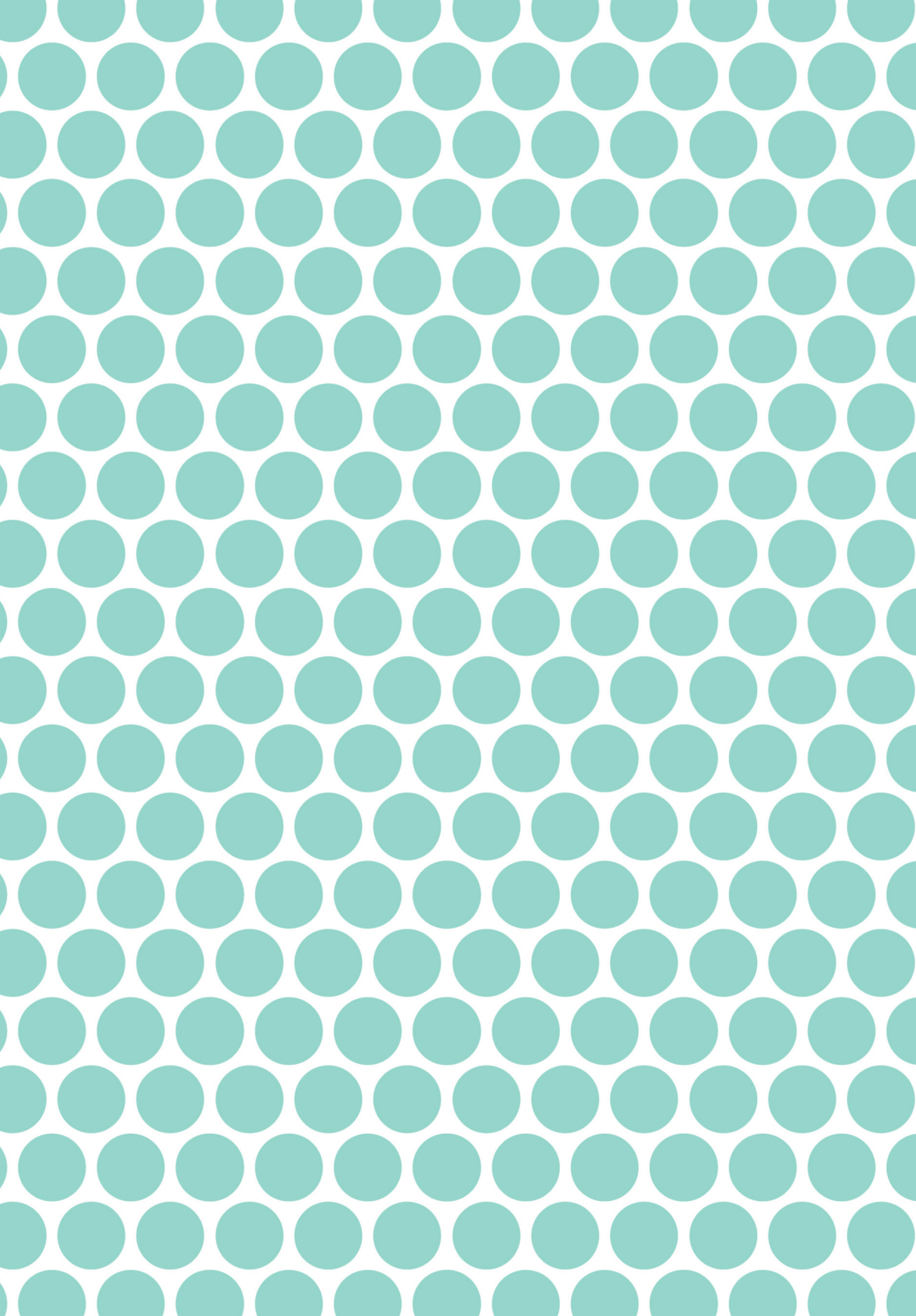**savvy·ware**
Smart system for food management
in the household environment

savvy·ware
Smart system for food management in the household environment

Carla Almeida Cotrim
mat. 834914
Supervisor: Lucia Rampino
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Aknowledgements

Abstract

Since the first decades of the 1900's, the refrigerator represents one of the items that compose the idea of modern living. The heavy appliances developed a modernization function of the house and food management since the initial models.

Introducing computers to kitchens is one of those seemingly obvious technology-led ideas that have appeared with startling regularity since the very beginning of personal computing. Nevertheless, it is only in the end of the 90's, following the popularity of laptops with LCD displays, that came to attention a proliferation of smart fridge prototypes.

In 2016, giant manufactures showcase their latest smart models releases with interesting results, however smart fridges cannot be considered successful products yet. Among other aspects that might be influential are the lack of the functional focus of the marketed models and a considerable decrease on the appliance lifecycle by the superposition of technologies that evolve in different speeds.

After analyzing the market scenario, as part of the design process, it was important to explore the consumer's point of view. The analysis was produced based an anonymous online survey, which was very helpful to realize that people, in most cases; (1) are interested in exploring the potentialities of the smart technology applied to the fridge; (2) feel the need of a better organization to avoid food waste at home; and (3) do not plan to buy a new refrigerator, as they are satisfied with the model they have at home. Finally, it led us to question how our fridge archetype influences our diet and its impact on the environment.

These conclusions were valuable for establishing the product brief: Smart system of accessories for food management, oriented especially for controlling unpackaged food items.
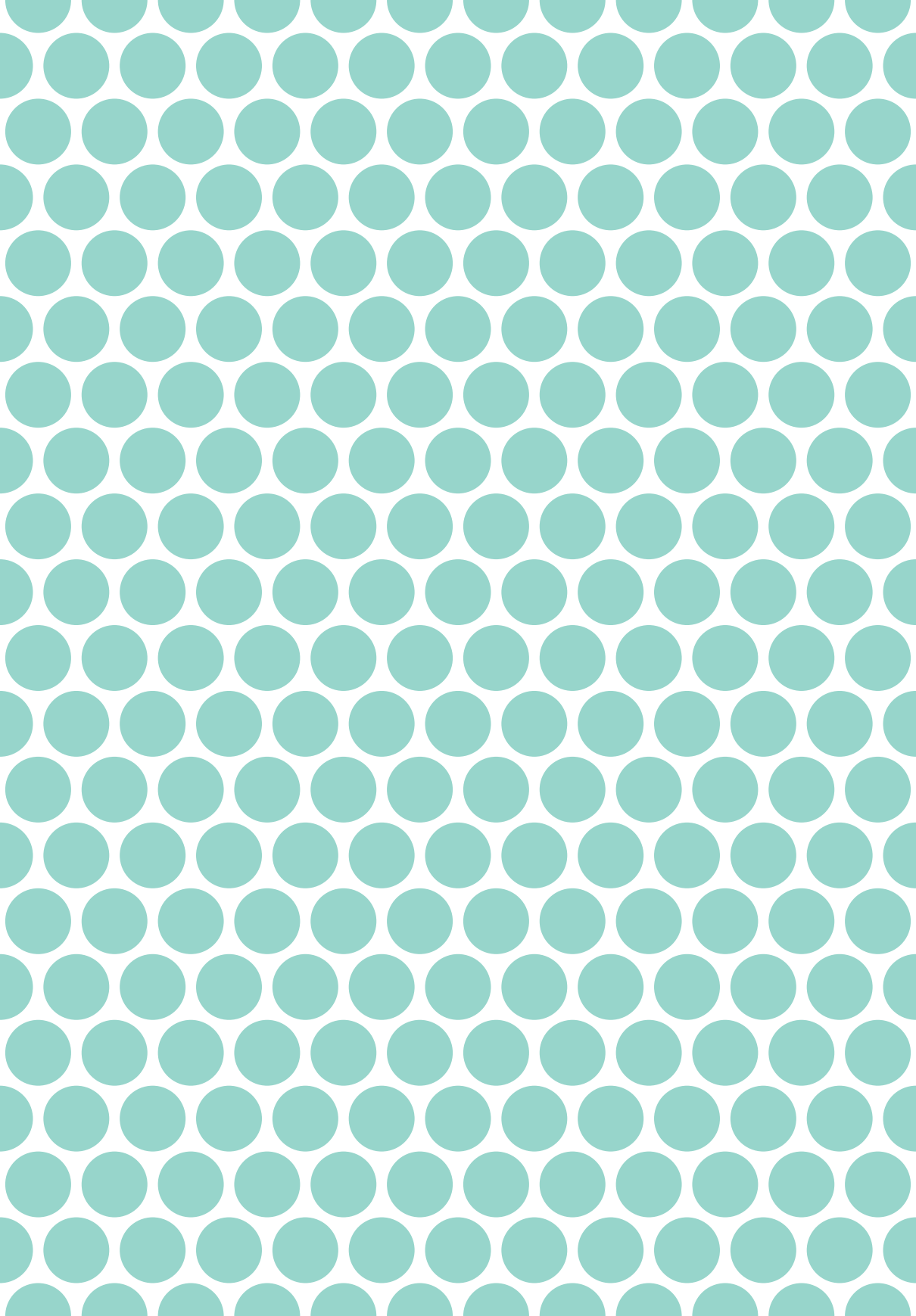
Contemplating that brief is the concept of Savvy.Ware: a system

that creates and controls household food inventory with the use of physical devices (containers, bottle stoppers, clips) and a mobile app.

The system is collectible and expandable; the number of items will depend on the inventory size the user aims to have. Savvy.ware is carefully designed to be user friendly - the information input is performed in the most seamless way, through a very few steps. The technology inside was defined as a consequence of that, but also guaranteed to be accessible and inexpensive; while the materials were selected prudently to be free of risks when in contact with food.

Several prototypes were developed, as expected to be a part of the design process. Further developments and testing should be considered as next steps for turning this product system into reality.

1
Introduction

This research is result of a two-year path, although it began to be written a few months ago. It is a consequence of a deep interest on design associated to technology, provoked on the early classes of this Master course, mainly in the Interaction Design Studio classes.

Specific terms like smart products, IoT, interactive design, dynamic products and so on were new to me and got my attention. The first step for starting this thesis was an extensive research about the most innovative objects available in the market related to home automation.

It got a little more specific after a three-month internship in AE S.r.l, a company dedicated to testing and developing projects of household appliances, mainly refrigerators, freezers, washing machines and ovens. They count on a design and engineering team, which work together since the early phases of concept, through engineering development to prototyping.

One of the first projects I could participate there was the development of a refrigerator for the Pakistani market. This job challenged me to go a bit deeper in the refrigerator and food-preserving subject.

Refrigerator is, among big household appliances, a very interesting one: in a household, it is indispensable, the most important one and usually the first one to be purchased. Requires very low maintenance and has a very long useful life, usually more than 10 years.

Except for a few attemps to make it smarter in the latest years, it has changed very little since its first commercialized versions, showing that it tends to evolve in a very slow pace.

Its productive process is consolidated; with very optimized costs for production and distribution. Which means that innovation must be very significant to justify the changes, and that would require high investments.

During Salone del Mobile/ Eurocucina 2016, the Milanese household appliance and kitchen furniture fair, it was possible to identify not only many market consolidated refrigerator models but also to spot trends that face the European market. Combining the information collected there with the user analisys it was possible to define the path of this research.

The study will be presented in the same order as it has been developed, and it will be divided in two main parts.

The first part will describe objects; presenting first what are the most innovative fridges available in the market, then presenting fridge features that can be considered already consolidated on the market.

Following that is the user analysis. An on-line survey, carried out during April showed some data regarding their routine, their interests and their expectations concerning fridges and food preserving. The result was very interesting and evolved to an investigation about the relationship between our diets and the environment, also considering differences between packaged and unpackaged food.

The second part will display the brief, the concept and the project development. The brief is a conclusion of the first part, listing a series of indispensable concept needs, then contemplated in the concept development.
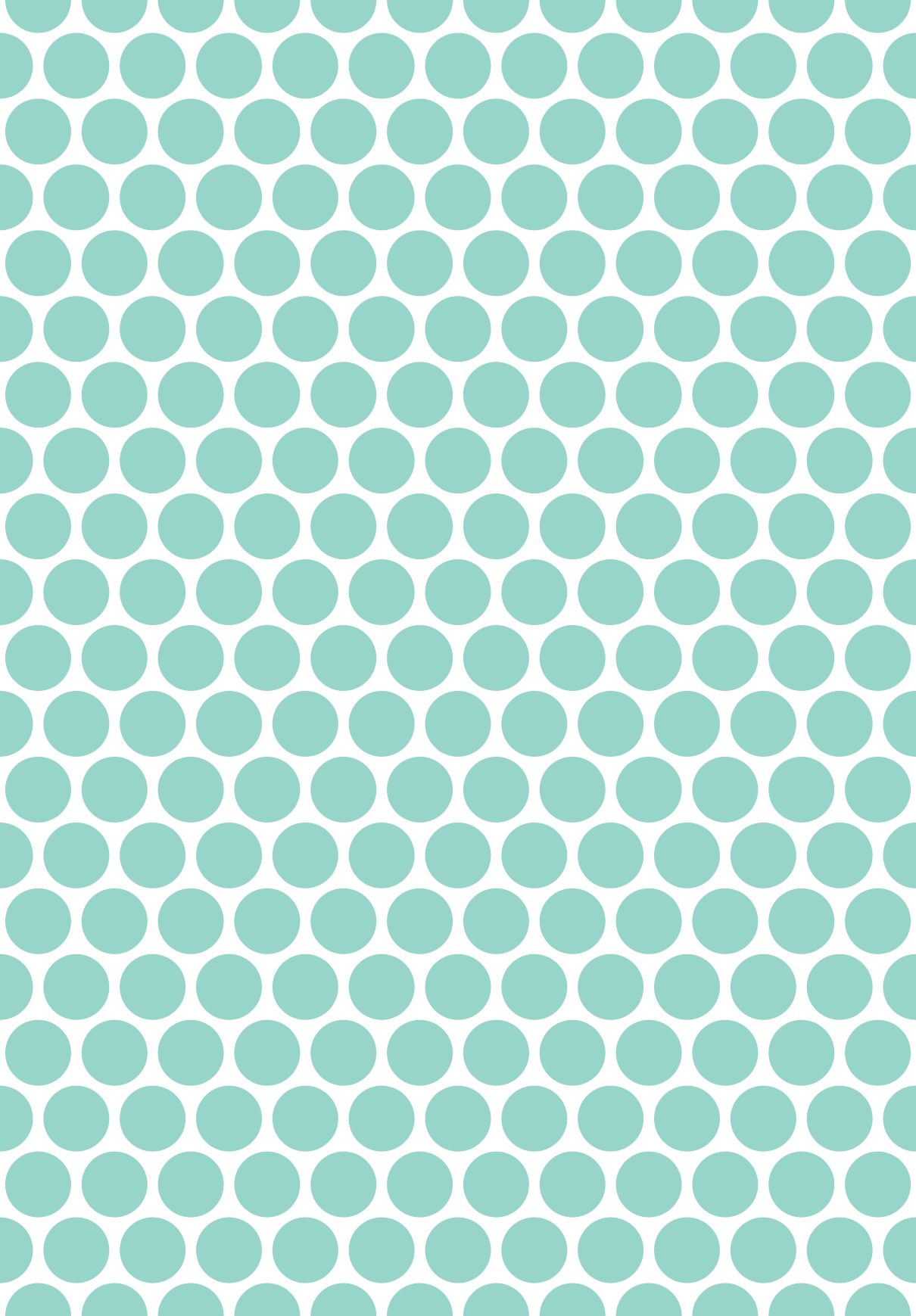
The sustainability issue will be mentioned throughout the study, in three different levels:

First, we will illustrate the paradox regarding layering electronic/ smart technology over the fridge hardware, which is mainly mechanical and electro mechanical. It is true that it brings a series of innovations and advantages, but on the other hand, this offers the risk of decreasing the appliance's useful life. Consequently, could cause early obsolescence and premature disposals.

On the user analysis, it will become clear their inspiring concern of having a more sustainable way of life, questioning how our fridge archetype influences our diet and its impact on the environment.

Finally, in the product development part, will be presented as part of the product concept the intent to avoid food waste by controlling the expiring dates of the food purchased.

2
The refrigerator market scenario

A house is a machine for living in.

Le Corbusier

2.1. The evolution of the Domestic refrigerator

Since the times of these words prophesized by Le Corbusier in 1923, in his book *Towards a New Architecture* [1] the refrigerator represents one of the items that compose the idea of modern living. The heavy appliances developed a modernization function of the house and food preserving since the initial models, although it is only in the years after WWII that the first fridge models with compressor motor begin to be mass produced and conquer the market, followed by the popularization of other white appliances, such as freezers and washing machines. In this process, the kitchen space passed through a radical transformation.

In the eighties, heavy appliances face a big wave of innovation: it is when electronic components are massively introduced in the sector. Even if that has not changed much the appliances appearance, it has improved their efficiency and functionality. This reflected on the adoption of a more compact overall aspect, a reduction of tangible commands such as buttons and controls, and an increase of screens. This attention to the interface design and user interactions is a consequence of the multiplication of new extra functions, only possible due to the introduction of digital elements.

Between eighties and nineties companies begin to become more aware of environmental issues, such as pollution and energetic efficiency, presenting to the market new models that take in consideration energetic savings, enhanced quality and bigger efficiency.

The following decade, there is a claim for simplicity and a bigger

concern towards usability. At the same time, takes place the trend of home automation, and is in the beginning of the 2000's that breaks through the first attempts of smart appliances, which are able to communicate between them through internet.

At this point is also when the product stops being the only key element and gets enriched by service and communication. This means that the strongest companies are the ones that contemplate this point of view in their dynamics. [2]

2.2. Types of refrigerator

Once a simple box mechanically filled with ice, refrigerator is an object that have evolved in types, features, style and efficiency. Regarding their most basic expected functions, here are some ways of classifying them **[3]**:

CLIMATE CLASS

Refrigerators are designed to operate under a certain range of room temperatures and are rated according to their climate classes. Some fridge models may have combined climate classes, allowing them to operate within a wider temperature range.

- SN or Sub Normal: from 10°C to 32°C
- N or normal: from 16°C to 32°C
- ST or Sub Tropical: from 18°C to 38°C
- T or Tropical: from 18°C to 43°C

ENERGY RATING

The energy rating of the refrigerator is estimated in terms of a set of energy efficiency classes that range from A+++ to G, A+++ being the most energy efficient, G the least efficient.

The classification is defined in terms of an energy efficiency index EEI, which is an indication of the annual power consumption relative to a reference consumption that is based on the storage volume and the type of appliance. **[4]**

TYPE OF BODY

Freestanding refrigerators are more common and usually less expensive than built in models. They can be installed, moved or

changed easily. Alternatively, built-in models need a professional installation for being fully integrated with the kitchen cabinetry.

NO FROST/ STATIC/ STATIC-FAN

In the No Frost system, defrosting of the freezer section is not required and odors caused by mildew is significantly reduced. In the Static models, most common system, the cooling is produced by the inner gas movement until the desired temperature is reached. The static-fan refrigerator uses the same principle of static model, with the addition of a fan in the refrigerator compartment for the circulation of the cold air in a more uniform way.

There are also models that combine the advantages of two systems. The fridge works in the static or static-fan system, and the freezer in the No Frost system. This way the refrigerator has the type of cooling that does not dry foods out and the freezer that avoids the need for manually defrosting. **[5]**

UNIT LAYOUT

Fridges are available in a wide range of designs, and most common models are: french-door, side-by-side, top-freezer, bottom-freezer or single-door.

The Food and Drug Administration recommends keeping spoilable food like dairy products, meats and veggies below 4°C and above 0°C (preventing from freezing). The technology magazine CNET ran a series of tests to compare unit models and temperature behaviors patterns associated to fridge unit layout. **[6]**

The coldest zone location may vary regarding the unit layout. However, the doors of all models tend to run warmer than 4°C. This is the reason the most delicate food like meat and dairy products should be placed in the cabinet interior, rather than the door bins.

cold zone (below 4°C)

coldest zone

warm zone (over 4°C)

warmest zone
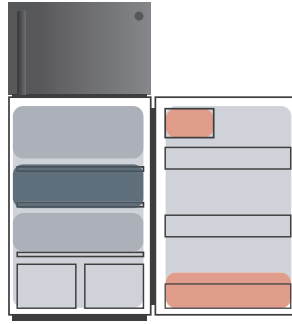
Top-freezer
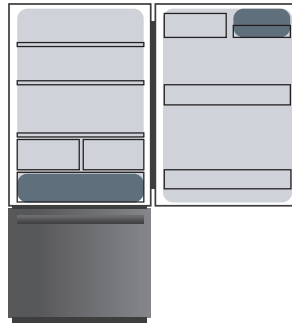
Bottom-freezer
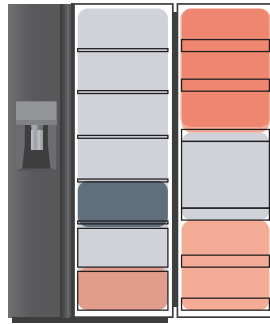
Side-by-side
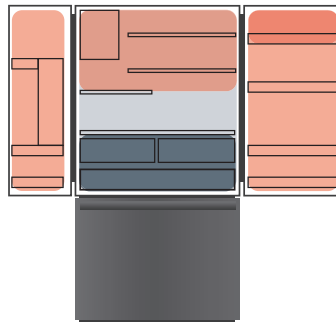
French-door

2.3. From kitchen computers to smart fridges

Introducing computers to kitchens is one of those seemingly obvious technology-led ideas that have appeared with startling regularity since the very beginning of personal computing.

The first proposed "kitchen computer" was the 1969 Honeywell H316, pedestal model, of 1969. [7] It was a product offered by Neiman Marcus, sold for $10,000 ($77,804 in 2016 dollars), weighed over 45 kg and was advertised as useful for storing recipes. It had a cutting board and had a few recipes built in. However, reading or entering these recipes would have been nearly impossible for the average housewife or cook, since the user interface required the user to complete a two-week course just to learn how to program the device - making the product absurd from a consumer point of view. [8]

[Right] Advertisement for Honeywell kitchen computer, 1968

Although a fantasy gift, the Kitchen Computer represented one of the first times a computer was offered as a consumer product. Nevertheless, it is only in the end of the 90's, following the popularity of laptops with LCD displays, that came to attention a proliferation of smart fridge prototypes.

In 1998, Japanese brand V Sync releases its Internet Refrigerator [9], and on the following years several brands like Electrolux, Whirlpool and Samsung made their own pilot studies. However, the smart fridges cannot be considered as successful products yet. It is still a very challenging market – some reasons will be detailed more ahead.

2.4. The importance of the market research

In the heavy appliances (or white goods) business, sector with high technological content, the designer's input is less influential than sectors where technology is not substantial, in comparison for example with the furniture sector. Design is not present as a relevant value that defines by itself the customer buying decision. Innovation is something to be considered when sales are low. [2]

The process of product redefinition begins from the market itself: first takes place an analysis of the market supplies, then, an interpretation of the market expectation and demands. Here, the market research is the most useful starting point. It helps to assimilate the business behavior, observe the competition, and extract knowledge analyzing the designs available, by comparing and criticizing them.

It can be considered a key step – this analysis will help to understand the users' attitudes and their options. The understanding of the "state of the art" will give some insights regarding the most significant innovations presented by the lead companies worldwide, market trends, and opportunities for improvement.

Here it will consist on the analysis of innovative refrigerator models presented to the market in 2016, followed by a trend research of models displayed during Eurocucina trade fair that took place in Milan in April 2016.

2.5. CES

CES, the Consumer Electronics show, is one of the most important, most advertised Technology Trade Show in the world. It takes place once a year in Las Vegas, USA, and it is where the next-generation

innovations are introduced to the marketplace, by major manufacturers and suppliers (Sony, LG, Samsung, Intel) and by other hundreds of small companies. It's overwhelming, disorienting, and hard to remember one product from another. And yet, some devices certainly remain memorable.These three fridge models selected to be described below were presented on the 2016 edition of the event and can be considered technology trends for this year. After each brief description, the most interesting features will be highlighted through Pros and Cons, summarizing a critical overview expressed by the media at the time.

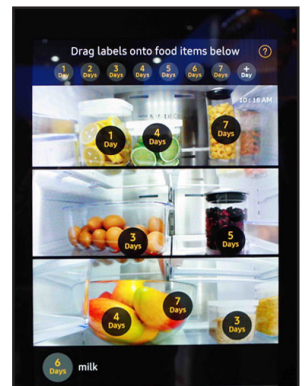### SAMSUNG FAMILY HUB REFRIGERATOR

Price: estimated $4000,00
Launch Date: April 2016
Input: app and touch screen controlled 4-door refrigerator
Aesthetics: stainless steel, futuristic 4-door refrigerator with touch screen interface and water and ice dispenser.

[Left] Samsung Family Hub Refrigerator [Right] Detail of the door screen and the countdown icons

Interaction Mode: The Samsung Family Hub Refrigerator is a multi-tasker that reconnects families, organizes groceries and home tasks and provides entertainment. All communications are displayed on a screen located on the upper right exterior door. It offers options for music streaming to play through its built-in speaker and displaying television programs. In the apps available in the screen, it is possible to make shopping lists, display photos, draw a quick doodle or write a note. There is a calendar app that imports the family members existing calendars and merge into a shared fridge calendar. Moreover, three high quality cameras inside the fridge capture an image every time the door closes. On the app it is possible to see the pictures and drag little countdown icons over specific ingredients to help track expiration dates. [10]

PROS
- Contains features that perform new functionalities, such as inner cameras and drag and drop timers for controlling expiring dates.

CONS
- Putting a tablet in a fridge poses multiple issues such as hardware updating and Wi-Fi standards evolution. Probably that will speed up obsolescence and turnover, and it seems that it is not environmental-friendly idea.
- Most of the apps keep this fridge in a normal use we expect from a fridge.

WHIRLPOOL SMART FRENCH-DOOR REFRIGERATOR (CES 2016)

Price: estimated $3800,00
Launch Date: May 2016
Input: app controlled 4-door refrigerator
Aesthetics: fingerprint-resistant stainless steel French door refrigerator.

Interaction Mode: It has modular shelves that slide and flip out of the way as needed and features a Party Mode, for moments with intense opening/ closing door movements. It is Wi-Fi connected and can be controlled remotely through an app. It is able to notify the user in the case the fridge ever loses power or needs a new filter.
Whirlpool's fridge also synchronizes with Nest for setting the most convenient time for the defrost cycles. [11]

PROS
- It is wi-fi connected and can be remotely controlled through the app.

CONS
- The connection with Nest doesn't seem a huge advantage.

LG SIGNATURE REFRIGERATOR (CES 2016)

Price: $4000,00
Launch Date: 2016
Input: tangible interaction refrigerator
Description: Polished, silver T-type fridge - a French-door fridge on top and two doors for the freezer on the bottom
Features: LG's new fridge has two big features. The first is the door itself, which now has the Knock-On feature, which allows the user to knock on the door to reveal what is inside by turning on the internal light. The second, and probably most important, is the Auto Door feature, which allows the fridge to detect when your foot is nearby to open the door gently. [12]

[Right, Above] Whirlpool Smart French-door Refrigerator

PROS

- Solves real problems by simple tangible interactions. LG seems to be investing in new ways of interaction, with sensor-activated door and lights, rethinking the human relationship with the appliance.

CONS

- No internet connection.

2.6. Eurocucina

CES is a trade show mainly focused on technology and innovation. Meanwhile, although there is a technological approach, Eurocucina, the Italian Kitchen trade fair has its own particularities; more oriented to innovations regarding kitchen interior design. As a philosophy of the event, most appliances presented are built-in, leaving space for presenting new materials, furniture, finishings, lighting; in other words, presenting the kitchen as an integrated space.

Regarding the household appliances market, major companies

such as Electrolux, Bosch and Whirlpool were present, displaying consolidated, market-oriented, and less experimental refrigerator models. Analyzing every feature of the presented designs could become a repetitive task, so here the output is an examination of the trendiest features.

CRISPER DRAWER WITH HUMIDITY CONTROL

The typical crisper drawer is simply a partition inside the refrigerator that offers a more humid environment than the rest of the cabinet.

Many drawers have a sliding humidity control setting that ranges from "Fruit" to "Vegetables" and others from "High" to "Low", and these low-tech sliders usually just reveal or obstruct a little hole in the drawer that allows moisture—and also ethylene gas, which causes ripening—to escape. [13]

The right use of the crisper drawer and the humidity control helps to prolong the life of vegetables and fruits. It is better when the refrigerator model offers two crispers, even if there are not any humidity control sliders. This way it is possible to separate ethylene-emitting fruits from ethylene-sensitive vegetables. In addition, crisper drawers work better when they are almost full. Here is a list of what should be stored regarding the right humidity settings:

Fruits or low humidity setting
- Ripe (yellow) bananas;
- Figs;
- Avocados.

Vegetables or high humidity setting
- Watermelon
- Unripe (green) bananas
- Strawberries
- Herbs

BLUE LIGHT TECHNOLOGY

Fresh fruits and vegetables maintain their vitality for a while after harvesting. According to Beko company's website, the blue LED light technology helps to keep the process of photosynthesis inside the fridge, providing prolonged storage life of fresh fruit and vegetables while maintaining their natural flavors and nutritional elements. [14]

That's because blue LED light simulates natural lighting

[Left, Above] LG Signature Refrigerator

conditions so that the amount of vitamin C is preserved.

In a recent article for Daily mail newspaper from UK [15], "a team of scientists from the National University of Singapore (NUS) have shown that blue light emitting diodes, (LEDs) have an antibacterial effect on pathogens commonly found on food including E. Coli and Salmonella."

FLEXIBILITY

Flexibility is a frequent marketing term used by refrigerator brands. Taking into consideration that consumer profile may vary vastly and that food packaging lacks standardization [16], personalization of the interior space of the refrigerator is something well appreciated
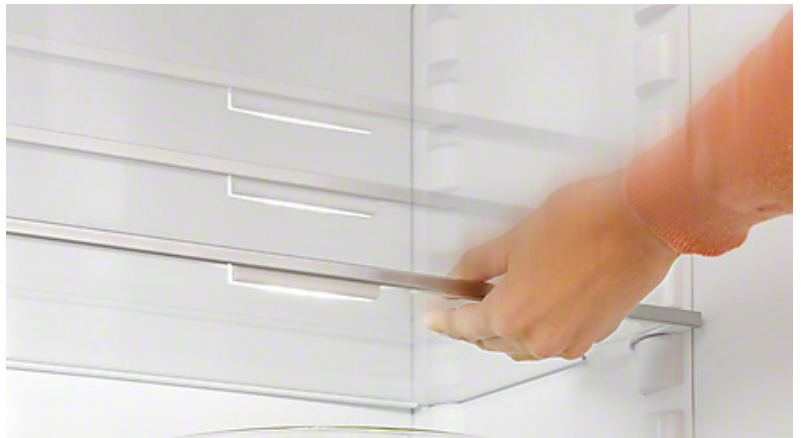
by the market.

Following this idea, Bosch created the "VarioShelf", a glass shelf that is divided in two: one half is fixed and the other can be moved. One can be slid towards the other releasing extra space inside the fridge.

Miele, German manufacturer, presented the "FlexiLight" concept: refrigerator shelves that have built-in LED lighting that illuminates the fridge interior and that can be positioned on any shelf level available, depending on the size and number of food items. This way the light source can be positioned so that it is not blocked and so the illumination of the interior is not impaired. [17]

Meanwhile, Electrolux has taken some inspiration from Frigidaire (one of the company's brands since 1986) and has launched in 2015 [18] its flexible storage system called "Customflex", which allows consumers to move around several detachable door compartments alongside the fridge door. The also suggest handling these bins in other ways outside the refrigerator, such as taking them to the dining table, chopping board, the wall support or countertop.

The idea that the food bins could no longer belong only to the refrigerator merges the concept of fridge accessories and food container, or eventually food packaging. By exploring these other spaces where these attachments could inhabit, Electrolux reaches other possibilities concerning the idea of customization.

AIR PURIFICATION

Whenever associated with the fridge ventilation system, air purification systems can, besides cleansing the air, slow down the food aging process. Refrigerator models produced by Hotpoint, company that belong to the Whirlpool group, include this feature by the name "Active Oxygen". They state that this technology inhibits the growth of bacteria by up to 90% reduces bad odors by up to 70%. Thanks to that, the food aging process is slowed down considerably. [19]

Electrolux takes a similar path and proposes "TasteGuard" charcoal filters. The porosity of the carbon component absorbs undesirable smells as the air circulates inside the fridge. [20]

HOME CONNECTION

[Left, Above] FlexiLight shelves from Miele
[Left, Below] Electrolux-CustomFlex door bins

With the increasing popularity of internet and mobile phones use, it is possible to say that home automation is the biggest trend regarding home appliances. Each company has its approach to the theme, which may vary from the most basic functions such as turning the

device on or off remotely to performing truly smart functions with the help of cameras and sensors, as shown by Samsung on CES.

For example, Homewhiz is the name of the smart home system presented by Grundig, German brand owned by Turkish company Arçelik. Several household appliances including dishwasher, washing machine, oven and refrigerator can be controlled via Wi-Fi network, through mobile app, tablet or smart TV. It is possible to remotely switch them on, off, change settings, make software upgrade, receive alerts and control energy consumption. [21]

German company Bosch has developed its own home automation standard, called Home-Connect. It encompasses only Bosch and Siemens appliances and in a near future intends to interact with Nest thermostat. [22]

Similar solutions are available, like the ones developed by GE (GE Kitchen), LG (SmartThinQ), and Electrolux (My AEG). Nevertheless, it is a big market yet to be fully explored: Apple Home kit and other platforms such as Wink and Wemo are not compatible with any heavy appliance.

Meanwhile, Samsung shows who is the leader in this trend: its SmartThings platform is the widest available, connecting from ligh bulbs, security cameras, switches, valves, doorbells, Amazon Alexa and many other things. **[23]**

2.7. Conclusions

This market overview was a fundamental part of this research. With all the data collected, it became possible to realize why this is a very challenging market, and the observed reasons are listed here below. Joining this perception to a further step which is an user analysis will drive us to a more precise product brief.

SCREEN

One of the decisions facing device designers is whether or not to have a display screen on the device. The decision is both aesthetic and functional, and once a screen is placed on a object, in most instances the object feels like an electronic device. It becomes categorized as a gadget and expectations are set accordingly.

For smart refrigerators, the choice of having a screen is almost unanimous, although many authors insist to question if that is completely necessary. One increasingly employed method of getting around a lack of screen is to simply move the screen to another

platform, like for example a mobile phone. Anyway, the feedback and controls must remain on the appliance that is being controlled. The user can get very annoyed if it is demanded to pull out another device to control the object in front of him [24].

FUNCTIONAL FOCUS

Refrigerators have one of the clearest justifications of all appliances: keep the food fresh. Introducing a general-purpose computer must be justified by the contribution of useful tools.

James Surowiecki created the term "feature paradox"; which he uses to say that the more features the devices have, better they are. It means that the number of features is very often crucial for the client when deciding between buying one product over another similar one - the user will most of the times select the one with more features. However, it is only when the user gets the product home and try to use he realizes the virtues of simplicity. Too many functions might be too confusing. Great devices are those that fulfill a real, deeply-felt need.

LIFE CYCLE

Large kitchen appliances have struggled behind other gadgets in the connected home. It takes a lot longer to design, produce and upgrade them as opposed to smaller smart products such as a frying pan or coffee maker. [25]

In addition, refrigerators and computers have different life cycles. A refrigerator can be replaced every 10 or even every 15 years, while computer lifetimes are measured in months.

These two technologies evolve in different speeds; superposing the two hardwares can demand for a more frequent maintenance and/or a shorter replacement cycle for the smart fridges.

Technological innovation is progressing at an ever accelerating pace while raw materials disappear. But it is obvious that in a world of need, innovative answers to the question of obsolescence and value must be found. [26]

PRICE

Among many possible differentiators, price is one of the most important ones. It is part of the business model defining it, and a wrong decision could turn the product into a success or not.

In the case of smart fridges, they are not considered luxury goods – instead, they are marketed as appliances with new functionalities, with an improved user experience. However, very often their retail price is greater than the sum of a regular refrigerator and a tablet computer [7], and this is not justified.

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3
Users analysis

When talking to subjects, it's best to have what Buddhists call the 'beginner's mind'. Designers should be open and non-judgmental and should not assume that they know the answer beforehand. Simple questions can reveal powerful answers.

Dan Saffer [1]

Design Research is a powerful tool in the development phase of a new product. It helps the understanding of the users and their environment, this way designers obtain the fundamental empathy with users. This awareness directs to better solutions and helps avoiding inappropriate, confusing or frustrating choices.

There are two main types of design research: qualitative and quantitative.

Qualitative Research is primarily exploratory research. It is used to gain an understanding of hidden reasons, attitudes and motivations. It provides insights into the problem and helps to develop ideas or hypotheses for potential quantitative research. It can also be used to uncover trends in thought and opinions, and dive deeper into the problem. Usually contains subjective questions, such as the ones starting with 'how' and 'why'.

Quantitative research, on the other hand, is more objective and needs large amount of people to answer to be statistically significant. It uses measurable data, like questions starting with 'what' and multiple-choice prompted answers. As a part of the research, it can be used to confirm a trend or to test a theory or a hypothesis.

In this moment of the Design Research, it was more suitable the Qualitative approach, as a very preliminary investigation about refrigerators. The objective here was to observe the relationship between people and their appliances, look for wide-eyed insights and potentials ways of managing it. However, during the organization of the findings, similar answers were arranged in order to identify patterns

and phenomena.

A Pattern is a body of similar answers. It is important because it represents a collective knowledge, a standard opinion about something. Nonetheless, Phenomena can be interesting as well. It can be recognized as an unusual behavior, reactions coming out of the curve, which can suggest a different direction for the product development depending on the further analysis.

3.1. Survey

On the anonymous online survey conducted between the 22nd and the 28th April 2016, a sum of 66 people answered the posed questions. The only criteria applied in selecting the group of people was to have a fridge at home. With this high eligibility, people with different ages and from different backgrounds could contribute. In addition, even with a small number of answers due to the short period, a very interesting result came out.

From the seven-question questionnaire, four of them were free to answer. The objective of the first question was to make the user start thinking about his relationship with his home's fridge. The other open questions left the subject completely free to make a hypothesis about the appliance's functional potentials, his expectations regarding the interaction and its future. Here are the questions in a more detailed approach:

1. DESCRIBE YOUR FRIDGE WITH 5 WORDS, INSIDE AND OUTSIDE

This free-answer question allowed the subjects to express the first words that come up in mind when they think about their fridges. It showed many different words, but many times with similar meanings.

Here are the results: putting the related words together and facing them with their antonyms make it easier to analyse the answers. The number next to the words is the sum of times the word or its analogue appeared in the listing.

It shows that this group of people have an emotional relationship with their fridges. Most of the users pointed only qualities. Almost half of the subjects stressed its efficiency, practicality, usefulness and/or reliability. Appearance was also an important topic: many users expressed their opinion about the overall aspect, describing beauty or just colour and size. Moreover, some smaller results show that organization and cleaning could be also a frequent concern.

This could mean also that a fridge can tell a lot about people's
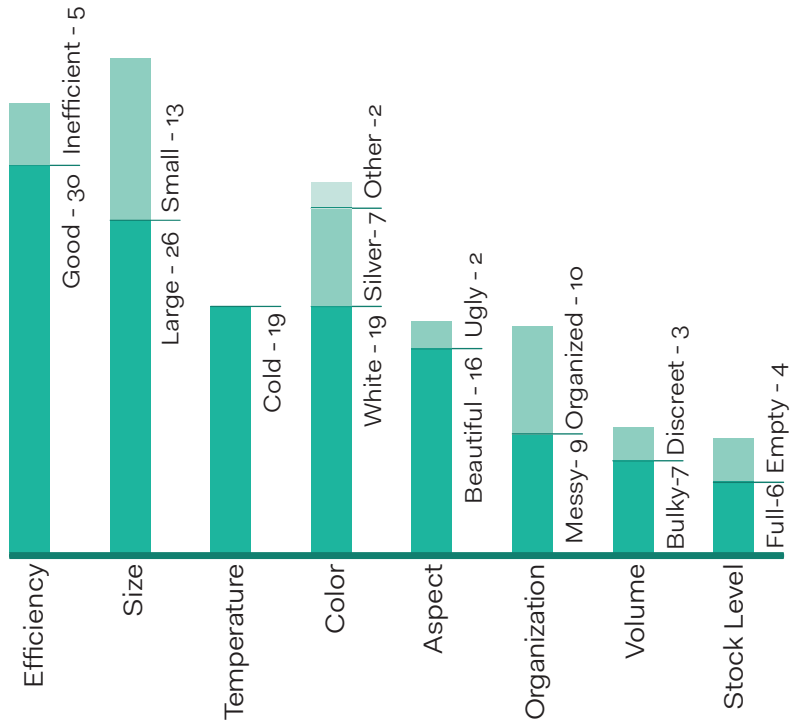
lives. From the outside, it is easy to recognize the care for the style just by how it fits with the rest of the kitchen. On the door, it can show some family communication (notes), memories (postcards, pictures, magnets) or attempts of life organization/ management (buying lists). The contents inside the home fridge consists essentially a reflection of owner's diet, although it could show also some organizational habits.

2. HOW MANY PEOPLE USE THE FRIDGE IN YOUR HOME?


16%

43%

21%

15%

5%
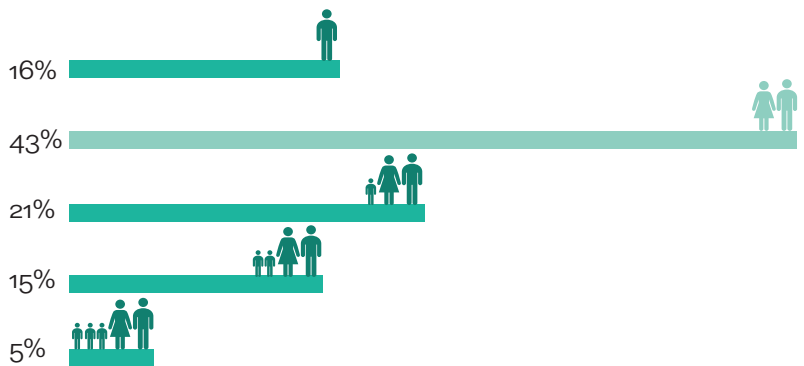
With this result, we see that the fridge is an appliance rarely personal. More than 80% of the times it is managed and used by more than one person. This information is important because reflects people with different behaviour and needs uses the appliance, filling and emptying it, and some communication between them is indispensable.

3. HOW OLD IS YOUR FRIDGE?

0 - 3 yrs	26%
3 - 5 yrs	19%
5 - 10 yrs	47%
+ 10 yrs	8%
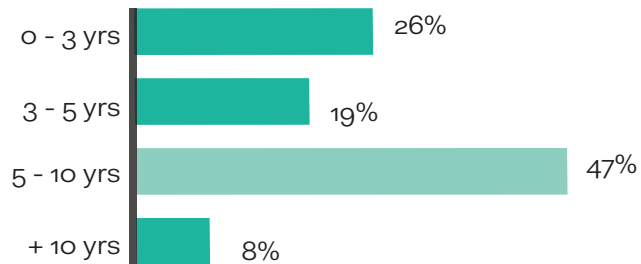
4. ARE YOU SATISFIED WITH IT?

79%   21%
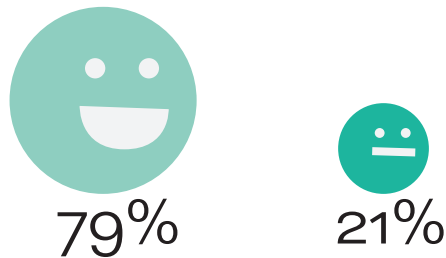
These two results show that fridges are appliances that have a long life expectancy, and most of the times work just as expected. In 78,7% of the cases there is no need for considering buying a new refrigerator. Furthermore, if they work properly, designing a new model and bringing it into market should have a very well justified reason.

5. HOW COULD IT BE BETTER?

The objective with this question was to see the immediate expectations concerning fridges. Considering the household economy and available models on the market, which feature could lead to changing the one at home?

Results show that flexibility and organization is the main concern, followed by having a more efficient size (on second place) and embodying smarter technologies that help the food management (third place).

6. IF YOUR FRIDGE WERE A PERSON, WHAT WOULD IT SAY TO YOU?

Discovering what people expect to hear from their fridges shows important aspects of the interaction they wish to have. Most answers again show that cleaning, organization and food management (avoiding waste) were the biggest concern.

Organize me! - 10

Count on me! - 7

Good morning! - 7

Eat this soon! - 6

Don't leave me open. - 5

I am sad! - 5
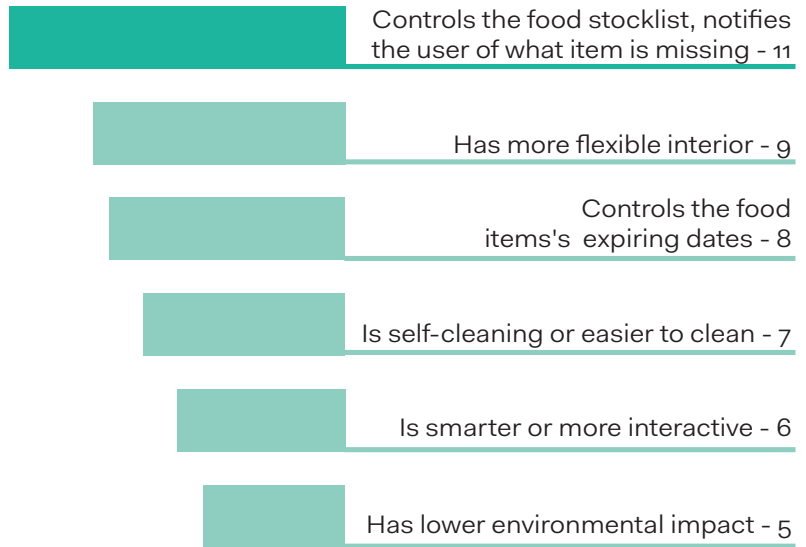
Feed me! - 5

Stay Healthy - 3

7. How should it be the fridge of the future?

These opinions show that people are aware of the fridge's potential to be smarter and help their routines. Technology available nowadays could be used for controlling food items; suggesting what should be eaten first, detect what is missing, what is already expired consequently avoiding food waste and helping to save money. As an example, one specific person answered:

I'm super concerned about how environmentally unfriendly it is now! What should change a lot is how we buy stuff or how things are sold in the supermarket. We accumulate terrible amounts of waste and fridges are helping us doing it.

The way we manage and preserve food is highly influenced by the way we buy food. This rather thoughtful observation pointed by the anonymous user above shows that there is a connection between our refrigerators and the way we buy food, which can be basically divided between packaged and unpackaged items. This matter and how it reverberates on our diets and our environment will be the subject of the next chapter.

Controls the food stocklist, notifies the user of what item is missing - 11

Has more flexible interior - 9

Controls the food items's expiring dates - 8

Is self-cleaning or easier to clean - 7

Is smarter or more interactive - 6

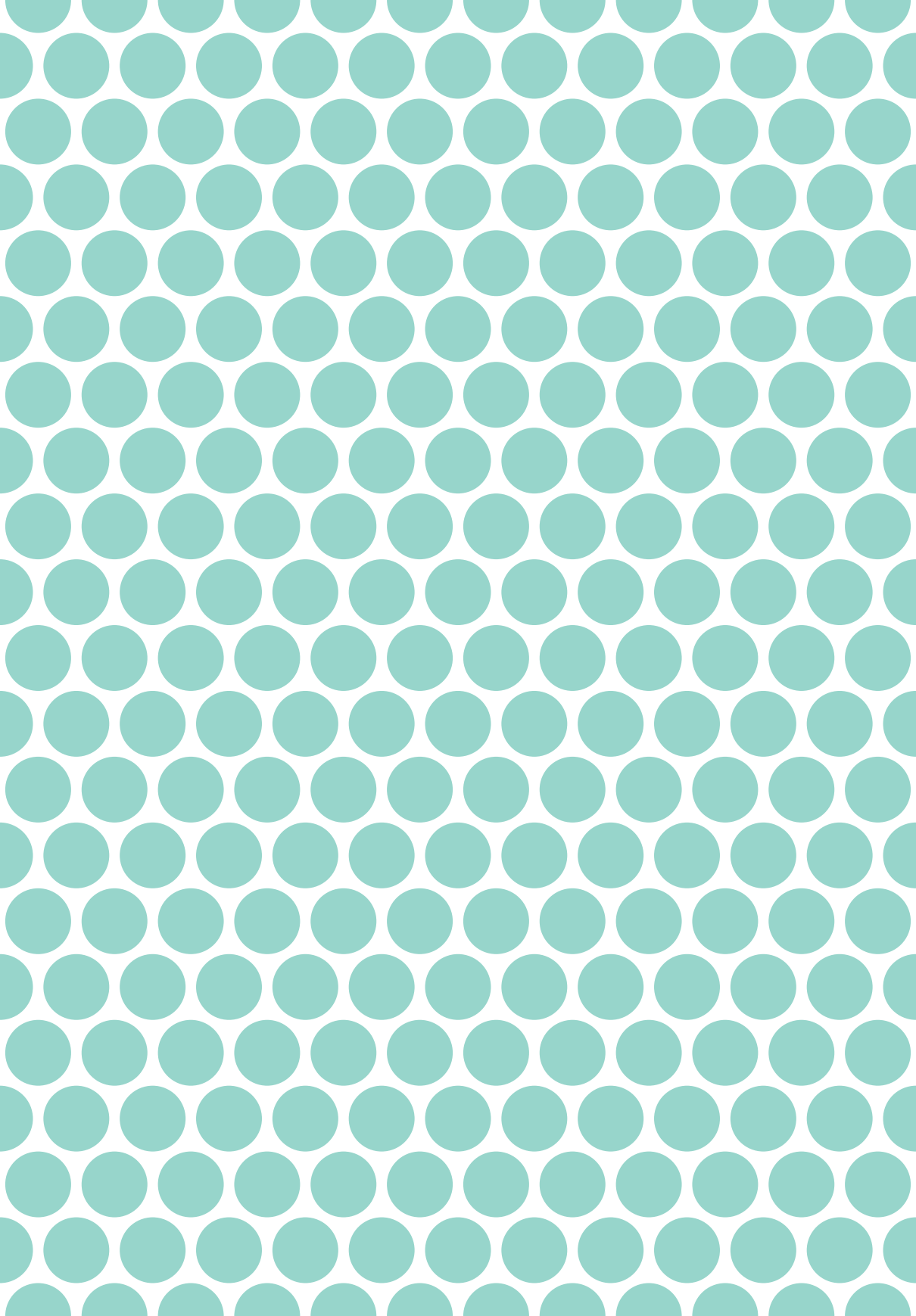Has lower environmental impact - 5

3.2 Conclusions

The survey is a very helpful tool to get closer and understand better the users. Here is a list of the main patterns found:

- Most of the people is interested in exploring the potentialities of the smart technology applied to the fridge.
- They feel the need of a better organization to avoid food waste at home.
- They do not plan to buy a new refrigerator.

In the end of the survey, an insight lead us to question how our fridge archetype influences our diet and its impact on the environment.

3.3 References

[1] Saffer, Dan. *Designing for interaction: creating innovative applications and devices*. New Riders, 2010.

4
Environmental Impact of Food

Nowadays is more than obvious the connection between food quality and people's health. However, is getting bigger the awareness of the environmental, economic and social impact of food production. For example, due to increased deterioration of the environment, in some specific areas, some agricultural practices caused a reduction in biodiversity.

4.1. Sustainable diets

Sustainability implies the long-term equilibrium of environmental, social and economic factors. FAO, The Food and Agriculture Organization of the United Nations, has developed a broader definition of the 'sustainable diet':

Sustainable diets are diets which have a low impact on the environment, contributing to food and nutritional security as well as to a healthy life for current and future generations. Sustainable diets that contribute to the protection and respect for biodiversity and ecosystems are culturally acceptable, economically fair and accessible, adequate, secure and healthy from a nutritional viewpoint and, at the same time, optimize natural and human resources. **[1]**

This definition recognizes the interdependence between food production and consumption, dietary requirements and nutritional recommendations and that human health is interrelated with the health of ecosystems. According to them, sustainable diets can reduce water consumption and minimize CO_2 emissions, promote food biodiversity and increase the value of traditional and local foods that are rich in nutrients due to their variety.

In order to illustrate and go deeper on this matter, The Barilla Center of Food and Nutrition developed a scientific research called Double Pyramid, presented the first time in 2009. In this paper, they

ENVIRONMENTAL PYRAMID

FOOD PYRAMID
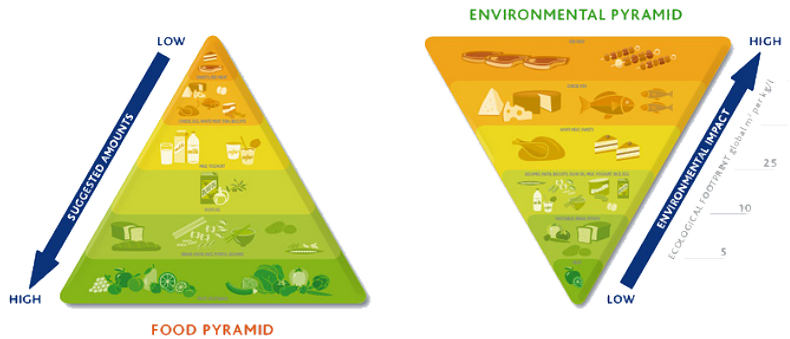
could demonstrate the close relationship between the environmental impacts caused by the production and consumption of food and their nutritional aspects. In particular, by adopting a dietary pattern that is in line with nutritionists' recommendations, it is possible to reconcile the health of people with the sustainability of the environment, without negatively affecting the economy. [2]

It became clear that the foods creating a lower environmental impact are those, which, according to nutritionists, should be consumed in larger quantities while those that have a more pronounced environmental footprint on the Planet should be consumed in moderation. The diagram that illustrates this concept is the classical food pyramid aside with the new upside down 'environmental' pyramid in which foods are classified according to their ecological footprint.

4.2. Slow Food Movement

In Europe took place years ago the Slow Food Movement. Their philosophy envisions a world in which all people can access and enjoy food that is good for them, good for those who grow it and good for the planet. In their manifesto, they present a concept of food that is defined by three interconnected principles: [3]

- Good: quality, flavorsome and healthy food
- Clean: production that does not harm the environment
- Fair: accessible prices for consumers and fair conditions and pay for producers

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They say also that choosing the food we eat is an individual responsibility, through which everyone can daily contribute. This is a pledge for a better future, an act of civilization and a tool to improve the food system as it is today.

In general, these researches, definitions and philosophies approach the same point. Fortunately, people are getting increasingly concerned about environment. They are willing to make choices on everyday life, like choosing what to eat, based on the effects they might bring to the planet.

This individual responsibility raises consumer's questioning towards the environmental effects of food industry and increases their search for alternative answers.

4.3. Unpackaged Food

Also associated to the idea of responsability towards the environment, is the amount of waste produced by food packaging. Not only more eco friendly, buying unpackaged food is most of the times a healthier option. It also offers some sense of community, considering a closer relationship between user and producer. As it is a more human connection, it can become easier to know:

- Where does this food come from?
- What distance did it travel?
- Is it OGM? Were there any toxic substances in the production?
- Is this company/ producer trustworthy? Do they respect their employees?
- Do they respect the environment? And so on.

Among many ways of purchasing unpackaged food available, here below are listed a few traditional yet trendy ones:

STREET MARKETS

There is nothing new about the street markets. They exist since ancient times, and changed little through the years. What is interesting about them is how and why they still survive in the cities.

The farmer's markets are a peculiar experience of sociability and street use, which for decades has suffered obsolescence due to modernism, the increasing number of cars on the streets and new forms of retail, such as online sales and the emergence of

[Left, Above] Double Pyramid illustrating the connection between nutritional diets and the environment

supermarkets. As result, the open market has undergone changes and a certain decline that, however, did not disappear as a public place and way of encounter and sociability. In this sense, to preserve it is to preserve an area of traditional folk and urban culture, a matter of citizenship. [4]

One big advantage for shopping in the street market is having a closer relationship between consumers and producers, consequently getting a deeper understanding about the origin of the food consumed. In addition, preferring seasonal and local foods make the products spoil less quickly.

It is less comfortable, less formal, but it is a more responsible way of shopping. With the increase of demand for organic, sustainable and/ or quality healthy food, these markets are becoming more popular.

ZERO PACKAGING MARKETS

The zero packaging markets produce zero waste by allowing customers to purchase exactly how much they need. Usually they do not carry any products under popular brand names; instead, they offer mostly organic products. In Europe, there are some examples of this kind of initiative, such as in Biocoop 21 in Paris, Effecorta in Milan and Original Unverpackt in Berlin. [5]

In the German case, the stocks are displayed using a bulk bin system with an assortment of fruits, vegetables and grains. Even shampoo, yogurt, honey and milk are dispensed from refillable containers.

The shopping system works like this: the customer must bring from home bottles, boxes and bags. Each recipient must be weighted and tagged in the store's entrance. Then the customer fill each

container with the chosen products, and only pays for the content inside.

   The environmental advantages are many. It has a low ecological footprint because most of the products have not travelled long distances, does not leave waste behind and it is a good opportunity for the locals to eat local and healthy food without having to pay more than in other shops. Reusable containers are also available for buying in the stores, in case the consumer steps by offhand. [6]

   The impact of this new way of shopping in the user's daily routine reflects also in the way of conserving the food. The absence of the packaging for example results in the nonappearance of the information of expiring dates, contents and on the demand for reusable boxes, bottles and bags.

[Left] Effecorta - italian zero packaging supermarket
[Right] Latte Crudo urban equipment in Gavirate, Italy

Latte Crudo, or in English "Raw milk" is fresh milk in its natural state, unpasteurized and not packaged, sold in bulk on the farm or in the special milk distributors on tap. It does not undergo any heat treatment and in the fridge, lasts from 2 to 5 days. Producers list a series of nutritional advantages, aside from its creamy texture and full and genuine taste.

In Italy there is a big network of the raw milk dispensers, and the machines can be located on the www.milkmaps.com website. The milk dispensers provide cheaper milk by supporting local farmers and reducing cost with packaging and transportation. The machines are emptied and refilled every 24 hours. Nothing is wasted: the remaining non-dispensed volume is collected and used to make cheese.

For containing and preserving the milk, producers suggest the use of reusable glass bottles, very well cleaned, secured from temperature exchanges. It should go directly to the fridge, preferably protected in a thermic bag. [7]

Growing our own food

People have managed to feed themselves for all of human history, by either fishing, hunting, gathering and/or subsistence farming. Now, with large-scale food production, gardening is often only a hobby. However, growing our own food could mean increased food safety, health and enjoyment. [8]

Growing our own food depends on obvious factors including climate, soil, rainfall, and the most important, the available space. Cities like Milan have nice initiatives for contributing with the city environment encouraging the development of urban gardens. The project is called "Giardini Condivisi" or in English "Shared Gardens".

Shared gardens are built and managed by the citizens themselves to make their neighborhood more livable and represent an innovative method of recovery and maintenance of degraded and/ or abandoned public areas which the Municipality it is not in a position to re-qualify. However, this activity is supported by the municipal administration with a very active role especially in the initial phase, which facilitates the activities of volunteers who want to take care of the collective public good.

In areas affected by the project, takes place gardening and farming activities, performed by those who live the neighborhood and want voluntarily to engage in these activities. Nevertheless, the

most positive consequence is the contribution to an environmentally sustainable management of the city.

As we can see, even life the big cities can allow being aware of the origins of what we are consuming. [9]

4.4. Packaged Food its importance and sustainable trends

Every day we open our refrigerator several times, for brief moments, to search for and grab food; food that can yet be contained in another protective layer, a package. Besides protection, its core function, there is communication. On average, a person interacts with a package thirty times per day. From a brand perspective, this creates thirty opportunities to communicate with their consumer and to increase loyalty and satisfaction. [10] Additionally, packaging provides many other valuable functionalities, as detailed below: [11]

- Physical protection – Protection from shock, vibration, compression, temperature, contamination etc.
- Barrier protection - Barrier from oxygen, water vapor, dust. Some food packages are maintained in modified or controlled atmospheres - keeping the contents clean, fresh, and safe is a primary function.
- Portion control – Can be used for offering more suitable sizes for individual households, or for usage controlling
- Containment or agglomeration - Small items are typically grouped together in one package to allow efficient handling. Liquids, powders, and granular materials need containment.
- Information transmission - Packages and labels communicate how to use, transport, recycle, or dispose of the package or product.
- Marketing - The packaging and labels can encourage potential buyers to purchase the product.
- Security - Packages can be resistant to tampering or have tamper-evident features. They may include authentication seals that prevent counterfeiting or anti-theft devices, such as dye packs, RFID tags, or electronic article surveillance tags. Using packaging in this way is a means of retail loss prevention.
- Convenience - Features which add convenience in distribution, handling, stacking, display, sale, opening, reclosing, use, and reuse.

Although having all these important functions, consumers are increasingly aware of the environmental impacts of the food packaging industry, as seen on the survey's result.

Food packaging can be seen by some consumers as "annoying waste" and a "burden for the environment"; notions that do not necessarily coincide with the reality. In fact, nowadays over 90% of packaged products would not be available without its packaging.[10]

However, packaging has been evolving focusing among other purposes, on sustainability. It is becoming easier to find options of products that have recyclable, renewable or biodegradable packagings.

Very often packaged food can be also related to unhealthy food. Unfortunately, most processed foods are laden with sweeteners, salts, artificial flavors, factory-created fats, colorings, chemicals that alter texture, and preservatives.

4.5. The relationship between food and refrigerator

Several movements and researches connect the individual responsibility of choosing a healthy diet to a bigger respect to the environment. It becomes clear that it is not enough to take care of our health and our household economy as in a hermetic atmosphere. It is important to have a wider consciousness regarding what we are buying and how it is affecting our environment, economy and society.

In this sense, analyzing our refrigerator, we notice that they are adapted to both two basic categories of food: packaged and unpackaged. There we find many accessories, such as shelves, bottle holders and compartments that are very suitable for packaged items.

However, the unpackaged items – such as vegetables and fruits – have a specific place in every fridge – the crisp drawer.

As showed on the second part of this research, this compartment's design is very adequate in the technical aspect of food preserving. There are several technologies available to make the food last longer inside them, such as special lighting and humidity controls.

Yet, it is located in a lower part of the fridge, away from the user's eye-level. It can be considered underrated - regarding other compartments inside, because usually is not the first to be spotted.

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[3] http://www.slowfood.com/about-us/our-philosophy/

[4] https://pt.wikipedia.org/wiki/Feira_Livre; https://en.wikipedia.org/wiki/Farmers%27_market

[5] http://www.effecorta.it/fc/rete/milano/; http://www.biocoop.fr/actualites-bio/Le-magasin-ephemere-bio-vrac-et-sans-emballage-Biocoop21-prolonge-de-deux-mois-jusqu-au-27-fevrier-2016; https://www.zerowasteeurope.eu/2014/04/packaging-free-shopping-on-the-rise-in-europe/

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[8] https://www.theguardian.com/lifeandstyle/2013/may/19/grow-your-own-veg-advice

[9] http://www.comune.milano.it/wps/portal/ist/it/vivicitta/verde/partecipazione/giardini_condivisi

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[11]https://en.wikipedia.org/wiki/Food_packaging

5
Concept Development

Design depends largely on constraints.

Charles Eames

5.1. Brief

The objective of the previous parts of this research part was pointing out and defining the most important needs regarding food management and food preserving.

We could consider that from the very beginning fridges are helping us to avoid food waste, once it makes the food last longer in its lower temperature. It is not only something directly related to our health, but also to our environment and economy.

A good management of food that we purchase, keep and preserve at home could help avoiding this misuse. and this idea led to this product brief:

Smart system of accessories for food management, which could be used inside or even outside of the fridge.

This system should especially make more convenient and pleasant the management of unpackaged food. It should engage the user to have a more concerned attitude towards health, food quality and sustainability. However, the solution should be flexible beneficial to contemplating as well the traditionally packed items. By accessories for food management, we mean devices that aim to:

- Displaying a list of the food inventory;
- control expiring dates, avoiding food waste;
- suggest recipes with the food available, about to expire;
- identify buying patterns;
- generate shopping lists;

- allow the user to check what is on your fridge remotely, without the need of opening it;
- suggest better practices of organization and cleaning;
- control other products that are not necessarily placed inside the fridge.

5.2. How first ideas were born

The biggest challenge in facing this brief is the idea of joining the ubiquitous computing technology to unpacked food, a subject that is not technological at all.

Here, we enter the convenience matter. The information input, done by the user, must have an ideal proportion relative to the benefits the system can manage to transfer to the consumer. If it demands from the user too much time to introduce new items or to manage them, the system risks becoming bothersome.

HYPOTHESIS 1 – BEST TECHNOLOGY AVAILABLE

In the ideal situation, the information input is completely seamless. Let us say for example that the user arrives home from supermarket full of bags. As he enters the home environment, and as he checks in the products inside the fridge, the appliance examines the products by cameras, or sensors and by object detection recognizes them and updates the food inventory, everything automatically.

It is established that nowadays object detection is an existing technology, although not yet completely developed therefore not yet explored by the market. The concept reported here could be feasible in a near future. [1]

In this scenario, the fridge is central; it concentrates the information input and its updates. It suggests that food that is kept in the kitchen cabinetry, the ones that do not need refrigeration, would be hardly controlled by the system.

HYPOTHESIS 2 – THE WIDESPREAD TECHNOLOGY

Supermarkets have control of their inventory based on the barcode technology, which is something completely feasible for industrialized, packaged products. In several efforts, the same technology has been adopted by home appliances with the ambition to interact with packed food - for example microwaves that can set the cooking time read from product information.

Somehow the idea of adopting the barcode technology on home appliances has not gone very far. In a domestic environment, we usually face two challenges [2] :

(1) Unpacked food items. If a product has no packaging, it has no barcode. In this sense, there should be an alternative way of inputting information that could include that. The same conclusion we can apply to cooked food items and leftovers.

(2) Opened packagings. Once unwrapped, the product expiration time changes, getting shorter. There should be a way of inputting the information of when the product has been unwrapped.

In this scenario, even using accessible widespread technology, it is required a second way of information input. Therefore, the ideal system should have an information input that could be applicable to all products, even if it is not the most seamless one.

Anticipating these two hypotheses was important to emphasize the most important constraints in this process. One should be usability, or better, convenience; and second one should be flexibility – the devices should be designed to deal with different types of food; regardless they are raw or cooked; packed or unpacked; inside or outside the fridge.

5.3. Inspirations

Once deepened the design problems, as part of the design process, it is time to look for some inspiration. Design is about problem solving, and researching good solutions for similar problems can be a big stimulus. Here is a list of successful design products that were very inspiring, that influenced the consolidation of the product concept. [3]

Egg Minder: the usability

Egg Minder is a good example of how I-o-T technology could be used for food management. This simple egg tray is powered with sensors and Wi-Fi connection, which communicate to a mobile app when an egg is placed in the tray.
Remotely, the user can check the number of eggs available and their estimated expiring dates (based on the date the egg was placed). The tray contains LED lights that indicate the oldest egg, while push notifications alert on the user's mobile phone when it is time to buy another dozen.

Although with a very specific purpose, this device is very coherent from the usability point of view. The information input is seamless, sparing the user any effort except to place an egg in the tray. [4]

Tupperware: the versatility

Since the fifties, Tupperware developed plastic containers used in households to contain food and keep it airtight. It defined the market for plastic food storage containers to such an extent that the trademark is often used to refer to similar containers from other manufacturers.

Until nowadays, a very wide range of containers is commercialized by the brand, diversified by color, shape and purpose. The most common models are boxlike modulated containers, designed to be juxtaposed and stacked.

On the other hand, the odd-looking vegetable shaped containers, designated to preserve remnant halves, personifies in a communicative way the vegetable which is supposed to be inside.

Another interesting model is the container with air control vents.

The company propose this solution sustaining the fact that each vegetable demands the preservation of a certain level of humidity, and the openings on the cover can provide the required specific air change. This feature is very similar to the humidity control that we can find on many refrigerator models, more precisely on the vegetable crisp drawer.

In other words, Tupperware produces very low technology food containers, although they are versatile: can be employed on many ways, like outside or inside the fridge and from freezer to microwave. They even might have analogue functionalities compared to the fridge's crisper drawer. [5]

O'CLOCK: THE CUSTOMIZATION

The accessory brand established in Italy in 2009 has as a philosophy the idea of customization of their products. The clock as an example, has its parts sold separately. The dial and the bracelet are presented in a simple design but in several different playful colors.
This way the brand transfers to the consumer the idea of freedom, providing him the choice to make the desired combination; meaning also the idea of personalization or even uniqueness. [6]

5.4. The first attempts

These three products helped to outline the first solutions of Savvy. Ware. And here, in consequence of the flexibility constraint, became clear the fact that three physical products should compose the system:

- The container, suitable for cooked food, unpacked items and left overs;

[Left] O' Clock flexible use [Right, Above and Below] First shape ideas for the food container

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- The bottle holder (which evolved to the bottle stopper), suitable for liquids

- The hook clip (which evolved to the clip), suitable for opened packagings

The products should be brainstormed together, however the container represented a leading part of the system development, for its size and apparent bigger complexity. Once defined the container, the other products would come out easily.

Since their first sketches, humidity control was a big concern. It is placed on the cover and is responsible for the product's character. The shape of the box is a consequence of that associated to an attention with stacking the boxes: even if one box is placed over another, the one below should have the humidity control free so that the food can still breathe. In these propositions, the technology part, called "intelligence" is on the bottom area of the container.

5.5. To scale or not to scale

One big question on this sketching phase was whether to have or not a scale attached to the product. That could allow automatic immediate updates regarding quantities, generating a more precise food database. However, a few questions were part of that discussion:
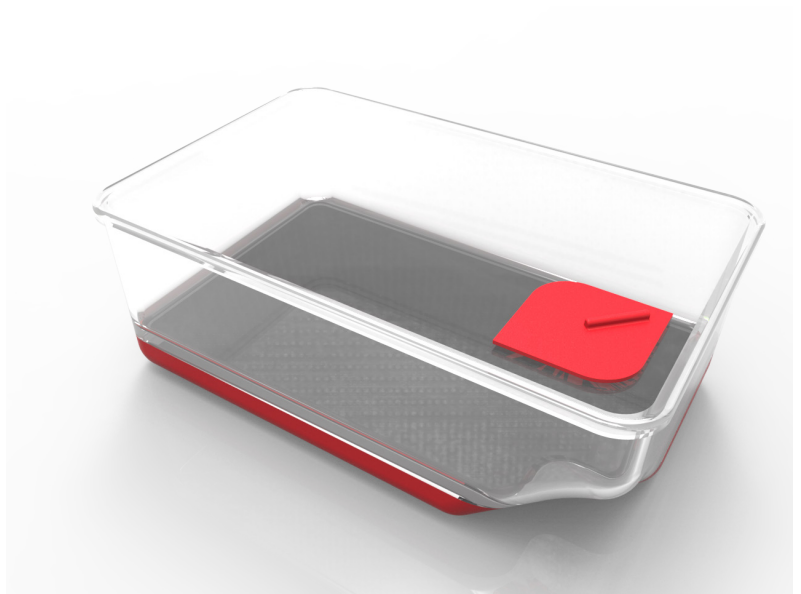
- Cost was one of the things taken in consideration: is that necessary to have one scale sensor for every box (or bottle, or clip), just to have more a precise update?

- The scale, to be used properly, must be placed on the bottom of the box. This demanded that the centralized and detachable technology remained hidden. On the other hand, should not this detachable part an identification, the symbol of the whole system? On the design point of view this part should to be on the top.

- How important was to know precise quantities? Would that change much the user interaction?

After a long mental analysis of the designer, weighting all the pros and cons, it was decided that the product should make a step towards simplicity, and the scale was discarded.

INTELLIGENCE ON THE TOP

With the definition of keeping the intelligence on top, the humidity control takes a more discreet position around the detachable circle. It was time to define the desirable feedbacks, that occur through LED light. In this phase, takes place a research for the electronic components, and that is going to shape accurately the final proposal.
Meanwhile, part of the simplification process, the bottle holder becomes a simpler product – a bottle stopper, capable of holding the same intelligence on top. The hook-clip goes through the same path.

[Left] Food container with the scale on the lower part [Right] First proposal with the intelligence on top

5.6. References

[1] https://www.technologyreview.com/s/523561/
the-tricky-problem-of-making-smart-fridges-smart/

[2] http://www.dailymail.co.uk/news/article-311516/Smart-micro-
wave-reads-barcodes.html

[3] http://whiteboard.is/
inspiration-and-its-place-in-the-creative-process/

[4] https://www.cnet.com/products/quirky-egg-minder/
review/; https://www.manualslib.com/manual/683284/
Quirky-Egg-Minder.html#manual; https://www.amazon.com/
Quirky-Minder-Wink-Enabled-Smart/dp/B00GN92KQ4

[5] https://en.wikipedia.org/wiki/Tupperware

[6] http://www.fullspot.uk.com/O-clock-watches-s/1817.htm; http://
www.obag.eu/

**[Left] First proposal for
the bottle stopper**

6
Introducing Savvy.Ware

Savvy.Ware is a system for food management. It creates and controls a food inventory with the use of physical devices and a mobile app. It is originally designed for unpackaged food, but it must be as well useful for packaged items.

The system is collectible and expandable; the number of items will depend on the inventory size the user aims to have. To have a complete experience of the food management system, the user should have many devices. The more products the user has, the more integrated becomes the food inventory.

The defining feature of collectible items is that they do not stand alone. Each gadget is a small part of a larger narrative that connects the series, and the diversified range of color helps to compose it. [1]

6.1. Color blocking, Mix and match and Customization

Color blocking in fashion design is the combination of complementary solid colors. [2] This system is composed by items colored in
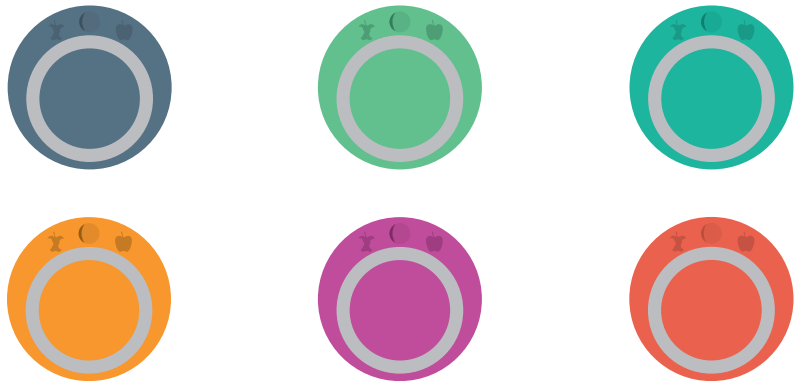
**[Right] Savvy.Ware's
Color Palette**

six different tones, arranged originally in pairs oppositely in the color wheel:

- Dark Blue – Orange
- Blue – Red
- Turquoise Green – Magenta

However, the colors were selected to allow joyful, but still balanced combinations in any of the possibilities. This composition flexibility, that makes possible many different arrangements, is known as "Mix and Match". It allows the user to contribute in some level to the design of the product, suggesting the idea of personalization and customization.

6.2. The system
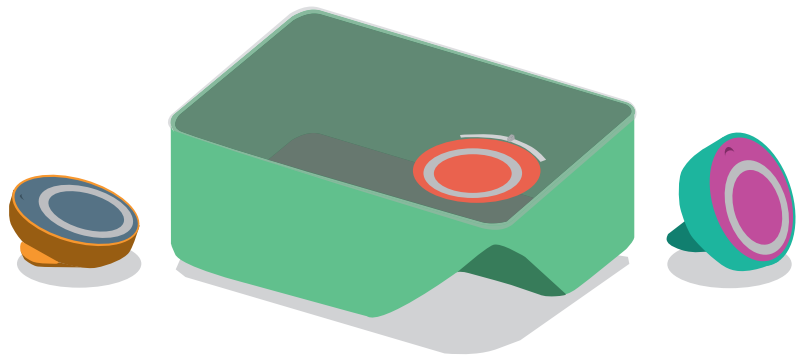
The system is mainly composed of six items, amongst physical objects, computer hardware and software, as listed below:

- The mobile app
- The container with humidity control cover
- The bottle stopper
- The bag clip
- The exchangeable intelligence
- The battery charger

6.3. The intelligence

The intelligence is the rounded interchangeable part that turn the container, the bottle stopper and the clip into smart devices. It is equipped with sensors, Wi-fi connected board and other technologies that are responsible for the communication between the user and the database. At a glance, on the surface there are 3 main elements:

- The off-centered LED circle is the responsible of the system feedback. It will light differently in consonance with the message to be delivered.
- The tiny bass-relief button on the surface represents its singular affordance and it is designed to accommodate a fingertip. It is to be pushed when a product is being checked in or whenever a more precise information about the food endurance level is wanted.
- On the center of the circle the tiny spot is the photo sensor, which will be responsible for "waking up" the system.

The size (10mm x Ø 55mm) is a consequence of the technology carefully chosen to be inside, result of an equation of cost and performance. There we can find:

button

photo sensor

LED light ring

55 mm

10

[Left] Savvy.Ware's physical devices
[Right] The intelligence part at a glance
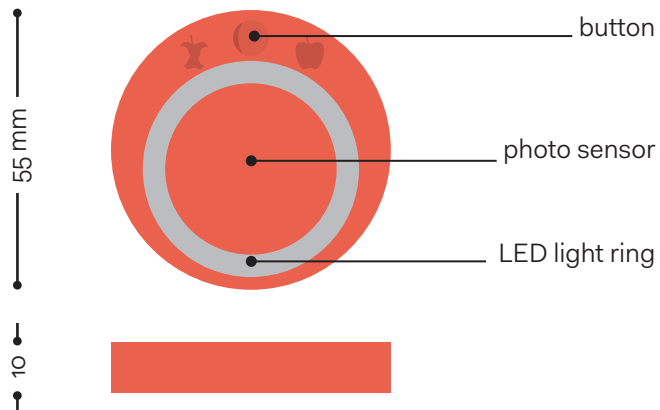
Microcontroller with integrated Wi-Fi ESP 8266

This small (16mm x 24mm) and very cost effective board (price is around US$3,00) is a very suitable solution for I-o-T projects, mainly because of its ability to access to Wi-Fi network through its integrated TCP/IP protocol stack. It has an excellent on-board

processing and storage capability that allows it to be integrated with the sensors and other application specific devices. Its high degree of on-chip integration allows minimal external circuitry, and is designed to occupy minimal PCB area. [3]

RGB LED Pixel Ring

This ring is a circular strip with RGB LEDs attached on it. The advantage of this technology regarding other similar LED solutions is the programmable system. Each pixel (or LED unit) can have time, color or intensity individually programmed by the micro controller. This guarantees distinctive feedbacks regarding each message that the product needs to deliver to the user. [4]

The Charging Technology

In order to remain constantly inside the refrigerator and to be eventually in contact with food and humidity, the intelligence part should be sealed and water resistant. This constraint became important for the definition of the battery charging system - any holes or cable openings to outside should be avoided. For that, the wireless charging technology is much more convenient.

In fact, this technology uses inductive electrical power; there are many standards available, but the chosen one – called Qi – is the most commonly used nowadays, especially by mobile device manufacturers such as Asus, Samsung, LG and Motorola. [5]

The furniture retailer IKEA also has adopted this charging technology standard. Many of their products such as nightstands, lamps and pads and have Qi chargers incorporated. [6]

This technology is capable of transferring power up to 5W, over distances of up to 4 cm through coupling of the electromagnetic planar coils working in a unidirectional way, from the transmitter to the receiver module.

The battery charger part (which includes the universal transmitter module), in order to be a standard part, in this project is considered a whole "bought part" in the Bill of Materials, and was not incorporated in the design of the product intentionally. [7]

Qi Receiver Module

The receiver module, integrated in the "intelligence" part, is a flat coil that allows the coupling for charging the battery inside. It can be

customized according to the product format. The rectangular coil size of 41mm x 29mm was the one considered in this project.

The coil comes on a metallic sticker that is used to isolate the other components from the coil. To work properly, the coil must be facing outside.

Photo Sensor

The photo sensor is the responsible for triggering the main feedback, which we call "eat me first" notification. The product will have the LED light ring blinking when the containing food is on the top of the food list to expire.

Each time the user opens the fridge or kitchen cabinet door, which are sealed dark places, light gets in. This sensor is able to detect this light alteration and deliver the message to the board to activate the feedback.

LiPo Battery 3.7V 110mAh

The battery was specified after defining the LED source and the frequency of necessary rechargings – about a month. Of course, it may vary depending on many factors, mainly on how often the user opens the door and lights are triggered. Regardless, the gadget itself will be able to notify the user whenever it is expected to be recharged, without damaging the flow of the food management process.

In general, the intelligence consists on gathering very simple and accessible technology, and that is hoped to reflect on the cost of the devices.

6.4. The container

The container is presented in two modulated sizes. The small version is slightly smaller than half of the size of the big one. This way two small containers can be perfectly placed over a big one.

The transparent cover has a concavity designed to accommodate the intelligence, and to allow the easy interchangeability. Many small holes are displayed around this circled cavity – they serve as vents, which can be open or closed depending on the position of the sliding control over them.

Many boxes can be stacked with no damage to the system flow – that is the purpose of the odd shape on one of the extremities. The

173 mm — 122 mm — 173 mm — 243 mm — 90 mm — 90 mm
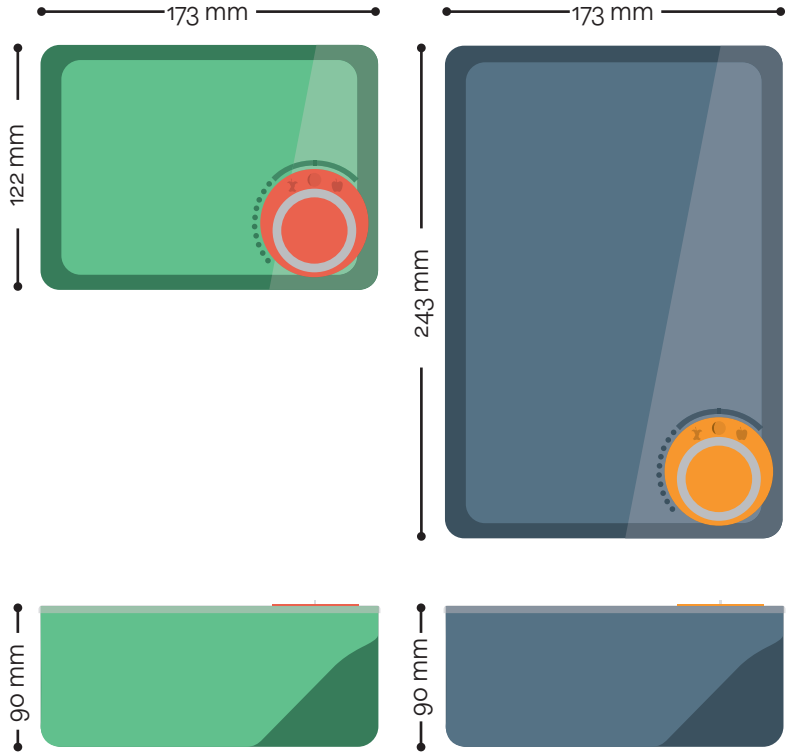
feedback and ventilation zone is always visible and free even when two or more boxes are stacked. The user won't have any trouble to interpret the messages and the food will be able to breathe through the vents whenever convenient, thanks to this detail.

57 mm — 16 mm
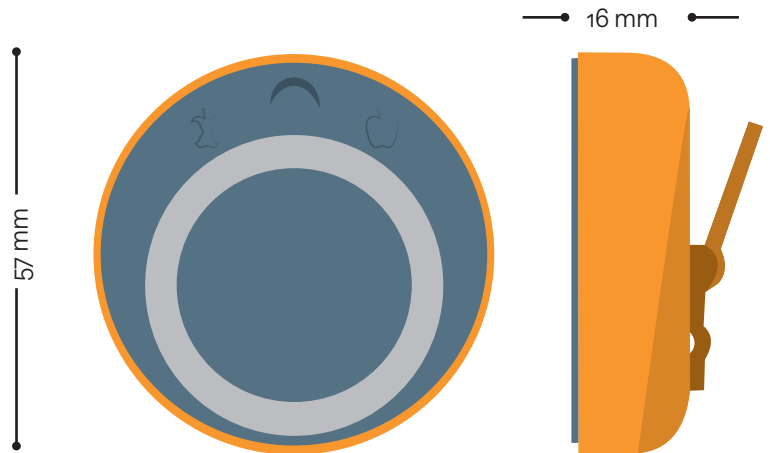
6.5. The bag clip

It works simply and mechanically closing and opening any packaging – needs a small pressure on the tip to make the spring move back and forth, opening and closing it. However, it becomes smart when the intelligence is attached – its rounded shape is determined to shelter this interchangeable part.

It is ideal for re-closable, sealable or not opened bags, like selected salads, cereals, dried Fruits, chips and other snacks.

6.6. The bottle stopper

The stopper is an accessory to close leftover bottles. It seals the air out of the bottle, reducing the speed of deterioration of drinks – it can

58 mm

59 mm
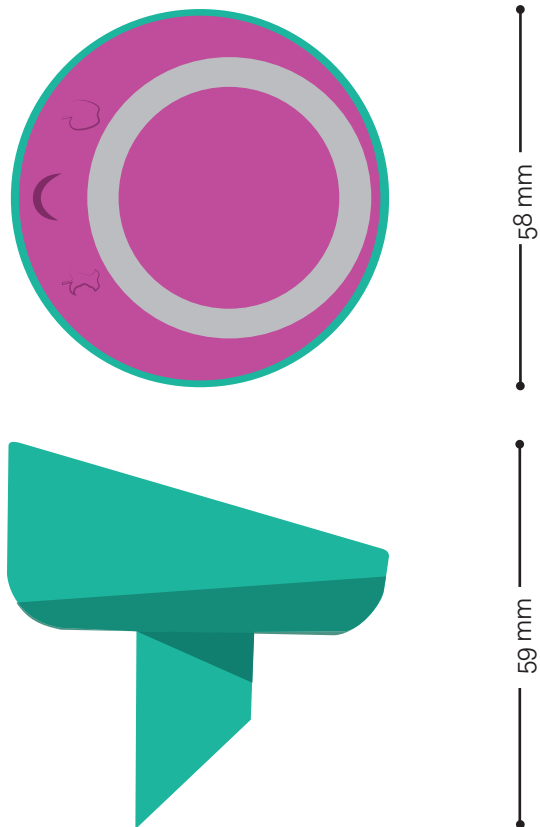
**[Left, Above] The 2 sizes of the containers
[Left, Below] The clip
[Right] The bottle stopper**

extend a wine's life a day or two for example. They are very suitable also for raw milk, tap wine, beer, fresh Juices, iced tea etc.

The base is designed to fit standard sized necked bottles and hold the intelligence in a slight angle, making clearer the feedback surface, as the bottles are supposed to be regularly on the upright position (it minimizes the surface area exposed to oxygen).

6.7. The mobile app

The app is key element of the product, being responsible for a big part of the interaction with the system. Its role is to be a hub of the devices and to display and manage the inventory database.

Its graphic design is outlined to be flat, simple, clear, communicative and joyful. Similar color palette and rounded shapes were considered to perform with consistency as a part of the system as a brand. Also in consonance with the system concept, is the care with usability. The information input that is responsible for creating the food inventory, mas be performed very easily. On the next chapter, the main app functionalities will be detailed on storyboards.

The prototype is available for downloading on the site: https://popapp.in/w/projects/5593e5bb8973848072551abb/mockups

6.8. The material selection

Plastics play a part in every phase of food production, preparation and preservation. Food gets processed on plastic equipment, and packaged and shipped in plastic boxes and cans. At home, food is preserved and often heated in plastic containers.

However, recent health controversies have spawned new discussions about the safety of plastics in the food industry. What is really concerning are the potential health risks from bisphenol A (BPA), a common chemical in food packaging, and a class of chemicals called phthalates.

It's long been known that infinitesimal bits of plastic get into our food from containers. The process is called "leaching" or "migration." The chemical industry acknowledges that it is inevitable. In addition, heating food in plastic seems to increase the amount that's transferred to food. Migration also increases when plastic touches fatty, salty, or acidic foods.

Research results so far are not enough to prove the effects of these substances on people; however, since 1940s they are being

observed, and very are often connected to diseases related to hormonal dysfunction.

In any design development related to food packaging or kitchenware, there are two types of plastics that should be avoided: Polyvinyl Chloride (PVC) and Polycarbonates (PC).[8]

INTELLIGENCE HOUSING

This part should be rigid, because it will contain all the electronic parts. In addition, it will be constantly manipulated by the users, so it should be produced in a resistant material.

ABS is the selected one because it is a stable resin that didn't leach toxic chemicals under normal, everyday use. Moreover, it is considered a higher quality plastics with increased strength, rigidity, toughness and temperature and chemical resistance.

It is a hard and durable plastic that is stable through a broad range of temperatures. It is commonly used in toys, kitchenware (water bottles) and household products. It is provided not only in a wide range of colors but also on a transparent version, which will be useful for the light cover detail.[9]

FOOD CONTAINER

This part should be made in non-toxic material, considering that it will be constantly in contact with food. Also, it should be produced on a more flexible material than ABS, now that the intelligence must be ejected with some easiness from the container cover.

Polypropylene (PP) is a suitable material because it does not leach harmful chemicals into foods or liquids. Yogurt, medicine, drinks, ketchup and medicines are commonly packaged in this material. This plastic is flexible, resistant and can be presented in opaque and semi-transparent versions, this last one more suitable for the container cover. [10]

BOTTLE STOPPER AND CLIP

Part of the design concept is the "rubber-like" appearance of these two parts. Nowadays Silicone is a very popular material used on the kitchenware industry, claimed to be non-toxic, non-sticky, easy to clean, very resistant to high temperatures and, of course, very flexible. [11]

The inner part, the core, must have an added strength to give

the proper shape to the parts, and to support the intelligence whenever it is attached. Nylon (PA) is a good choice for that. The material process is more complex because it must be done in two steps, associating the thermoplastic molding with a second phase of thermoset molding.

Although similar to thermoplastic injection molding, where the material is heated and injected into the molds, the thermoset process demands first a premixture at a low temperature of the two parts of the material system to inhibit the premature curing reaction. Then this blend can start to be injected into the heated mold assembly where the material cures to form the product.

6.8. References

[1] Kuniavsky, Mike. *Smart things: ubiquitous computing user experience design.* Elsevier, 2010.

[2] https://en.wikipedia.org/wiki/Color-blocking

[3] https://www.sparkfun.com/products/13678

[4] https://www.adafruit.com/product/1463

[5] https://en.wikipedia.org/wiki/Qi_(inductive_power_standard)

[6]http://www.ikea.com/us/en/catalog/categories/departments/wireless_charging/30612/

[7] https://www.alibaba.com/product-detail/2016-wireless-qi-charging-pad_60444433749.html?spm=a2700.7724838.0.0.sZYrQk

[8] https://www.theguardian.com/lifeandstyle/2015/feb/10/phthalates-plastics-chemicals-research-analysis; http://www.huffingtonpost.com/maia-james/phthalates-health_b_2464248.html

[9] Ashby, Michael F., Hugh Shercliff, and David Cebon. *Materials: engineering, science, processing and design.* Butterworth-Heinemann, 2013. ; CES Software database; http://thesoftlanding.com/is-acrylonitrile-butadiene-styrene-abs-plastic-toxic/; http://www.webmd.com/food-recipes/features/cookware-plastics-shoppers-guide-to-food-safety#3

[10] http://www.livestrong.com/

article/158674-which-plastic-containers-can-i-safely-use/

[11] http://thesoftlanding.com/bpa-and-pvc-free-food-storage-containers/; http://thesoftlanding.com/how-to-avoid-toxic-chemicals-in-food-containers-and-kitchen-appliances/; http://www.momentive.com/brands/silopren/; https://www.leaf.tv/articles/silicone-versus-nylon-utensils/; https://www.kickstarter.com/projects/productofgir/gir-bottle-stoppers?ref=nav_search#;

7
User-product interaction

User-centered design is a philosophy based on the needs and interests of the user, with an emphasis on making products usable and understandable. Design should make sure that the user can understand the product's feedbacks and easily can figure out what to do.

Design should use the natural properties of people and of the world: it should exploit natural relationships and natural constraints. As much as possible, it should operate without instructions or labels. [1]

Savvy.ware is carefully designed to be user friendly. The information input must be performed in the most seamless way, through a very few steps, otherwise the user might lose interest, based on the proportion of benefits in relation to the effort to be employed.

For example, checking in the products can be a tiresome activity, imagining a situation in which the user has brought from the market more than 10 items. That is an important and complex part of the process flow – for that, the connection between intelligence and app is planned to the easiest as it can be. To register a new item, the user needs to press the intelligence button – which will trigger the app to send a push notification – and select the right option from the app database.

7.1. Prototyping

Prototyping plays an important role on the design process. It must be done early and often, making each iterative step a little more realistic. [2] It helps bringing to the physical world something that used to be only abstract ideas. It is also a tool for the concept development, giving the designer the opportunity to make more tangible decisions.

PAPER PROTOTYPE

Paper prototyping uses the oldest, cheapest, more flexible and most common everyday technology: paper. It is quite straight-forward and can be done fast and easily. There is a long tradition of reduced scale models in industrial design, architecture and urban planning. In this case, it made sense to choose the 1:1 scale, to have the right perception of the product's proportions related to a human hand.

APP PROTOTYPING

Software prototyping can be very tricky. It can be confused with the finished system although it typically simulates only a few aspects of the final product. In this case, it was developed with the objective to have the graphic design tested, functionalities represented and navigability experimented. [3]

A first version of the app was developed in the early stages of the design process, and throughout the progress it was repeatedly tested and evaluated. At some point, it became clear that it contained an excessive number of screens. The second version was designed to be straight-forward and clearer, with more simple graphics and fewer steps performing the same activities. That was the biggest benefit of developing this software prototype – it helped to get valuable feedback and consolidate the most important tasks of the Savvy.ware system.
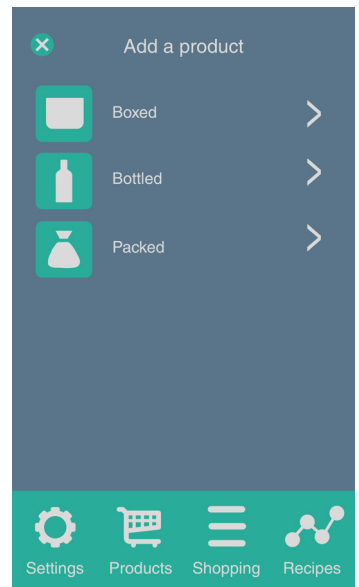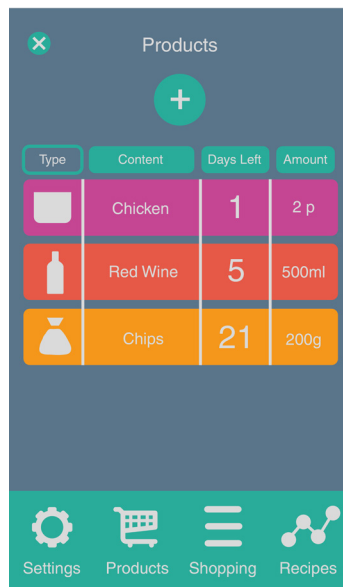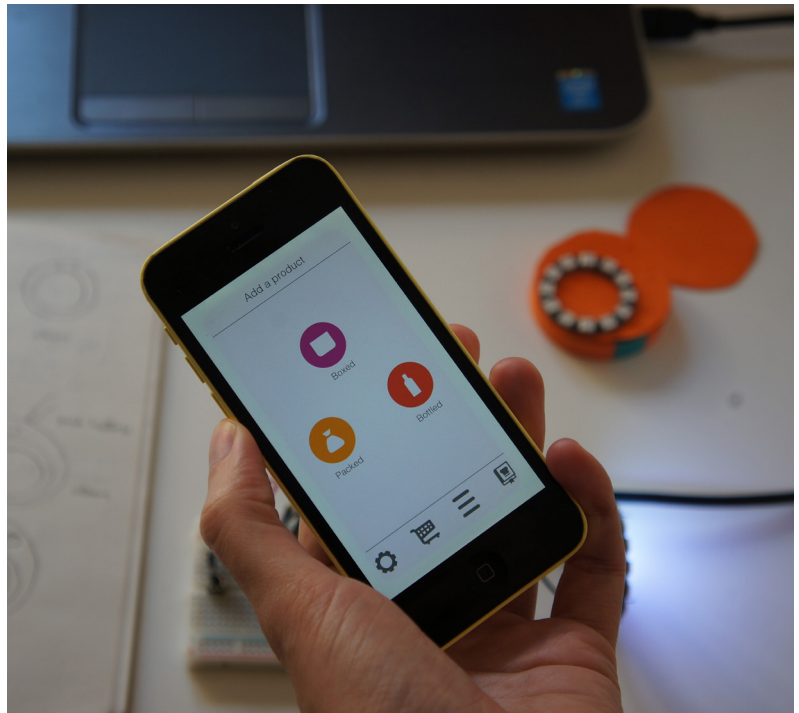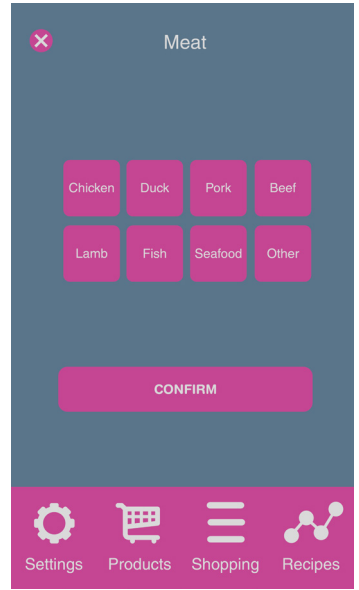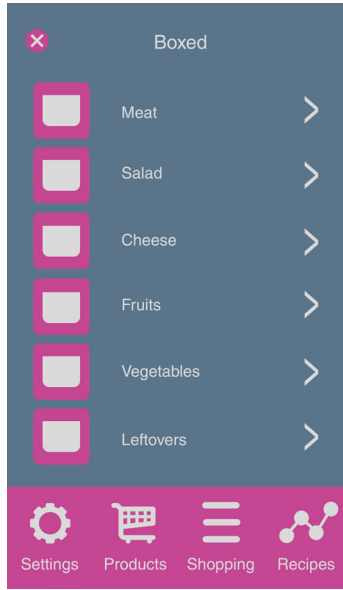
[Left and Right, Above]
First prototyped
version for the app
[Right] Testing the final
prototype usability

Products ⊕

Type	Content	Days Left	Amount
▢	Chicken	1	2 p
🍾	Red Wine	5	500ml
🛍	Corn Flakes	19	Default

Add a product

Boxed

Packed

Bottled

Boxed

Dairy Salad Vegetables Meat Fruits Cooked Meals ...

Meat

Beef Chicken Pork Duck Fish Seafood ...

Chicken

Estimated expiring date

+ 1 day

Estimated amount

| 2 | portions |

Organization tips

**place on lower shelf
close box tiightly**

Lettuce

Done

Settings

My Profile

Portions and Units

Default Expiring Time

Default Products

Notifications

Shopping List

Red Wine

Bananas

Bread

Milk

Tomatos

Yogurt

Onions

Coffee

Salt

• • •

**[Left and Right]
App screens of the
prototype on its final
version**
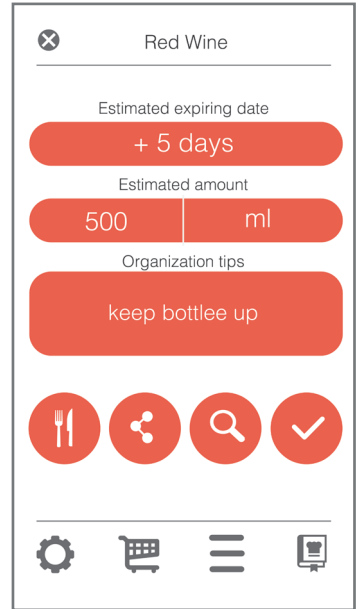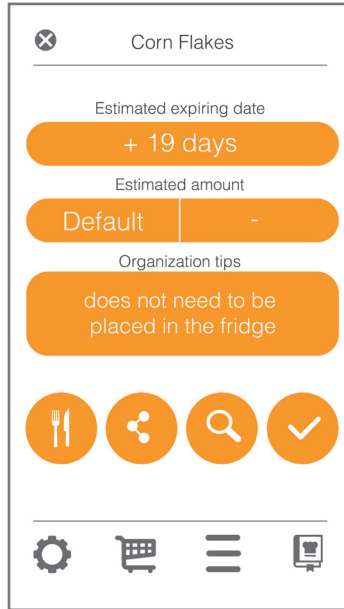
3DPRINT PROTOTYPING/ RAPID PROTOTYPING

Rapid prototyping is a group of techniques used to produce a physical model using 3D computer aided design (CAD) data.[4] The construction of the assembly of the intelligence element was done using additive layer manufacturing technology. It was 3D printed in several parts to facilitate the assembly of some of the electronic components, and to evidence clearly the contrast between the white and colored parts.

SKETCHING IN HARDWARE

Developed specifically for ubiquitous computing user experience design prototyping, Arduino I/O board has become the most popular platform for such prototyping. It blends the idea of easy-to-learn microcontrollers, blended with a rich development environment and active user community of open-source development.

Hardware sketches are simple systems designed to quickly explore design directions using actual electronics. It is possible to combine components and give designers the ability to explore
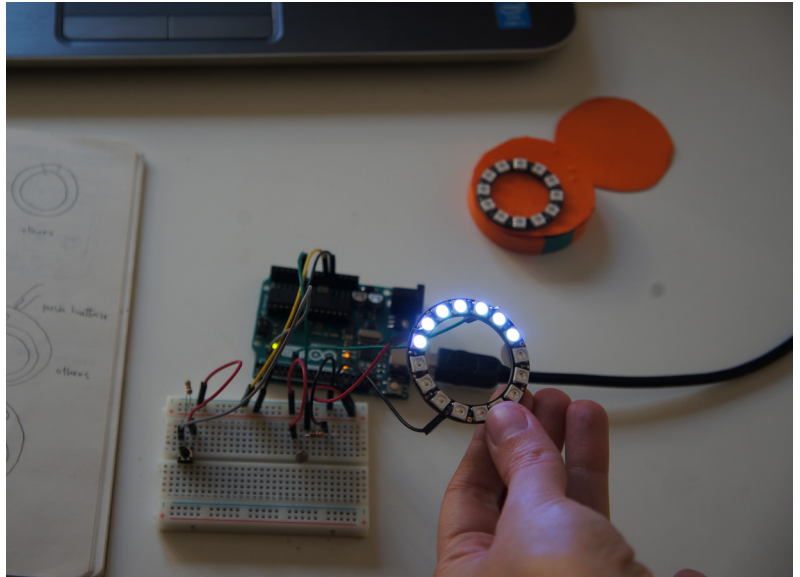
design concepts much more quickly than traditional engineering methods.

Here, some other components such as the Neopixel ring, the button switch and the photo sensor were combined with the Arduino board, to illustrate some of the Savvy-ware's most important physical interactions.

7.2. Storyboards

User experience storyboards describe stages in a technology interaction. Unlike a film, however, user experiences can have multiple outcomes based on the user's choices.

Sketching multiple storyboards describing possible interactions is very important. The first storyboard sketches in this design process requested a further detailing, and made possible the other ways of prototyping.

Here they are displayed helping to illustrate the various scales of the user interaction.

[Left, Above] App screens of the prototype on its final version
[Right, Above] Hardware prototyping with Arduino

83

Getting started

Tap for signing up

savvy•ware

Carla

Email address

Password

New family profile?

Fill up the form with personal data

Check to create a family profile

savvy•ware

Family Name

Email address

Email address

Email address

Email address

SEND INVITATIONS

Write other family member's e-mails

Send invitations and the account is created.

Products

Type   Content   Days Left   Amount

First screen is the home inventory.

Registering an item

Fill the box with the desired item and close it.
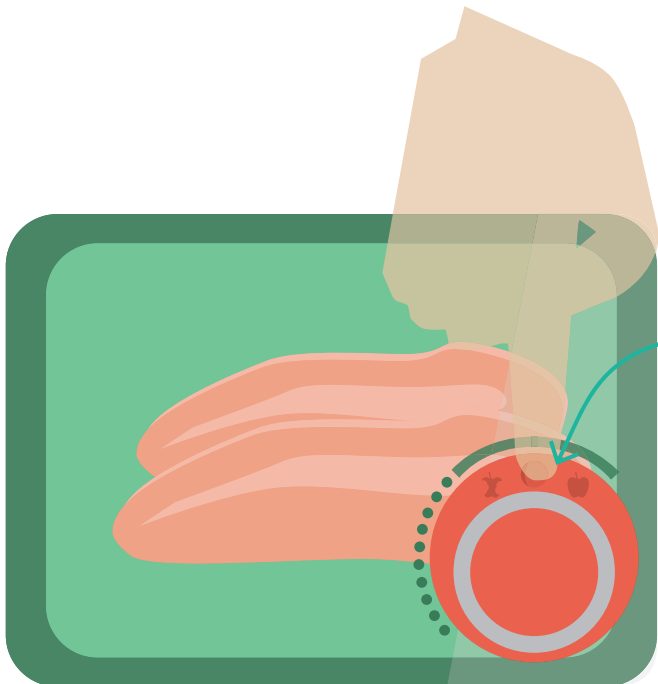
Push the button and it will communicate with the app. Lights will turn on for a few seconds.
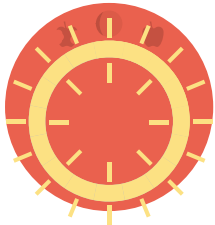
A push
notification
arrives
automatically-
unblock
to access the
app directly

Savvy.Ware há 5 m
Add new product...
deslize para ver

13:39
quarta-feira, 14 de setembro

deslize para desbloquear
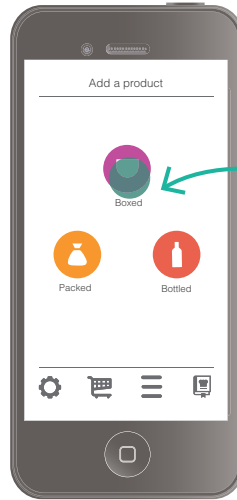
The app will guide
the user in a few
steps to choose
the right item.
In this case,
choose box

Add a product

Boxed

Packed   Bottled

Then, tap
meat...

Boxed

Dairy   Salad   Vege
tables

Meat   Fruits

Cooked
Meals

... and chicken.

Meat

Beef   Chicken   Pork

Duck

Fish   Seafood

Chicken

Estimated expiring date

+ 5 days

Estimated amount

2   portions

Organization tips

place on lower shelf
close box tightly
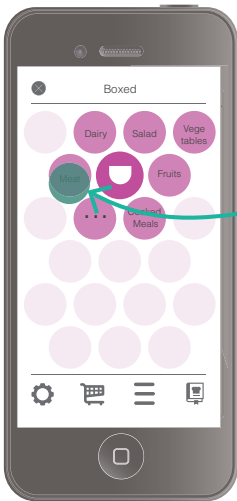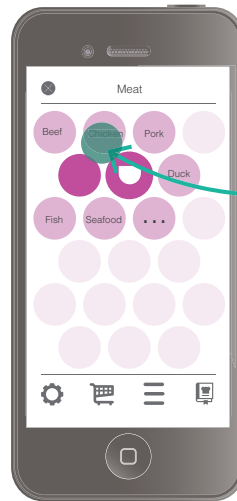
The app will display default estimated expiring time and amount. Swipe right to change.

Chicken

Estimated expiring date

+ 1 day

Estimated amount

2   portions

Organization tips

place on lower shelf
close box tiightly
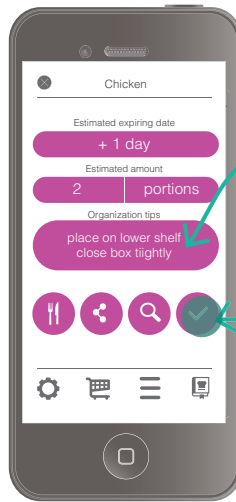
The app will suggest better practices on organization.

And once everything is set, tap the check icon

Chicken

Done

The app will display the "done" screen for a moment...

Products

Type	Content	Days Left	Amount
	Chicken	1	2 p
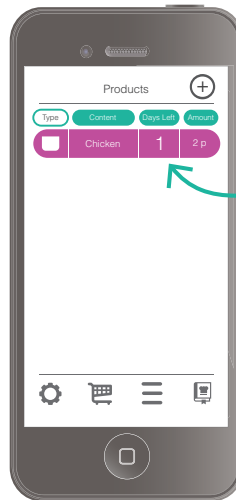
The item registered will be displayed on the product list.

Controlling the inventory
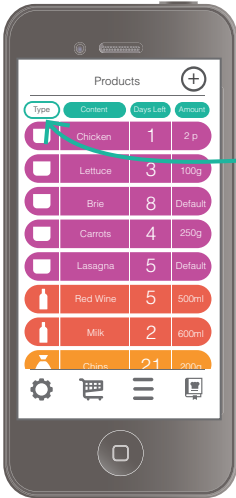
The app by default displays the product list organized by type...

...however it can be reorganized by content, amount or days left
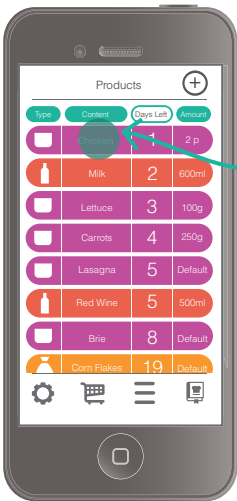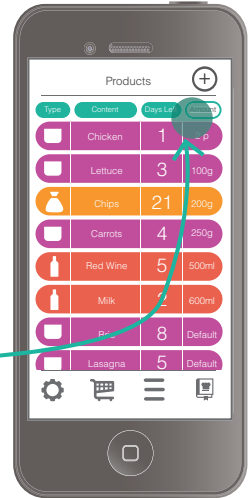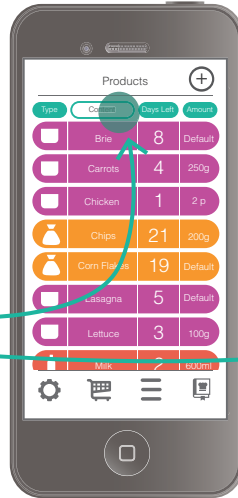
To find a specific item in the fridge, choose it first from the product list...

...then tap the magnifier icon
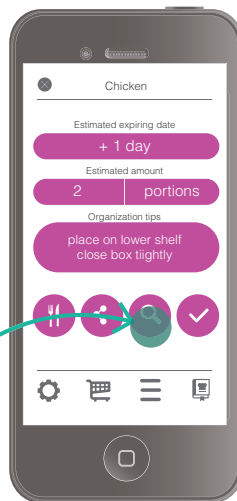
The app will display a status screen for a few moments.
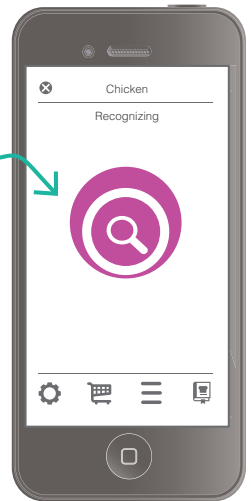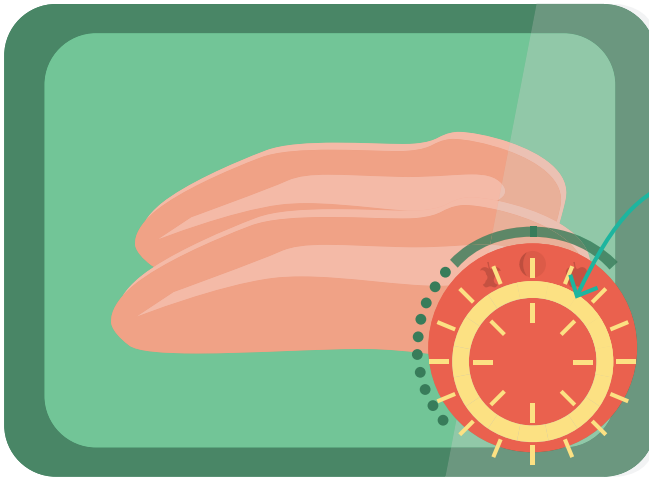
and it will
comunicate
with the box
making the
lights blink.

Type	Content	Days Left	Amount
	Chicken	1	2 p
	Milk	2	600ml
	Lettuce	3	100g
	Carrots	4	250g
	Lasagna	5	Default
	Red Wine	5	500ml
	Brie	8	Default
	Corn Flakes	19	Default
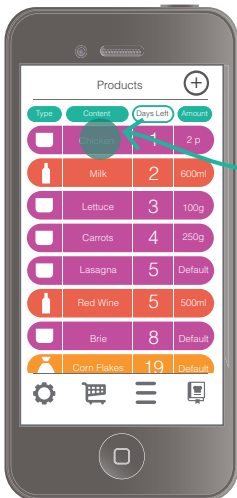
Products

To delete a
specific
item
from the
database,
choose it
first from
the product
list...

...then
tap the
cutlery
icon

Chicken

Estimated expiring date
+ 1 day

Estimated amount
2   portions

Organization tips
place on lower shelf
close box tiightly
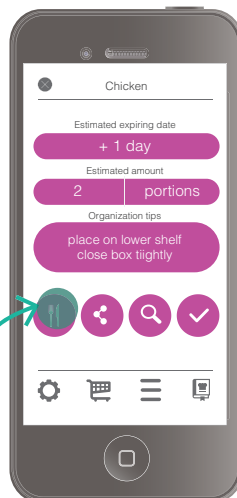
The app
will
display
a status
screen
for a few
moments.
After that,
the box is
ready for
reuse.

Chicken
Consumed
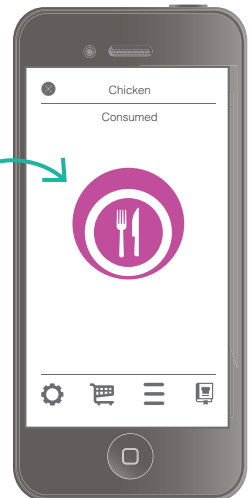
Searching for a recipe with the items about to expire
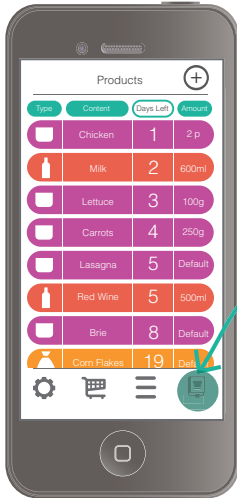
To find a recipe, first tap the recipe icon
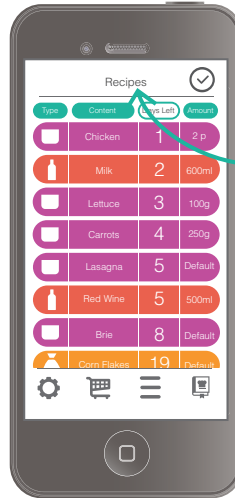
It will change to the recipes mode.
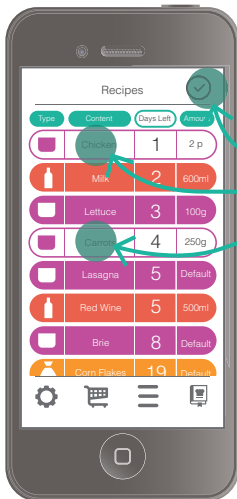
Select the desired items to compose the recipe and tap the check icon

The recipe found containing the selected items is displayed

Chicken Katsu Curry

Succulent breast of chicken golden fried in breadcrumbs, generously topped with a rich Katsu curry sauce and served with rice and salad. Fresh, simple and totally delicious.

Ingredients

Adding a product to the shopping list

Screen 1 (top left)

Products ⊕

Type	Content	Days Left	Amount
☐	Chicken	1	2 p
🍾	Milk	2	600ml
☐	Lettuce	3	100g
☐	Carrots	4	250g
☐	Lasagna	5	Default
🍾	Red Wine	5	500ml
☐	Brie	8	Default
👤	Corn Flakes	19	Default
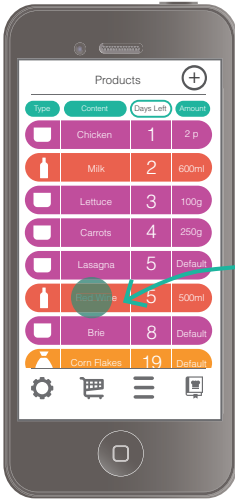
Select the item from the list

Screen 2 (top right)

⊗ Red Wine

Estimated expiring date
+ 5 days

Estimated amount
500 | ml

Organization tips
keep bottlee up

🍴 ⤴ 🔍 ✓

Tap on the sharing icon

Screen 3 (bottom left)

⊗ Red Wine

Add Notification

Notify me before expiring date
+ 1 day

Add automatically to shopping list?
Yes | No

Share notification with family?
Yes | No

✓
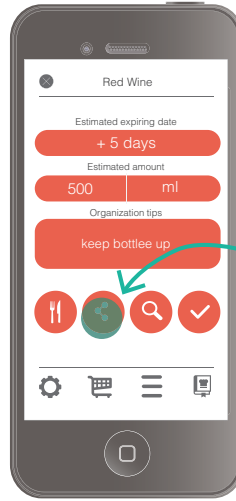
Make sure to select the option to add the item automatically- the list will be updated whenever the item goes missing from the inventory.

In this screen it is possible also to choose to share a notification of a specific product with the family members.

Then, tap confirm.

Screen 4 (bottom right)

Red Wine

Done

✓
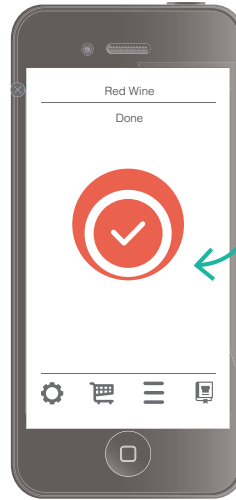
Once more, the app will display the "done" screen for a moment- this will happen whenever the inventory is updated.

Managing the shopping list
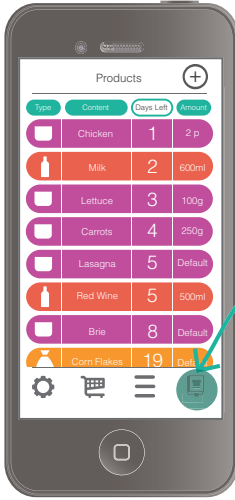
To edit the shopping list, tap the kart icon
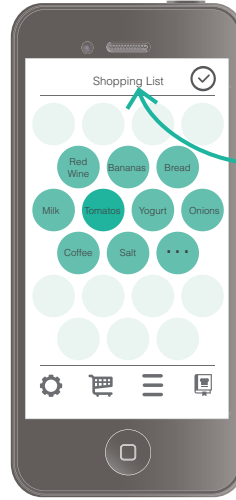
It will change to the shopping list mode. Here displayed are both the manually and automatically items added.

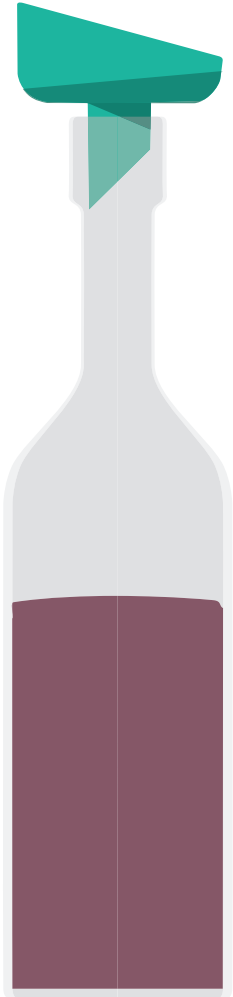Select the desired items to delete from the list and tap the check icon.

To add a product manually, tap the ... icon and type the product name. Another option is to create a list automatically...

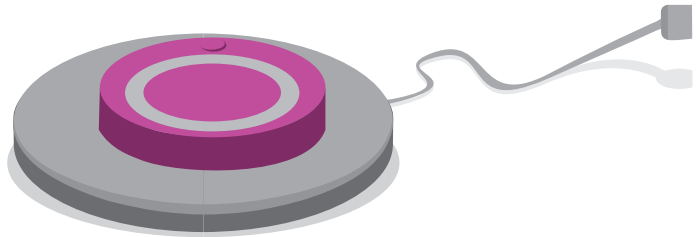...In this case, go back to the by tapping the list icon.

Recharging the battery
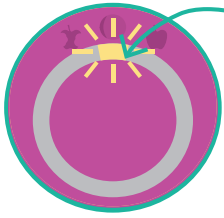
When battery needs to be recharged, the top light will blink constantly
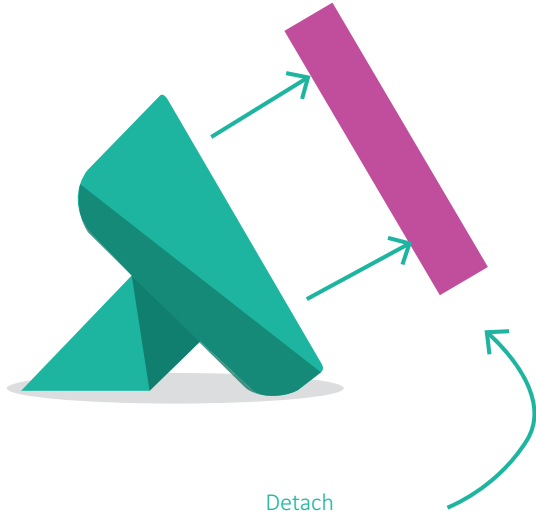
Detach intelligence...

... and place it over the recharging plate. It will stop blinking when recharging is complete.

Recognizing most common feedbacks
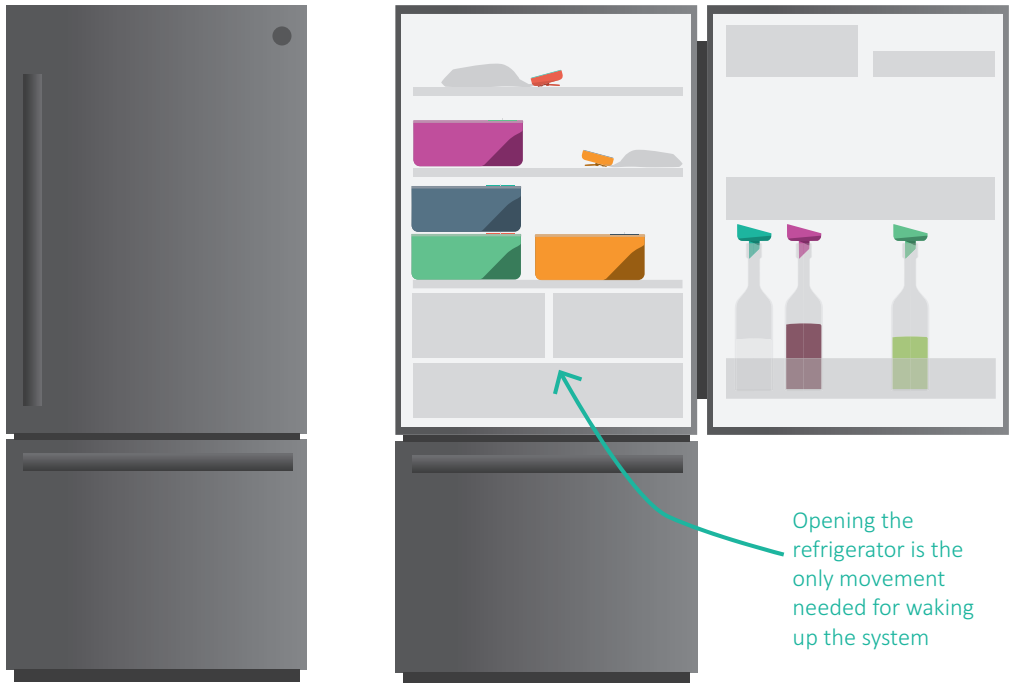
Opening the refrigerator is the only movement needed for waking up the system
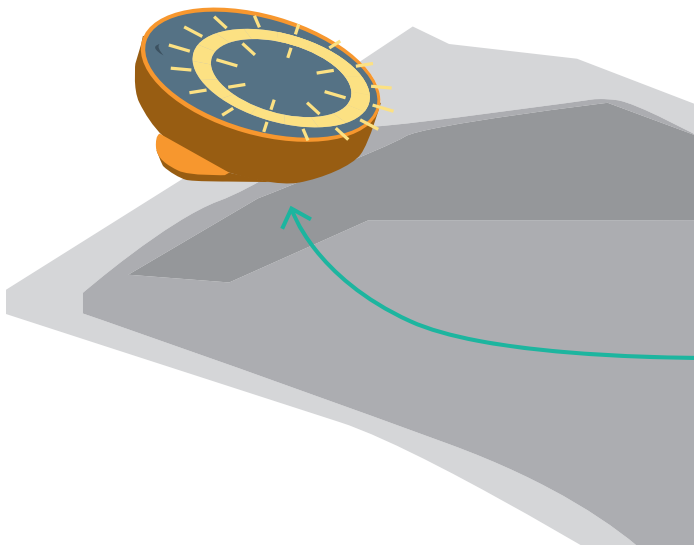
The three products that are closer to expire will blink. The others will remain with the lights off.
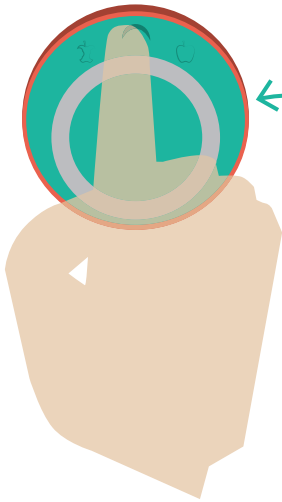
For obtaining the information concerning the level of endurance of a specific item, it is necessary to push the button
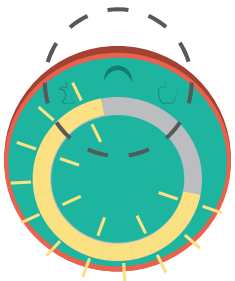
The led lights will display a qualitative feedback - the bigger the number of lights on, the fresher is the product.

Small icons of apples in the fresh and rotten state make this message clearer.
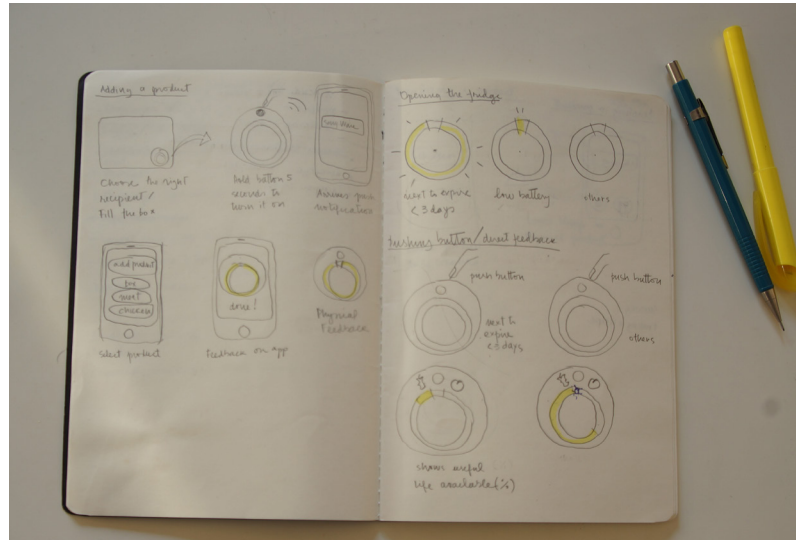
Although several prototypes were developed, further developments and testing should be considered as next steps for turning this product system into reality.

7.2. References

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[2] Moggridge, Bill, and Bill Atkinson. *Designing interactions.* Vol. 14. Cambridge, MA: MIT press, 2007.
[3] https://en.wikipedia.org/wiki/Software_prototyping
[4] https://en.wikipedia.org/wiki/Rapid_prototyping

Bill of Materials

Level 0	Level 1	Level 2	Name	Quant.	M/B
Product	Assembly	Group			
0			**Intelligence**	**1**	
	0.1		**Cover Assembly**	**1**	
		0.1.1	Main Cover	1	M
		0.1.2	Light Cover	1	M
		0.1.3	Middle Cover	1	M
	0.2		**Shell Assembly**	**1**	
		0.2.1	Back Shell	1	M
		0.2.2	Qi Receiver Module	1	B
		0.2.3	Microcontroller Wi-Fi ESP 8266	1	B
		0.2.4	Button Nut	1	B
		0.2.5	Micro Switch	1	B
		0.2.6	Bezel	1	B
		0.2.7	Spring	1	B
		0.2.8	Button Cap	1	M
		0.2.9	Battery	1	B
		0.2.10	Light Ring	1	B
		0.2.11	Photosensor	1	B
1			**Container**	**1**	
	1.1		**Cover Assembly**	**1**	
		1.1.1	Main Cover	1	M
		1.1.2	Humidity Control	1	M
	1.2		Back Shell	1	M
2			**Bottle Stopper**	**1**	
3			**Clip**	**1**	
	3.1		Back Shell	1	M
	3.2		Holder	1	M
	3.3		Spring	1	B
	3.4		Axis	1	B
4	**3.4**		**Battery Recharger**	**1**	**B**

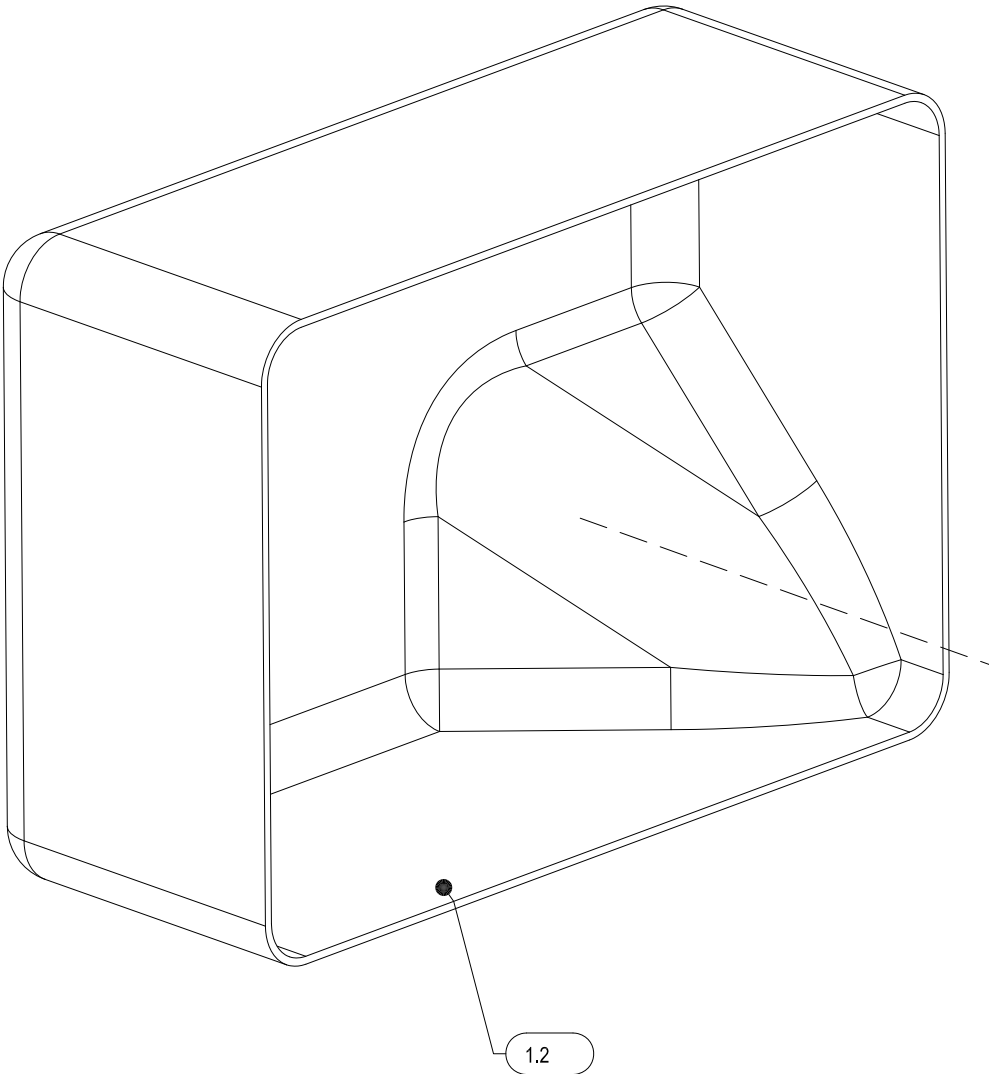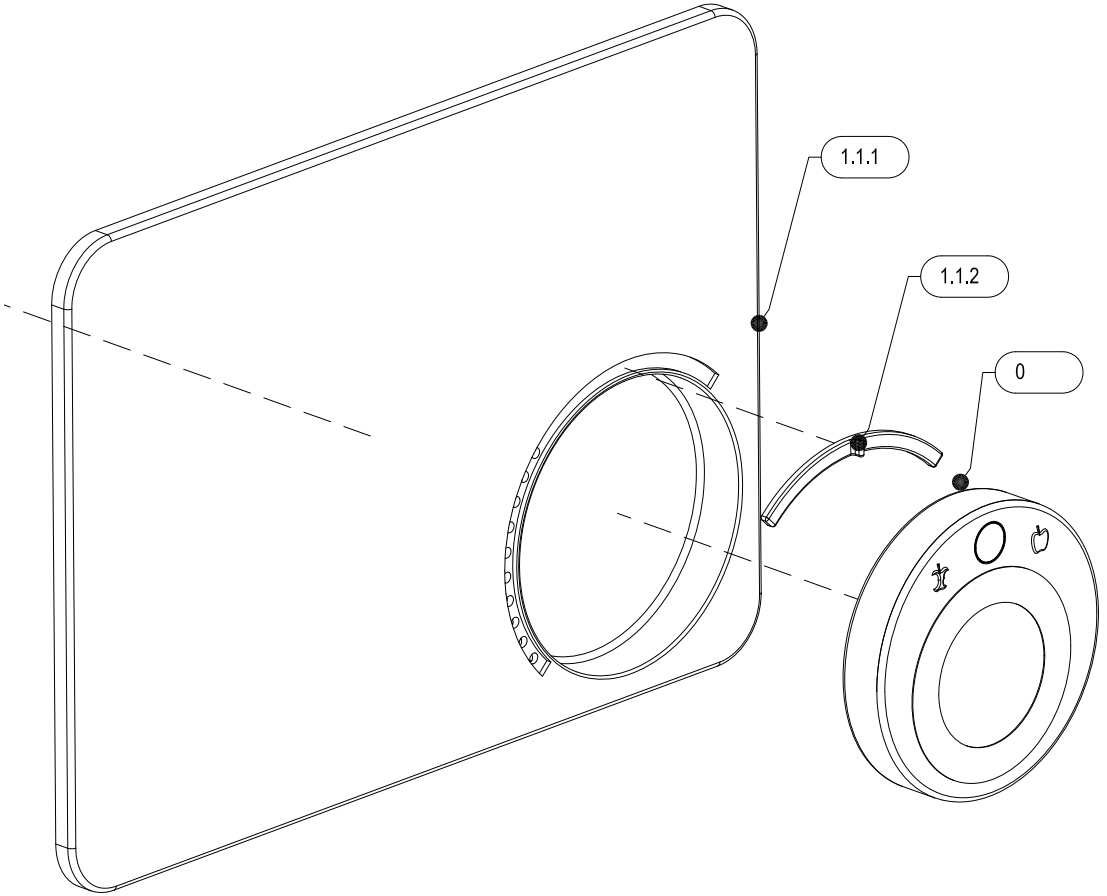| Material	Mat. Process
ABS (Heat resistant, injection molded)	Injection Molding
ABS (Transparent, Injection Molded)	Injection Molding
ABS (Heat resistant, injection molded)	Injection Molding
ABS (Heat resistant, injection molded)	Injection Molding
ABS (Heat resistant, injection molded)	Injection Molding
PP (random copolymer, clarified/ nucleated)	Injection Molding
PP (random copolymer, clarified/ nucleated)	Injection Molding
PP (copolymer, 40% calcium carbonate)	Injection Molding
SILICONE (VMQ, heat cured, 10-30% fumed silica) + Nylon	
SILICONE (VMQ, heat cured, 10-30% fumed silica) + Nylon	Injection Molding
SILICONE (VMQ, heat cured, 10-30% fumed silica) + Nylon	Injection Molding

0.2.1

0.2.2

0.2.3

0.2.4

0.2.9

0.2.5

0.2.6

0.2.7

0.2.10

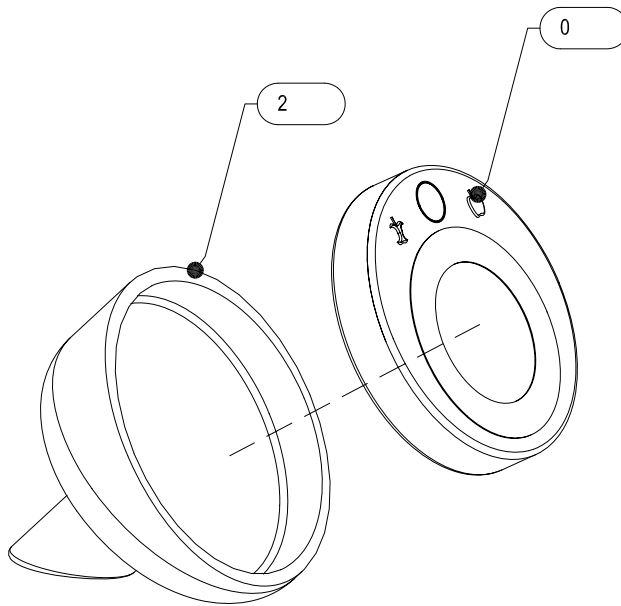0.2.8

0.1.2

0.1.1

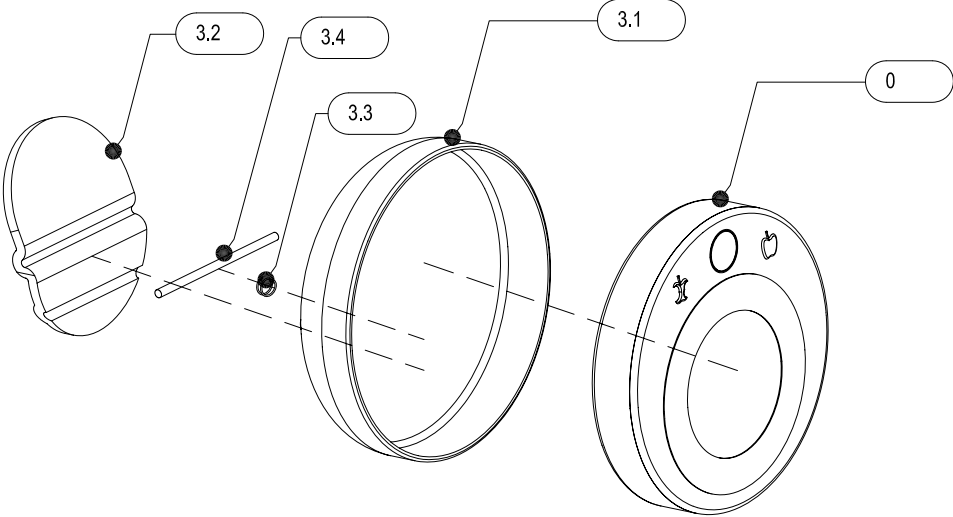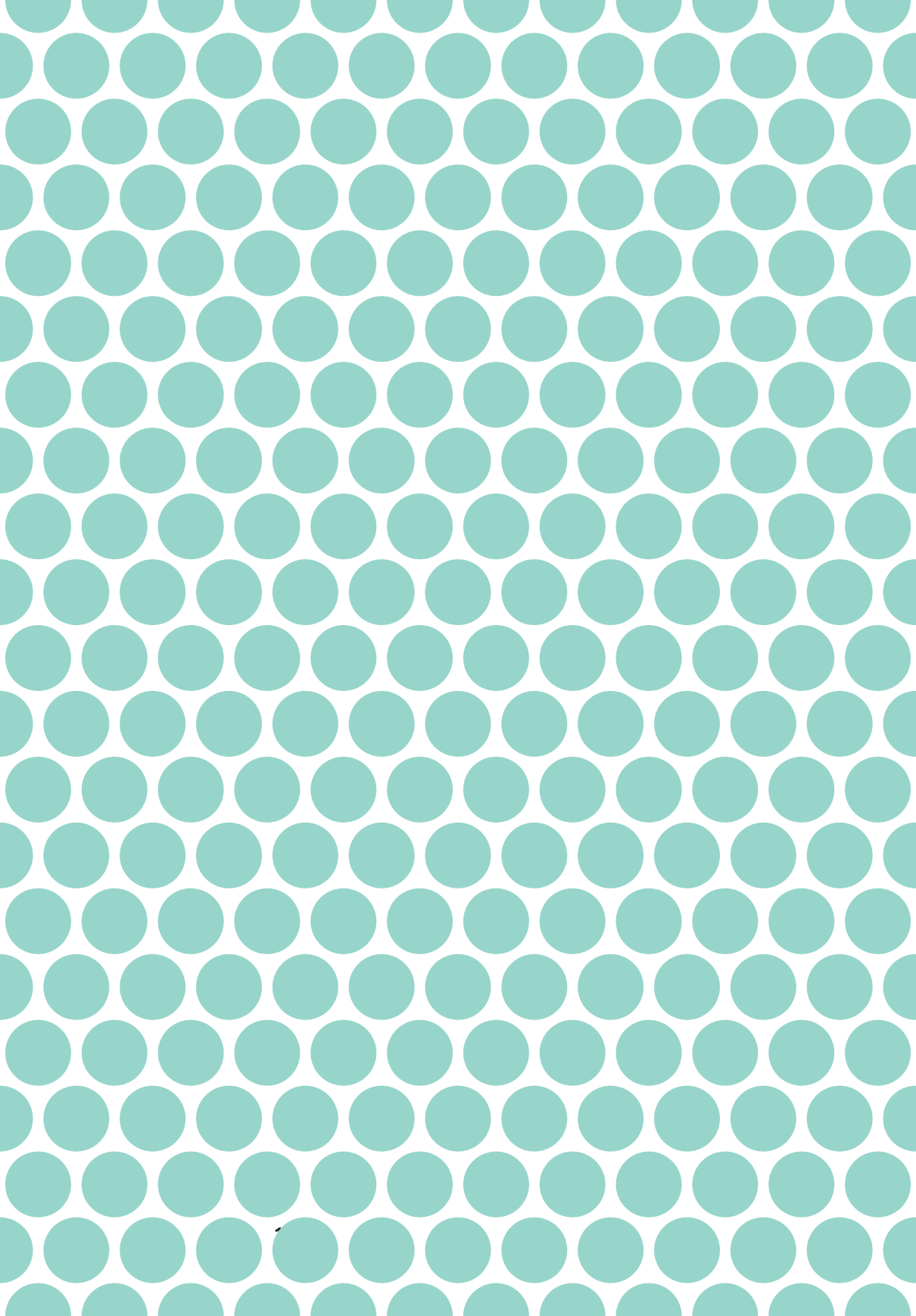0.2.11

0.1.3
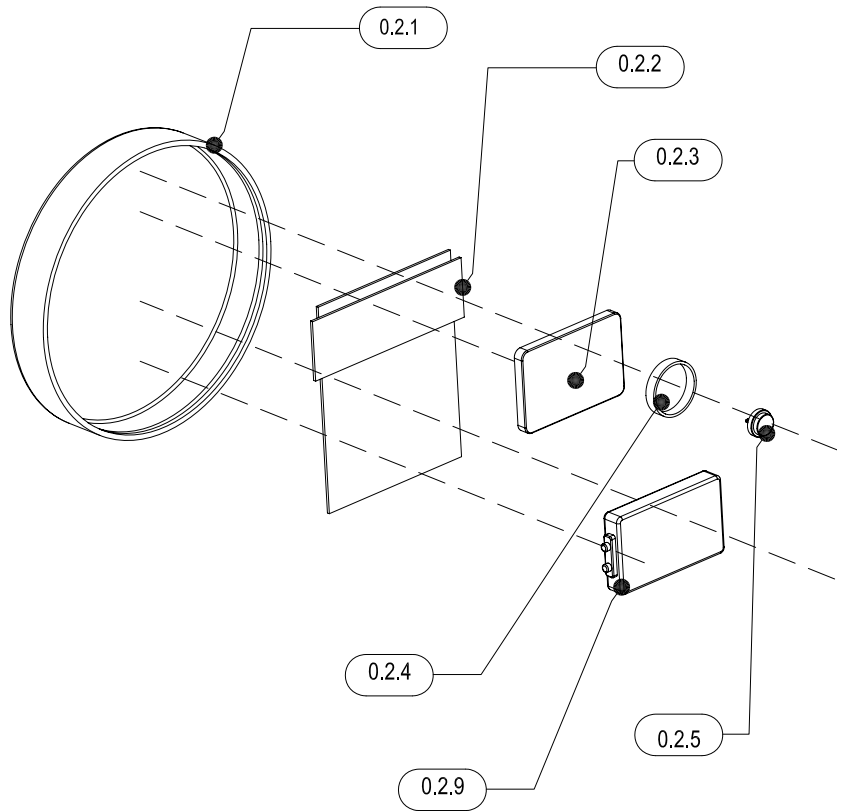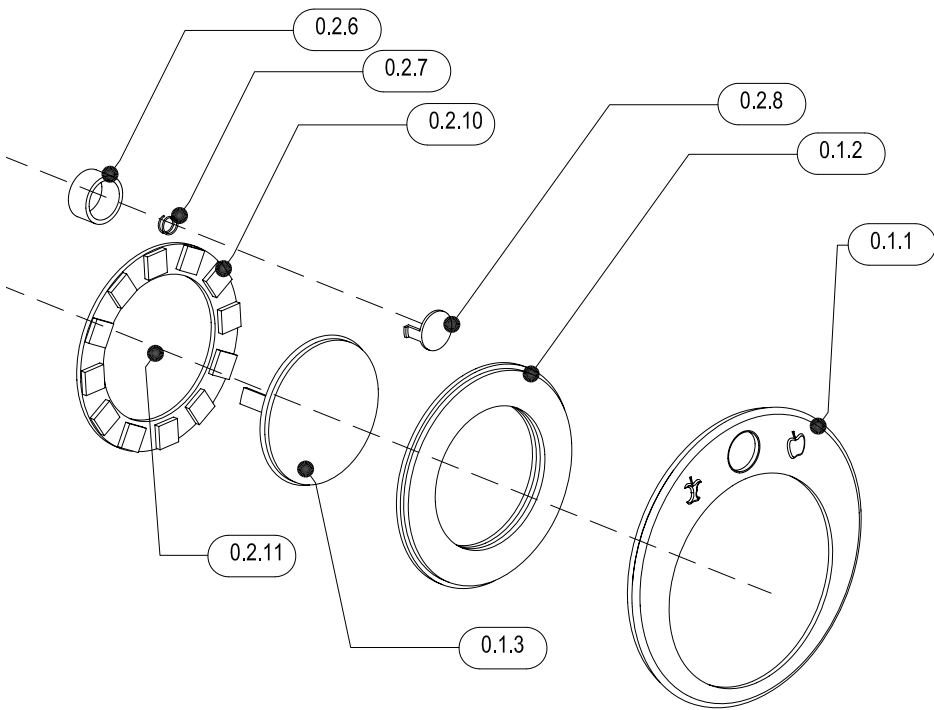
Container - Exploded View

1.1.1

1.1.2

0

Bottle Stopper - Exploded View

Clip - Exploded View

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