CHALMERS
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The zero-waste kitchen

Design of a domestic waste sorting solution to improve environmental behaviour

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Department Architecture and Civil Engineering
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2019

Bachelor of Science Thesis

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The zero-waste kitchen
Design of a domestic waste sorting solution to improve environmental awareness and consumption patterns
Bachelor of Science Thesis in the Bachelor Degree Program, Industrial Design Engineering

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Cover Photo: Rendering of the sorting system in context

PREFACE AND ACKNOWLEDGEMENTS

This bachelor thesis is the result of a product development project carried out in Chalmers University of Technology during the spring of 2019. The project covered 15 credits, developed and presented in Chalmers, it finalizes my Erasmus exchange year and my four year of Bachelor in Universidad Politécnica de Valencia, studying Industrial Design and Product Development Engineer.

I want to thank Ulrike Rahe, for her excellent feedback as a teacher and for adapting the situation to fit a bachelor thesis in her project.

Thanks to The Circular Kitchen project team for the inspirational and fun workshops, specially to my supervisor Giliam Dokter, for guiding me through this design journey, helping to find the right directions.

HSB for the Living Lab installations, Vedum for the furniture and ATAG for the appliances. An excellent tool to prototype and test ideas in a real environment.

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Finally, thanks to my family and friends for supporting me along my education, this couldn't have been possible without you.

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Hal

ABSTRACT

The kitchen is the core of households and domestic activities. It is also were our main technology investment is placed. According to the trends both aspect are expected to grow in the near future.

Furthermore, other big reality will be the change from a lineal economy to a circular one. Waste will need to be treated as a resource to ensure the planet sustainability.

Connecting both topics, there are big quantities of materials and products in the kitchen environment which need to be re-thought to reduce impact and fit the new socio-economic needs. From this urgency originated The Circular Kitchen Project, the research that fosters this project.

Different challenges must be addressed, in this case, the goal of *The zero-waste kitchen* thesis is to explore design solutions to improve the relation between waste and users, supporting more sustainable consumption, use and disposal patterns. Taking into account new technologies and kitchen trends.

Several waste flows were explored, finding improving potential in the way we sort and throw away food and packagings, since existing solutions do not support reduction, only recycling.

The proposed solution is Less, an interface added to the existing sorting bins, using the advantages of growing technologies such as sensors and AI, minimizing own waste and helping the users to track and improve their wasting behaviour, resulting in a more sustainable kitchen and household. The research explore also the future possibilities and implications of this kind of product.

Keywords: *zero waste, food waste, recycling, sorting system, domestic waste, circular economy, sustainability, waste management, internet of things, sensors, behavioural change, industrial design, product development.*

0.0 CONTENTS

1. PROBLEM STATEMENT

1.1 THE CIRCULAR KITCHEN PROJECT

This project is part of a bigger research project, where more students and researchers will be working during four years. As a public/private partnership, it is a collaboration between Chalmers University of Technology and TU Delft, funded by the European Institute of Technology with support of the industry.

The kitchen forms a central place in the home, for cooking and social interaction. It is a key point where furniture, appliances, energy, water and food converge, sometimes, not in the most sustainable way. Our behaviour towards the kitchen usually creates a lot of undesired waste, mostly because designs do not support replacements and sustainable consumption patterns. As data shows: 10 million tonnes of furniture are thrown by companies and consumers in EU Member States each year, the majority of which are dedicated to landfill or incineration (Circular Economy Opportunities in the Furniture Sector, 2017), an this is only a part of the waste generated in the kitchen.

The objective of the project is to understand the material flow and create climate smart solutions and circular kitchens design for an early future. This will be made co-creating, developing, testing and evaluating.

1.2 BRIEFING

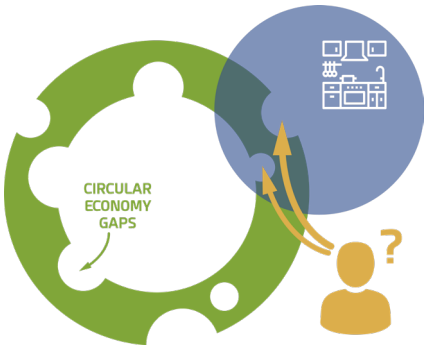
As the kitchen research domain is quite broad, different topics have to be addressed. The focus of this thesis is zero-waste households. Nowadays, our waste production patterns easily fall into overconsumption, fast fashion, plastic over-use, etc. There is a lack of knowledge about the waste loops and the waste management system must be improved to support sustainable choices and become fully circular, as nature is.

Research guidelines:

- Exploring current user behaviour patterns in the kitchen with different user groups.
- Investigating predictions about the kitchen of the future.
- Understanding the current kitchen layouts, available products on the market (furniture, appliances, kitchen equipment etc.)

Goal:

- Explore design solutions that support zero waste kitchen.



How to support the user to close the circular gaps in the kitchen?

Fig. 1: Briefing diagram

The aim is clear, but several elements take part in this complex problem, having several paths to solve the problem, this made the first stages of the project longer and exploratory, understanding the whole environment to find a focus point.

1.3 ORGANIZATION

Since the beginning, the different stages were set up to keep in mind the project's milestones, making some changes during the process due to the exploratory nature of the briefing. It needs much more time to explore solutions, behaviours and scenarios, finding a problem to solve. It's better to create a concept with potential to solve real problems than a fully developed product yet not realistic.

Although the stages were set up from the beginning, the design methodologies weren't chosen from the start, leaving the process indicate what techniques are the best in each moment. The different methods used came from own experience, obtained with the different project during the Bachelor, although the Delft Design Guide was really helpful to find methodological inspiration (Boeijen and Daalhuizen, 2017), as well as the online Circular Design Guide (Circular Design Guide, 2018) for circular methods.

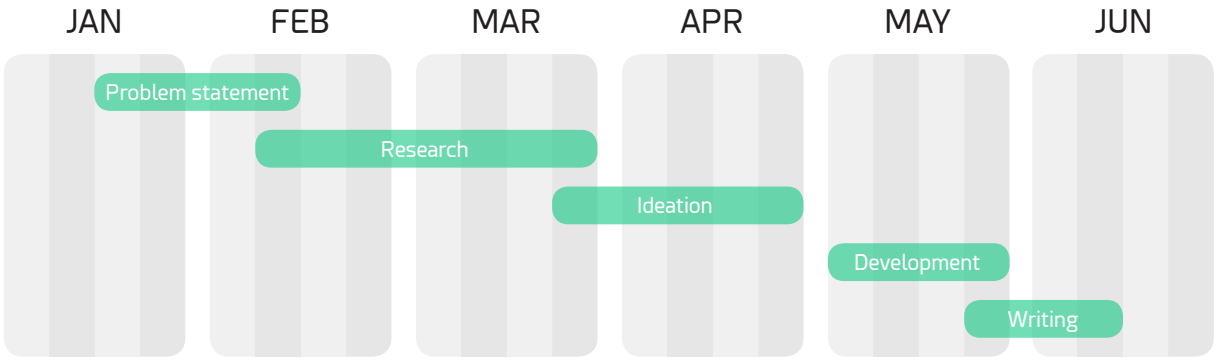


Fig. 2: Project organization

1.4 PARTNERS

In order to find a successful orientation, the first task was to map and understand the different stakeholders around the project. Following what great designers have made: finding your own interest, your client interest and the social one, is key to make something real from a project, is important to use all the potential and interest around it. On the side, how Charles Eames explained this (Foley, 2018) quite creatively with a diagram.

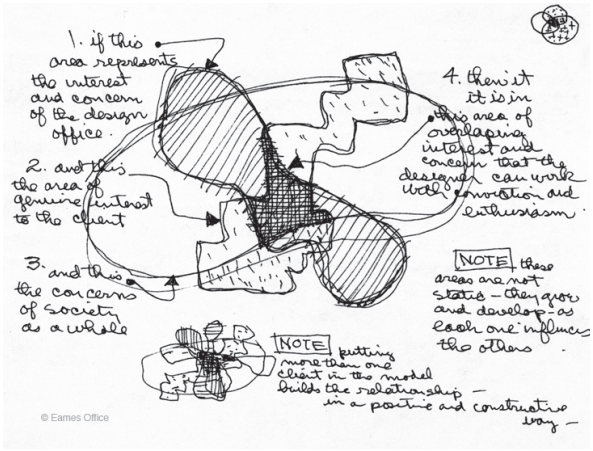


Fig. 3: Eames stakeholders diagram

Now, the different interests around The Circular Kitchen Project, explained:

- **Climate-KIC:** their work is to put investment, education and companies in contact looking for innovation in the sustainability field. All the companies and organizations must work with sustainability in mind. In the project, TU Delft will be more focused in the business model and Chalmers on the kitchens designs and user behaviours, sharing knowledge, of course.

- **HSB:** as one of the main Swedish housing agencies, they have interest in the future of living, adapting to the new environmental challenges. In their Living Lab installation, some researches are been carried out. For this project, they provide a room with a movable kitchen witch allows user studies, product testing and eventually, building the future kitchen concept. So it's positive if the result fits there.
- **Vedum:** Swedish furniture firm with focus on kitchen installation and accessories. Their main interest in the project is how to refurbish kitchens in a more sustainable way, but they also want to explore how to integrate smartness in their products creating value. Vedum sponsor the furniture for the testing kitchen.
- **Atag:** Appliances group, with producers such as Asko in his brands, providers of the appliances in the kitchen lab. They make great quality products with high energy efficiently, material passport and high price. Their new challenges are improving the connection between devices and appliances and supporting the users to make always the right choice.
- **Students in the project:** Three more student have been doing their thesis in the same project, so having a more similar scope allows collaboration and an inspiring workspace. Their topic was flexibility in the kitchen.
- **Own interest:** From my own design point of view, I am interested in problem solving products, preferably physical to be able to work with form and measurements. In the project context, the appliances are the most interesting field for me. Using smartness cleverly to solve sustainable problems.

1.5 UNDERSTANDING THE DOMAIN

Once the challenge and the entities involved were set up, it was the moment to reduce the design domain with strategy, the problem of waste management and reduction can be faced in several ways, only though a few of them would be supported by the stakeholders.

This has been done studying the state of art, drawing the opportunities and checking for common interest, reviewing the different fields related to the problem, mainly reading publications about circular economy, food, packagings, furniture, appliances and kitchen living.

Fig. 4: Kitchen fields

1.5.1 Circular gaps

The reason why projects such as The Circular Kitchen, and tons of researches about sustainability is quite clear. All the experts, media and governments are warning that the

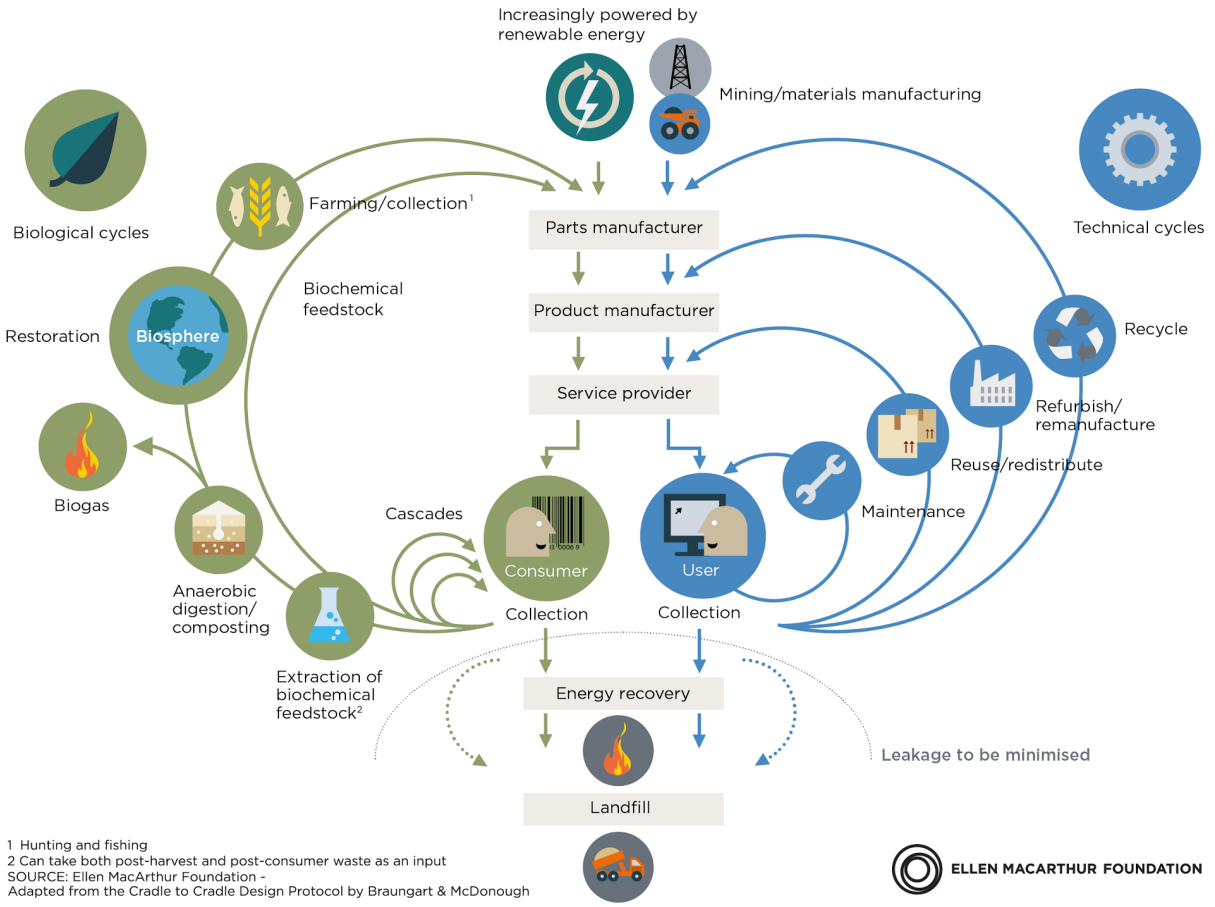


Fig. 4: Circular economy loops diagram (Ellen Macarthur Foundation)

world is reaching a non-return point, our economy model is outdated, extracting, using and wasting resources with a linear model that has to be closed into a circular one; reducing our extraction, improving our stocks' management and recycling what we have. Only 9.1% of our material flows are circular (Circle Economy, 2018).

This is not an easy task and the collaboration of public entities, companies and people is crucial. We need to find ways to close more loops, using the potential of today's infrastructures to create the path of the future ones. A clear way to sum up the opportunities that we have are the seven key elements that Circle Economy describe:

- **Prioritise Regenerative Resources:** Design with renewable, reusable, non-toxic resources. Using energy and materials efficiently.
- **Preserve and Extend What's Already Made:** Maintain, repair, upgrade and create take-back strategies to maximise lifetime.
- **Use Waste as a Resource:** Use waste streams as a resource. Reuse and recycle.
- **Rethink the Business Model:** Consider opportunities to create greater value. Mix product and services.
- **Design For the Future:** Create using systemic methods, adapting for future changes.
- **Incorporate Digital Technology**: Track and optimise resources and build better connections between stakeholders.

- **Collaborate to Create Joint Value:** Make the whole chain work together, increasing transparency and sharing value.

All these factors will be used to check how circular is each solution, find problems and improvements.

Apart from the general system view, the situation of the different resource loops is also important. Products such as energy, water, furniture, appliances, food, packagings and tools are constantly entering an living our kitchens. The ones considered interesting for this issue and reviewed were: food, packagings, furniture and appliances.

1.5.2 Food waste

After infrastructure; nutrition and all it's implication, is the second economic activity more harmful for the planet (Circle Economy, 2018). Every human need food and food's life-cycles are much shorter, therefore, the management is really complex. The production system is incredibly wasteful, is estimated that for every $1 spent in food, you need $2.27 to clean up the damage (KPMG).

There are several reasons why this is happening: changing nutrition habits, land over-use, logistic problems, pesticides, water usage, etc. All these is creating a nutrient flow that born in the lands and die in the cities, not going back. If anything change, these nutrients flows will be disrupted, breaking the production system (The Ellen MacArthur Foundation, 2018). The biocycle problem needs intervention from all the parts. The kitchen domain is one a key part and there are room for improvement in so many ways. Next, a summary of the different interventions and explorations already done.

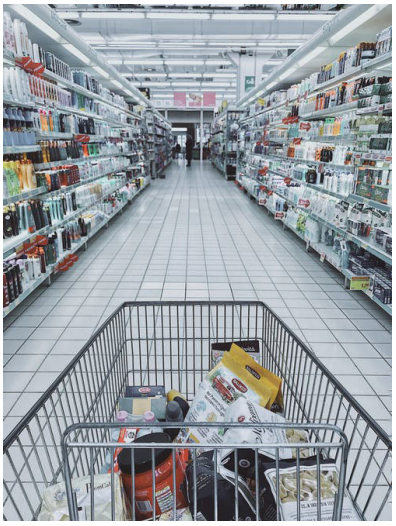


Fig. 5: Shopping scenario (Pexels)

- **Planning and buying:** The best way to cut waste is to cut from the source, a clear plan of what and how much to buy is positive, but difficult to integrate on daily routines, were flexibility rules. The solutions are mainly using shopping lists and planned recipes, usually integrated into applications or interfaces. In the other hand, buying with sustainable values in mind is complex, there are a lot of offers knowing the impact of your product is not clear and takes time.
- **Diet and cooking:** Managing portions, and structuring a healthy diet and uses low impact is other important challenge. It requires population's awareness and guidelines to support choices while cooking.
- **Stock managing:** The way we store is incredibly important to tackle food waste, several factor are part of it: keeping the food in the correct environment and temperature, lack of information about how to store, problems with visibility and tracking your stock, consume leftovers on time and big numbers of aspect related to packaging technologies. It's considered the most critical practice to face food waste (Hebrok and Boks, 2017).
- **Food risk:** Lack of information about nourishment's lifetime can cause diseases but is also creating a lot of waste. Some systems to notice when a product is really in bad conditions are being developed.

- **Recycling:** Ensuring that what is going to be wasted any way enters the recycling system ready. Correct sorting education and improving the experience is need it, because managing liquids or smells usually is a unpleasant task.
- **Reusing:** Other kind of scopes aim to use what is going to be discarded anyway. Domestic composting systems, food obtained from peels, or materials. Some examples use potato peels to 3D print creative food (Morris, 2019), or create packaging (Hitti, 2019). With shrimp skin is even possible to make polymers (Hitti, 2019). This progresses are really promising, however it's difficult to integrate it in big scale in user's kitchens, maybe better in an industrial level.

A demographical study (Diaz-Ruiz, Costa-Font and Gil, 2018) shows that when it comes to food waste reduction, the main drivers to improve user's behaviour are purchasing discipline, waste prevention behaviour and materialism values; with even more influence than a positive recycling habit. Until today, the focus is the products are not helping to cultivate that values, kitchens are full of products that interact with food and are excellent touch points to create that awareness and information.

The industry knows that this is a big problem and also a new market. The problem is that a lot of the solutions are still in development or difficult to integrate in today's user routines, and is difficult to really know if the impact of the product on itself would be less than the food waste saved. This ideas need to be supported with effortless interactions to enter people routines, and the sustainable improvements in materials and technologies are also crucial, as well as cost reduction to be competitive in the market.

1.5.3 Appliances

Looking now to the machines used in our kitchens, the efforts to reduce waste and create circular products could be summarized in three points:

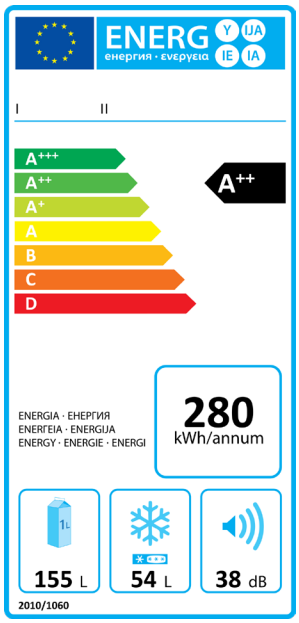


Fig. 6: EU energy label for appliances (Wikipedia)

- **Energy efficiency:** What could be said that is the main firms' effort. Having good efficiently labels is key to sell good products and in also reduce electricity cost and impact. However, white-wares are a big material investment and a constant interaction interface, and they also need the focus of innovation in those aspects.
- **Modularity and repairability:** This field is well know for its obsolescence, the market is constantly pushing with better materials and innovations and soon they lose their value, being plenty of valuable pieces and resources and without the possibility to be updated or be used with other purposes. In the other hand the repair services are usually complex and annoying for the user, not fostering longevity.
- **Food management:** Apart for cleaning, preparing and stocking up food are their main function. For cocking, is expected that in the next years our cooking methods and habits will change drastically. Also for storage, fridges and freezers are increasing the lifetime of our food much more than years ago. However, a bigger revolution is coming, the era

of information. All the high range appliances today include touch-screens, interfaces and sensors and this only seem to grow. It has a lot of potential to smooth complex everyday activities, supporting sustainable choices and reducing friction.

1.5.4 Furniture

Kitchen's build system are not circular at all and do not pay attention to people's flexibility challenges. In order to reduce, recycle and re-use, rethink is need it.

The industry is based on frames and covers, having different measurements for every producer, and making difficult to apply new ownership models or customization in big scale.

To don't spread too much the focus and observing the noticeable problems with food waste, the research was reduced to storage systems, which commonly are drawers and cabinets.

Furniture and consumer goods design have always had a discussion about openness and closeness, the way we furnish our homes is very personal and says a lot about ourselves, some people feel more confident and pleased showing stuff and other prefer to cover and have order and privacy. Historically the main trend in the kitchen has been to hide everything behind, drawers, cabinets, doors, etc. Some new trends propose more open designs, but it is not the mainstream.

The consequence of covering is that it makes really difficult to grasp all the nourishment quickly and usually it's complex to remember were things are and when should be consumed, in addition, families also have to deal with the lack of space and the usage and diet needs of different members.

The same spaces are used to place cans, bags, tools, bread, fruit, etc. And each kind need different conditions, or it fills space differently. This occur in furniture, fridges and freezers. Apparently, consumers have a big lack of knowledge about how to store the information is contradictory (Hebrok and Boks, 2017), reducing food quality and lifetime. This field is full opportunities.

Changing the subject, according to the companies' motivations, the next furniture element that will receive innovation will be the counter top (Global kitchen, 2017), probably integrating the stoves in the surface, and sensor to guide diet and quantities. There are clear design opportunities to define this new technology and redefine how counter tops are installed today, being one piece cut for each kitchen, being difficult to reuse.

1.5.5 Packagings:

Unfortunately, in our logistic system, food usually need packaging to ensure preservation, transportation, conservation, marketing, etc. This creates huge material flows parallel to the food loop and taking care of them is equally important.

A lot of innovative sustainable products are being developed, using biomaterials, reducing plastic use, using mono-material, eliminating the water to compact them, etc. Several innovation paths are being developed, but competitive prices and food safety standards make difficult to implement them in big scale. Further development, better consumer acceptance and public incentive schemes are need it.

Other related issue is the recycling system, design interventions are complex because it

varies a lot depending on the country and the city, as well as the user recycling education and commitment. But it is also a big pain point for the user, because a lot of packages are really uncomfortable to fit in our bins' form, or difficult to carry, separate materials ,etc.

1.5.6 Living in the kitchen

The importance of the kitchen in the home has been growing in the last years. More activities are starting to be done there and tends to be more open to the living room and the rest of the house. This is happening due to societal changes, such as the entering of the majority of the women in the job market and the changes in our daily quickly routines. Most experts agree that this trend will keep growing even more (Global Kitchen, 2017). The future kitchens need to be designed with a new open mind-set, taking in account the new activities and social interactions that would occur.

In terms of technology, the expected innovations will focus on connectivity, IoT and smartness

Fig. 7: Different kitchen use scenarios (Pexels)

mainly. In second level will be innovations in terms of water and energy saving, as well as smart waste managing systems and new cocking methods, probably from high-cuisine, will be integrated in the same way that microwave enter a decade ago. This trends are more or less prominent depending on the country culture, the Swedish market is more interested in connectivity for example (Global Kitchen, 2017).

There are several opinions around this information/smart/connectivity revolution. It is determining to innovative based on human habit and necessity, not pushing appealing innovation to the market without solving the main problems. The kitchen will be the brain of our house and the core of our routines, being the room with more investment and technology. Products with exceptional user experience must guide us to be better consumers, cook healthier, better, more sustainable…

Regarding circularity, apart from efficiency improvements, a big research in new materials is being done, and we need ways to track how much we buy, prepare, eat and waste. According to the director the Circular Economy foundation (Global Kitchen, 2017). It's the only way to know how much, how and why are we wasting.

1.6 MAIN FINDINGS

Insights summary, recapitulating the state of art of the different fields within the kitchen and the developing paths being explored. These are four main trends affecting the future of kitchens. They sum up the readings and researches in order to have a clearer briefing in following stages.

Compact living

Houses are going to be smaller and the kitchen will take more importance, being the hub for more activities apart from cooking. Kitchen furniture needs to be multifunctional and adaptable.

Information era

AI, IoT and big data are already entering the way we live and all the predictions expect an exponential grow. All these information is highly valuable to create value, supporting our actions and behaviours, with several benefits and risks.

User experience

As a result of the last one, products expect to be more interactive. This excess of interfaces is already creating over-information and health issues. Interactions will be reduced, nudging and guiding us kindly and clever.

Circular economy

Customization and modularity will rule in product design. The change towards a circular society will limit the way we design today, nevertheless it will be an environment much more open towards new ownership models, services, scalability and repairability. This will also trigger lots of material innovations, having better sustainable choices.

Fig. 8: Main findings chart

1.7 ORIENTATIONS

With a clearer view of the whole design domain and the state of art, different direction to address the briefing start come up. Trying to solve current and future problems in the kitchen and closing the domain with something more concrete that could interest several partners in the Circular Kitchen Project.

The fist idea appeared mixing the interest of other student researching about flexible cabinets in the project, mixed with the integration of ASKO appliances, aiming to design an better storage system to hold all the food (refrigerated and non-refrigerated) in the same place. Taking a big inspiration with the Ideo's kitchen concept for Ikea (Ideo, 2019).

This path seemed promising because it allowed co-design with other student, promising to solve a lot of problems cutting food and appliances waste. However, after receiving some feedback, the view changed, realizing that it was aiming to solve too many problems without even knowing if the user wants that. Considering this, a new direction was evaluated.

Domestic waste sorting systems are critical for the user and the waste journey. Too little innovations are being made on this kind of products, users usually have negative experiences with them, and they are not always adapted to the changing recycling habits. Apart from supporting a correct and comfortable sorting, would be positive to create feedback or awareness with our waste. Being one of the main touch-points to deal with waste in every kitchen, there are tons improve opportunities and chance for innovation.

The new solution should take into account the aspects learned from the state of art. Being adapted to the new trends in kitchens, to ensure that the product could be used over without obsolescence. Furthermore, must be adapted to Swedish recycling infrastructure, due to could be quite different in other countries.

1. PROBLEM STATEMENT

2. RESEARCH

3. IDEATION

4. DEVELOPMENT

5. RESULTS

6. DISCUSSION

7. REFERENCES

8. APPENDIX

2.1 THE WASTE FLOW

Waste management are complex systems integrated in our social and economical net and are influenced by several factors, such as consumers behaviours and awareness, producers commitment, public entities, logistics, etc. The process aims to by a cycle, but is challenging to have synergy between all the stakeholders, the system is so far to be perfect, creating big gaps and lost of resources.

In order to understand the issues and gaps created by domestic waste systems, the research has been structured analysing the different stages that the waste follows, focusing first in the infrastructure.

2.1.1 Supply points

Shops and market represent an important point of choice, the offer and our consumption habits are a significant influence to the amount of waste that we produce. The best way to fix circular gaps is reducing from the source and choosing the right source.

In the one hand, reducing waste by planning seems the best way to reduce waste (Diaz-Ruiz, Costa-Font and Gil, 2018), having a better overview of the stocks and avoiding overbuying. However, this task is complex and takes precious time from busy lifestyles. The main ways to solve this seems planning with exhaustive lists and buying frozen, canned food, but eating is a pleasure, social and healthy ritual for a lot of people and change this seems difficult (Hebrok and Boks, 2017).

In the other hand, choices are increasingly improving in selling-points, offering more ecological, local or plastic-free products, but people is looking for one-stop supermarkets, letting less time to find the right nourishment, and the choices are reduced.

Another aspect is that our information level about the emissions of each product is usually wrong. Knowing the impact of something is much more complex than expected, the emissions level of an product is determined by several aspects. For example, doing a route by car could be less harmful that do it by walking and recover the calories drinking a glass of milk (Goodall, 2010).

In conclusion, there is a big lack of information, we need better guidance to help us decide the right product and the right amount, offering better buying experiences. It's crucial to cut waste from the root. Our domestic bins are constantly showing the result of this bad choices and error, there is an opportunity to show impact better, creating feedback and awareness.

Apart from the classic supply points, there is a increasingly growing trend affecting. New generation's lifestyles and digitalization is fostering the grow of delivered food, specially online. This market expect to increase the sales three times before 2023 (L.E.K. Consulting, 2019), representing an important change in how we consume food. Designs should consider it to be ready for future changes.

2.1.2 Entering the house

After shopping, the resources are stocked up in our kitchens, prepared, consumed and then disposed. These stages have been analysed during the problem statement, but now, the

outreach of sorting systems seems to be reduced to awareness that waste could create, promoting a more responsible behaviour stocking and preparing food.

What it was interesting to observe were the different solutions out there in the market, and how they fit in the current and future concepts of kitchen. They can go from improvised solutions with cardboard boxes, basic buckets, based on plastic or more complex based in modules inside a drawer. They can have sliding, swivelling or pedal mechanisms, or extra functions as stacability or others. Below, some interesting solutions already in the market:

Fig. 9: Sorting bins solutions moodboard

All these configurations are conditioned by house recycling habits, the consume and the recycling company involved. Each user group sort in more or less categories, correctly or wrong depending on convenience, awareness or situation of the different family members. These make every sorting system unique for each house, being a product that needs extreme customization and usually a little space, thus could create a lack of performance.

2.1.3 Exiting the house

When bins are full, everybody has to experience one of the most unpleasant task of this process. Dealing with accumulated waste, smells, liquids and dirtiness from the kitchen to the street bins. As well as the sorting system set up, this experience is really diverse depending on the distance to the recycling station, physical abilities and the recycling service. The experience will vary depending if the house is in the city centre or in residential areas. It's also common that neighbourhoods with higher income will pay for curbside collection or sorting services.

Depending on the country, waste management is a public or a private issue. Sometimes with more or less common regulations. For example, in Spain everybody pays the same tax and the system is quite homogeneous across the country. In South Korea there are plans to cut the food waste and citizens have to pay as they throw, which have reduced the waste in a 95% (Kim, 2019).

In Sweden, the management is in the hands of Avfall Sverige. It's a organization that embrace and hundreds of private and public partners which are spread all around the country. Depending on neighbourhood or the hired service varies. Could be single-stream (all together), taxed by weight, using colour bags for subsequent optic sorting, kerbside and using wasting stations.

Kerbside collection is more common in rural and residential areas, within the system there are variations too, this is the current distribution (Avfall Sverige, 2018):

- **49% Two separated bins** (one for food waste and other for residual waste that goes to combustion)
- **25% Only one bin**
- **15% Multi-compartment bins**
- **10% Different colour bags in the same bin** (usually food and residual waste)

The other solution, more common in cities, and also used by citizens wanting to recycle better are collection stations. Usually works parallel to organic and non-sorted collection and the categories varies, having several categories, sometimes is complex for the user and requires correct information and motivation.

- **Plastic packaging:** one of the most complex and environmental dangerous waste-streams to manage, having several kind of plastic to be sorted. The government target is to recycle a 50% by 2020 and that target have been already reached by some companies, such as FTI, which manage 1.6 million households in Sweden.
- **Paper packaging:** holds all kind of papers apart from the ones with adhesives that goes to unsorted waste and the newspaper category. It's being recycled in a 80%.
- **Newspapers:** contain newspapers, magazines, flyers, writing paper, etc. It's separated from regular paper and it has a 95% rate of recovery.
- **Metal packaging:** all king of metal packagings go here. Plastic caps should be left to avoid smells, and the content should be emptied and cleaned well, it can't be recycled

if maggots or infections appear because of biological danger, it's a common issue in recycling centres according to workers. The recycling rate is around 80%.

- **Aluminium cans and PET bottles:** the pant scheme has been in Sweden since the 1984, adding a tax to these products that could be returned in some machines. The government target is a 90% of recovery. Being 86.2% for cans and 82.5% for bottles (The Local, 2017).
- **Glass packaging:** it's commonly sorted in colour and clear glass. But in some municipalities is collected together with metal, because the recycling centre technology allows it. The recycling rate over 90%, being a good choice for packaging design.

Fig. 10: FTI waste collection point (FTI)

Apart from packaging, there are other waste streams managed in different channels, with less collection points, or directly to a drop-off centre.

- **Clothes:** apart from local waste facilities, it usually goes to charity or free-shops, a common phenomenon in Sweden.
- **Hazardous waste:** products with chemical substances, really harmful for the environment, with complex recovery processes.
- **Bulky waste:** all the big pieces and materials not corresponding to the packagings are part or other waste streams. Toys, furniture, frying pans, porcelain, etc.
- **Electronics:** the recovery in ruled under the producer's responsibility. Managed by El-Kretsen.

All the recycling rates are provided by annual report (Förpacknings & Tidnings Insamlingen, 2017). Sweden has already overcome the landfill challenge, almost nothing goes there. The waste that is nor recycled now goes to energy recovery plants, which is positive but still creates a lot of emissions. The challenge for the next years is to increase even more the recycling loops, giving more value to the materials.

2.1.4 Recycling industry

The last point of the waste journey were domestic sorting has influence is the recycling industry. The waste is sent to factories spread across Sweden and near countries to be

recovered and send it again to material producers. The research and technology is improving in the field, getting smarter and more automated machines, but in practice this is not applied everywhere, having different needs depending on the municipality or the funds.

The most basic scheme is human-based, with workers sorting by hand. Other schemes work with pre-sorted waste, having a line for each material and the most advanced systems could separate all together using filters in different steps. The filters could be based on size, form, weight, density, or optical properties; being mainly binary, that is, selecting a kind of element a leaving the rest in the line.

The current systems' design need the packagings as one piece, the possibility if sending the materials already shredded from the collection system would cause identification problems. Another common problem is the cleaning process, if citizens don't clean enough the garbage it could cause health problems. Some advanced schemes also provide cleaning.

How waste is processed depend on the collection system and the available technology, so it could change and with the expected improvement of sensors and machine learning in the coming year would be more automated, not needing to sort packagings in any municipality. A circular and long lasting domestic sorting system should be flexible to not become obsolete if the system change.

Other interesting stakeholders taking part in this process is El-Kretsen, which manage the WEEE (Waste Electrical and Electronic Equipment). The recycling of this materials in Sweden is driven by producer responsibility, transferring the responsibility from the consumer to the producer. El-Kretsen is the logistic web that keep consumers, producers and recyclers connected and their performance is one the best in the world, but the electronics industry is still too far to be circular and mayor changes are need it to face its gaps, and plenty of them depend on the design and development stage.

More sustainable products have to keep materials more pure, keeping rare metals clean to be melted into new uses and plastic without additives. The current methods crush all the components, then sorting the different materials, but new products are increasingly smaller and more compact and new materials are starting to be used, making difficult to perform with the existing infrastructure (El-Kretsen, 2018).

Producing with recycled material consume less energy than mining but is becoming more complex and expensive, the research and regulations should keep growing to recover value from broken components, but the existing functional components should be reused in other products. A truly circular model needs to reuse before recycling to use the whole material value, products needs to be designed modular, improving disassembly.

2.2 THE WASTING EXPERIENCE

Apart from the infrastructure, systems and trends; there is one more topic to care about. The user experience. Knowing the pain points during the recycling process is crucial to close circular gaps and create pleasant experiences, ensuring product profitability.

This have been done mainly using surveys, user observations and own experience; summing up everything in an user journey.

2.2.1 Survey

The aim of the survey was to understand the how people experience the different configurations that have been observed in the recycling scheme, aiming to get quantitative data about their set ups and qualitative data about their interactions and pain points.

The survey was framed only to Swedish habitants, to base their answers on a known system. It gathered information about their kitchens, sorting habits, the throwing away process and demographics. It was done online receiving 71 responses and the participation was a bit heterogeneous, receiving more replies from young segments. The sample is not good enough to stablish a demographical study, but enough to find problems and tendencies. It was specially useful to understand personal experiences and problems with sorting systems. Below, some remarkable results, for further details, go to the appendix chapter.

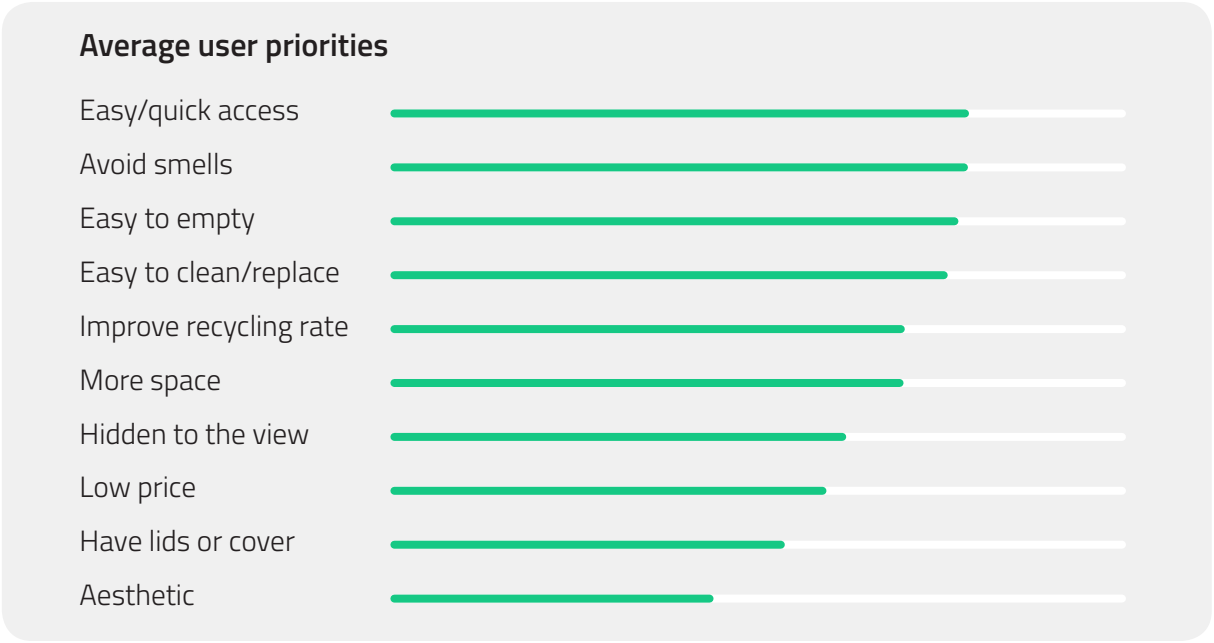


Fig. 11: Average users priorities stadistics

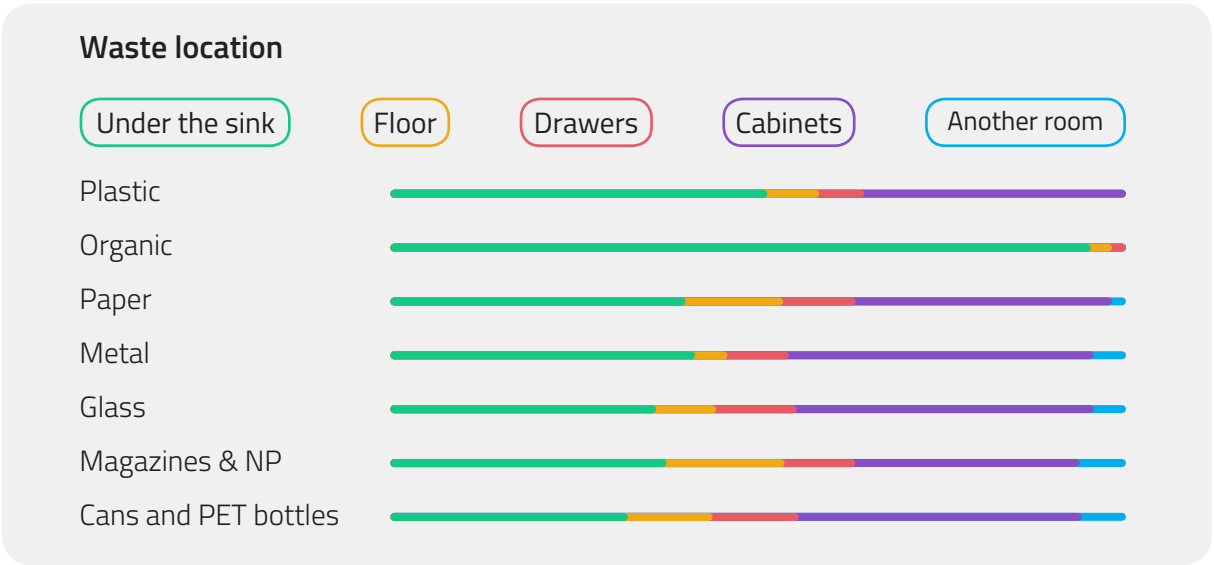


Fig. 12: Waste location stadistics

2.2.2 User observations

To be able of see users performing real tasks and receive feedback more spontaneously, the students writing thesis for the Circular Kitchen Project got together to organize a workshop.

HSB's living lab offers a big room with movable kitchen furniture, tools and appliances to do any kind of testing. After some discussion the decision was to invite eight users with different backgrounds to make two teams and test two separate scenarios. They were invited to snacks and drinks to encourage a relaxed and social environment, reducing pressure. Next, the activities done.

N° 1 Design your dream kitchen

They were given the task of designing their dream kitchen, containing at least one sink, appliances of their choice, dinning table, chairs and waste system, using post-its to indicate extra elements if they wanted. The difference was that one group had indefinite space, using as much as they want, and the other had to fit everything in very reduced an delimited surface.

After the activity, focusing on bins, the main observations were that is commonly decided in the last steps of the kitchen design, the big kitchen group was straightforward, going directly underneath the sink with a compartmentalized solution in the drawer. In the other hand, the small kitchen team struggled with the lack of space. They tried first outside the cabinets, making room for other things, facing to the wall or to cabinet's sides, stacking to gain height and space. The final choice was also inside some bottom drawers, as they considered disgusting having garbage in sight. The drawers on top were emptied to avoid smell contamination.

N° 2 Cook in your dream kitchen

Once the spaces were stabilised, each team had to cook something following a recipe. They were requested also to put the table and clean a bit to observe more behaviours.

It was difficult to get insight from this activity, the focus wasn't in the bins. The only thing was that the small kitchen had the bins right under the working area and the big one had them far from the island were they worked. The result was that the small one was much cleaner at the end, because they were throwing as they use.

Fig. 13: User testing

Nº 3 Eat and discuss

After both tasks everybody sat to enjoy the food and discuss the about the event and the research topics.

It was interesting how they describe their relation with sustainable decisions, explaining that they care, but it gets difficult to be responsible in all situations, being driven by convenience. They also explained that it's easier to behave better when you have choice and information about them. Choosing the plastic-less apple instead of the wrapped one, or choosing the vegan menu when the carbon footprint is displayed in comparative to the meat one.

2.2.3 User journey

All the information gathered about the user experiences had to be mapped and simplified to find the circular gaps and pain points. The experience was divided in 10 activities and there were information about the user experience and the sustainable performance.

The first intention was to map the average happiness of the users along the journey, but they were two problems:

One. Each experience was totally different depending on the user, the interactions are shaped by different scenarios and habits and making personas would only take into account the necessities of a concrete target group, not solving the extended problems. A bigger target group can close much more circular gaps than a niche solution.

Two. Understanding their usability problems were quite simple, but knowing their real sustainable behaviour and recycling rate is complex, real statistics extracted from their bins were need it.

So other direction was taken, opting to map the potential improvements for each activities in terms of circular improvement and experiential improvement. In the following chart the different user activities are represented with the orange colour, and the waste journey with green. The amount of warning signs represent found problems in term of sustinable behaviour (green) and user experience (orange).

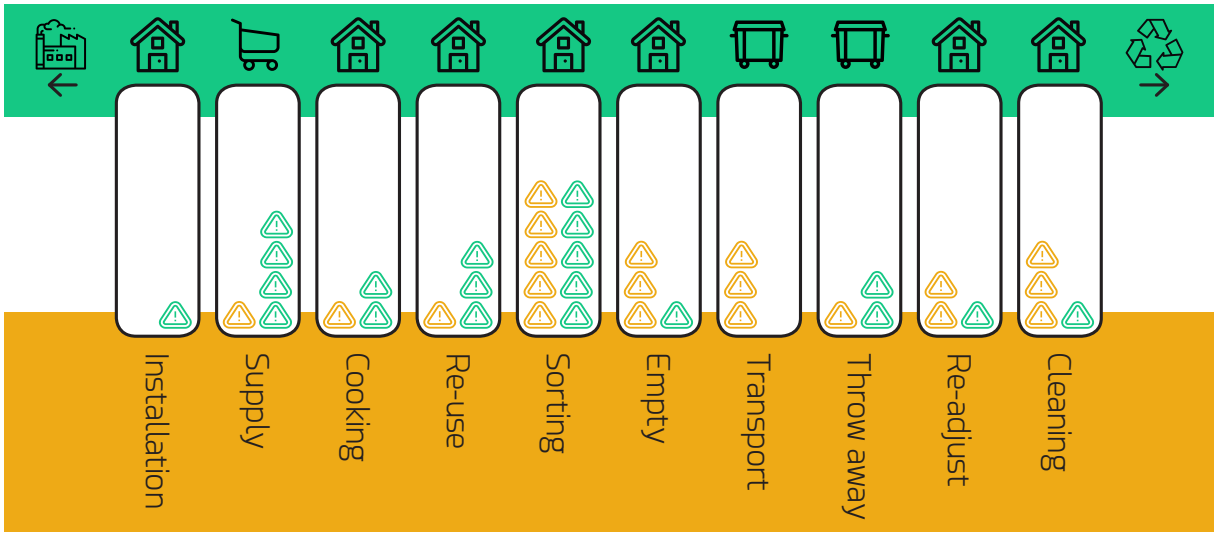


Fig. 14: User journey diagram

This state the main existing problems, being the starting to point to the ideation stage.

3.1 BROAD IDEATION

The ideation process was quite diverging and unstructured at the beginning, mainly exploring ideas that started to appear before, during the research.

Apart from this, an ideation workshop was organized together with more students researching in the project, and an adaptation of the 3 6 5 method was done, sharing opinions and discussing about ideas.

All the ideas were mapped in the user journey it was not surprising that activities with more potential improvements end up with more ideas. Below, the main ones:

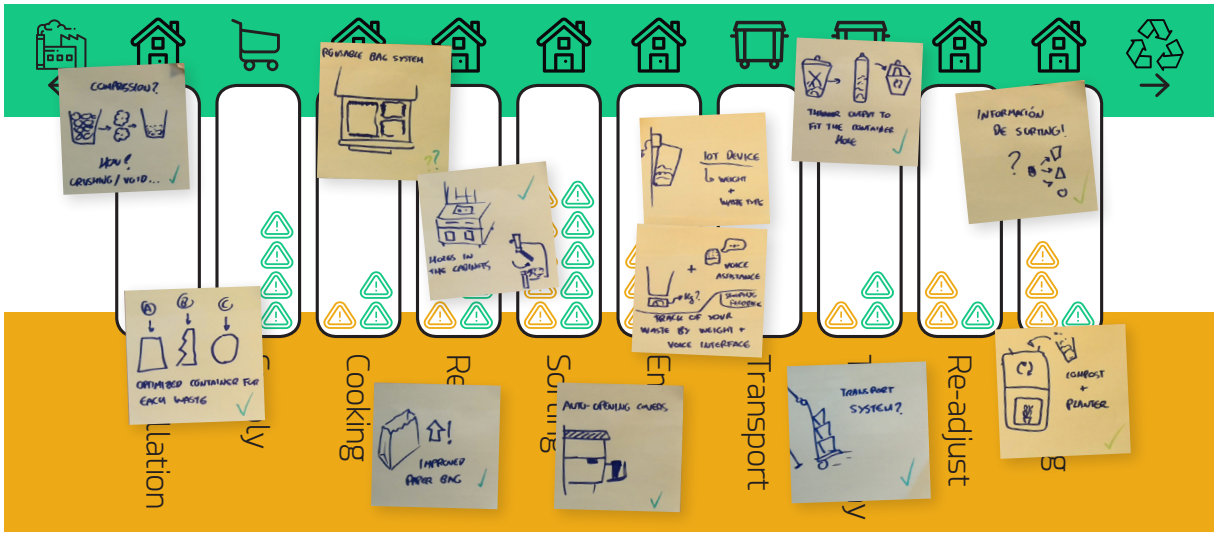


Fig. 15: First ideations

The different rough proposals were compared with the briefing objectives. It was noticeable that plenty of them were aiming problems related with the user experience, and, in fact, offering a smother experience is a way to ensure better recycling rates, however, it's more effective to offer loop closing products, being that their main target.

For these reasons, ideas with better circular potential were outlined. This doesn't mean that the user experience and the market requirements were forgotten during the ideation process, a truly circular product needs to care about people experience and profit to succeed.

3.2 TRACKING WASTE

The concept chosen for further ideation was a waste-tracking bin. The idea was simple, having three main elements, a container, an interface or way to communicate to the user and some kind of smartness to track and process waste data.

The concept selection was supported by several reasons:

Reducing is always better than recycling, source reducing is always efficient than recycling and apparently, domestic recycling is being done increasingly better in countries such as Sweden, and will be even better with the education of coming generations (Förpacknings & Tidnings Insamlingen, 2017). It's necessary to address new challenges.

In a world saturated with information is important to offer true valuable data. According

to circular economy experts, we desperately need to know what we buy, use and waste to improve our systems (Global kitchen, 2017). There are a lot of value is waste data and correctly managed, the big data of a whole community could be incredibly helpful for face sustainable problems.

The use of IoT and AI expect to grow drastically in the next years, going from $170 billion in 2017 to a $561 billion market in 2022 (Reply, 2018), creating a strong framework to integrate this kind of products and better consumer acceptance. In addition, it seems that the brain would be the brain of the house (Electrolux Group, 2019).

Fig. 16: Main concept explanation

There are some interventions already done, tracking waste working really well. Using weight sensors, South Korea government has reduced food waste by 95%, adding a little tax (Kim, 2019). Winnow, other existing solution in the hospitality sector that track the amount and kind of food wasted in professional kitchens, reduce a 50% the waste using weight and camera recognition (Winnow solutions, 2019).

3.3 FUNCTION ANALYSIS

The concepts was still too broad to further develop. A function analysis helped to figure out the different alternatives. All the sub-function come from two: sorting waste and creating awareness.

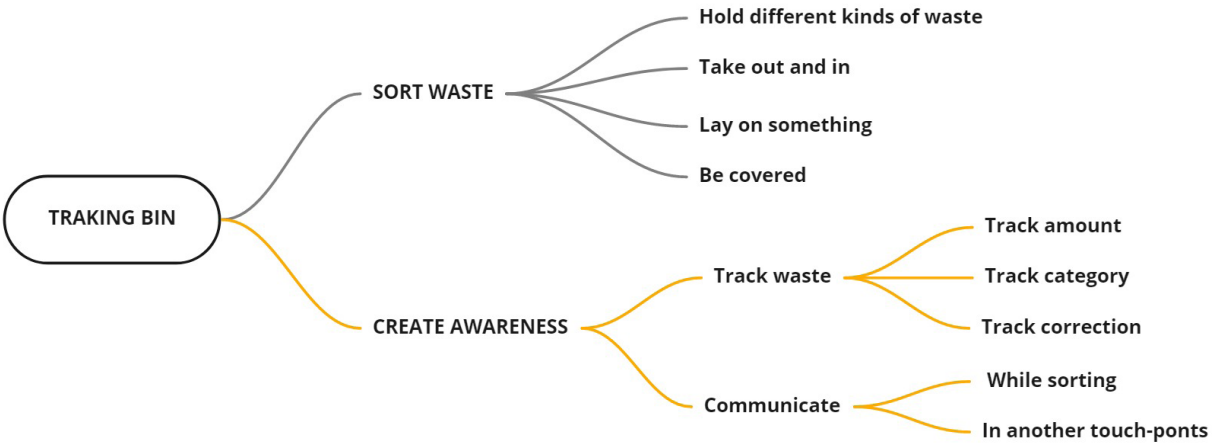


Fig. 17: Function analysis

3.4 MORPHOLOGICAL CHAT

Naturally from the sub-functions drawn, it came the necessity to define the components that would perform that action. The concept was still quite open and plenty of combinations were possible. Morphological charts offered a way to see the whole picture, but some research were need it, specially to see the market possibilities in tracking sensors and user interfaces.

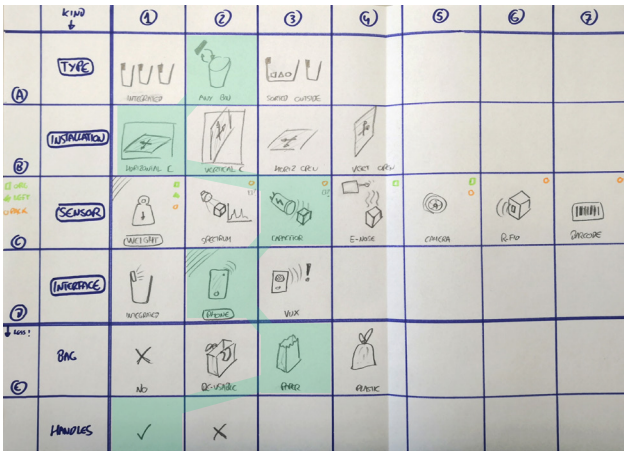


Fig. 18: Chart combination example

3.4.1 Data input (sensors)

All the existing ways were studied, taking into account the data generated, cost, possibilities and requirements to work in a kitchen environment.

- **Weight sensor:** the only mandatory sensor to have due to the fact that seem to be the only feasible way to have quantitative data (amount). It's called load cell and there are several sizes and accuracies. The generic ones are quite compact and cheap enough to be integrated, the main disadvantage is that do not give any qualitative data, and knowing the kind of waste is really useful to give more valuable feedback.
- **Spectral sensor:** materials reflect light differently, this is a science called spectrography. These sensors are becoming more affordable and are being used in other applications. A company called Matoha is starting to use them to sort different kinds of plastic (Matoha Ultrascience, 2019), and there are even smart phones with this kind of sensor, but the state of art needs to improve to be feasible in a domestic environment. Maybe more interesting to indicate the correct bin in street collection systems.
- **Capacitive sensors:** similar to spectral sensors but using the response of materials to electromagnetic fields, some researches have already test this to differentiate materials (Kirchner et al., 2008), but it's also a bit far to give the expected performance.
- **Electronic nose:** the alimentary industry uses sensors that measure volatile particles to analyse food's properties using AI. Its state of art have been analysed (Keller, 1995) and the potential to be applied in this issue seem far away also.
- **Image recognition:** with a powerful machine-learning's algorithm and a cheap, small camera is possible to determine elements. It's a well developed field and is feasible to recognise food according to Winnow's new technologies. With packagings could be a bit

more complex because the designs are constantly changing and that would confuse the system. For sure, it has some privacy issues.

- **RFID and bar-code:** this option only is only applicable to packagings and need public regulation to be made. RFID tags are being used in Amazon's supermarkets to buy without cash register. It's a good way to keep the material passport together with the product. The bar-code could be used to track the packaging generation with a straightforward action.

3.4.2 Data output (user interface)

In order to communicate the data and give data, user interfaces are need it, these are the appreciated options.

- **Integrated interface:** having the interface in the product adds limitations but is a good way to give direct feedback too. Could by done with lights, sounds, vibration or image. Using images the less energy consuming option are e-ink screens, displays that come in different sizes with reduced amount of colours (usually black and white). The advantage is that only uses energy when the image changes.
- **Application:** an mobile application seem a must for the system. Is need it to give more complex feedback and engage the user to be a better consumer. Could be also useful for the product installation or to create feedback in remote situations, for example, giving suggestions in the supermarket based on wasting habits. The app could work in different platforms: phone, tablet, computer in appliance's screens, which seem the next big innovation in fridges, being already integrated by Samsung with their family hub.
- **Voice interface:** with the huge spread of smart speakers and voice assistants and the improvements in voice recognition algorithms seems like the future will be more open to this kind of interactions. It has disadvantages, it's not comfortable in all situation a could be a bit awkward to speak with your bin, but could be easily installed as an Alexa skill and it's a very direct to get qualitative data about what is being wasted.

3.4.3 Chart combinations

More categories were added to the charts, representing the other sub-functions existing in the product, however, it became a bit irrelevant defining concepts, being the sensors and the interfaces the determining factors.

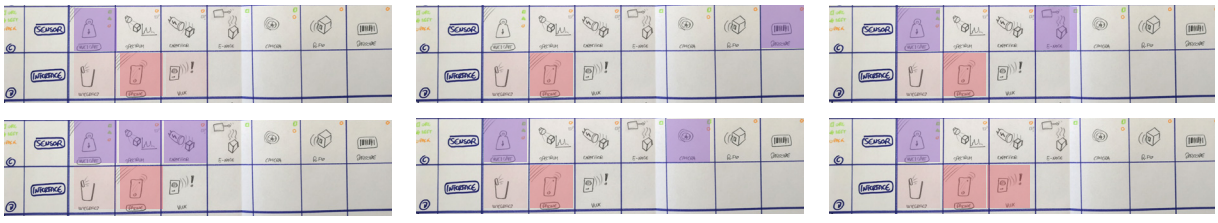


Fig. 19: Final chart combinations

- **Weight-based:** the simplest version, consisting in one scale underneath the bin sending data to an application. Being possible to do the same with a hanged version, using bags.
- **Supermarket-based:** only applicable to track packagings, using a bar-code reader to generate information about every element.

- **Smell-based:** the opposite, only applicable to food waste, using e-noses to track the kind of waste thrown. Together with and scale could track quantitative and categorical data.
- **Material-based:** spectral and capacitor sensors together could generate data to be compared with a reference and determine what is being thrown. Weight sensors would help with the quantity.
- **Camera-based:** Using a camera and machine learning, also with weight sensor.
- **VUX-based:** doing the categorization using user's responses and the quantity, as well, with a scale.

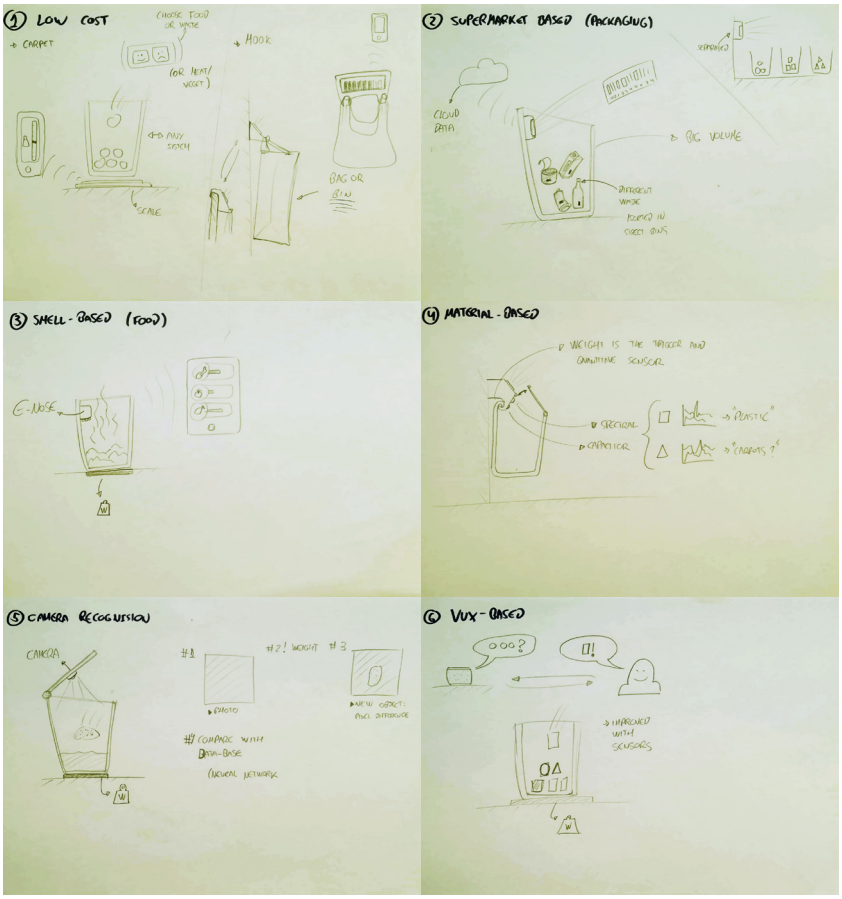


Fig. 20: Concept selection from the morphological charts

3.5 CONCEPT SELECTION

Choosing a variant to keep developing wasn't intuitive, having a lot of advantages and disadvantages in each solution. A selection method was applied to simplify the choice, defining checking parameters, giving value to them according to their influence and rating one by one. The parameters were divided in the three categories that a circular product should accomplish: people, profit and planet, or usability, feasibility and circularity.

PROFIT (Industry)		LOW COST	BARCODE	E-NOSE	MATERIAL	CAMERA	VOICE
PRICE	30	5	2	1	1	3	3
SCALABILITY	10	4	1	5	5	5	5
COMPATIBILITY	20	4	5	1	3	1	4
REGULATIONS	10	5	1	5	5	2	3
FEASIBILITY (SoA)	30	5	1	2	3	3	4
	100	470	211	182	223	213	284

PEOPLE (UX)		LOW COST	BARCODE	E-NOSE	MATERIAL	CAMERA	VOICE
INSTALLATION	10	5	5	2	2	1	4
INTERACTION EFFOR	20	5	2	4	2	4	1
INTERACTION REP	30	5	1	3	3	4	1
SORTING	20	5	3	5	1	5	5
MOBILITY	20	4	5	2	3	1	5
	100	480	280	330	230	330	290

PLANET (CIRCULARITY)		LOW COST	BARCODE	E-NOSE	MATERIAL	CAMERA	VOICE
OWN-IMPACT	10	4	5	3	3	3	4
AWRNS. QUANTITY	30	3	3	5	5	5	5
AWRNS. QUALITY	30	1	3	3	4	4	4
CORRECTION	10	1	5	3	4	4	5
MODULARITY	20	4	5	2	2	2	4
	100	250	380	340	380	380	440

Fig. 21: Weight based selection

The results shows that the weight-based seem the most suitable concept to be implemented kitchens from a practical and experiential point of view. However it has less potential to close big circular because the information generated is less valuable.

The final choice was to go for the simplest solution, only using weight sensors and an integrated screen to receive direct feedback, working together with an app and seeming the

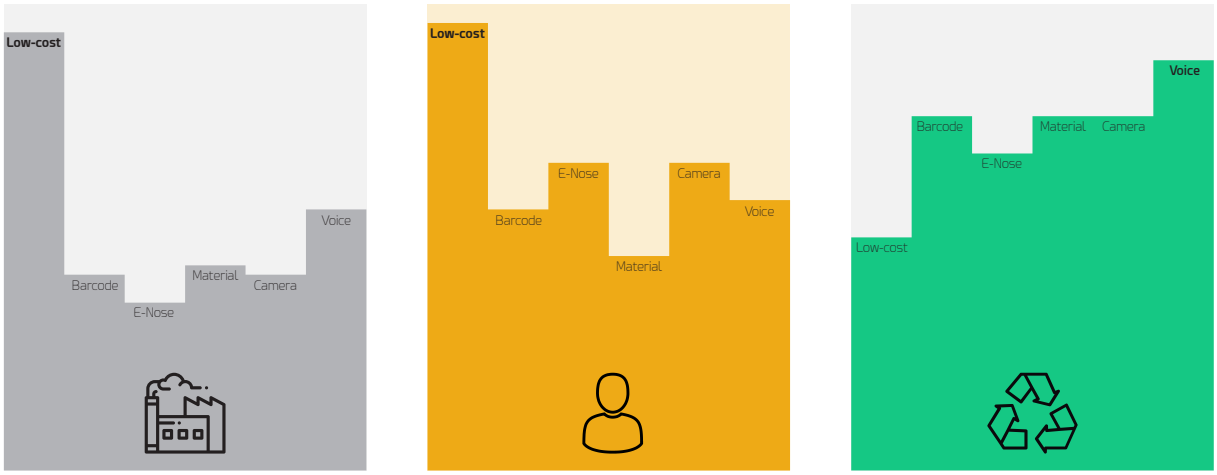


Fig. 22: Selection results

best way to launch to the market a product category never seen before. Nevertheless, it will be developed with the possibility to be updated with voice interface, and camera recognition technologies seem a promising way to get better data in some years.

Fig. 23: Concept choice for further development

4.1 FISH TRAP METHOD

After defining the concept the ideation stage turns into development. To give an structure and order the followed method was fish-trap. With a diverge vs. converge structure, it alternates it alternates design iterations with evaluation, going step by step, from the basic structure to the small detail. The focus was set on hardware, the interface development will be explained later.

4.1.1 Topological level

There are several ways to combine the components, the first ideation explored the different layouts. Playing around with the scale, the user interface and the structure.

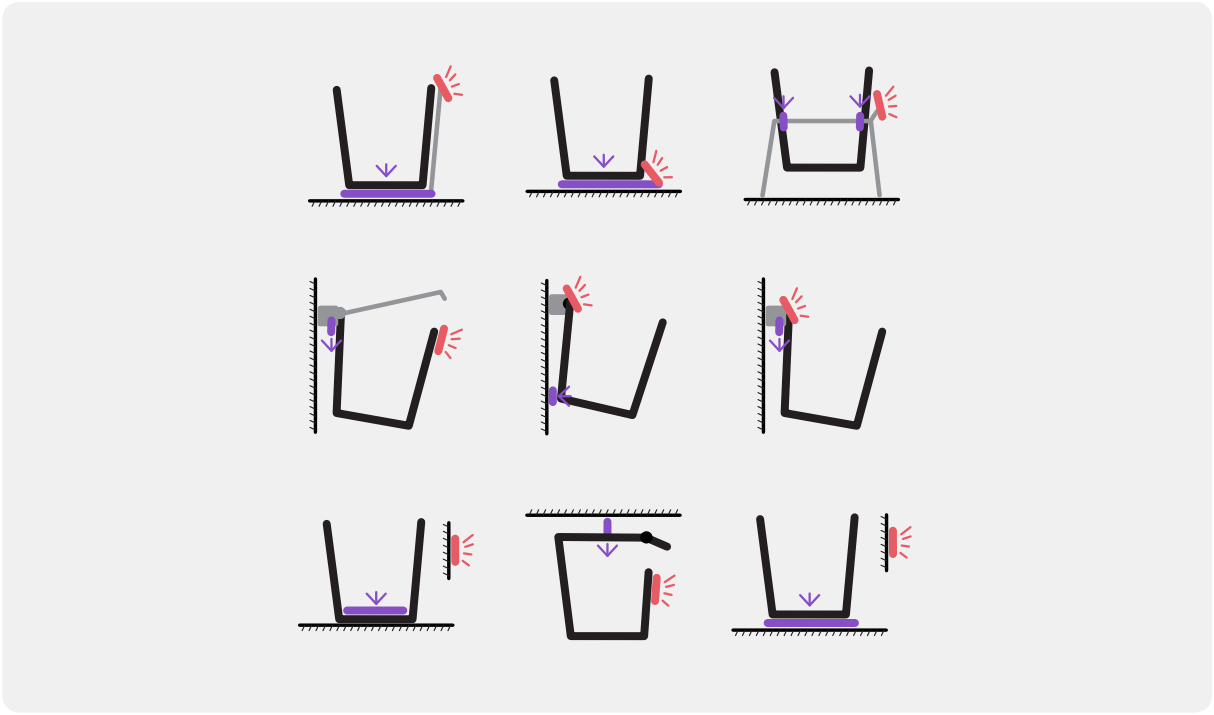


Fig. 24: Topological explorations

On the basis of this, three concepts were proposed, the advantages and disadvantaged were discussed with external feedback.

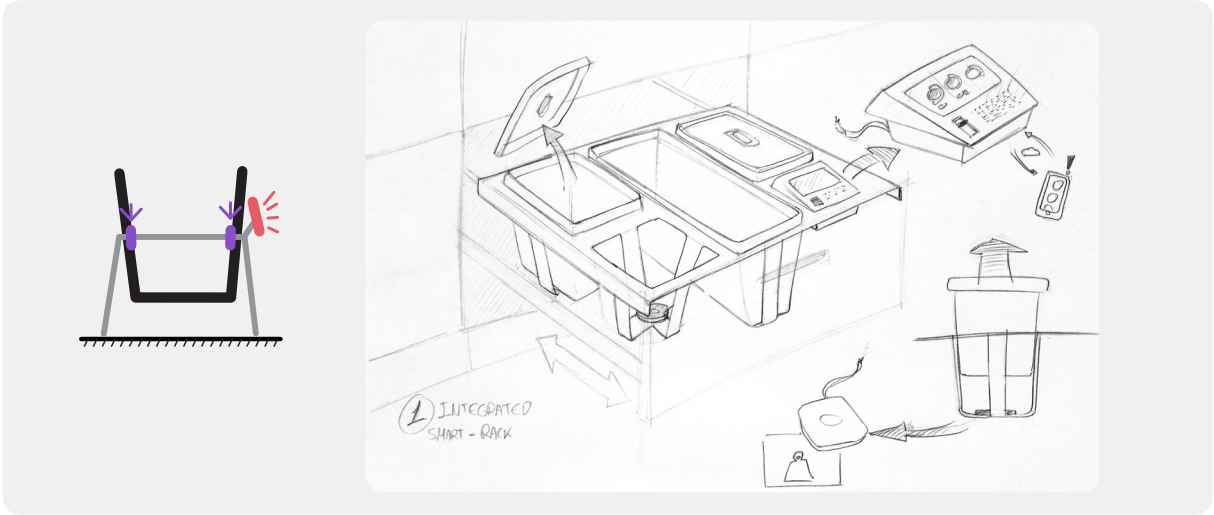


Fig. 25: First topological concept

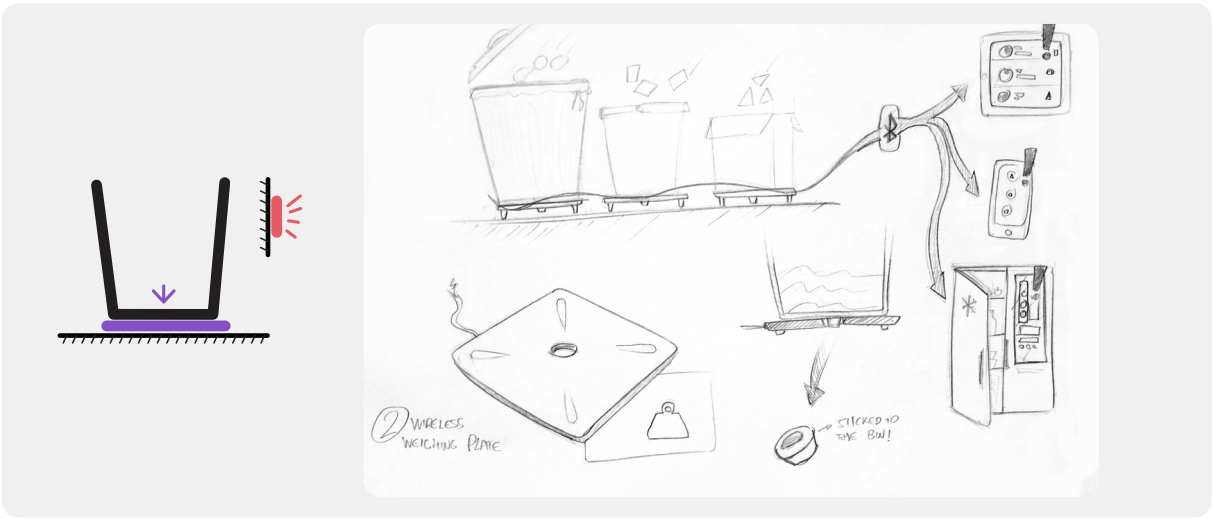


Fig. 26: Second topological concept

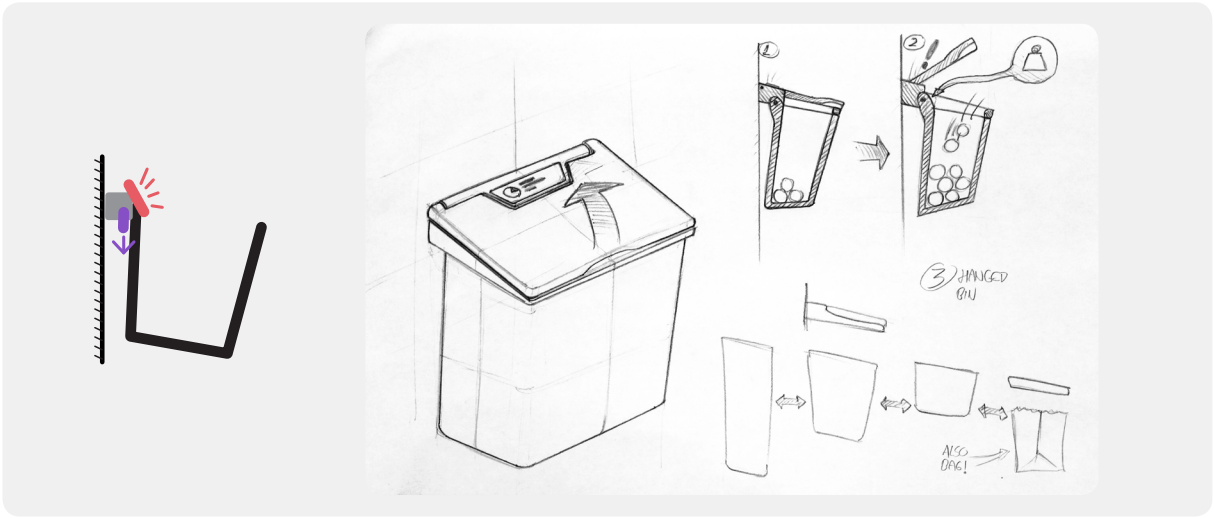


Fig. 27: Third topological concept

The selected concept is intended to be used in drawer-based sorting systems. It seems the easier to integrate in short term period, using the existing framework of the systems could e seen as an complement. The main disadvantage is that only aims to target groups with high level equipment in their kitchens and this reduces the market, however, according to the survey, the most interested users in getting waste-saving solutions are the ones with that kind of systems and all the kitchen's furnisher are betting on that kind of solution.

Vedum's rack was taken as a reference, taking measurements of its in the living lab and intending to add it to the system without too much changes in the current design. Nevertheless, it could be easily adapted to other kind of buckets form other companies, or even isolated bins with a proper rack. For example, Ikea offers a mid-level solution that hang to bins in the cabinet wall with a slider, allowing user users with other kind of kitchens to improve their usability with a simple installation. This product could fit with this target group too.

4.1.2 Typological level

The typological structure was defined, having the bin suspended over a rack. However, the components and pieces still had chance to be combined better, ensuring easier installation, use, compatibility with the system and material savings.

The proposed concepts took the form of a frame, placed in between the bin and the rack, creating a movable product, more flexible and adjustable. The screen was combined with the frame, keeping all together.

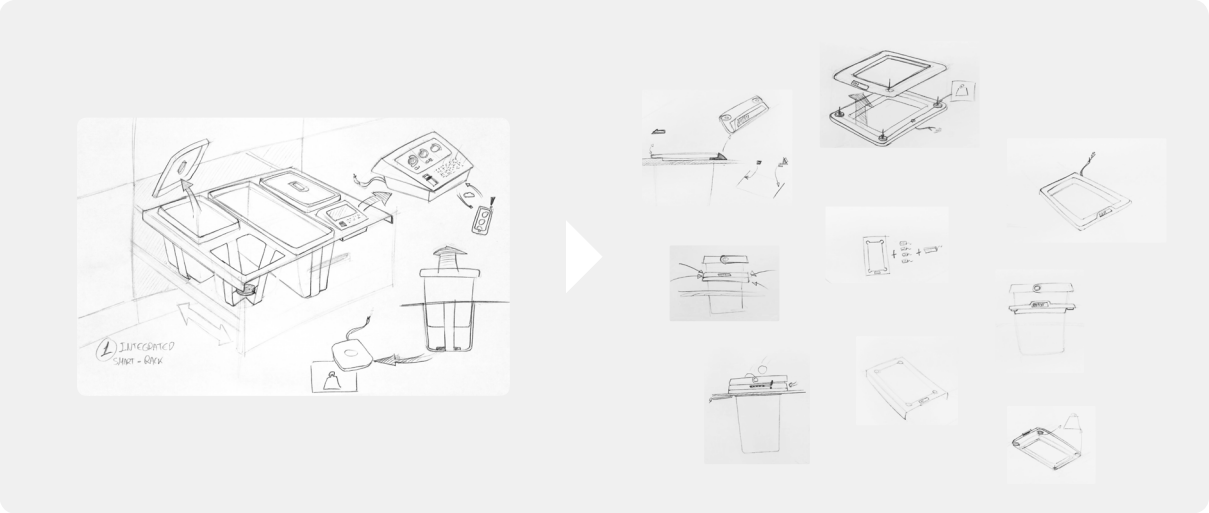


Fig. 28: Typological exploration

As can be seen, the concepts were quite similar, and several doubts appeared regarding further resolution. Apart from online searching, and interview with some experts in the interaction field was incredibly helpful to clarify matters. Peter Ljungstrand and Niels Stor Swinkels researchers in RISE. Below, some of the topics discussed.

Both agree with the components choice, ensuring that load cells and e-ink screen could be really cheap in big scale, though the screens could have problems with bad light conditions, needing back-light.

Other remaining decision was the power supply, considering cable connection to the net, induction and batteries.

- Induction was discarded because currently it's intended to really close transmissions and doesn't expect a big change.
- Net supply is the most sustainable option, but it implies a quite complex installation and transformers, because of kitchens are still not designed to hold that kind of devices. It's possible that future electrical installations would have room for direct current nets.
- Batteries, thought not being the most sustainable solution due to their toxicity, is the best way to supply energy to the frame. From a user point of view, it's easier to install and using e-ink and components with sleeping mode could last even six months without charging.

The experts had more opinions regarding connectivity, security and improvements. As not being relevant for the current development, will be mentioned later, in the discussion's section.

4.1.3 Morphological level

The morphological stage address more detailed aspects as the measurements, assembly, manufacturing process, form details and expression. It started taking all the measurements of a Vedum's cabinet with waste sorting system in the drawer. Duplicating the whole cabinet

in CAD helped to iterate quickly and test dimensions without making a lot of cardboard models.

Dimensions

As have been appreciated in the research stage, space saving is key, so the first step was to find out which was the minimum size needed to fit the electronics. The first try was to design the frames with a "puzzle" form, although it saved a few centimetres, the result form wasn't too aesthetic and mechanically resistant, so a simple rectangle worked out better.

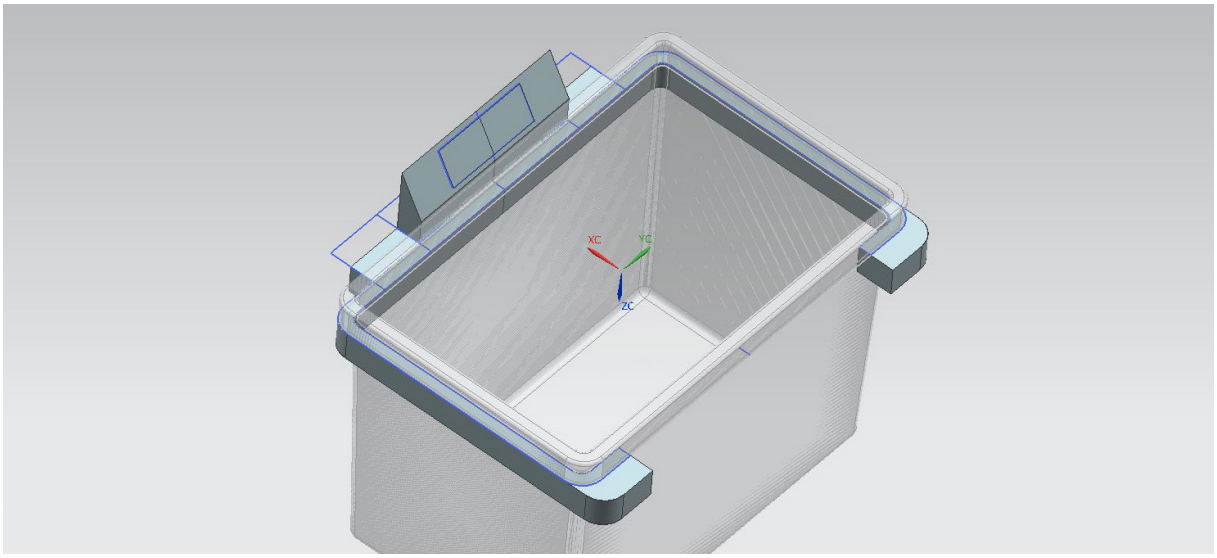


Fig. 29: CAD dimensions exploration

Assembly and materials

The design of the frame body was intended to be done for injection moulding, reducing part amount. The material could be polypropylene as being the most common and versatile material in the industry, having very good recycling rates with the correct management. Leaving potential to use bio-plastics too. It's formed by a main body, four scale pads and a cover to protect the electronics from liquids, dirtiness, etc.

The electronics inside were integrated allowing comfortable access for the assembly and intuitiveness for the disassembly, opening the cover and pulling the whole circuit together. A port to charge the batteries was include, together with an entry for a microphone and a air pressure sensor. The microphone could be eventually used if the system adds voice interface features and the air pressure to notify the system when is being open the drawer, leaving it in sleeping mode when it is closed.

Form language

The expression tried to be as simple as possible without being boring. Details were added using smooth and subtle transitions, keeping edges and corners rounded to ensure easy cleaning. The colour palette is a set of dark greys, the intention is to fit common bins' aesthetic and leaving it quite neutral to not become obsolete when trends change.

4.2 USER INTERFACE

The user interface design was done in parallel to the hardware, ensuring that both work together without causing problems. The chosen concept uses one integrated screen for each kind of waste and an app to hold more complex data and interactions. Due to time constrains the only fully developed is the screen, taking into account the app features. UI design is not my field but it was important to explain draw the next steps for further development.

4.2.1 The basis

The primary function of the interface is to track waste, however, the real goal behind that is to improve wasting behaviour closing user's circular gaps. The design had to be structured based in some kind of behavioural changing technique, and gamification models were chosen as a reference, existing very good habit creation examples in the market.

Gamifying and experience doesn't necessarily mean to transform an app into a game with levels and scores; is a method to trigger user conduct using behaviourism's psychological foundations with a positivist scope, creating positive and rewarding experiences to hook the user.

Some key elements need to be present to create the gamification (Teodorescu, 2019), all of theme were defined in order to design the interface:

1. The goal

The goal has to be closing circular gaps, improving users' sustainable performance. All the design decisions should aim to that.

2. The user

Could sound a bit obvious, but the user needs to have a bit of interest and motivation to achieve the goal. The design would support it and increase the motivation and engagement, but something have to light the first spark. According to the trend, social awareness is constantly growing and could be enough to start. A well studied marketing champaign would definitely help.

3. The rule

In order to achieve the goal, some effort must be done. This is made defining rules to follow. The rule has to be clear and simple,

The chosen rule was to achieve a number of kilograms per week, reducing gradually as the user improves its behaviour. Weeks were chosen as the time frame because they are easy to remember and according to food waste statistics in Sweden the average per person is around 1.5 kilograms, so it's a good number to handle. Tracking daily would be too variable and monthly too much time to receive feedback.

An existing problem of tracking using time as reference is that waste stream is not perfectly constant all weeks, could vary if the user eat outside, for example. In this case, the air

pressure sensor could help, notifying to the system when is not being used to readjust the week target.

4. Feedback

Process feedback is key to show to the users how well are they doing in the according to the target that have been agreed with them. Here is were the integrated screen is more useful, showing direct feedback every time something is thrown, giving importance to every item disposed.

To keep it simple, the screen will only display the weekly target and the current state according to that target. Long term feedback and other data will be given in the app.

5. Rewards

Rewards are a good way to highlight positive behaviours, keeping the user engaged throughout the process to the goal. Could be any kind of point, trophy, badge, leaderboard, etc.

To not overwhelm the user with too much information, the rewards would be just shown in the app, preferably receiving them daily, to create an extra interest for the user to know how is he/she doing and be more aware. Not only checking the weekly target.

6. Motivation

It's the reason that moves users towards their goals. Boosting it means more engagement. It's powered by intrinsic factors (curiosity, pride, responsibility, etc.) or external (grades, money, etc.).

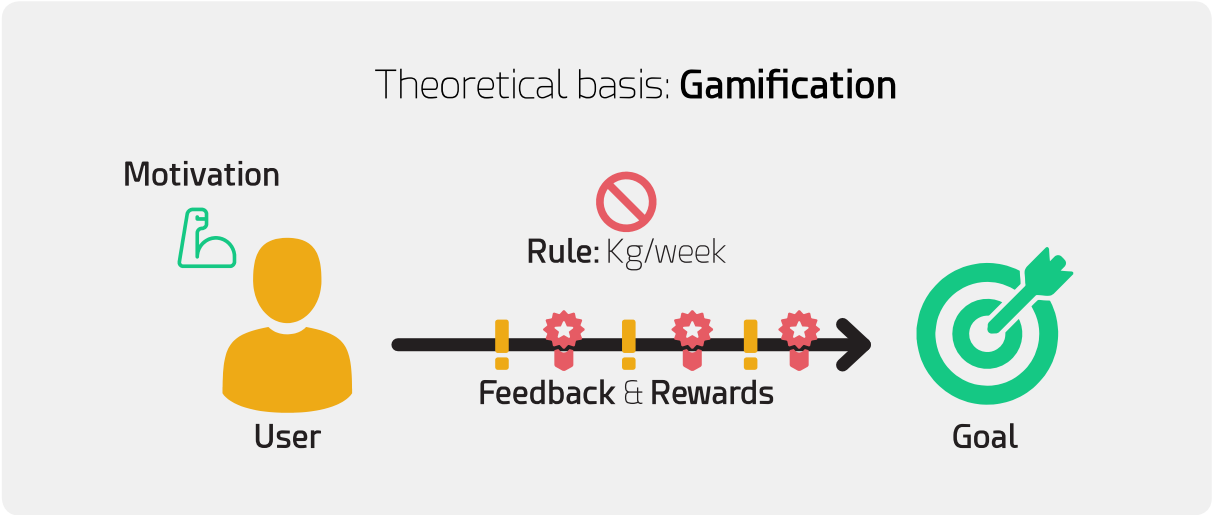


Fig. 30: Gamification structure

4.2.2 Integrated screen ideation

Limitations

The chosen model was the one used for supermarket prices, being small enough to save space but big enough to be seen from a reasonable distance. Nevertheless, big figures are

more inclusive for people with eyesight problems, so clarity and size was an important design driver.

The energy efficiency of e-ink screens came with some downsides. It works with a limited amount of colours, being black and white the cheapest option, allowing greyscale tones combining both. In addition, their potential to display animations is limited due to a low frequency, being possible but not as smooth as regular screens.

Design choices

The design's main function is to communicate the rule and the feedback, rewards and motivation will be handled with the app. Several design decisions carried out this:

- **Number and figures:** Quantity will be shown both with numbers and figures, so the real quantity is always clear but the graphics support a quick communication in a glance. Fitting different kind of perceptions.
- **Zooming:** In order to create more awareness and stronger feedback, process indicators intend to be show in a bigger scale, "zooming" the changes.
- **Tokens:** Intending to simplify the kilogram's count, the idea of token was added. Representing each kilogram with a recognisable form, giving a more material feeling to the process, instead of just statistics.

After some iterations, three main design paths were explored, using dots (surfaces), bars (lines) and loops (circles); using different methods to represent the target (rule) or the process (feedback). Below the outputs.

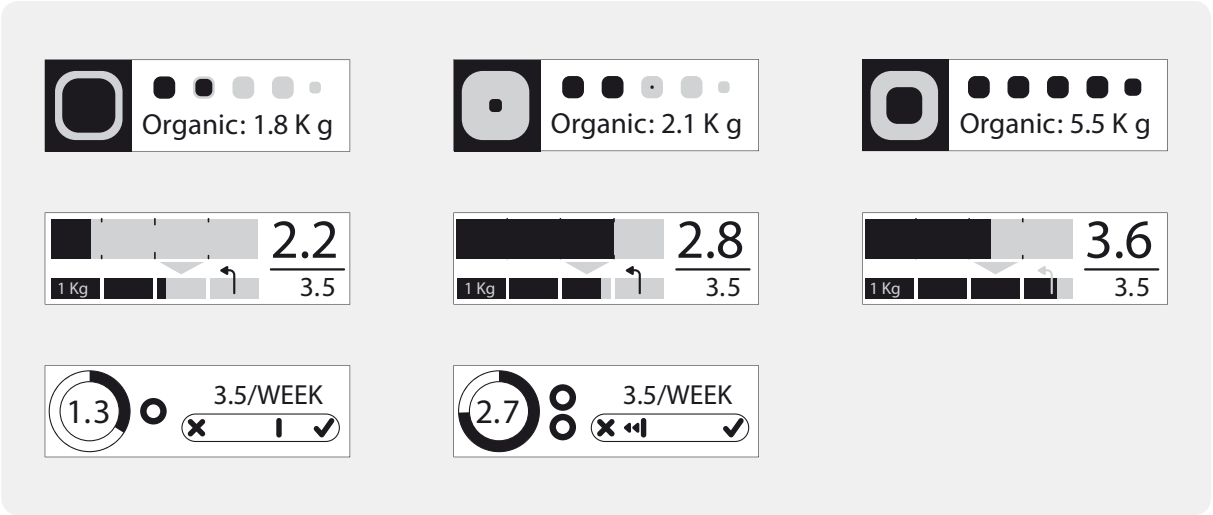


Fig. 31: User interface concepts

4.2.3 User testing and feedback

The three concepts were tested to check the intuitiveness. The prototype consist of a cardboard frame with room to put paper prototypes representing an interaction process. It has limitations without any app explanation or animation, but it showed some important problems when users tried to understand it. They were asked to throw something on the bin, observe what happened, and repeat, using the three versions.

They had problems understanding the target graphically in the three concepts, as well as the "zoom" concept. After a feedback session with colleagues, some ways to solve this problems were proposed, defining the final design.

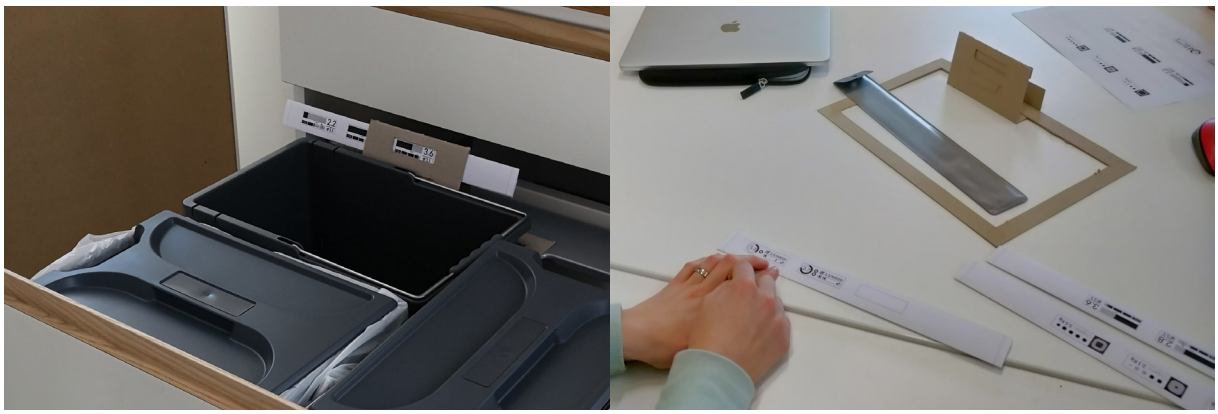


Fig. 32: Paper user testing

People is more used to watch process bars, so one simple bar would be easier to understand, leaving the tokens for the app and making some changes in the numbers. Adding more decimals and highlighting the digit change with animations. A third red colour was added to enhance when the target is exceeded.

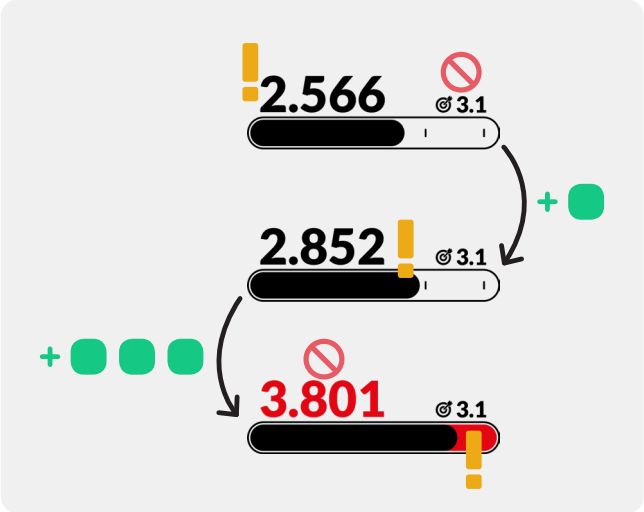


Fig. 33: User interface final concept

4.2.4 The app potential

Has have been mentioned, there wasn't time to design the app, but has been taken into account to be correctly integrated with the frame. Drawing the utilities and recommendations for further design.

It will be used to install the frames, only using Bluetooth to connect the frames with the WiFi the first time, matching each frame with a waste category.

This process will be used also to ensure a correct understanding of the integrated screen and set up the user profile, agreeing on the target and filling the family profile (members' number and basic demographic info).

Apart from that, the app won't disturb apart from weekly notifications that could be disabled. It's important freedom to the user to engage in the challenge or not, gamification works

better when the subject have freedom of choice and negative behaviours are not punished (Teodorescu, 2019).

Apart from the commented features, the app should offer more: engaging users to be better wasters, offering more data, statistics and configurations, without overwhelming.

Optional but powerful

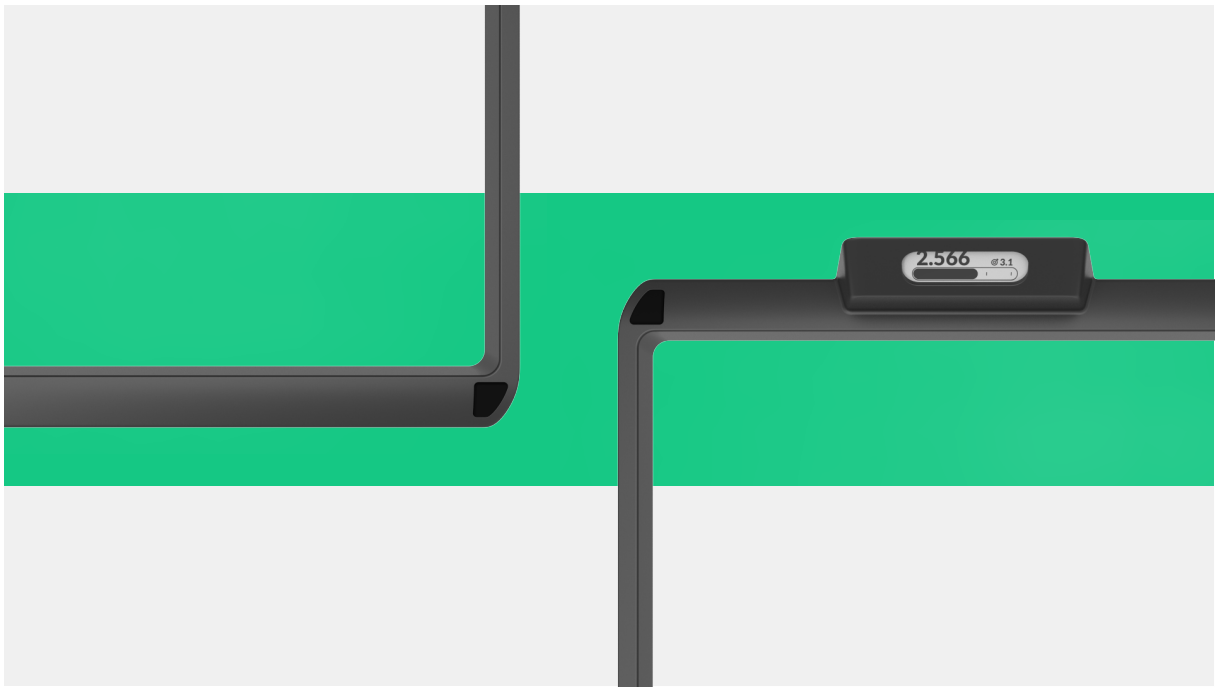
Weekly feedback is good, however, showing the evolution over moths could be interesting, or showing big quantities creating visual impact.

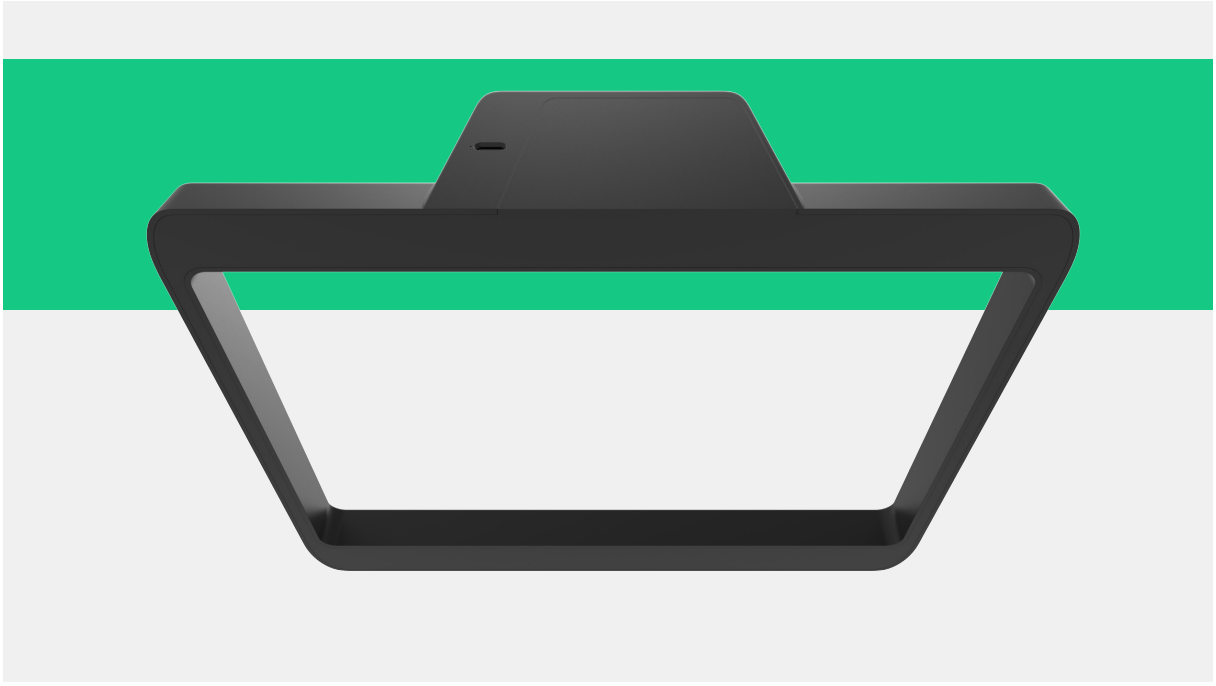
A concept that didn't work out in the small screens could work in this interface. Representing each kilogram as a simple geometrical form and giving them gravity is a fun and intuitive way to be aware of weight, allowing balance comparisons.

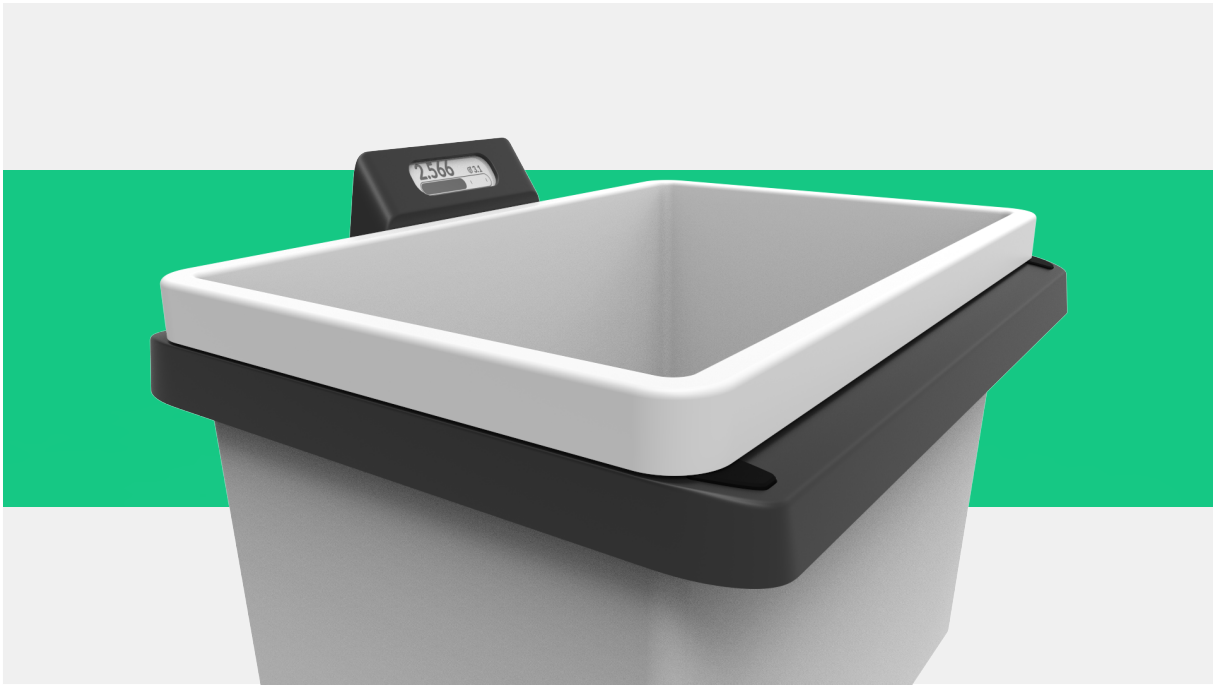
Offering a reward system could be a really useful way to make the experience more fun and rewarding, increasing the motivation.

Something powerful about digital products is the customization aspect. Based in the weight data and the user reaction to questionnaires or options, the system could be adapted to work with each kind of user. Fostering different kinds of rewards or motivations.


2.566


2.566





6.1 LIFECYCLE

Yes, the whole product's intention is to close circular gaps, however, is it closing more gaps than the ones that creates? Well, it's difficult to predict and it depends on several internal and external factors, but personally, I would say yes.

6.1.1 Material choice

Polypropylene was chosen because is the most used plastic in the industry and it has a big recycling infrastructure behind, providing possibilities to avoid virgin plastic in production and recirculate the frame when its life ends.

Anyway, as its made with injection moulding, it has the chance to be made with other new polymers, bio-composites based in wood for example, or future ones. This shouldn't mean a problem.

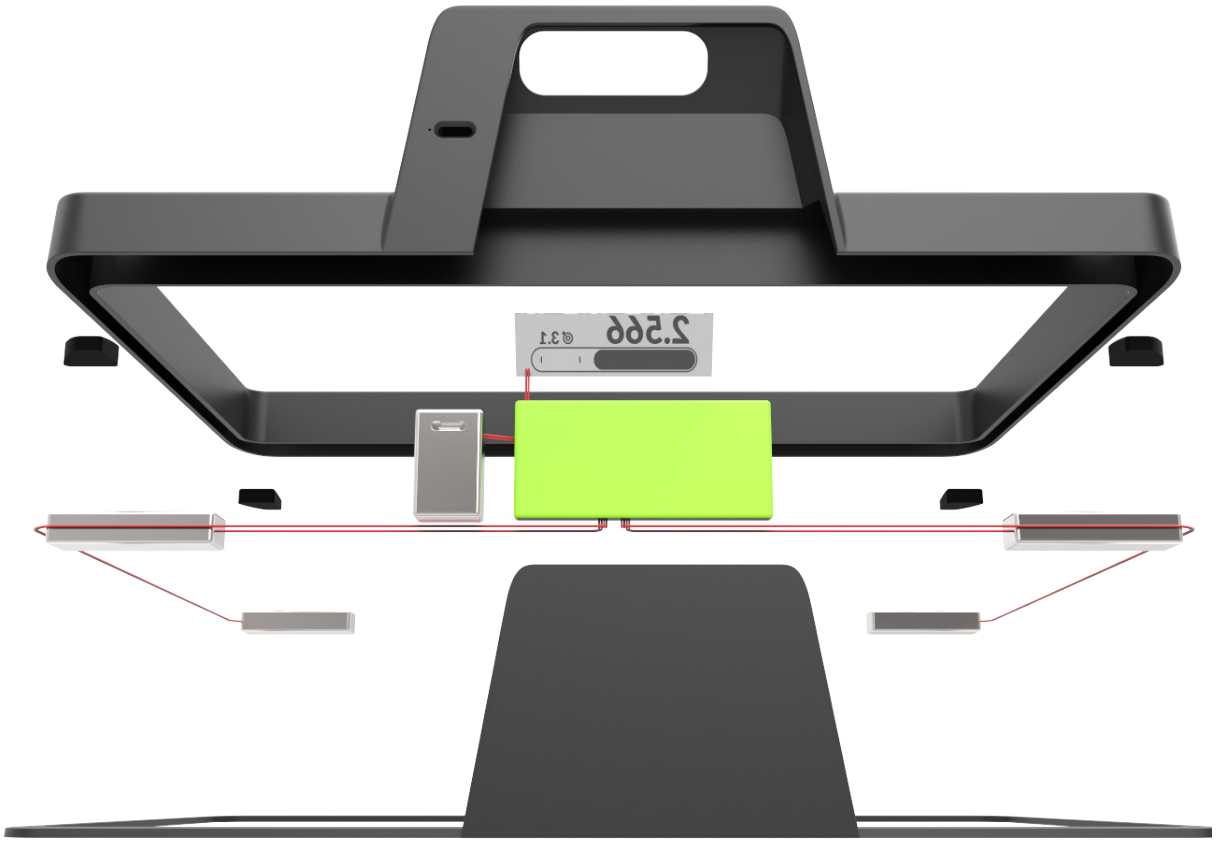


Fig. 34: Exploded view

6.1.2 Electronic components

The electronics were chosen to reduce energy consumption, being really efficient. Their main impact came from the recycling process, so the frame body keeps all together, assembled with snap fits, avoiding screws and glue and facilitating easier replacement in case of fault.

Nowadays, the electronics' impact depends strongly in the country recycling infrastructure. Normally it will be separated from the plastic, shredded, sorted and melted into different metals but the ideal model is to reuse the electronics for other purposes; the e-ink could be

used in a supermarket to display prices for example. The design provides support for both models.

The main weakness is the battery, being quite complex to recover and toxic. It seems the best option because net plugging takes a lot of flexibility and simplicity to the product.

6.1.3 Obsolescence

A big advantage of digital and connected products are their opportunity to be updated. If the user change or has different needs it could be fixed easily. Connectivity also allow better communication with the producer, improving the repair service and allowing a direct contact medium if the user wants to terminate the service, ensuring component recovery with this feedback loops.

It's more complicated when it comes to hardware, being modularity, adaptability and standardization the main approaches to solve it. Since bins are varied in forms, brands and sizes; standardization is impossible to attend form a designer point of view, so it's better try to be modular or adaptable.

The frame is something isolated from the bin, module could be installed, replaced or retired without altering the sorting system. Besides, it's upgradable, so the users could buy more to track more different waste streams, or could be reconfigured if the recycling infrastructure improves and we have to sort less.

The main problem here comes when the user or the company decide to change the system, becoming instantly obsolete. In the worst case the material could be recycled, creating a new frame form but reusing the electronics, but better solutions could be found.

A possible solution is to separate the screen form the frame or using other integrated screens in kitchen appliances. One comes with a energy supply issue, duplicating charging problems, and the other could break the instant feedback link, so it has to be explored and maybe the situation gets better in a nearly future.

6.2 PROFITABILITY

Okay, it's closing loops, but would people pay for it? Would it create benefits in a company? Difficult questions to answer too, but let's see their strong and weak points.

6.2.1 Business model

Designing a business was too much for this project, but the product have been designed to support the change into circular and open ownership models eventually. Connectivity and sensors create useful feedback loops and the target group for this product would probably be with this kind of proposals.

Under my point of view, it should be a B2C product. Sustainable responsibility is still a personal choice, and the user must want to use it to really be useful. There aren't any cost

estimation, but shouldn't be too expensive for the average user considering the simplicity of the components.

During the development, a lot of colleagues recommend me to explore the potential in B2B models. It was rejected, afraid of the consequences of forcing the user to use it, cheating or disposing waste in wrong places. Nevertheless, without any doubt, could be really interesting to explore its integration into house owners, public services, or even companies that are already counting waste weight to write sustainability reports.

6.2.2 Marketing

Such an unknown and new product like this won't be easily sold putting it in a shop shelve. Consumers need to understand its function and be convinced by its advantages. A correct marketing campaign is need it, as well as the development of an strong brand.

Strategic branding is a really powerful method to add create an emotional link between the product and the consumer. Design a brand with a holistic approach would be key for the success of this product.

Another improvable aspect is the form language. With the branding the product's form language would be much more coherent, matching the real customer values. The existing one lacks in meaning, aiming for neutrality and functionality.

6.3 EXPERIENCE

Apart from sustainable and profitable, a product have to be useful, delightful, and intuitive. They must provide a positive experience to people to carry out their experience. The design process take all these aspects into account, but as an interactive product under the scope of industrial design, further research and testing in terms of interaction design is need it.

6.3.1 App and user testing

The app is a key part of the experience, supporting and augmenting the interaction. This design process have to be complemented with a thorough UX and UI process. Having the complete system prototyped would allow to test the whole product experience for the first time.

In my opinion, will be very important to test this with real user with real routines in real kitchens, sorting waste, making mistakes and being human. It's impossible to know if the product will work until the whole interaction is tested and iterated properly.

In order to ensure a flawless product, the development process should have been make co-working with interaction design professionals, but it's not a big issue, the product is only in paper, could be still modified based on users tests.

6.3.2 Installation

When it comes to hardware, the installation experience is quite straightforward, just adding the frame into the existing product, however, it's far of being perfect. It's easy because in

intended to only one kind of waste bins. In order to increase the potential target group the product must be adaptable to more kitchens, bins, set ups, boxes, bags, etc.

Betting for modularity and customization could fix it, but could ruin the product performance too. Definitely, a interesting issue to explore. Performance for the a few user or customization for everybody?

6.3.3 Data management

Quantitative data

The current solution, using weight sensors, only generates quantitative data for each waste stream. This data is a simple way to create feedback without overcomplicating the hardware and the interactions.

When it's displayed, it's not really showing the real impact of what we throw away. One kilograms of beef is vastly more harmful for the planet than a potato peel kilogram. Anyway, it's still a very intuitive way to communicate waste, creating much more awareness than a simple container, as current sorting systems are.

Adding categorical data

Even thought the my vision of quantitative data is optimistic, I truly believe that categorical data will elevate the product potential incredibly, multiplying the number of applications. Categorical data means that you not only know that amount of matter entering the bin, also the category or kind of product/food. This information has much more value, being plenty of new feedback opportunities:

- **Real carbon footprint:** mixing weight, category and a database could be possible to track with environmental impact units instead of weight, communicating what our decisions mean with hight fidelity. Now users will definitely notice a huge difference when meat is being wasted, instead of vegetable peels; education in sustainable choices.
- **Correct recycling:** the system could inform the users when something is sorted wrong, increasing recycling rates.
- **Recommendations:** the information together with and AI could be give useful recommendations, supporting our daily decisions. For example, could recommend what to buy or in which quantity based on wasting behaviour, reducing costs and overconsumption. Could create synergies with the new developments in smart fridges, cooking guides, etc.
- **Big data:** if the use is extended and there is a big sample, common data could be used to create useful statistics, clearly mapping our consumption models and waste loops. This information could be used to improve the efficiency and effectiveness in the recycling infrastructure, selling points, producers facilities, etc.

Development paths

Taking the research as a reference, there are two main feasible ways to create categorical data:

- **Voice recognition:** today 600 million people worldwide use voice-controlled assistants once a week (Reply, 2017). This, together with the growth of the smart-speaker market, is building a new way to interact and people is more open to use it. If the user already have an smart speaker, a new skill could be installed to work together with the frame and the app as they have been designed. However, must be something optional for really engaged users, it requires too much collaboration an responsibility.
- **Image recognition:** cameras are cheap components and the science of image recognition algorithms is a very active field today. During the design process this technology was valued and seemed powerful but a bit futuristic, choosing simpler paths.

  Nevertheless, in the last stages of the design some insights shown that is more than feasible. Professional researchers in RISE were very optimistic about the performance of this system. This was totally proved when Winnow, a company offering weight tracking solutions for restaurants, launched a solution based on this, saving big amounts of costs and food waste with customers as big as Ikea restaurants.

  Seeing that has already bee developed in big scale, could be really interesting to explore the adaptation to domestic environment, with the consequent implications.

Privacy implications

Managing such an amount of personal data takes a big responsibility, preventions should be implemented since the begging. What we waste is a big reflect of what we do and what we buy. As well as is convenient to improve the circular economy, could be used for marketing and publicity purposes, or even to track how healthy are the habits of life insurance customer. Violating user principles and giving a very bad image to the company

In order to avoid infiltrations, security costs must be planned in the budget, and some design decisions could help, for example, keeping the information locally and only sending when a physical interaction occur with the product.

Other possible approach is to inform to user that the information will be used for publicity purposes, yet the product price would be reduced, or zero (as well as Google do).

It's a complex problem and any decision should be meditated before launching the product.

6.4 CONCLUSION

The design journey followed in this project has been extremely challenging but really educational. Solving such a problem as household waste require more than an bachelor thesis, my solution lacks on time, proffesionals and testing, however, it can open new visions regarding the same topic. We live in the data society, and we have to use data power to solve complex problems.

The project has teach me a lot about sustainability matters, broad research processes and collaborative design. Usually, the methods involving more people to create feedback were the most insightful. If I would be starting again, I would focus in the beggining to close the domain much earlier. Too much time was spent in the beggining collection information that

was not used later. Doing the documentation during the process would have been much easier for the writing stage.

As a designer, I don't think that my product is ready to be developed, marketed and solve the problem; it needs to be rethought.Nevertheless, I believe that the research and vision has potential to cut out waste and change how we behave and consume today. I am expecting to see future works in The Circular Kitchen Project, elevating the idea into something better, changing our kitchens to close the circular gap and improve our planet.

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1. PROBLEM STATEMENT

2. RESEARCH

3. IDEATION

4. DEVELOPMENT

5. RESULTS

6. DISCUSSION

7. REFERENCES

8. APPENDIX

For the survey data management and analysis, a specific shoftware called Q was used. But the data was collected using google fonts. All the responses are puclished, access clicking the link below. This information is open, if you need someting in special, contact to my email (halcmr18@gmail.com), I will be pleased to help you.

https://docs.google.com/forms/d/1r8StWGRKNPnx9_KuhDfZoBPuFcjK9TKv6LqIg9bZ6l8/viewanalytics