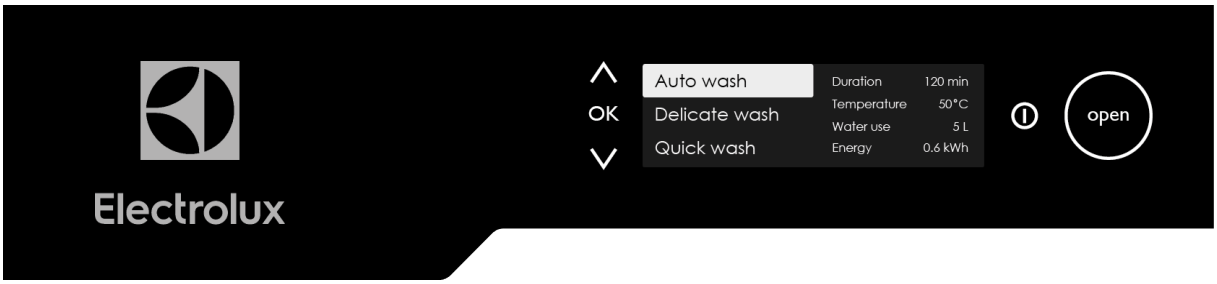

Figure 10.25 – The menu shows other available programs and information about the duration, temperature, water and energy use for the currently marked program

Figure 10.26 – While a program is running, the display shows the time left of the wash cycle

When the dishwasher is passive and the on/off button is pushed, the display image that appears will show a default auto wash program, which will be the most water and energy efficient option available. It also presents the estimated time, temperature, water and energy use and the possibilities of either starting this program or moving back to a menu (see Figure 10.24). The menu contains options of other programs that can be selected by using the arrows and the 'OK' button (see Figure 10.25). By having the auto wash program as the default option, this will be the most easily accessible choice for the user. Once a program is running, the display views the time that is left of the cycle (see Figure 10.26).

10.5. Form design and expression

The expression of Uniwa is aimed to be consistent with Electrolux's brand identity. Some of Electrolux's design cues, described in section 4.1.1., has therefore been implemented in the product. The implemented design cues of Uniwa are shown in Figure 10.27. The overall expression that was aimed for in the product is summarised by the words in Figure 6.5 and the expression board, which is shown together with Uniwa in Figure 10.28. Uniwa is also shown in the context of a compact kitchen in Figure 10.29 and 10.30.

Uniwa has a clean and precise expression that is supported by simple shapes and clear distinctions between different surfaces. This is achieved by clearly marked split lines and contrasting colours, materials and surface finishes. Softness is added by small radiuses of edges and corners, and slightly arched surfaces found in the faucet and in the bottom of the sink. This contributes to a more encouraging, honest and reliable expression of the product. The Electrolux flow line is implemented in the upper interface panel as well as in the sink contour which adds a dynamic dimension to the design.

The front panels of Uniwa can as mentioned previously be exchanged to use the same panels as the rest of the kitchen. The front panels included in the product from the beginning have a glossy black finish creating a contrast to the brushed metal found in the upper panel, which is also commonly found in other premium products from Electrolux. The Electrolux logo is given a central position above the flow line of the interface panel, where it is coloured in a light silver tone contrasting the black base. Another place where the logo is found is on the vertical surface of the flow line in the sink. It here constitutes the flood protection and is a silver detail with a slightly arched surface thickness that makes it protrude from the sink wall. Another silver detail in the sink is the sink filter placed on a short distance from the inner sink wall. The sink is made in a black composite material with a smooth surface finish. Its edges are chamfered with a small radius on the edges.

Chamfered edges are found also in the faucet, at the top rotating section of the body and at the nozzle. It is plated with a shiny chrome finish. The arm sections are slightly tapered towards the nozzle, creating a clear directional line within the product. A direction is also given to the nozzle by giving it a slightly conical shape. The nozzle and the faucet arms are arched slightly, contributing to a more flow like and dynamic shape. Contrast is created by the black buttons on the nozzle as well as by the symbols denoting temperature and pressure adjustment.

Figure 10.27 – Some of the Electrolux design cues implemented in Uniwa

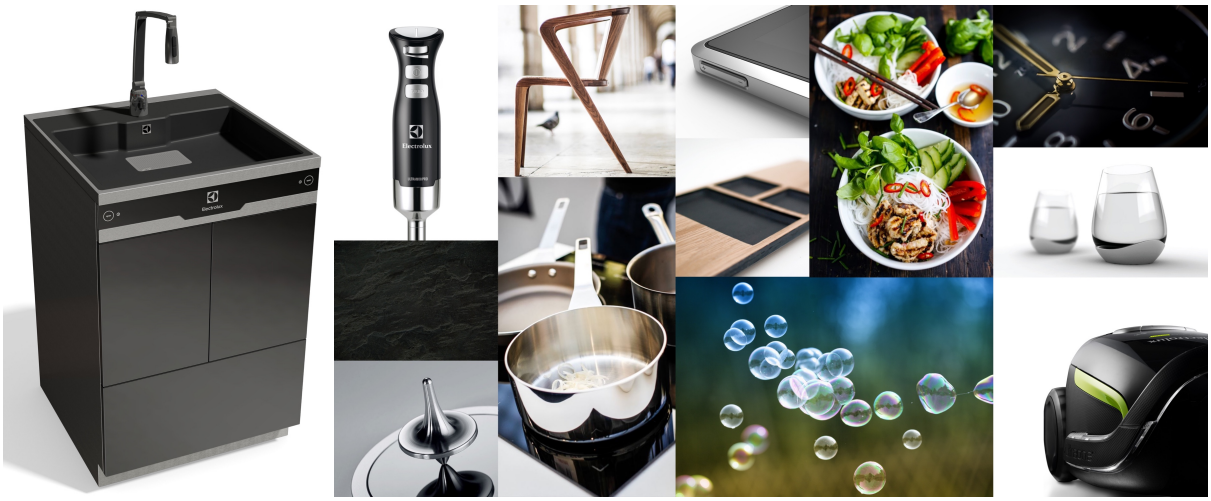

Figure 10.28 – Uniwa together with the expression board

Figure 10.29 – Uniwa in the context of a compact kitchen

Figure 10.30 – Uniwa in the context of a compact kitchen

11

Evaluation

This chapter includes evaluation of the concept from the perspectives of possible energy savings and design for sustainable behaviour.

11.1. Calculation of possible energy and water savings

As Uniwa is a space efficient solution designed with the user in mind and to minimise the water and energy consumption in the kitchen, it truly seems to have the potential for being successful as a product. The natural question to ask is then, how much water and energy will actually be saved in a live scenario? As the concept is based on utilizing resources that would otherwise go to waste, the result will of course vary depending on the water and energy use in the kitchen. As different users have different behaviours the unit will have to adapt to each user and to each specific case. Perhaps the best way to evaluate the potential is with a few examples. After all, this is a concept that differs a lot from products available on the market today. To pre-rinse dishes with a higher temperature will definitely have a positive effect on the cleaning performance, but to predict exactly how much and to translate that into, for example a shorter main wash phase, is more difficult to answer. In attempt to answer these questions, simple equations will show the potential savings for different cases. Water and energy that would otherwise be wasted and not fully utilised, must be considered as 'free' when it gets reused by the dishwasher sections. This means that the concept can utilise more water and energy than an existing dishwasher without resulting in a higher environmental impact.

The calculations on water and energy savings are based on different scenarios and an example which can represent a washing cycle of an existing dishwasher. The calculations are only based on differences in water use and energy consumption and will not calculate the actual water and energy use as this includes several other factors like heating of interior and dishware, work performed by the circulation pump or water and energy losses. To simplify the calculation a few assumptions and approximations have been made.

As water stored in the semi-tank and the dishwasher drawers are thermally insulated they are regarded as a closed adiabatic system, which means that there is no exchange of mass or heat with the surroundings. As the water is mixed well and heated slowly it is also regarded to be in thermal equilibrium. The system will not be pressurised and the temperature of the water will stay well above freezing and below boiling temperature, which means that there are no phase transformations and can be regarded as an isobaric and isochoric process since water is considered to be

incompressible. This also means that the pressure will be considered as atmospheric and the specific heat capacity to be constant, which is also reasonable given the rough assumptions of the system. As heat exchange occurs due to a temperature difference and always move spontaneously from hot to cold, the dishwasher should be able to save energy from the heating process as long as the temperature is higher in the semi-tank than the dishwasher drawers and the surroundings.

It is important to note that a temperature raise of the inlet water, which is then transferred from the semi-tank to the dishwasher drawers, will not result in the same temperature of the water that circulates inside the dishwasher drawers due to the fact that dishware and interior will absorb a lot of heat from the water. This also means that heater will be used in order for water to reach desired temperature.

Due to the quality of the water that is reused from the sink unit, it is assumed that it can only be used for the pre-wash and the main wash phase, but not the final rinse phases. Since a wash cycle includes at least four steps and that there is a maximum and minimum level of water to be able to run the circulation, each phase will stand approximately for one fourth of the total water consumption. This means that 25% water can be saved during the pre-wash and up to 50% if main wash is included as well. To estimate how much water the concept will need it has been discussed with Electrolux. Based on the size of 6 place settings, which equals the total capacity of Uniwa, a volume of around 2-3 litres will be needed for each phase. Other factors that have also been considered are the volume and temperature of the water that the semi-tank will have to deliver within a reasonable timeframe. In the example, volumes of 2-3 litres of water with a temperature of 35 degrees have been used and are considered to be realistic in a real life scenario. If this water would be reused by Uniwa, the possible energy savings equals the heat exchange Q that can be calculated by the following steps:

$$q_r = c_p \cdot \Delta T$$

Where
q_r is heat per mass unit $[J/kg]$
c_v is the specific heat capacity $[J/kgK]$
$\Delta T = T_2 - T_1$ is the difference in temperature [°C]

The work for heating the water can then be calculated by multiplying with the mass of the water, which gives:

$$Q = q_r \cdot m$$

And the mass can be calculated by using the density:

$$\rho = m/V$$

Which then gives us:

$$Q = c_p \cdot (T_2 - T_1) \cdot \rho \cdot V \quad [J]$$

The heat capacity of $c_{p,20°C} = 4.181\ [kJ/kg \cdot °C]$ and density $\rho_{20°C} = 998.2\ [kg/m^3]$ are taken as average which can then be translated to kWh (3600 kJ) and calculated for the different scenarios. Energy is then compared to an existing dishwasher of six place settings using 0.7 kWh and 8 litres per cycle for a normal program. The result of the calculations are shown in Table 11.1.

	Recycled water	Q: Possible energy savings (kWh)	Q compared to total energy use for a normal cycle* (0.7 kWh)
Scenario A 20 – 35°C ΔT = 15°C	2 L	0.0348	5 %
	3 L	0.0522	7.5 %
Scenario B 15 – 35°C ΔT = 20°C	2 L	0.0464	6.6 %
	3 L	0.0696	9.9 %

Table 11.1 – Possible energy savings for different scenarios
**Energy use for an existing dishwasher of six place settings using 0.7 kWh and 8 litres for a normal wash program*

Through these assumptions it should be possible to save between 25-50% fresh water and 5-10 % energy compared to not reusing water. However, to compensate that reused water has lower quality than clean water that is used for existing dishwashers, more water may need to be used in total to achieve the same result. The pre-wash could for example be performed in several steps depending on the available resources from the semi-tank.

11.2. Implemented design strategies for sustainable behaviour

Connecting back to the design strategies for sustainable behaviour by Lidman and Renström (2011), described in section 2.3., the concept has been evaluated focusing on its different elements. Generally, the concept is designed to match the behaviour of the users while saving water and energy. By automatically reusing the water, no intervention is needed from the user. The reuse of water also gives a higher tolerance to users that consume more water and energy through the tap.

The faucet is also designed to match the behaviour of the users by providing flexibility without restricting the functionality. The impression of the project team was that existing solutions with water saving properties were mainly based on restricting the water flow in order to save water and energy, but regarding the user involvement they gave little or no guidance for the user to act sustainably. In some cases, the products even seemed to have a negative effect on user's behaviour as they were sometimes difficult, if even possible to control with precision. The temperature and pressure adjustment of this concept is designed to give the users both visual and haptic feedback of the settings to give the users more control as well as to enlighten them about the current setting. The flow control buttons are designed to steer the users towards using just the amount of water that is needed for the task.

By using the auto program as the default program the user is steered towards selecting the most water and energy efficient option. To select a quicker program, the user has to move back and toggle in the menu which demands several steps of action. By providing information about the water and energy use, the users are also enlightened about the difference in consumption between the different programs.

The two sections of the dishwasher make it easier to fill up the machine with dishes and prevents running a machine that is only half

full. This matches the behaviour of users who need to do the dishes frequently since they often need the kitchenware again relatively soon. The separate bins inside the recycling drawer matches the behaviour of users who usually sort their waste and spurs other users to start sorting their waste more.

12

Discussion

This chapter discusses the process and methods used as well as the final result of the project.

12.1. Process and methods

The process in this project has been far from linear and has rather included many iterations. Some of the methods used have been 'followed by the book' while others have been tailored to suit this particular project. The project team's impression is that a suitable amount of methods have been used. If more methods had been included in the process, this could have hindered the open approach of the project. The methods used, however, have been an important part of structuring and documenting the project work.

12.1.1. Planning and structuring

The project had a time frame of twenty weeks, which were distributed between different activities in a Gantt chart at the very beginning of the project. The chart was not given too much detail as a more thorough planning was made each week concerning the activities to be performed in the coming days. The Gantt chart was then followed well and each activity was experienced to be given an appropriate length of time, except for one activity, which was the form development of the faucet. This activity, which was part of the concept refinement phase, took longer than expected due to difficulties in achieving the desired expression. Its design was given several changes late in the project and this mainly affected the time that had been intended for preparation of the final presentations. The changes that were made, however, were considered by the project team to be worth the extra time that it took as it greatly improved the overall expression of the concept.

Meetings were held with the supervisor at Electrolux as well as the supervisor at Chalmers on average once every two weeks, respectively. This frequency was considered by the project team to leave enough time to be able to discuss new aspects of the project work each time and it also helped the project team not to linger for too long on specific activities. Conclusions from the meetings were noted down in an online document shared by the project team to make sure that they would not be forgotten.

12.1.2. Data collection

Basic knowledge about dishwashers was gained rapidly thanks to the briefing that was given at the very first meeting at Electrolux in Stockholm. This made it possible to perform the user study at an early stage of the project, which meant that more time was given to the concept development phase later in the project. However, it may have caused interesting areas that was found later in the project to not get fully investigated in the user study. The literature study was,

however, spread out during a large span of the project and was able to complement as well as confirm the findings of the user study. One very interesting area of information that the literature study contributed with was measurements of water consumption as this would have been both a complicated and time consuming activity to perform in the time frame of this project.

Both the literature study and the user study went from a wide and explorative phase to deeper investigations of certain areas. The semi-structured character of the interviews was perceived to be suitable for the aim of the interviews. By asking questions not only concerning dishwashing but also about cooking and eating habits as well as the kitchen in general, the project team felt that they gained a holistic view over the needs and wants of the target group, related to dishwashing.

12.1.3. Analysis

The different methods used to analyse the collected data were all useful in different ways. Some of them mainly structured the data while some others contributed to making important conclusions. One method that the team in particular found to be both useful and effective was the fishbone diagram, that were used to structure up the reasons to water being wasted from the kitchen tap. This method brought up a discussion that greatly affected the continued work in the concept development phase. With its simple layout, it was easy for the team to go back to this diagram and review the documented reasons to the problem.

The personas that were created based on the user study findings and the target group were subconsciously kept in mind throughout the whole concept development phase. They were also used together with the Design Format Analysis and the study of the Electrolux brand in order to create the expression words in Figure 6.5. Those words were brought up frequently during the form development of the concept and found to act as a checklist and an evaluation tool of the design. The expression board that was created based on these words should have been given more time in order to truly achieve the desired expression. However, as the image search was very time consuming it was decided to not linger on this activity for too long.

12.1.4. Concept development

The idea generation started off very wide, which felt natural as the scope of the project itself was wide. Ideas were generated during many sessions by focusing on different problems as well as on different users and kitchens. These sessions were not very systematic or strict as the project team experienced that most of the ideas emerged through free discussions and sketching. The result might have turned out differently by using more structured methods such as morphological matrices.

Dimensions of existing kitchen modules were always kept in mind and the idea generation sessions were alternated with construction of simple physical models to make sure that the different ideas were realistic. To work on existing dimensions of kitchen modules may of course have limited the freedom of the idea generation but as the concept was decided to be feasible within five years, this was seen as necessary. Visits to Ikea were also very useful both for inspiration and for discussing the implementation of the different ideas in the kitchen context.

12.1.5. Evaluation

The concept was evaluated at several stages during and after its development focusing on different aspects. One way of evaluating the concept was through discussions during the meetings with supervisors, who contributed

with new perspectives as well as expertise in the area of dishwashers. It would, however, have been interesting to evaluate the concept by including potential users in the process, who might pay attention to other interesting aspects.

The Kesselring matrix that was used to evaluate different faucet configurations, helped to prioritise the different criteria and brought up a discussion about the negative and positive characteristics of each category. As some of the faucet configurations already existed on the market while others were only early concepts, the comparison between them was sometimes difficult. The discussion was therefore perceived to be of more value than the actual result of the matrix.

As the calculations concerning energy and water savings was based on some assumptions as well as approximations, the accuracy was of course not very high, but still considered to be high enough for the level of this project. Also, the calculations did not include the potential water savings from the faucet itself, which would need to be combined with testing.

12.2. Final result

12.2.1. Design and dimensions

The suggested concept for compact kitchens in this report is a 60 cm unit with two dishwasher drawers. This is, however, only one out of several possible options. Choosing the 60 cm unit rather than the 80 cm unit was partly because it was seen as a bigger challenge and that if a solution was found for this unit, a similar solution would be possible to implement in an 80 cm unit as well. As previously described, two dishwasher drawers implemented in an 80 cm unit would give the drawers a square bottom area, which would be more beneficial for the spray arm to be able to reach all the dishes and there would be a higher possibility of placing larger items in the machines. Another possibility would be to use only one dishwasher drawer in the 60 cm unit. This would reduce the amount of material and electronic components in the concept, thereby reducing the total cost. This would, however, be at the cost of losing flexibility. The different options discussed may be more or less suitable for different users, but all of them are relevant for the compact kitchen and could be an option for the larger kitchen as well.

The height has of course been the most limiting factor of the concept since the height of this unit needs to match the standard height found in other kitchen units. The sink depth as well as the depth of the recycling drawer had to be reduced in order to fit a dishwasher in between. How exactly to distribute the height between the different sections has been discussed with Electrolux and tested with mock-ups at several occasions of the project. However, as there are some uncertainties concerning the height needed for the technology at the bottom of the dishwasher drawers as well as for the piping connected to the sink outflow, the dimensions presented in this report should be seen as suggestions. The possibility of moving some of the technology to the space behind the drawers was also discussed, which would potentially give more height to the other sections. Regarding the sink, its dimensions have only been tested by placing different kitchenware inside a simple mock-up. It has not been tested together with a faucet to see how well it works with the existence of water.

12.2.2. The pre-rinsing system

The main concern of the pre-rinsing system may not be related to the dishes themselves but to how much soil the dishwasher drawers would be able to handle during the rinse phase, while still providing a good result over time. This is important to consider as regular maintenance is needed for today's

dishwashers in order to provide a good cleaning result and this is likely to be a limitation of the pre-rinsing system as well. In a dishwasher, the filtration system prevents larger particles from reaching sensitive components included in the circulation system. Still, the system of dishwashers today manage to handle relatively soiled process water. By pre-rinsing dishes with reused water, this means that even more soil will pass through the dishwasher filtration system, possibly resulting in an increased need for maintenance. It is therefore important that the dishwasher drawers have sufficient self-cleaning in order for the pre-rinsing system to be effective. Another key factor to avoid this problem is the evaluation of water quality in the semi-tank, which enables to exclude water or other substances that are not suited for pre-rinsing. This evaluation is done by using sensors in the semi-tank. A problem with using sensors in the semi-tank is the build-up of soil, which will affect the accuracy of the sensors negatively. The turbidity sensor, which determines the level of soil in the process water, is a widespread technology in dishwashers today. The question is how well different sensors will handle the environment in the semi-tank.

The semi-tank will have a relatively fine filtration placed in the sink unit to prevent larger particles from entering the semi-tank. This filtration should be sufficient in most cases. The main concern here are the extreme cases, for example, if the user would empty a bottle of cooking oil or other substances not suitable for pre-rinsing dishes or unhealthy substances. Different substances may not only damage the dishwasher drawers and affect the cleaning performance but can also be dangerous for the user if not removed at the end of the wash cycle. The semi-tank will need to prevent these types of substances from entering the dishwasher drawers due to the limitations of the filtration systems. Concerning the need for non-sudsing manual dishwashing detergent, investigating the market and chemistry of this type of detergent has not been prioritised in this project but is of course of great importance in order for the pre-rinsing system to be feasible. Additionally, non-sudsing detergent for manual dishwashing is something that would need to reach acceptance among customers.

From discussions with Electrolux it has been concluded that the pre-rinsing system will need to be tested in order to ensure the feasibility of the technique. It would also be interesting to do similar investigations related to the main wash as this can contribute to further savings of water and energy. As mentioned earlier the evaluation is only based on potential water and energy savings. Another interesting aspect is the potential time savings in the main wash phase. If warm water is reused for pre-rinsing, this will have a positive effect on the cleaning performance compared to just pre-washing with cold water. However, it was not possible in this project to estimate how much time that could actually be saved from the wash cycle.

12.2.3. Compliance with the target group

Uniwa provides flexibility and space efficiency for small households with dynamic lifestyles. For the persona Emma, who always wants the countertop to be clean before she starts cooking, Uniwa provides the possibility of always having one dishwasher drawer available for placing new dishes, even when the other section is running. The large baking trays and mixing bowls that she often uses for cooking and baking, are easier to wash in the spacious sink without creating a mess in the kitchen. For Isac and Daniel, who rarely do the dishes, Uniwa makes it possible to do the dishes more frequently with less effort. Anita

and Lars, who most often generate small amounts of dishes but sometimes use more kitchenware for more advanced cooking, get the possibility of washing variable amounts of dishes by running either one or both dishwasher drawers. Their special kitchenware that should not be washed in a normal dishwasher are more easily washed in the spacious sink. As users with compact kitchens have little room to store tableware, Uniwa is adapted to be run frequently and not occupy too large amounts of dishes at a time. This also prevents the generation of smell from the dishes, which was one of the reasons found in the user study for pre-rinsing the dishes.

Both the sink and the faucet differ from conventional products of this category on the market, and may require an open mind-set from customers to see the potential in terms of flexibility and water efficiency. Users who often wash their dishes under running water may be more easily convinced by this concept than users who normally fill the sink with water. Those users need to be convinced that Uniwa has the potential to save water also when washing dishes manually. The few items that cannot be handled by the dishwasher can be washed manually by using a low flow rate and a precise control of the faucet. Large items can be placed on the large flat sink bottom and filled up with water instead of filling the whole sink.

12.2.4. Uniwa in the context of a compact kitchen

As both the sink, faucet and the dishwasher drawers are included in the same unit, they share the same inlet and outlet of water. Therefore, the different parts do not need to be installed separately like in a conventional kitchen. What makes the installation slightly more difficult is the fact that Uniwa shares countertop with the rest of the kitchen. To install Uniwa, the main unit has to be positioned and connected to the external piping system. The dishwasher drawers may need to be removed temporarily in order to do the installation. To install the sink unit, a hole has to be made in the countertop to be able to insert the sink unit from above. It was considered by the project team to treat the concept as a complete unit, not sharing the countertop with neighbouring units, but the negative aspects of creating gaps on each side of the sink as well as a less unified expression was considered too significant. This option was therefore not further developed.

The decision to make all front panels exchangeable except for the upper panel including the interface was made with the purpose of creating a unified expression in the kitchen while at the same time giving the dishwasher more attention and a higher status in the kitchen. This is because it is often highly appreciated for its utility but not much for its status as was shown in Figure 5.10. Keeping the interface visible also gives better possibilities of providing feedback to the user.

12.2.5. Sustainability

Uniwa is sustainable in the sense of saving water and energy during its use phase. Its environmental impact during other phases of its life cycle have not been the focus of this project. However, since Uniwa is a compact solution that includes several units into one, it has the potential of saving material. On the other hand, the choice of including two dishwasher drawers instead of one will increase the number of components and electronics in the product, which of course contributes to a higher environmental impact. Though, this fact has to be compared with the increased amount of energy and water that is wasted if users run their dishwashers only half full. It is also possible that the two sections can contribute to the selection of a more energy saving wash program, as they give a higher tolerance to

longer durations with the possibility of alternating between using the two sections.

By reusing tap water, Uniwa gives a higher tolerance to water waste from the tap, but in order to work as energy and water efficiently as possible, Uniwa should prevent users from pre-rinsing their dishes manually. Users need to understand the concept of giving the dishes several rounds of pre-rinsing automatically in the machine, and that this eliminates the need to pre-rinse manually both considering the wash result and the reduction of smell from food residues on the dishes.

12.2.6. Price and value for the customer

A factor that has been discussed during the project is how the customer will perceive the value of Uniwa. Much of the customer value is expected to come from the compactness and the flexibility to support the user in the kitchen, since this was found to be of great importance in the user study. Since Uniwa includes more functionality compared to a standard dishwasher, it is likely to cost significantly more than the standard dishwasher. It is important that the customers perceive Uniwa as a high value product, not only when using the product but also when purchasing this type of product for the first time. Since Uniwa is a new type of product, there is a potential risk that the customer may compare the price of Uniwa with a standard dishwasher and not take the price of buying a faucet and sink unit into consideration. Another potential problem discussed is that even if the customer perceives Uniwa as a high value product, it may still be a large investment which the customer may not be willing to do. An alternative discussed to get around this problem is the possibility to involve housing companies as customers, who may be interested in doing more long term investments due to the water and energy savings Uniwa will offer.

Another aspect that might be interesting for housing companies is the installation process of Uniwa. In the interview with HSB it was learned that water leakages from dishwashers are not uncommon in rental apartments and that this in general was caused by incorrect installation work. As Uniwa combines all water management in the kitchen, this also gives Electrolux, as the manufacturer, more control over the installation between different components. If costly water leakages can be avoided it should indeed be perceived as beneficial by housing companies that will ensure a safe and reliable water use in the kitchen.

12.2.7. Consistency with the Electrolux brand

As described in section 10.5, Uniwa shares several design cues with existing products from Electrolux and in particular with the premium product segment, which gives it a visual consistency with the Electrolux brand. Moreover, Uniwa is very much focused on supporting the user and making life a little bit easier, which is also the main philosophy of Electrolux. Uniwa is innovative in the sense that it is developed from a holistic view over the whole water consumption in the kitchen and not just focusing on one single product individually. As Electrolux is a brand with an impressive heritage of innovative products, this too makes Uniwa a possible candidate to be included in the Electrolux portfolio. Additionally, Uniwa has the potential to further strengthen Electrolux as being a brand in the forefront of sustainability efforts.

13

Conclusion

The research of this project has shown that there is a lack of dishwashers on the market that are suited for compact living. It has also shown benefits of using a dishwasher from a sustainability perspective. The scope of the project was found to be highly relevant as the main reason found in the user study to not have a dishwasher was lack of space. The needs related to compact living found in the user study was mainly concerned with flexibility and a great value was put on the limited workspace and storage. From both the user study and the literature study it was found that the total water and energy consumption of the dishwashing process is greatly affected by the user behaviour of pre-rinsing dishes. To significantly reduce the environmental impact related to the dishwashing process, it could therefore be concluded that a more holistic view was needed, not only including the dishwasher itself but the total water consumption in the kitchen.

The project has resulted in the final concept Uniwa, which represents a new perspective of what a dishwasher is and what tasks it should handle. Rather than only treating dishes, Uniwa handles all washing and waste management in the kitchen. It suggests a system in which tap water can be reused to pre-rinse dishes in the dishwasher and where the risk of bacterial growth related to water storage is greatly reduced. Uniwa is also a highly relevant concept for compact living as it includes several functions into one single unit, while also considering important needs related to small households with limited living space.

In order for the concept to be realised as a commercial product, a lot of work still remains, especially concerning the pre-rinsing system that needs further investigation. Hopefully this concept has inspired Electrolux to view the dishwasher from a new perspective and to take the next step towards providing a more sustainable dishwashing process for people in the future.

14

Recommendations for Further Work

As the project has undertaken a holistic view to cover many aspects, there has been a trade-off between level of detail and distribution of the project work between the different areas. This chapter therefore presents recommendations of the most important factors to consider for further development of the concept.

- The pre-rinsing system needs further investigation and testing. The further development should aim at ensuring that the system is able to determine the quality of the water with sufficient accuracy. Which kinds of sensors to include for this purpose remains to be solved. Another issue that needs further investigation is how the semi-tank should be designed in detail, concerning dimensions as well as interaction between components.
- The wall thickness of the dishwasher drawers that would be needed in order to insulate heat and keep the noise level low enough needs to be considered.
- How to integrate the technology in the dishwasher drawers (including pumps, heater, filter etc.) to make it as compact as possible needs further development as height is a limiting factor of the concept. It has been discussed by the project team that some of the components may be possible to move into a position behind the dishwasher drawers.
- Further development is also needed concerning how to integrate the technology in the faucet to support its functionality.
- Regarding the interplay between the different components of Uniwa, a possibility discussed is how communication between the faucet and the semi-tank may support the use of sensors in determining the quality of the water. The faucet could send a signal to the semi-tank each time it is used, giving information about the temperature and volume of incoming water. This would help the semi-tank to determine whether the incoming substance comes from the faucet or from another source. The semi-tank could send information to the dishwasher drawers about the water available and in return, receive information about the current need of water for pre-rinsing.
- To improve the functionality of the system over time, it is advised that Electrolux collects information about the usage of the product. This information can then be analysed and used to update the system for a better adaptation of the wash cycle as well as an improved user experience.

- All materials to be included in the product need to be considered carefully in order to select materials with the lowest possible environmental impact that have the right properties and a reasonable price level. All parts should be designed for disassembly to enable recycling and reduce the environmental impact at the end of the product's lifecycle.
- The interior of the dishwasher drawers need to be designed in a way that provides flexibility of placing a variety of items while providing as large capacity as possible for the standard tableware. It was found in the user study that the ability to customise the interior was highly appreciated and it would be interesting to consider if the interior could be selected separately when purchasing Uniwa.
- The interface of Uniwa has not yet been fully developed and only some levels of the display have been designed. The way that it is suggested to be designed in this concept focuses on making it easier for the user to select the least water and energy consuming program and encouraging the user to select this program by providing information about its water and energy use. There may be other ways in which the user can be influenced to make the best choices from an environmental perspective. One idea discussed by the project team is to provide information about energy and water use of the dishwasher over time, to give the user a wider perspective over the consumption. Information about the need to perform maintenance and cleaning of the machine could also be included in the interface, as well as recommendations not to pre-rinse the dishes. Some of this information may be better suited to include in an app, which could complement the interface of the physical product. It could also give better possibilities of informing the user how to handle the dishwasher drawers as well as the rest of the unit in the most sustainable way possible. How clearly the information of the interface is presented and how easy it is to understand would need to be evaluated by performing usability tests with users.
- Another part of Uniwa that would need to be evaluated by usability tests is the faucet. It is needed to make sure that the symbols denoting the temperature and pressure controls are clear enough and that it is easy to understand how to make the different adjustments. It is also important to make sure that the faucet can be easily moved and positioned for the different tasks normally performed in the sink unit.
- The sink needs to be evaluated by testing its ability to prevent splashes and how much slope that would be needed to provide a good run-off and outflow of water.
- The form expression of Uniwa should be evaluated by including users. This could be done with the help of semantic word scales, including the expression words in Figure 6.5, to see how well it embodies the desired expression. It should also be evaluated in relation to other Electrolux products. Further work with the form development of Uniwa is needed at a more detailed level.

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Image References

*Images created by and belonging to the project team
**Images belonging to Electrolux

Chapter 1

Figure 1.1 - The Electrolux logo**

Chapter 2

Figure 2.1 - Sinner's circle*
Figure 2.2 - Technical principle of the dishwasher*
Figure 2.3 - Energy label (European Commission, 2016)
Figure 2.4 - Design strategies for sustainable behaviour (Lidman and Renström, 2011)

Chapter 4

Table 4.1 - Benchmarking of dishwasher configurations

	 Standard dishwasher	 Narrow dishwasher	 Compact/ benchtop dishwasher	 Drawer dishwasher (single drawer)	 Sink dishwasher	 Portable dishwasher
Width (cm)	60	45	55	60/90	-	45 - 60
Height (cm)	80 - 90	80 - 90	44 - 45	41/48	-	92 - 98
Capacity (place settings)	12 - 15	9	6	6/9	5	9 - 12
Price range (SEK)	2500 - 25000	2500 - 15000	1500 - 5500	8000 - 9500	-	-
Available on Swedish market	Yes	Yes	Yes	Yes	No	No

1. **
2. **
3. **
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Figure 4.1 - Function analysis of the dishwasher*
Figure 4.2 - Identified design cues* exemplified in the Electrolux Ultraone vacuum cleaner**

Chapter 5

All images*

Chapter 6

Figure 6.1 - User behaviour affecting the environmental impact of the dishwasher

1. *
2. *
3. *
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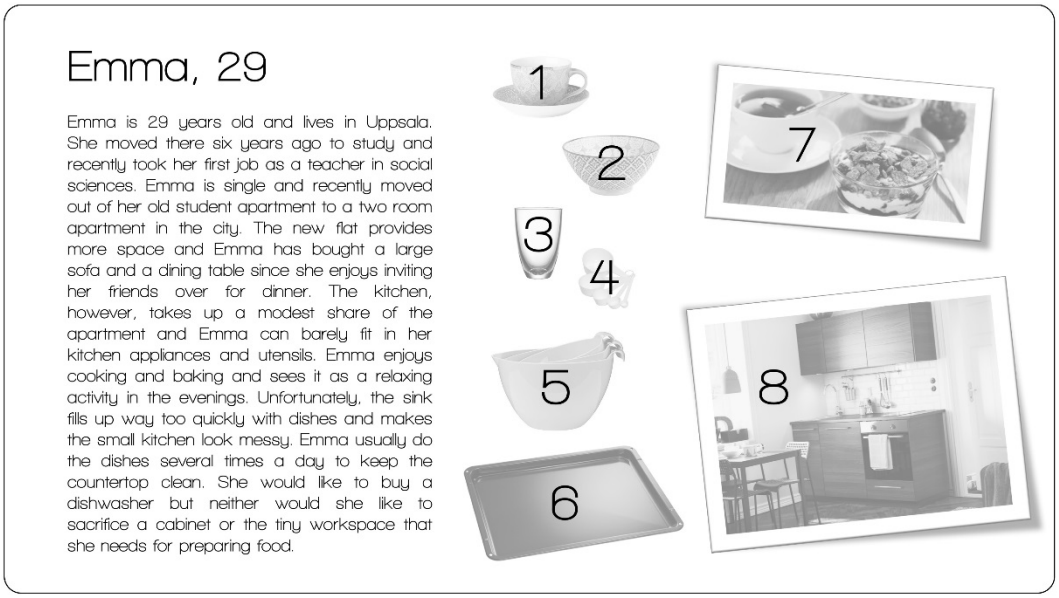
Figure 6.2 - The persona Emma



1. *Indiska*. https://indiska.com/se//BEAUTY-CUP%26SAUCER/p/1000004014439 (Accessed 26 June 2016)
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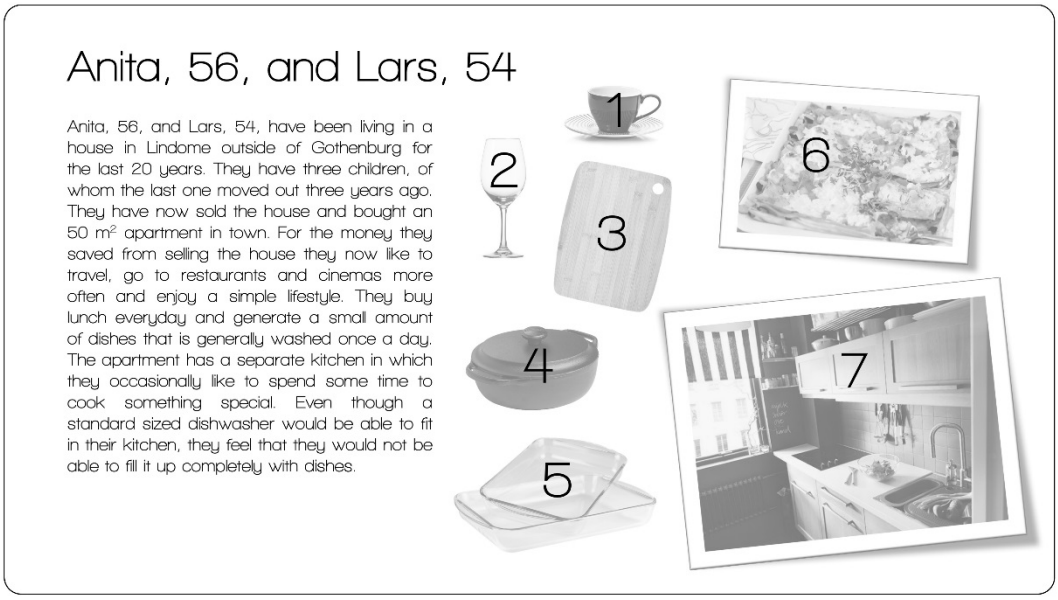
Figure 6.3 - The personas Anita and Lars



1. *Mio*. https://www.mio.se/produkt/zebra/25954742 (Accessed 10 May 2016)
2. *Dryckesglas*. http://www.dryckesglas.se/Vinglas-Festival-Chianti-6-st-40-cl-Spiegelau (Accessed 26 June 2016)
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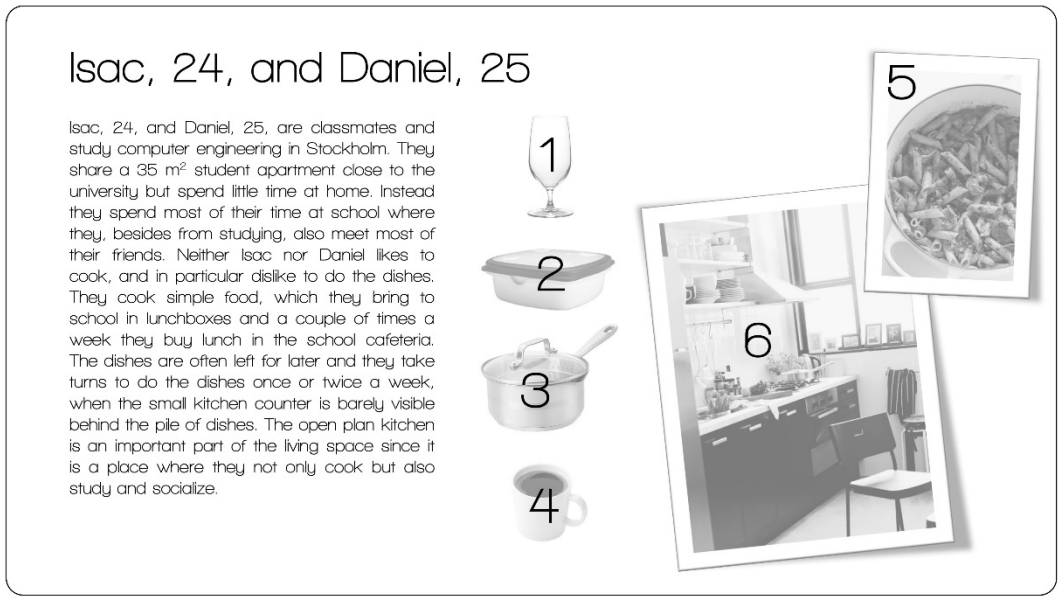
Figure 6.4 - The personas Isac and Daniel



1. *Pubshop*. http://www.pubshop.co.uk/catalog/reserva-beer-glass-38cl-p-63115.html (Accessed 26 June 2016)
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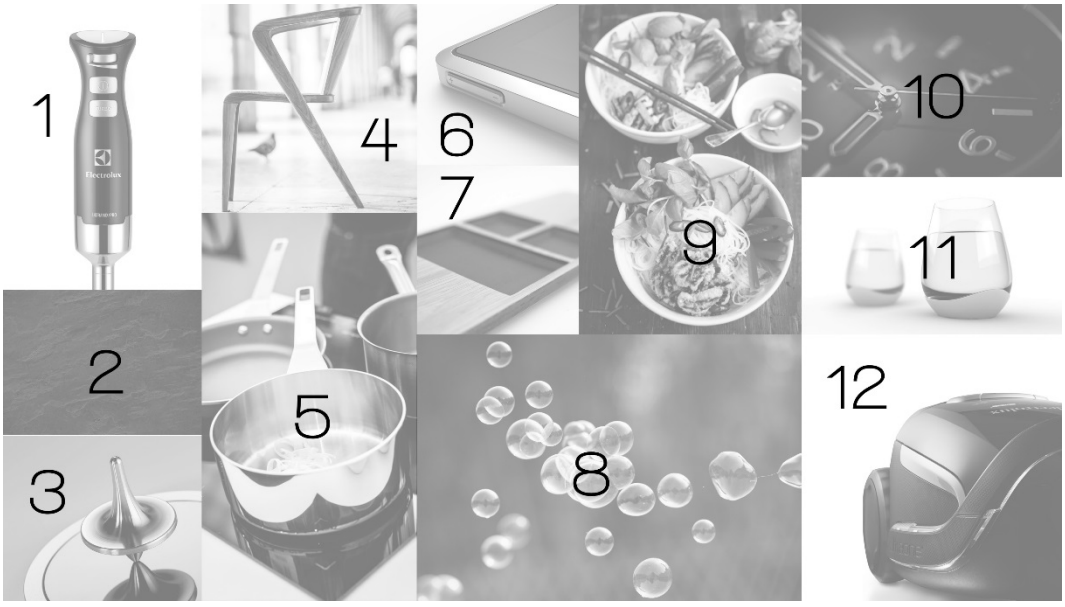
6. *Ikea*. http://livethemma.ikea.se/litet-men-naggande-gott/ (Accessed 10 May 2016)

Figure 6.5 - Expression words*
Figure 6.6 - Expression board



1. **

2. *Paulcharbonnet*. http://paulcharbonnet.com/textures/stone/index.php (Accessed 10 April 2016)
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11. *Looks Like Good Design*. http://lookslikegooddesign.com/one-cup-utopik/ (Accessed 20 April 2016)
12. **

Chapter 7

All images *

Chapter 8

All images*

Chapter 10

All images*

Appendix

Appendix I: Gantt chart

Appendix II: Design Format Analysis

Appendix III: Survey

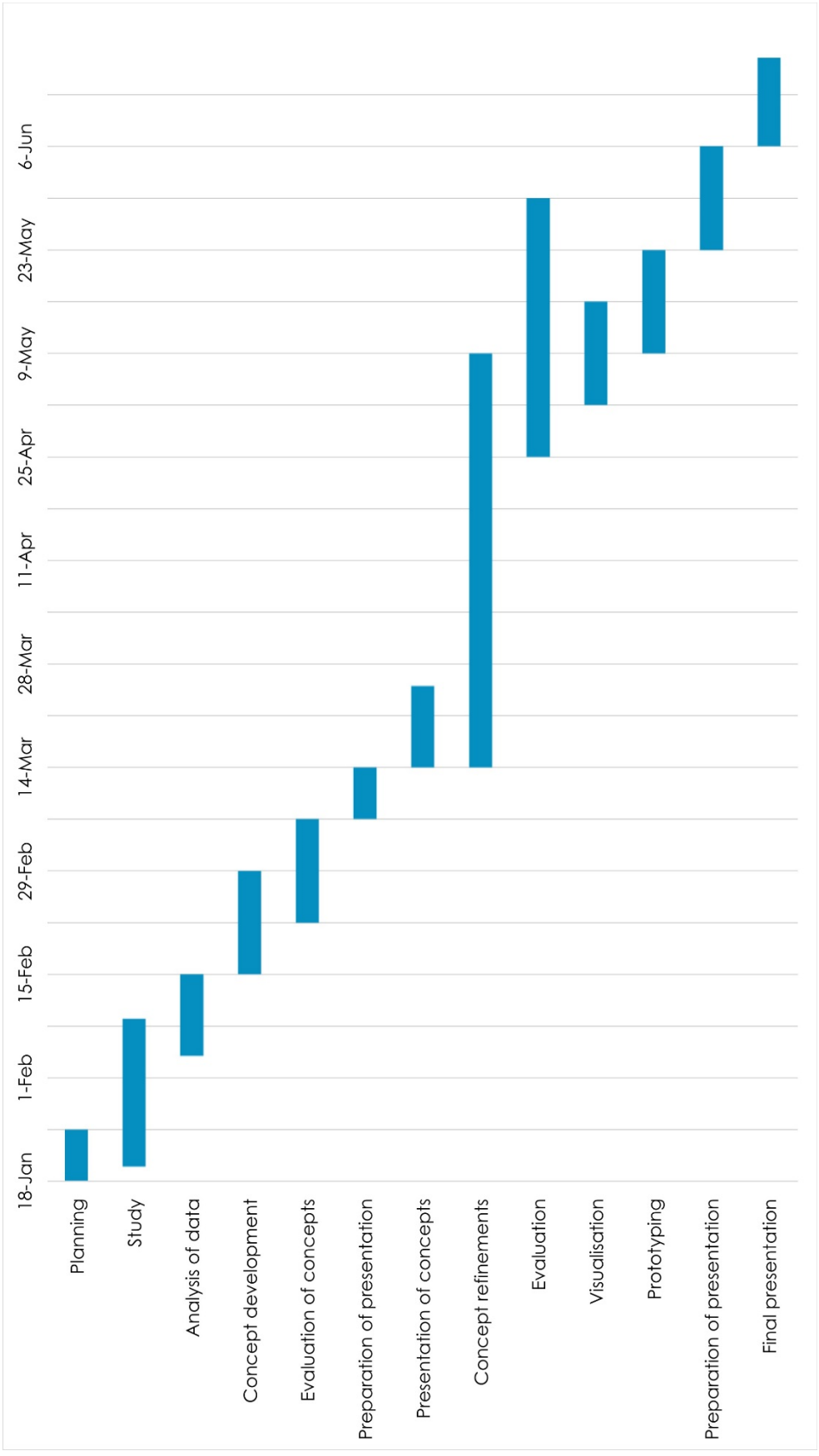
Appendix IV: Survey results (quantitative data)

Appendix V: Interview template

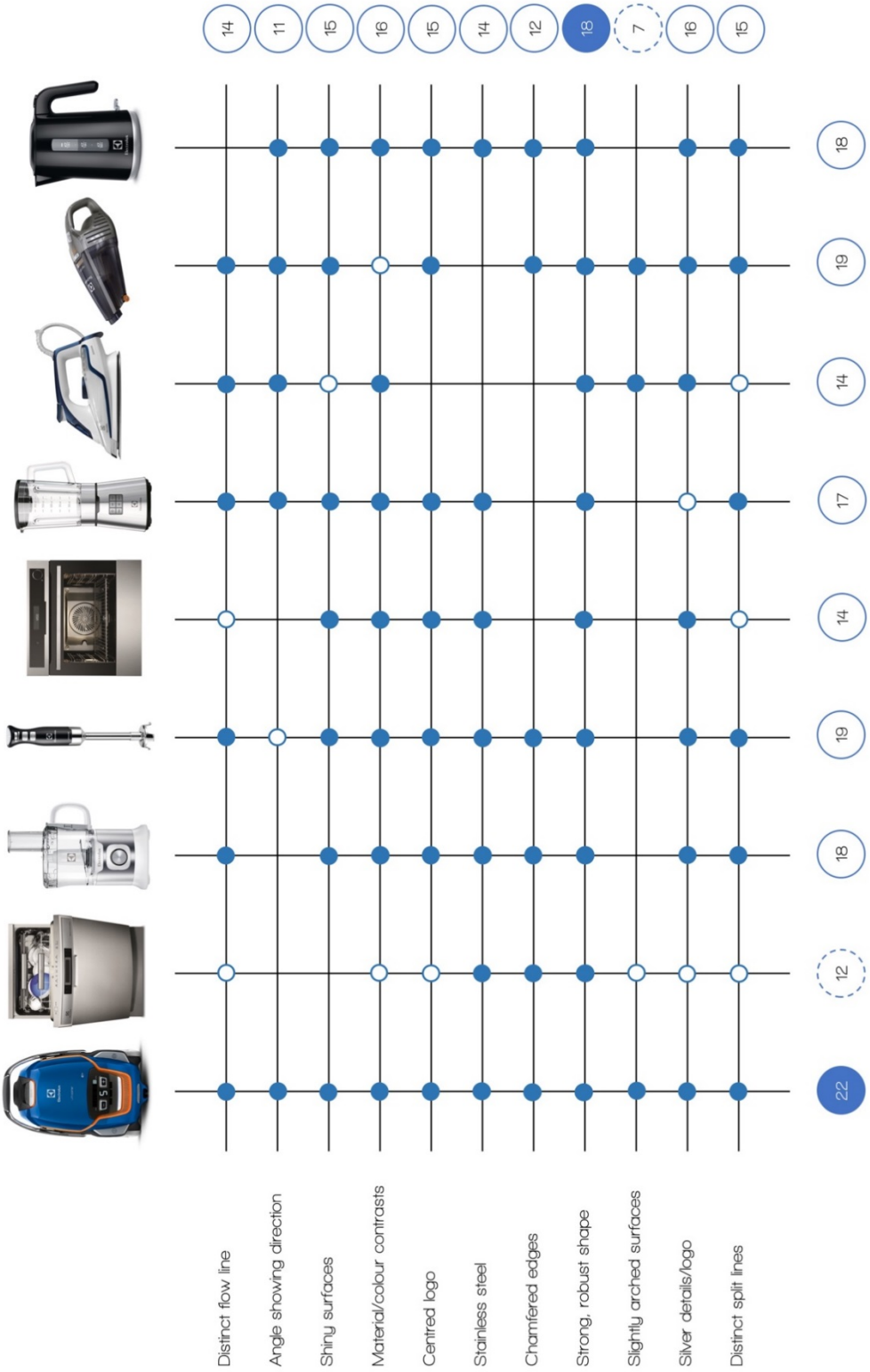
Appendix VI: Fishbone/Ishikawa diagram

Appendix VII: Kesselring matrix

Appendix I: Gantt chart



Appendix II: Design Format Analysis



Appendix III: Survey

Dishwashing

Thank you for participating in this survey and helping us with our master's thesis project about dishwashers! The survey will only take about 5 minutes to answer.

*Required

Age *

- 0-17
- 18-24
- 25-29
- 30-39
- 40-49
- 50-60
- > 60

In which type of housing do you currently live? *

- House
- Apartment
- Student apartment
- Other:

How big is your living space in square meters? *

- < 20
- 20-29
- 30-39
- 40-49
- 50-69
- 70-100
- > 100

How many people are there currently in your household? *

- 1
- 2
- 3
- 4
- > 4

Kitchen and cooking

What type of kitchen do you have? *

- ○ Separate kitchen
- ○ Open plan kitchen
- ○ Kitchenette (pentry)
- ○ Other: _____

Do you feel that the kitchen is big enough for your needs? *

- ○ No, it is way too small
- ○ No, it could have been a little bigger
- ○ Yes, it is adequate
- ○ It is too big

Is there anything you would like to change in the kitchen? What?

Your answer

Which of the following items do you use frequently? (Select several) *

- ☐ Cutting board
- ☐ Knife
- ☐ Non-stick frying pan
- ☐ Cast iron pan/pot
- ☐ Pot/saucepan
- ☐ Ovenware
- ☐ Mixing bowl
- ☐ Wine glass
- ☐ Porcelain/fine china
- ☐ Pitcher/carafe
- ☐ Measuring cup
- ☐ Strainer
- ☐ Grater
- ☐ Wooden utensils
- ☐ Plastic utensils
- ☐ Aluminium utensils
- ☐ Rolling pin
- ☐ Other: _____

During a normal week (excluding weekend):

How many times do you buy lunch instead of preparing it yourself? *

- ○ 0
- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5

How many times do you buy dinner instead of preparing it yourself? *

- ○ 0
- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5

Dishwashing

What do you think is most environmentally friendly? *

- ○ Washing the dishes by hand
- ○ Using a dishwasher
- ○ Both alternatives are equally environmentally friendly

To what extent do you think that dishwashing contributes to a household's total environmental impact? *

	1	2	3	4	5	
Small contribution	○	○	○	○	○	Large contribution

Which option do you think provides the most effective cleaning of the dishes? *

- ○ Washing the dishes by hand
- ○ Using a dishwasher
- ○ Both alternatives are equally effective in cleaning the dishes

Does your kitchen have a dishwasher? *

- ○ Yes
- ○ No

Owns a dishwasher

What type of dishwasher do you have? *

- ○ Standard (60 cm)
- ○ Narrow (45 cm)
- ○ Benchtop dishwasher
- ○ Other: _____

How old is your dishwasher? *

- ○ < 1 year
- ○ 1-3 years
- ○ 4-6 years
- ○ 7-10 years
- ○ > 10 years

How often do you run your dishwasher? *

- ○ Several times a day
- ○ Once a day
- ○ Every other day
- ○ Every third day
- ○ 1-2 times a week
- ○ More seldom

When you run your dishwasher... *

- ○ ...it is usually full
- ○ ...there is usually room for more dishes

What items tend to be problematic to place in the dishwasher? Why?

Your answer

Are there any items that you choose to wash by hand? What? Why?

Your answer

How often do you wash dishes by hand? *

- ○ Several times a day
- ○ Once a day
- ○ Every other day
- ○ Every third day
- ○ 1-2 times a week
- ○ More seldom
- ○ Never

After using your dishwasher, do you perceive that the dishes are clean? *

- ○ Yes, always
- ○ Yes, most of the times
- ○ No, most of the times there is some dirt/spots left on the dishes

Do you usually rinse the dishes before placing them in the dishwasher? *

- ○ Yes, with hot water
- ○ Yes, with cold water
- ○ No

Which of the following dishwasher programmes do you use frequently? *

- ☐ Main/normal
- ☐ Eco
- ☐ Intensive
- ☐ Delicate/glass
- ☐ Auto/sensor
- ☐ Quick wash
- ☐ Half-load program
- ☐ Rinse and hold
- ☐ Other: _____

Are the dishes usually dry when the washing cycle is finished?

- ○ Yes
- ○ No

What do you like best with your dishwasher?

Your answer

What could be improved?

Your answer

Does not own a dishwasher

What is the main reason for you to not have a dishwasher? *

- ○ Lack of space
- ○ It is too expensive
- ○ It is better to wash dishes by hand
- ○ Other:

Would you like to have a dishwasher? *

- ○ Yes
- ○ No

How often do you do the dishes? *

- ○ Several times a day
- ○ Once a day
- ○ Every other day
- ○ Every third day
- ○ 1-2 times a week
- ○ More seldom

How do you proceed? *

- ○ Wash in the sink and rinse in a tub
- ○ Wash in the sink and rinse under running water
- ○ Both wash and rinse under running water
- ○ Other:

Which of the following statements applies best to you? *

- ○ I wait until there are more dishes than the sink can hold
- ○ I do the dishes as soon as the sink is full
- ○ I do the dishes before the sink is full

How do you dry your dishes after washing them by hand? *

- In a dish rack
- Wiping with a towel
- Using a dish rack and wiping some of the dishes with a towel

Do you perceive that the dishes get clean when washing them by hand? *

- Yes, always
- Yes, most of the times
- No, most of the times there is some dirt/spots left on the dishes

How hot dishwater do you use? *

	1	2	3	4	5	
Cold						Hot

Approximately how long do you have to keep the tap open before the water reaches your desired dishwashing temperature? *

- < 5 sec
- < 15 sec
- < 30 sec
- < 1 min
- > 1 min
- The water does not reach the desired temperature

How long does it normally take to do the dishes? *

- < 10 min
- 10-20 min
- 21-40 min
- 41-60 min
- > 1 hour

What is the most difficult item to wash? Why?

Your answer

Are there any of your kitchen appliances that you would be willing to sacrifice for a dishwasher? What?

Your answer

Which kitchen space would you be willing to sacrifice to make room for a dishwasher? *

- Cabinet/cupboard
- Drawer
- Worktop
- Sink
- Dining area
- None
- Other: _____

Dishwasher purchase

If you would buy a new dishwasher, how important would the following aspects be to you? *

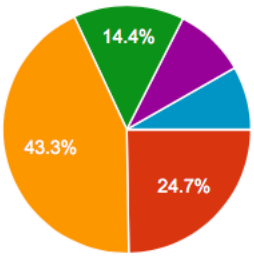
	1 Not important	2	3	4	5 Very important
Aesthetics and design	○	○	○	○	○
Energy efficiency	○	○	○	○	○
Brand	○	○	○	○	○
Price	○	○	○	○	○
Capacity	○	○	○	○	○
Noise level	○	○	○	○	○
Time	○	○	○	○	○
Extra features	○	○	○	○	○
Interior layout	○	○	○	○	○

How many years do you expect a new dishwasher to last? *

- < 5
- 5-10
- 11-15
- 16-20
- > 20

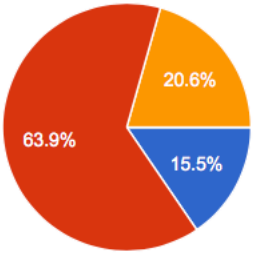
Appendix IV: Survey result (quantitative data)

Age



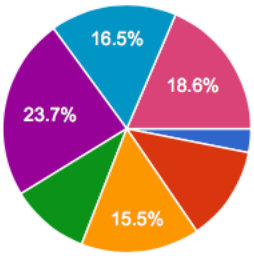
0-17	**0**	0%
18-24	**24**	24.7%
25-29	**42**	43.3%
30-39	**14**	14.4%
40-49	**9**	9.3%
50-60	**8**	8.2%
> 60	**0**	0%

In which type of housing do you currently live?



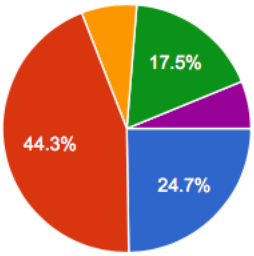
House	**15**	15.5%
Apartment	**62**	63.9%
Student apartment	**20**	20.6%
Other	**0**	0%

How big is your living space in square meters?



< 20	**3**	3.1%
20-29	**12**	12.4%
30-39	**15**	15.5%
40-49	**10**	10.3%
50-69	**23**	23.7%
70-100	**16**	16.5%
> 100	**18**	18.6%

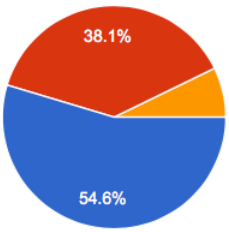
How many people are there currently in your household?



1	**24**	24.7%
2	**43**	44.3%
3	**7**	7.2%
4	**17**	17.5%
> 4	**6**	6.2%

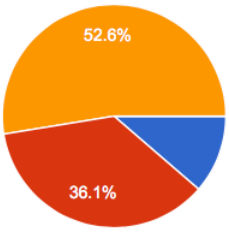
Kitchen and cooking

What type of kitchen do you have?



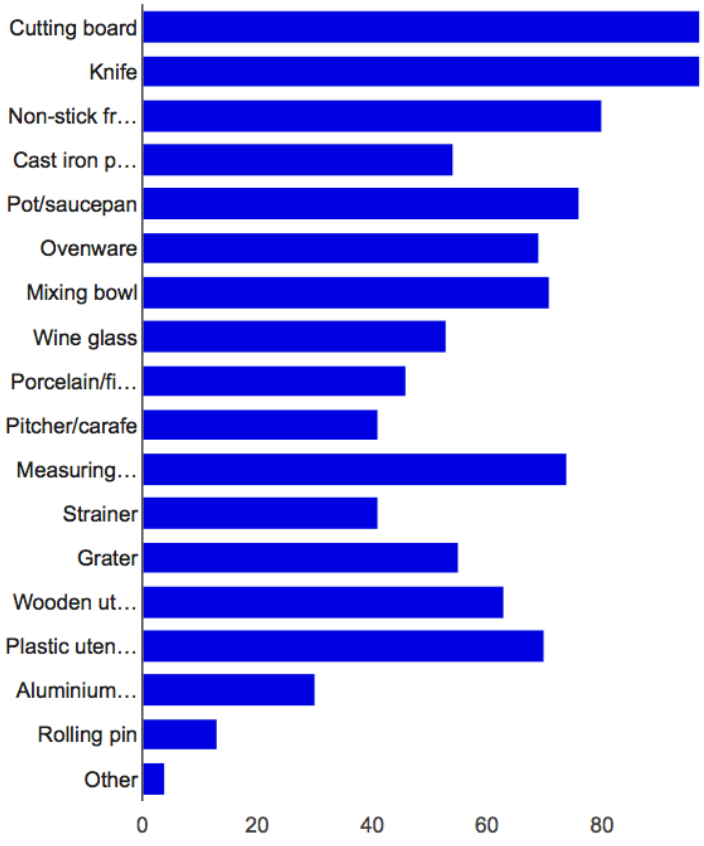
Separate kitchen	**53**	54.6%
Open plan kitchen	**37**	38.1%
Kitchenette (pentry)	**7**	7.2%
Other	**0**	0%

Do you feel that the kitchen is big enough for your needs?



No, it is way too small	**11**	11.3%
No, it could have been a little bigger	**35**	36.1%
Yes, it is adequate	**51**	52.6%
It is too big	**0**	0%

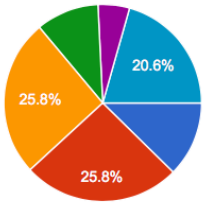
Which of the following items do you use frequently? (Select several)



Cutting board	**97**	100%
Knife	**97**	100%
Non-stick frying pan	**80**	82.5%
Cast iron pan/pot	**54**	55.7%
Pot/saucepan	**76**	78.4%
Ovenware	**69**	71.1%
Mixing bowl	**71**	73.2%
Wine glass	**53**	54.6%
Porcelain/fine china	**46**	47.4%
Pitcher/carafe	**41**	42.3%
Measuring cup	**74**	76.3%
Strainer	**41**	42.3%
Grater	**55**	56.7%
Wooden utensils	**63**	64.9%
Plastic utensils	**70**	72.2%
Aluminium utensils	**30**	30.9%
Rolling pin	**13**	13.4%
Other	**4**	4.1%

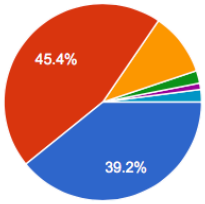
During a normal week (excluding weekend):

How many times do you buy lunch instead of preparing it yourself?



0	**12**	12.4%
1	**25**	25.8%
2	**25**	25.8%
3	**10**	10.3%
4	**5**	5.2%
5	**20**	20.6%

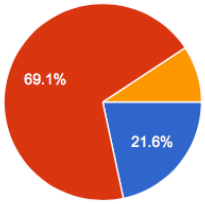
How many times do you buy dinner instead of preparing it yourself?



0	**38**	39.2%
1	**44**	45.4%
2	**10**	10.3%
3	**2**	2.1%
4	**1**	1%
5	**2**	2.1%

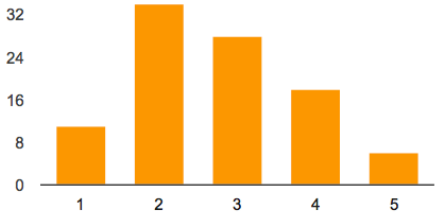
Dishwashing

What do you think is most environmentally friendly?



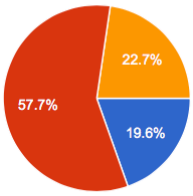
Washing the dishes by hand	**21**	21.6%
Using a dishwasher	**67**	69.1%
Both alternatives are equally environmentally friendly	**9**	9.3%

To what extent do you think that dishwashing contributes to a household's total environmental impact?



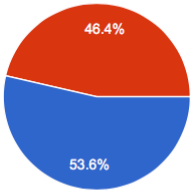
Small contribution: 1	**11**	11.3%
2	**34**	35.1%
3	**28**	28.9%
4	**18**	18.6%
Large contribution: 5	**6**	6.2%

Which option do you think provides the most effective cleaning of the dishes?



Washing the dishes by hand	**19**	19.6%
Using a dishwasher	**56**	57.7%
Both alternatives are equally effective in cleaning the dishes	**22**	22.7%

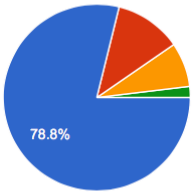
Does your kitchen have a dishwasher?



Yes	**52**	53.6%
No	**45**	46.4%

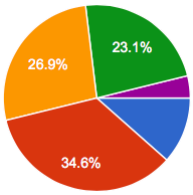
Owns a dishwasher

What type of dishwasher do you have?



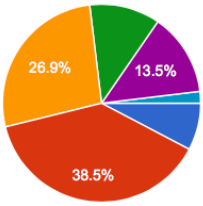
Standard (60 cm)	**41**	78.8%
Narrow (45 cm)	**6**	11.5%
Benchtop dishwasher	**4**	7.7%
Other	**1**	1.9%

How old is your dishwasher?



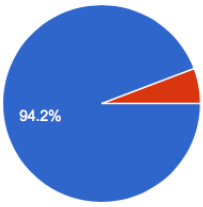
< 1 year	**6**	11.5%
1-3 years	**18**	34.6%
4-6 years	**14**	26.9%
7-10 years	**12**	23.1%
> 10 years	**2**	3.8%

How often do you run your dishwasher?



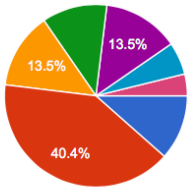
Several times a day	**4**	7.7%
Once a day	**20**	38.5%
Every other day	**14**	26.9%
Every third day	**6**	11.5%
1-2 times a week	**7**	13.5%
More seldom	**1**	1.9%

When you run your dishwasher...



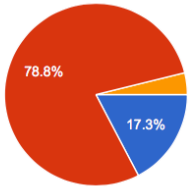
...it is usually full	**49**	94.2%
...there is usually room for more dishes	**3**	5.8%

How often do you wash dishes by hand?



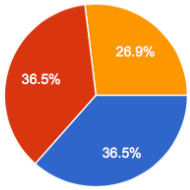
Several times a day	6	11.5%
Once a day	21	40.4%
Every other day	7	13.5%
Every third day	6	11.5%
1-2 times a week	7	13.5%
More seldom	3	5.8%
Never	2	3.8%

After using your dishwasher, do you perceive that the dishes are clean?



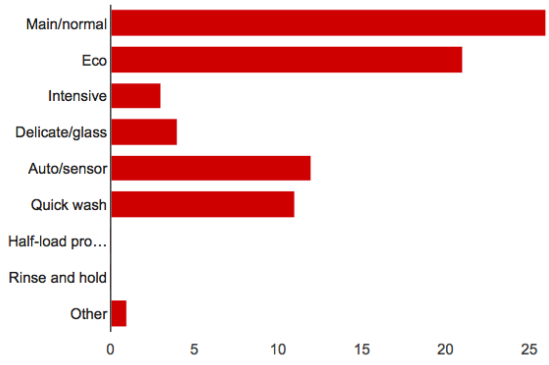
Yes, always	9	17.3%
Yes, most of the times	41	78.8%
No, most of the times there is some dirt/spots left on the dishes	2	3.8%

Do you usually rinse the dishes before placing them in the dishwasher?



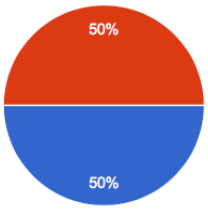
Yes, with hot water	19	36.5%
Yes, with cold water	19	36.5%
No	14	26.9%

Which of the following dishwasher programmes do you use frequently?



Main/normal	26	50%
Eco	21	40.4%
Intensive	3	5.8%
Delicate/glass	4	7.7%
Auto/sensor	12	23.1%
Quick wash	11	21.2%
Half-load program	0	0%
Rinse and hold	0	0%
Other	1	1.9%

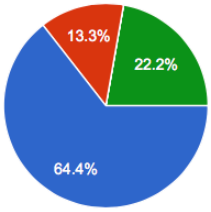
Are the dishes usually dry when the washing cycle is finished?



Yes	26	50%
No	26	50%

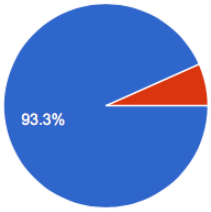
Does not own a dishwasher

What is the main reason for you to not have a dishwasher?



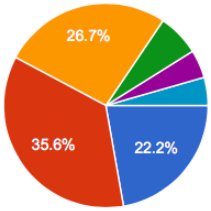
Lack of space	**29**	64.4%
It is too expensive	**6**	13.3%
It is better to wash dishes by hand	**0**	0%
Other	**10**	22.2%

Would you like to have a dishwasher?



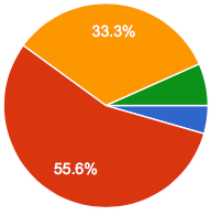
Yes	**42**	93.3%
No	**3**	6.7%

How often do you do the dishes?



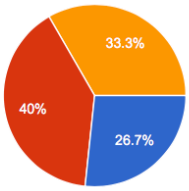
Several times a day	**10**	22.2%
Once a day	**16**	35.6%
Every other day	**12**	26.7%
Every third day	**3**	6.7%
1-2 times a week	**2**	4.4%
More seldom	**2**	4.4%

How do you proceed?



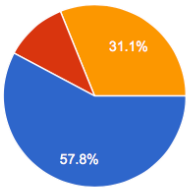
Wash in the sink and rinse in a tub	**2**	4.4%
Wash in the sink and rinse under running water	**25**	55.6%
Both wash and rinse under running water	**15**	33.3%
Other	**3**	6.7%

Which of the following statements applies best to you?



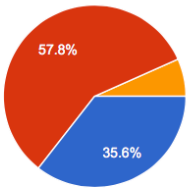
I wait until there are more dishes than the sink can hold	**12**	26.7%
I do the dishes as soon as the sink is full	**18**	40%
I do the dishes before the sink is full	**15**	33.3%

How do you dry your dishes after washing them by hand?



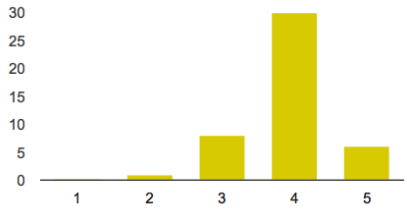
In a dish rack	**26**	57.8%
Wiping with a towel	**5**	11.1%
Using a dish rack and wiping some of the dishes with a towel	**14**	31.1%

Do you perceive that the dishes get clean when washing them by hand?



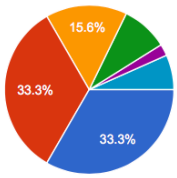
Yes, always	**16**	35.6%
Yes, most of the times	**26**	57.8%
No, most of the times there is some dirt/spots left on the dishes	**3**	6.7%

How hot dishwater do you use?



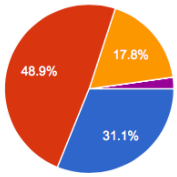
Cold: 1	**0**	0%
2	**1**	2.2%
3	**8**	17.8%
4	**30**	66.7%
Hot: 5	**6**	13.3%

Approximately how long do you have to keep the tap open before the water reaches your desired dishwashing temperature?



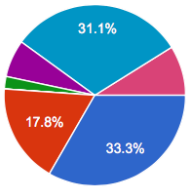
< 5 sec	**15**	33.3%
< 15 sec	**15**	33.3%
< 30 sec	**7**	15.6%
< 1 min	**4**	8.9%
> 1 min	**1**	2.2%
The water does not reach the desired temperature	**3**	6.7%

How long does it normally take to do the dishes?



< 10 min	**14**	31.1%
10-20 min	**22**	48.9%
21-40 min	**8**	17.8%
41-60 min	**0**	0%
> 1 hour	**1**	2.2%

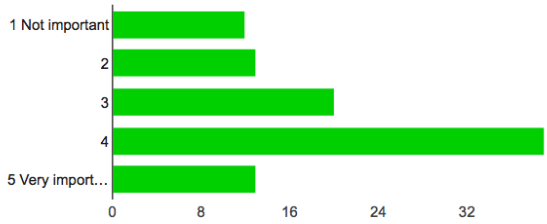
Which kitchen space would you be willing to sacrifice to make room for a dishwasher?



Cabinet/cupboard	**15**	33.3%
Drawer	**8**	17.8%
Worktop	**0**	0%
Sink	**1**	2.2%
Dining area	**3**	6.7%
None	**14**	31.1%
Other	**4**	8.9%

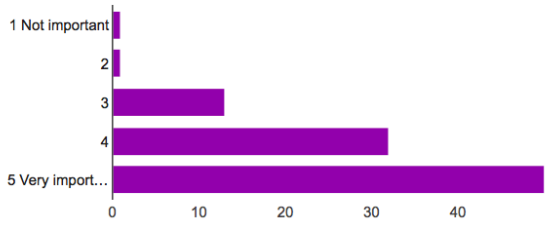
Dishwasher purchase

Aesthetics and design [If you would buy a new dishwasher, how important would the following aspects be to you?]



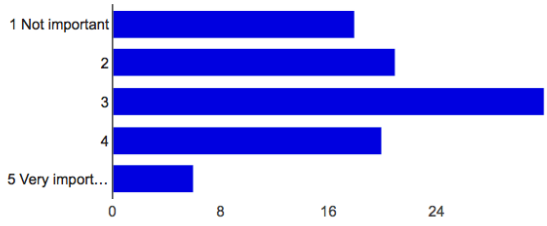
1 Not important	**12**	12.4%
2	**13**	13.4%
3	**20**	20.6%
4	**39**	40.2%
5 Very important	**13**	13.4%

Energy efficiency [If you would buy a new dishwasher, how important would the following aspects be to you?]



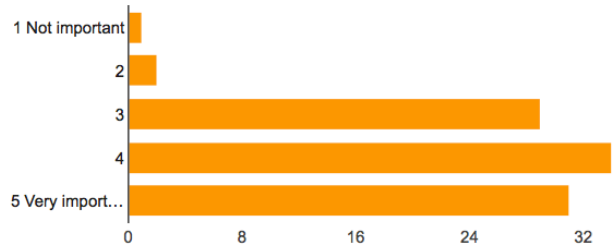
1 Not important	**1**	1%
2	**1**	1%
3	**13**	13.4%
4	**32**	33%
5 Very important	**50**	51.5%

Brand [If you would buy a new dishwasher, how important would the following aspects be to you?]



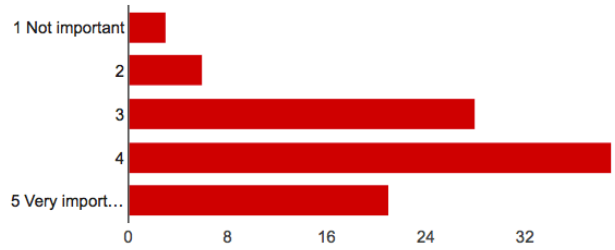
1 Not important	**18**	18.6%
2	**21**	21.6%
3	**32**	33%
4	**20**	20.6%
5 Very important	**6**	6.2%

Price [If you would buy a new dishwasher, how important would the following aspects be to you?]



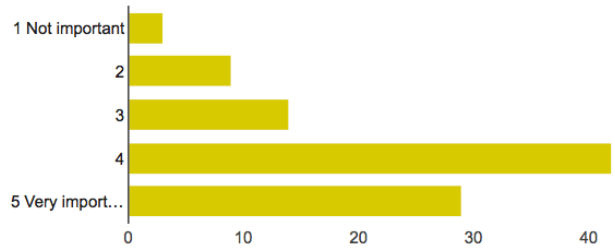
1 Not important	**1**	1%
2	**2**	2.1%
3	**29**	29.9%
4	**34**	35.1%
5 Very important	**31**	32%

Capacity [If you would buy a new dishwasher, how important would the following aspects be to you?]



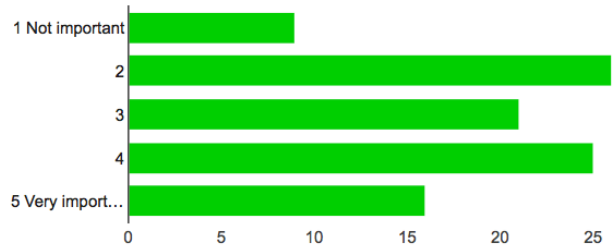
1 Not important	**3**	3.1%
2	**6**	6.2%
3	**28**	28.9%
4	**39**	40.2%
5 Very important	**21**	21.6%

Noise level [If you would buy a new dishwasher, how important would the following aspects be to you?]



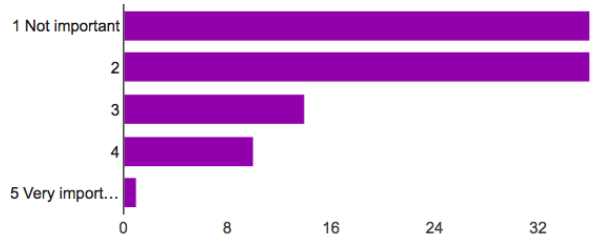
1 Not important	**3**	3.1%
2	**9**	9.3%
3	**14**	14.4%
4	**42**	43.3%
5 Very important	**29**	29.9%

Time [If you would buy a new dishwasher, how important would the following aspects be to you?]



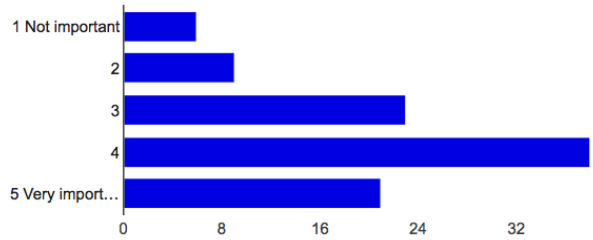
1 Not important	**9**	9.3%
2	**26**	26.8%
3	**21**	21.6%
4	**25**	25.8%
5 Very important	**16**	16.5%

Extra features [If you would buy a new dishwasher, how important would the following aspects be to you?]



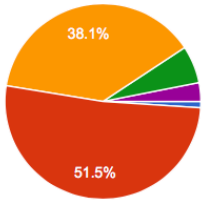
1 Not important	**36**	37.1%
2	**36**	37.1%
3	**14**	14.4%
4	**10**	10.3%
5 Very important	**1**	1%

Interior layout [If you would buy a new dishwasher, how important would the following aspects be to you?]



1 Not important	**6**	6.2%
2	**9**	9.3%
3	**23**	23.7%
4	**38**	39.2%
5 Very important	**21**	21.6%

How many years do you expect a new dishwasher to last?



< 5	**1**	1%
5-10	**50**	51.5%
11-15	**37**	38.1%
16-20	**6**	6.2%
> 20	**3**	3.1%

Appendix V: Interview template

Ålder: Kön: Sysselsättning:

Antal personer i hushållet: Antal kvadratmeter:

Köket

Hur stort är köket uppskattningsvis?

Hur ser layouten ut?

Har du en diskmaskin?

- Om ja, vad för typ?
- Standard, smal, bänk?

Matlagning och diskning

Tycker du om att laga mat?

Hur ofta lagar du mat?

Vilken tid på dagen brukar du laga mat?

Brukar det bli rester?

- Om ja, vad gör du med resterna? Hur förvarar du dem?

Hur varierar matlagningen mellan veckodagar och helger?

Vad är roligast med att laga mat?

Vad är tråkigast?

När du lagar mat, brukar du diska undan/placera disken i diskmaskinen allt eftersom eller väntar du med det tills du är klar med matlagningen?

Hur ofta brukar du diska?

Vilken tid på dygnet brukar du diska?

Brukar det bli samma typ av disk när du lagar mat eller varierar det mycket mellan gångerna?

- Vilka redskap brukar du använda?

Har diskmaskin

Har du något särskilt system för hur du placerar disken i maskinen?

Tycker du att diskmaskinens insida är anpassad för den typ av disk du brukar ha?

Är det tydligt hur man ska placera disken?

Finns det något du skulle vilja ändra på? Vad?

Känner du att du förstår vad alla diskmaskinens program innebär? Varför/varför inte?

Vilka av programmen använder du?

Är det tydligt när diskprogrammet gått klart?

Har det hänt att något föremål gått sönder när du diskat det i diskmaskinen?

Sköljer du disken innan du placerar den i diskmaskinen? Varför/varför inte?

Har du installerat diskmaskinen själv?

- Om ja, var det lätt eller svårt?
- Om nej, vet du hur du skulle gått till väga?

Hur ofta rengör du diskmaskinen?

- Hur gör du då?

Använder du något sköljmedel/spolglans?

Har du någon särskild dålig upplevelse kopplad till din diskmaskin?

Om din nuvarande diskmaskin skulle gå sönder, skulle du köpa en liknande för att ersätta den då eller skulle du vilja ha en annan typ/modell? Eller ingen alls?

Finns det något du tycker att diskmaskinerna idag saknar?

Har inte diskmaskin

Vill du ha en diskmaskin? Varför/varför inte?

- Hur kommer det sig att du inte har en diskmaskin?

Hur går du tillväga när du diskar?

- Diskho, balja, rinnande vatten?

Sköljer du disken innan du placerar den i diskhon? Varför/varför inte?

Har du något särskilt system för vilken disk du väljer att diska först för hand?

Har du något särskilt system för hur du placerar disken i diskstället?

Har du någon särskild dålig upplevelse kopplad till när du diskat för hand?

Har det hänt att något föremål gått sönder när du diskat det för hand?

Finns det något du tycker att diskmaskinerna idag saknar?

Miljöpåverkan

Vad gör du medvetet för att minska din miljöpåverkan i hushållet?

Vad är lättast?

Vad är svårast?

Framtidsscenario

Hur tror du att du kommer att bo om fem år?

Hur ser ditt drömkök ut?

Hur tror du att kök kommer förändras i framtiden?

Hur tror du att framtidens diskmaskiner kommer att se ut?

Finns det något tillfälle/aktivitet i köket där du känner att du skulle vilja ha mer kontroll över processen?

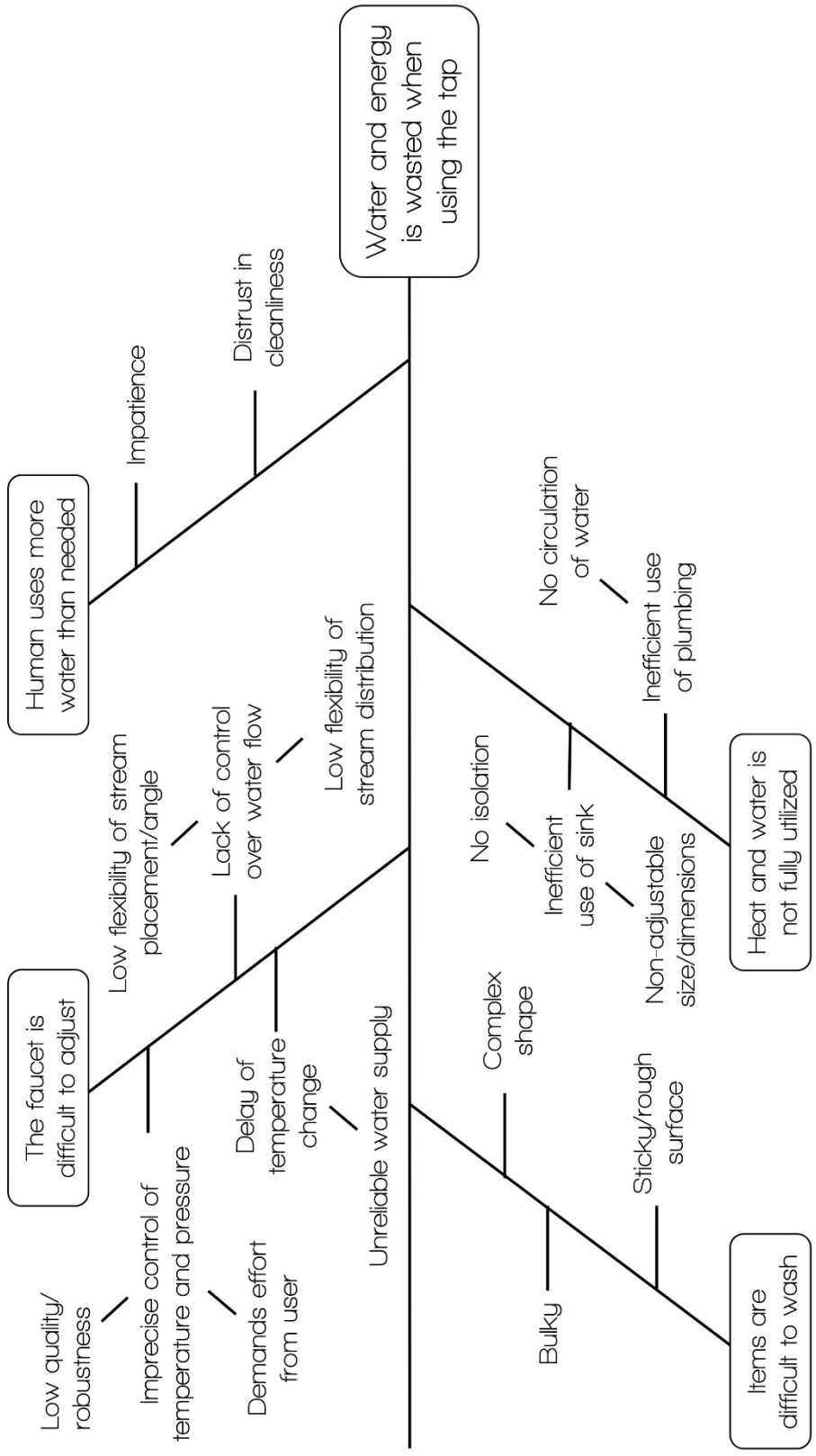
Finns det något tillfälle/aktivitet i köket där du känner att du skulle vilja ha en mer automatiserad process?

Uppgifter

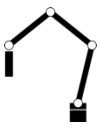
Hur stor nytta/status har diskmaskinen jämfört med andra köksmaskiner? (placera ut)

Skulle du kunna fotografera ditt kök?

Appendix VI: Fishbone/Ishikawa diagram



Appendix VII: Kesselring matrix

Criterion	Weight	Ideal															
C	3	5	15	-	-	-	-	-	-	5	15	5	15	5	15	5	15
D	4	5	20	1	4	2	8	3	12	5	20	5	20	5	20	4	16
E	4	5	20	-	-	2	8	3	12	5	20	5	20	4	16	4	16
F	4	5	20	-	-	4	16	4	16	3	12	3	12	3	12	4	16
G	2	5	10	2	4	2	4	2	4	5	10	5	10	5	10	5	10
I	4	5	20	-	-	3	12	3	12	3	12	3	12	3	12	3	12
K	4	5	20	4	16	4	16	3	12	3	12	2	8	1	4	2	8
Total score:		125		24		64		68		101		97		89		93	

CHALMERS UNIVERSITY OF TECHNOLOGY
SE 412 96 Gothenburg, Sweden

Phone: + 46 (0)31 772 10 00
Web: www.tekniskdesign.se