ENABLING HIGH-QUALITY PLASTIC RECYCLING WITH THE VIRTUAL CHEMIST,

a device that analyses the composition of plastic waste.

TU Delft

GRADUATION THESIS
INDUSTRIAL DESIGN ENGINEERING

SERGEJ SCHETSELAAR

December **2018**

COLOPHON

STUDENT
Sergej Schetselaar

MASTER THESIS
Enabling high-quality plastic recycling with the Virtual Chemist, a device that analyses the composition of plastic waste.

SUPERVISORY TEAM
Ir. Marc Tassoul | Chair
Dicky Brand | Mentor
Jeroen Cevaal | Company Mentor

DESIGN FOR INTERACTION
Faculty of Industrial Design Engineering
Delft University of Technology

INTERNSHIP
Polytential BV
Delft, The Netherlands

GRADUATION DATE
12 December 2018

SPECIAL THANKS TO

Andre van Dam
Antonio Arbues
Urban Avsec
Yuri van Engelshoven

Karin Hille
Jan van der Ven
Casper van der Meer
Ulphard Thoden van Velzen

EXECUTIVE SUMMARY

In the past 40 years an incomprehensible 8,3 billion metric tons of plastic has been produced and is primarily being discarded and incinerated, instead of being recycled. Only 10 per cent of this total amount has been recycled to date, therefore it was decided to focus on recycling of plastic waste to reduce plastic pollution which negatively impacts life on global scale. Through an extensive analysis of the recycling context it was found that the biggest problem in plastic recycling is the inability to achieve a constant production of high-quality recyclate.

With insufficient knowledge to address this found problem, it was decided to do an internship at Polytential BV, a start-up company located in Delft, the Netherlands. Their innovative product the Virtual Chemist, a device that analyses the composition of plastic waste up to 98,5 per cent accuracy, enables mechanical recyclers and compounders to analyse large volumes of plastic waste.

The solution will facilitate a transition towards a data-driven recycling industry, increasing profitability in processing plastic waste by providing the industry with accurate and representative composition data, as processing large volumes is currently not possible. However, The Virtual Chemist was still in an early development stage (MMP) and required further development to be presented to clients as a sellable product (MMP).

This was done by addressing the user needs and facilitating the right user experience, achieved through an analysis of the context, user, current system, and workflow to define a baseline for this project. Additionally, each step was completed by focussing on the user interaction and experience. The analysis results were used to formulate a design brief, which defined the goal and direction for the ideation and conceptualisation of the product.

This report present a summary of the completed design process, research findings, and concludes with recommendations that focus on further development of the Virtual Chemist.

TABLE OF CONTENTS

GLOSSARY

Additives Substances that can be added to the plastics during production to alter the mechanical properties; make the product more resistant to UV lighting; increase elasticity; and many more applications.

C-Box A method that uses a matrix of 2x2, which is applied in brainstorm sessions to create an overview of early ideas and enables selection based on two predetermined axis.

Closed-loop Recycling A production process, in which post-consumer waste is collected, recycled and used to make new products.

Consumable A commodity that is intended to be used up relatively quickly and recurrently.

Converters Companies that specialize in combining raw material such as polyesters, adhesives, silicone, adhesive tapes, foams, plastics, rubbers, and metals, to create new products.

Curing A term in polymer chemistry and process engineering that refers to the toughening or hardening of a polymer material by cross-linking of polymer chains, brought about by electron beams, heat, or chemical additives.

Flakes Is a name used to describe shredded plastic material.

Granulates After extrusion, the plastic material is cut into smaller sized parts so that further processing can be achieved; granules are necessary for injection moulding.

How-To An informal method used by designers where a, often short, description of how to accomplish a specific task is formulated.

Mechanical recycling Aims to recover plastics waste via mechanical processes (grinding, washing, separating, drying, re-granulating and compounding). It is a method by which waste materials are recycled into “new” raw materials without changing the basic structure of the material.

NAFTA Is an abbreviation for the North American Free Trade Agreement, and is an agreement signed by Canada, Mexico, and the United States, creating a trilateral trade bloc in North America.

NIR-technology An abbreviation for Near Infrared, which is a spectroscopic technique that makes use of the naturally occurring electromagnetic spectrum.

Polyolefins Is a term used to describe a certain group of plastics, consisting of PP and PE.

Polyurethanes Are used to produce foams and belong to both the thermosets and thermoplastics; varying the type or quantity of three basic chemical compounds can change the properties of polyurethanes.

Post-Consumer Waste A term to describe waste that is generated when a consumer product has reached it’s end-of-life and is discarded.

Re-Granulating The process of forming grains or granulates out of flakes; the flakes are heated, extruded, and cut into small pallets (granules) with an average size range between 0,2 and 4,0mm.

Recyclate A raw material sent to, and processed in, a waste recycling plant.

Thermoplastics Are plastics that become plastic during heating and harden when cooled; this process can be repeated.

Thermosets Are plastics that become irreversibly hardened after the curing process.

Transshipment The shipment of goods or containers to an intermediate destination, then to yet another destination.

Value Chain A high-level model developed by Michael Porter used to describe the process by which businesses receive raw materials, add value to the raw materials through various processes to create a finished product, and then sell the finished product to customers.

MVP An abbreviation for Minimum Viable Product, which is a product with just enough features to satisfy early customers, and to provide feedback for future product development.

Hyperspectral Imaging The goal of hyperspectral imaging is to obtain the spectrum for each pixel in the image of a scene, with the purpose of finding objects, identifying materials, or detecting processes.

Throughput A term used to describe the amount of material or items passing through a system or process.

Early Adopter An early customer of a given company, product, or technology.

Company If not stated otherwise, the ‘company’ refers to Polytential BV.

Client If not stated otherwise, the ‘client’ refers to the market segment that the company is focussing on, this being Mechanical Recycling and Compounding facilities.

User Flow Diagram A visual representation of the path a user follows through an application.

Big Bag A type of bag used in the recycling industry to contain and transport plastic flakes, with a maximum weight of up to 1000 kilograms.

(Task/User) Flow-Charts Are used to optimise users ability to accomplish a task with the least amount of friction.

Design Thinking Is a cognitive, strategic and practical process by which design concepts are developed by designers and/or design teams. Design thinking is also associated with prescriptions for the innovation of products and services within business and social contexts.

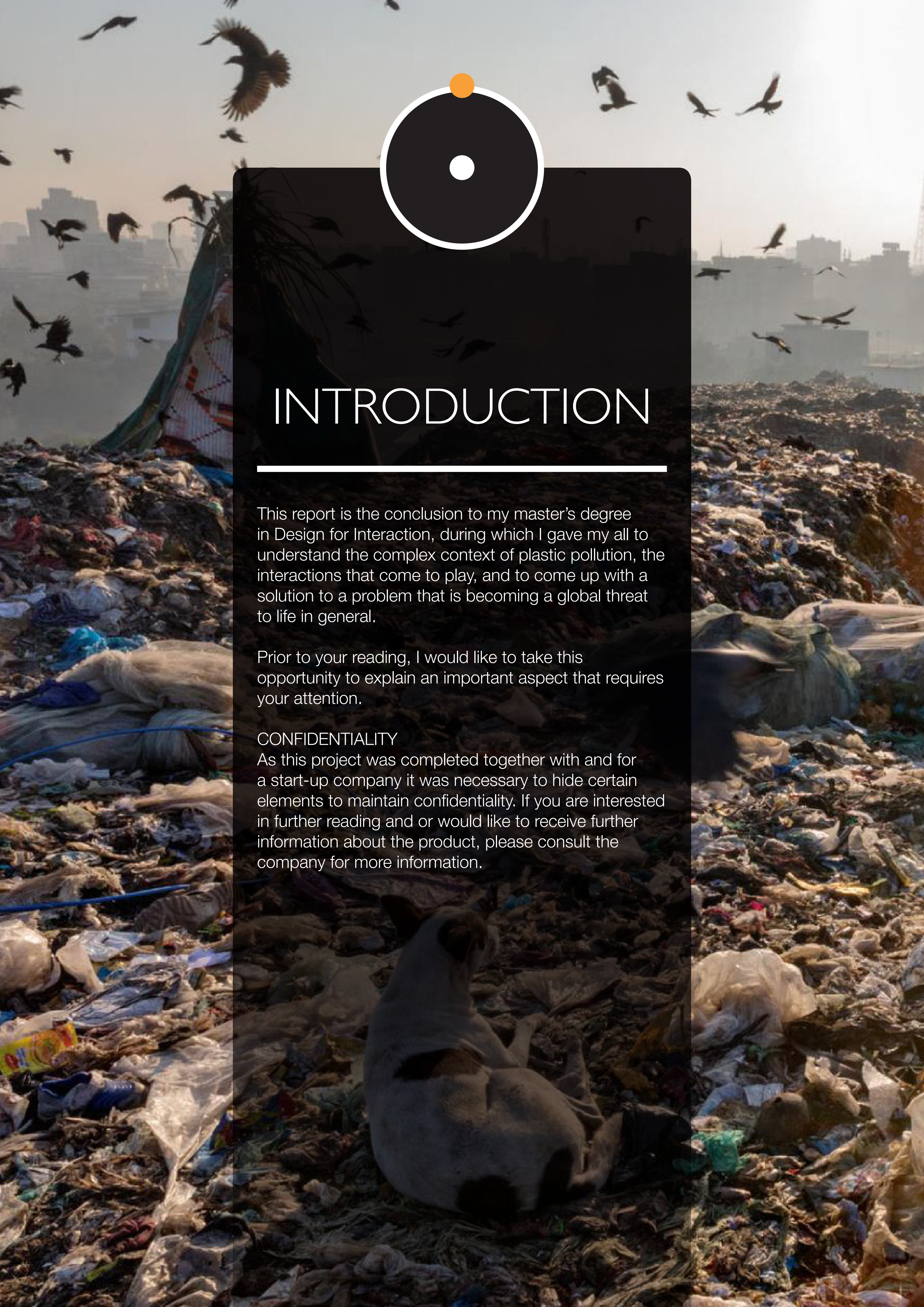
Persona Are fictional characters, which are created based upon research in-order to represent a user that might use a specific service, product, site, or brand in a similar way. Creating personas helps to understand users' needs, experiences, behaviours and goals. Personas guide the ideation process, and can be used to design a desired user experience.

Usecues (!) Enable intuitive use of products by understanding the cognitive perception of shapes, colour, and other external factors.

Archetype A word used to describe a very typical example of a certain person or thing.

Meme(tics) Is an idea, behaviour, or style that spreads from person to person within a culture—often with the aim of conveying a particular phenomenon, theme, or meaning represented by the meme.

Peripheral Sight Is a part of vision that occurs only on the side gaze. It enables recognition of movement and shapes, but is unable the perceive further details.

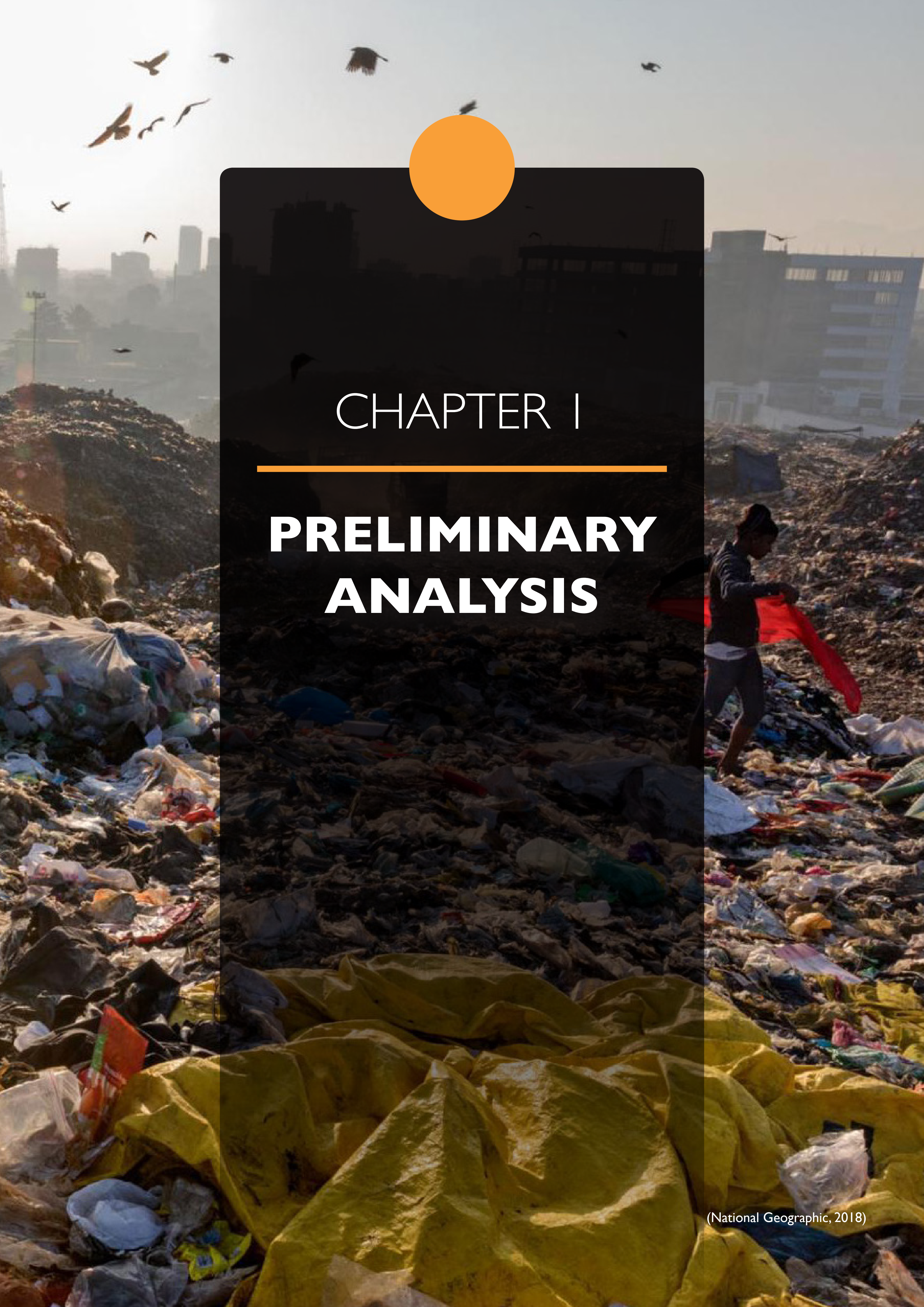


INTRODUCTION

This report is the conclusion to my master's degree in Design for Interaction, during which I gave my all to understand the complex context of plastic pollution, the interactions that come to play, and to come up with a solution to a problem that is becoming a global threat to life in general.

Prior to your reading, I would like to take this opportunity to explain an important aspect that requires your attention.

CONFIDENTIALITY
As this project was completed together with and for a start-up company it was necessary to hide certain elements to maintain confidentiality. If you are interested in further reading and or would like to receive further information about the product, please consult the company for more information.



CHAPTER I

PRELIMINARY ANALYSIS

(National Geographic, 2018)

CHAPTER 1.0 | INTRODUCTION

This chapter explains the process of defining the scope, which includes an analysis of the context, identification (and convergence) of possible bottlenecks, and concludes with a defined project direction based on an identified opportunity.

1 | the impact of plastic pollution was analysed first and used to convey the importance of addressing this problem.

2 | next step was to define the scale of the problem on a global scale, which led to the conclusion to focus on plastic recycling of household waste.

3 | having analysed the different types of plastic and the market demand led to the conclusion to focus on mechanical recycling.

4 | plastic recycling was mapped out to identify opportunities on a global, European, and Dutch context level.

5 | the results from this context analysis led to the formulation of a final context/scope, which was further analysed by mapping out the product journey of a laundry detergent in urban high-rise environments.

6 | based on the collected results, an opportunity was chosen with the use of a C-Box, focussing on feasibility and impact.

7 | not having the required knowledge in plastic recycling, a company that addresses this opportunity, with their product the Virtual Chemist.

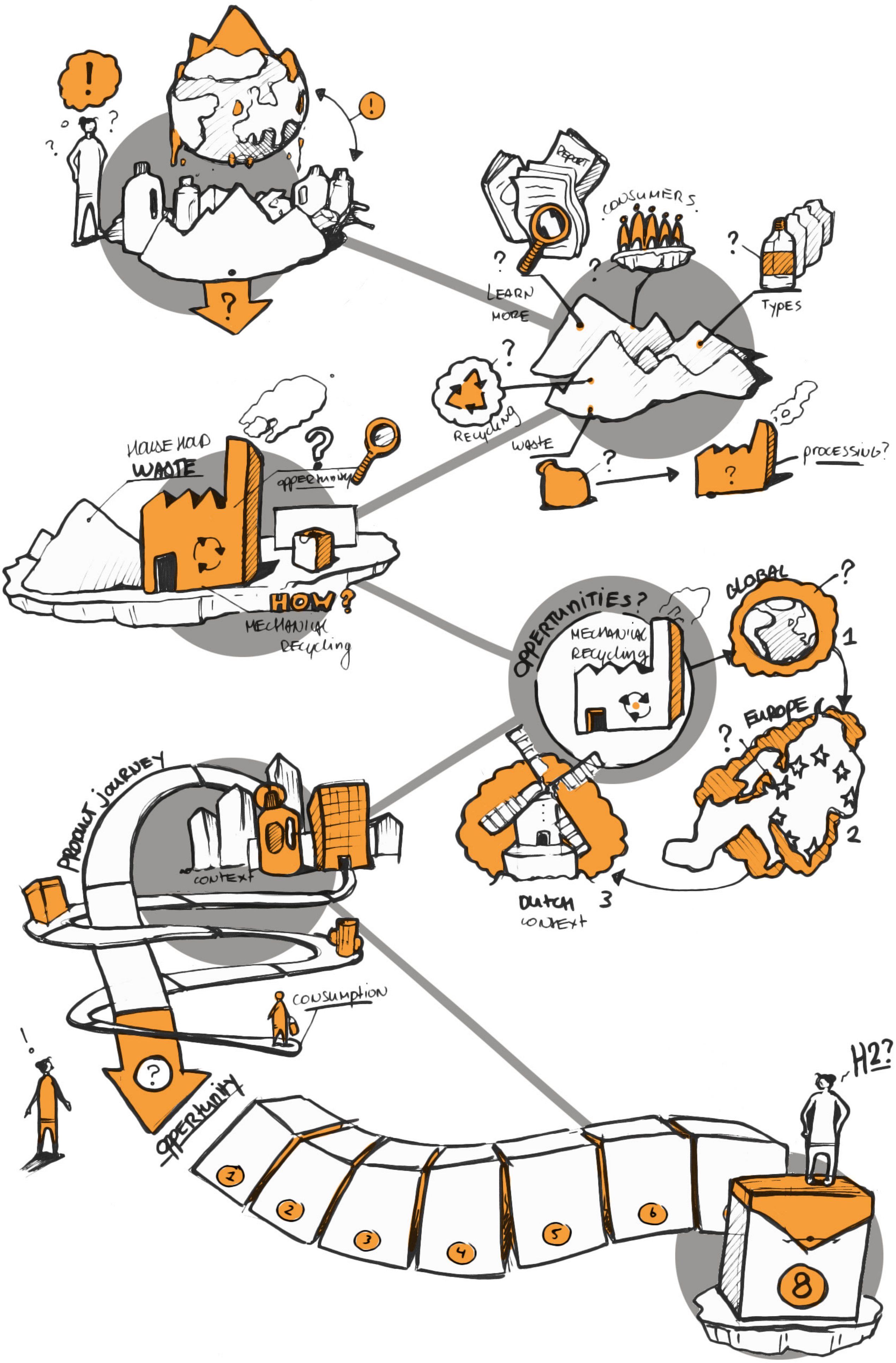


Figure 1: *A visualisation of the approach.*

CHAPTER 1.1 | IMPACT OF PLASTIC POLLUTION

1.1.1 FOOD CHAIN

Plastic doesn't degrade very well, as it just brakes down into smaller and smaller pieces. These small particles can then be ingested by the tiniest of organisms, such as plankton, which are a crucial step in the food chain. Doing so the plastic then finds a way up the food chain into the fish we that is being eaten all over the world. (Wilcox, Sebille & Hardesty, 2015)

1.1.2 GROUNDWATER POLLUTION

The World Economic Forum has placed the world water crisis in the top three of global problems, which includes climate change and terrorism. The problem affects about 66 per cent, 4 billion people, of the world's population who live without sufficient access to fresh water for at least one month a year. The consequences of water scarcity can lead to crop failures, food scarcity, and it can threaten environmental biodiversity. (Bellware, 2016)
Anyone can conclude that polluting the remaining water reserves will lead to even greater problems in the future. Yet this is what happens daily as rainfall causes the plastic to flow into the ground, polluting the groundwater in that area. (Bausback, 2016)

1.1.3 LAND LITTER

Landfilled plastics can be transported by the wind from one place to another, increasing land litter. It gets stuck on poles, traffic lights, trees, and in some cases animals which than suffocate to death. Collecting the same plastic over and over again is not economically feasible, which means that the pollution is ignored and keeps piling up. (Rinkesh, 2015)

1.1.4 AIR POLLUTION

Burning plastic in open air leads to environmental pollution as poisonous chemical are released. This polluted air than ends up in humans and animals, affecting their health. (Verma et al, 2016)

1.1.5 ANIMAL DEATHS

Despite countless TV commercials showing a dolphin or a turtle trapped in a six-ring plastic can holder, has not decreased the production of the mentioned items. Although the biggest problems occur in the oceans, also animals on land come into contact with this man-made material and in many cases do not get to see another day. (Henn, 2017)

1.1.6 POISONOUS

As mentioned in the previous point, plastic is a man-made material made of toxic materials. Holding a plastic product is not necessary hazardous for your health (although it is definitely not good either) but the making, storing, and disposing of most certainly is. It also needs to be mentioned that there are many different type of polymer types, which differ in toxicity. (Blastic, 2018)

1.1.7 ECONOMICAL IMPACT

In the US, the cost of cleaning up plastic litter was estimated at 11 billion dollars per year (1bagatatime, 2018). These numbers mainly focus on the clean-up of plastic bags, meaning that the economic strain of plastic pollution is even higher. Besides the high cost in processing the waste, excess pollution decreases tourism and with this impacts the economies. (Knapton, 2017)

(Ocean, 2018)

Plastics are light, easily shaped, strong, inexpensive, and their ability to guard against contamination makes them useful in sterile medical environments such as hospitals. It protects vulnerable products from damage whilst in transit and from damage by moisture, humidity, gases, micro-organisms, insects, and light. (Neil & Andrady, 2009)

| This project focusses on the disposal of plastics and not plastics themselves.

CHAPTER 1.2 | SCALE OF THE PROBLEM

Plastic, our lives are surrounded by this relatively new material that really started making an impact around 1940 and 1950 when the material was introduced to mass production. It was thought that we had found a "solution-to-all" material that we happily embraced (Thompson et al, 2009).

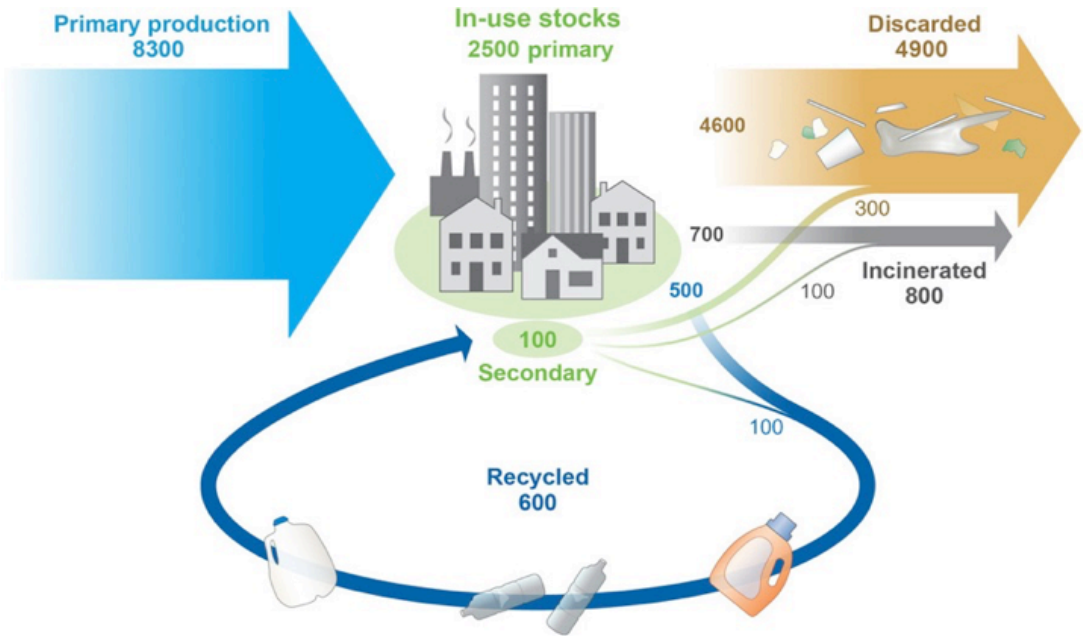


Figure 2: *Global production, use, and fate of all plastics (1950 to 2015; in million metric tons). (*Geyer, Jambeck & Law, 2017)

1.2.1 PLASTIC WASTE IN NUMBERS

It is estimated that since the beginning of mass-production of plastics (around 1950's), an amount of 8,3 billion metric tons (Mt) of virgin plastic has been produced to date. From this, a mere 600 million Mt has been recycled, 4,9 billion Mt has been discarded, and 800 Mt has been incinerated. (Geyer, Jambeck & Law, 2017).

So, 5 billion Mt of plastic waste is lost at landfills, where the plastic finds a way into waterways, rivers, and finally the oceans. One of the most shocking predictions made today, is that by 2050 there will be more plastic in the oceans than fish. (EllenMacArthurFoundation, 2016)

The projection in figure 3 illustrates that the amount of discarded waste is to decrease; the amount that is recycled and incinerated is to increase. Having explained the negative impact of incineration and landfilling on the previous pages, it was decided to focus further on recycling.

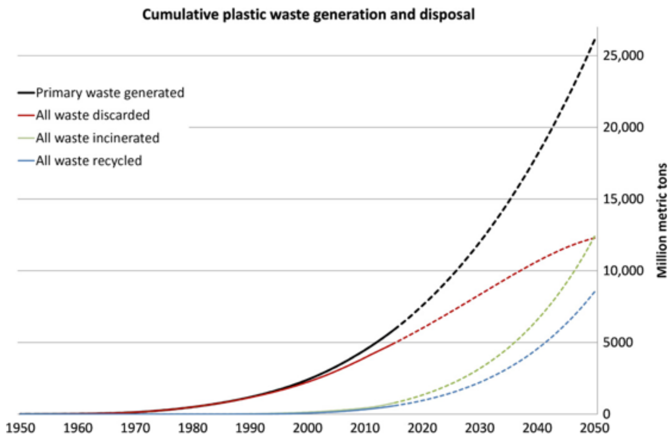


Figure 3: *Cumulative plastic waste generation and disposal, a forecast. (*Geyer, Jambeck & Law, 2017)

With a focus on plastic recycling, the market segments needed to be analysed to identify the biggest contributor.

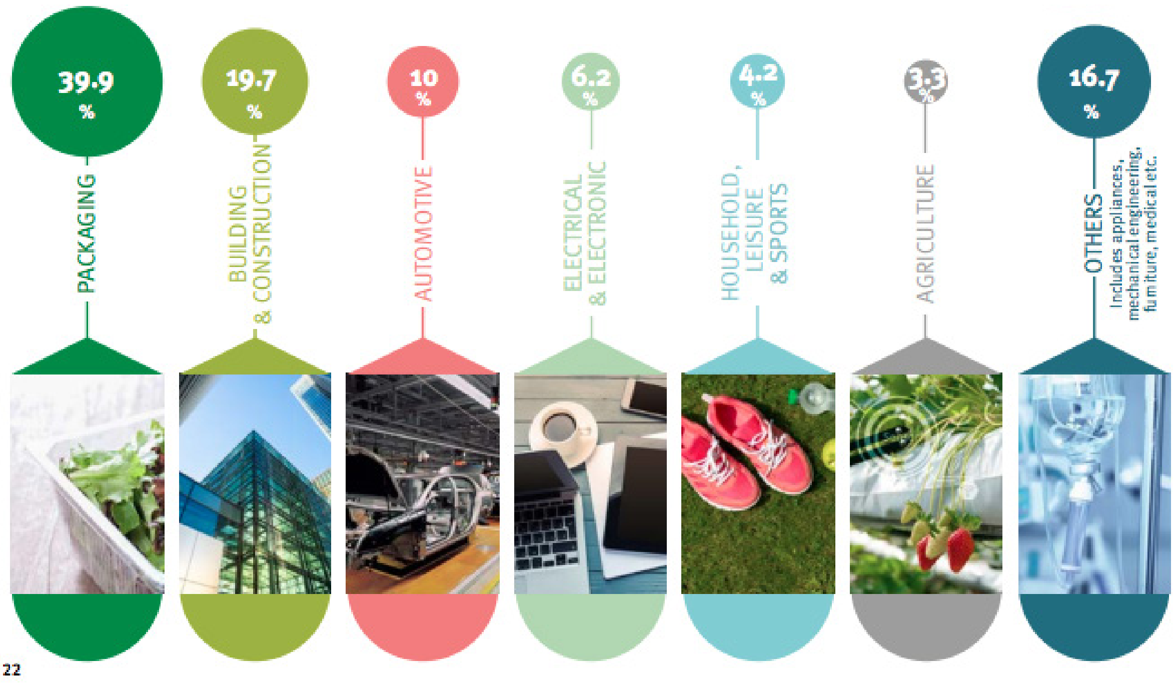


Figure 4: *The demand for plastics (EU28+NO/CH) by segment in 2016. Note, that these percentages are based on a European analysis.* (Luijsterburg, 2015)

1.2.2 PLASTIC MARKET SEGMENTS

Plastics can be categorized in a number of market segments, consisting of packaging (39% in volume), building and construction (20%), automotive (8%), electrical and electronic (6%), and agriculture (4%). Other market segments include consumer and household appliances, furniture, sports, health and safety. (Luijsterburg, 2015)

> Packaging market segment being the largest, the decision was made to focus further on this direction.

1.2.3 WHO RECYCLES WHAT?

Packaging is part of the post-consumer waste stream, which is widely collected and recycled by mechanical recyclers. Mechanical recyclers collect and process mainly polyolefins and PET, which are both found in post-consumer waste streams. These polyolefins are also by far the largest class of synthetic polymer made and used today, due to the low cost of production, lightweight, and high chemical resistance. (Lohse, 2000)

What types of plastic can be found within the post-consumer waste stream?

CHAPTER 1.3 | PLASTIC TYPES

Being able to identify the different plastic types is crucial in closed-loop recycling, as the different types of plastics have to be processed separately (Hopewell, Dvorak & Kosior, 2009). This supports the earlier statement of mechanical recyclers specializing in polyolefins and/or PET. This chapter focussed on this specialisation and discusses the ability to recognise the different types of plastic at a consumer level.

1.3.1 THERMOPLASTICS

First, it is important to understand that packaging is produced from thermoplastics, which are polymers that can be re-used almost indefinitely making them mechanically recyclable. The most common thermoplastics are:

PP | Polypropylene

PE | Polyethylene

PVC | Polyvinyl Chloride

PS | Polystyrene

PET | Polyethylene Terephthalate

PC | Polycarbonate

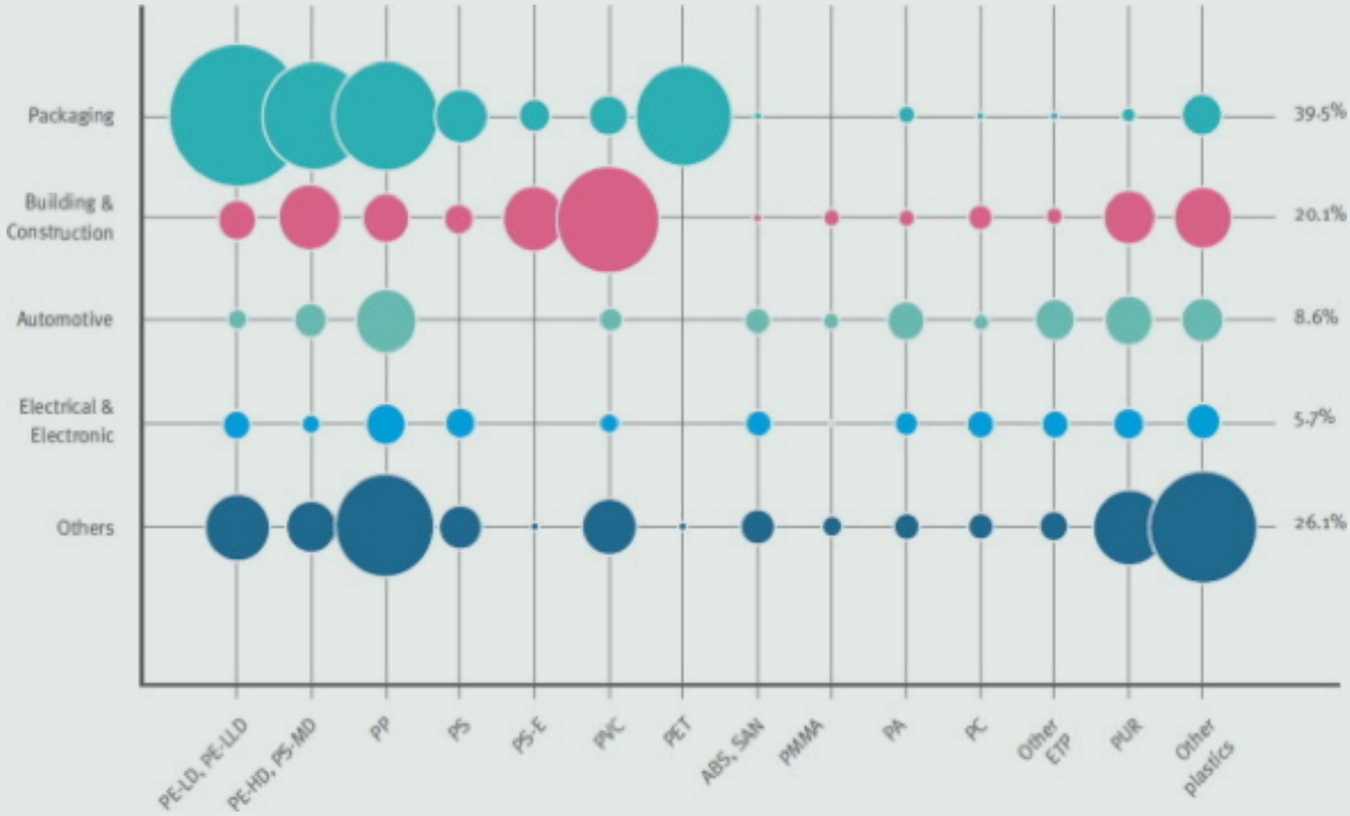
What drives mechanical recyclers to ignore the other types of thermoplastic materials found in packaging? For this, the market demand for packaging has been analysed.

Figure 5 shows that the market's demand is the highest for PE, PP, and PET. This suggests that the volume of these plastic types will also be the highest within the collected waste streams, enabling economical viability. This supports the earlier decision to focus on mechanical recycling of plastic packaging.

1.3.2 IDENTIFICATION CODING

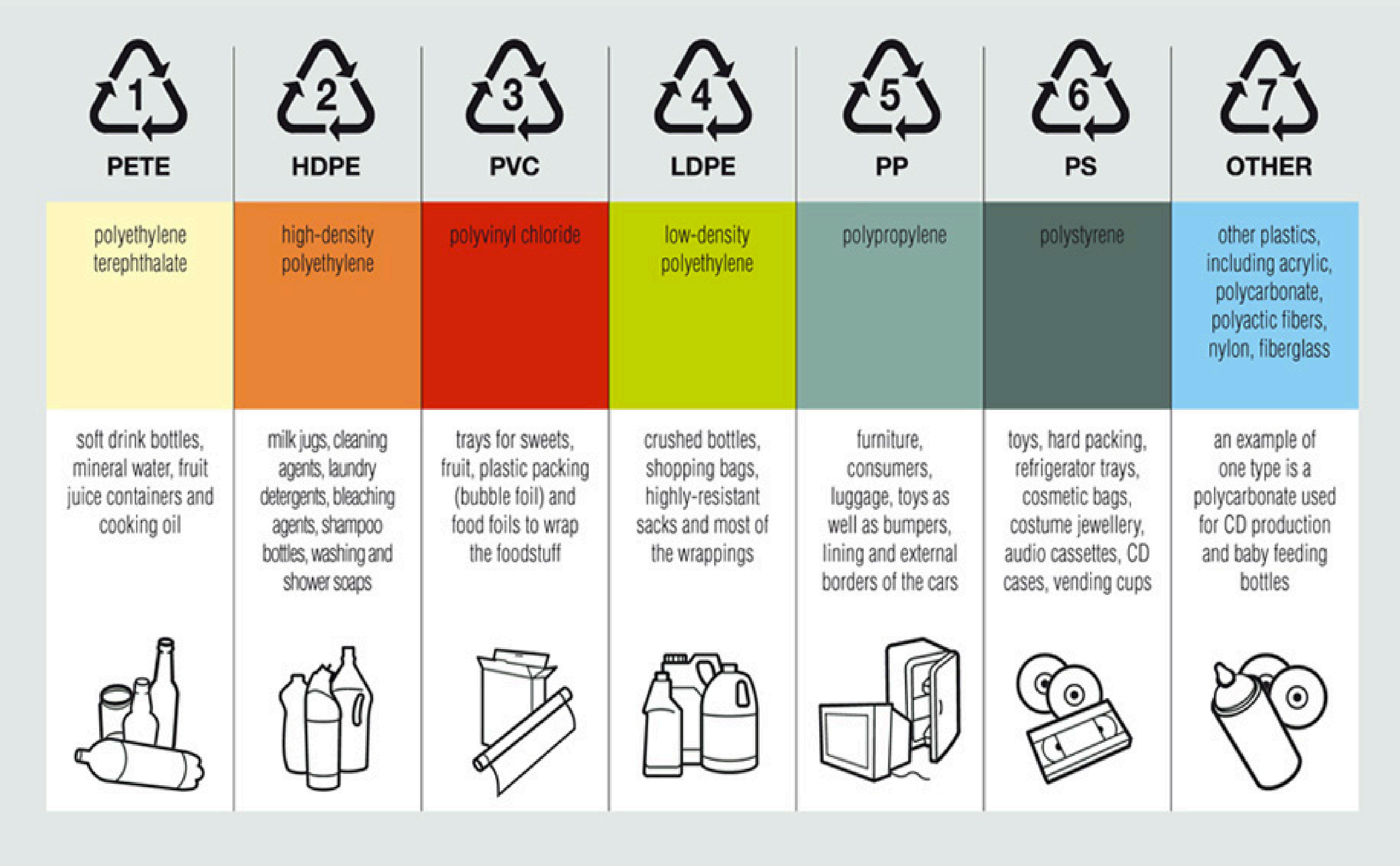
Many have seen the chasing arrow with a number on the packaging of their beverage, or the inside of a plastic product. These symbols are part of the ASTM International Resin Identification Coding System (RIC for short) that was developed in 1988 by the Society of the Plastics Industry, in the United States. But since 2008 it has been administrated by an international standards organization, ASTM International, and is used to identify the type of plastic resin out of which a product is made of. An overview of the different codes can be found in *figure 6*, accompanied with examples of products that are made from these materials. (ASTM International, 2014)

It is important to note that these symbols do not imply that a product equipped with one of the seven symbols is per definition recyclable. The sole purpose of the symbols is to provide information on the resin type that was used for the production of a manufactured product.



(Above) **Figure 5:** *Plastics demand per sector and per polymer type (Plastics Europe, 2018).*

(Below) **Figure 6:** *The different type of plastics, following the ASTM International standard.(ASTM, 2014)*



CHAPTER 1.4 | A FOCUS FOR CONTEXT MAPPING

The context of plastic pollution has been discussed in the previous sub-chapters, whereas the goal of this chapter is to summarize the findings (figure 7) and redefine the focus for the next context analysis phase.

First, the impact and scale of the problem was analysed. This analysis showed that only 7,2% of all the produced plastic waste has been recycled. Most of the waste has been discarded (59%) which means that it has been either landfilled or disposed directly into the environment. Incineration has been excluded from the focus, as it has a higher negative impact on the environment compared to recycling.

The focus was further defined by analysis the market segments, where packaging was found to hold the largest percentage (39%) in demand for plastics. Addressing this market segment should have a significant impact on the current recycling rates.

Next, it was found that plastic packaging is found in post-consumer waste streams, which are processed by mechanical recyclers.

It was also found that mechanical recyclers focus mainly on Polyolefins and PET. The decision to focus on these two types was confirmed as these types of plastic have the highest demand within the packaging sector.

THE FOCUS

| To identify opportunities within the context of mechanical recycling of PET and Polyolefins.

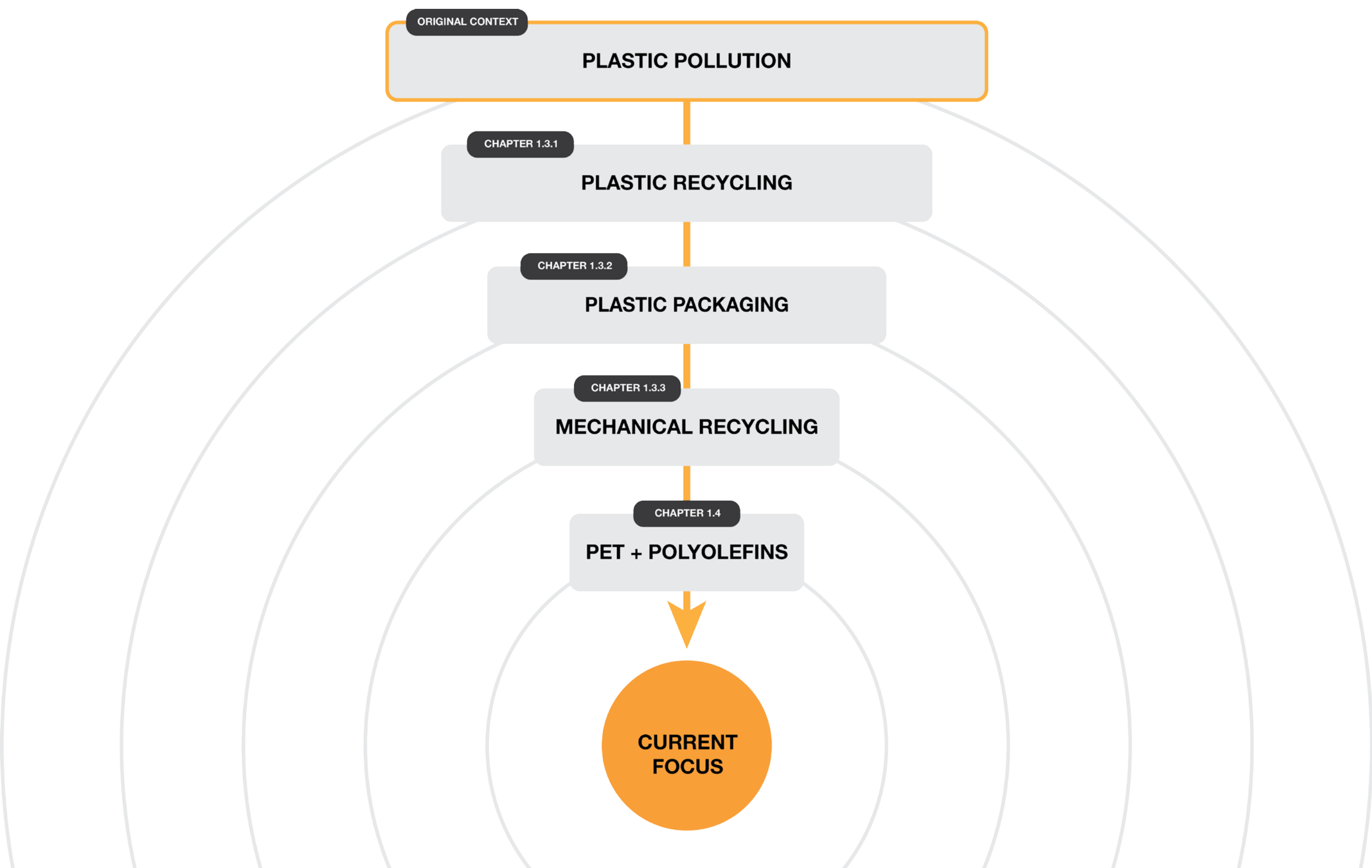


Figure 7: *The process of refining the scope, visualized.*

The chosen context focus was mapped-out in order to identify possible opportunities to address.

(Recycling magazine, 2018)

CHAPTER 1.5 | GLOBAL CONTEXT

The previous sub-chapter explained the reasoning behind the decision to focus on mechanical recycling, and how to increase the recycling rates of packaging waste. The next step was to identify opportunities that could be addressed during this project's timespan. To be able to identify opportunities within the defined scope, an analysis of the context was necessary. This sub-chapter presents the mapped out results and identified opportunities within a global, European, and local (Dutch) context.

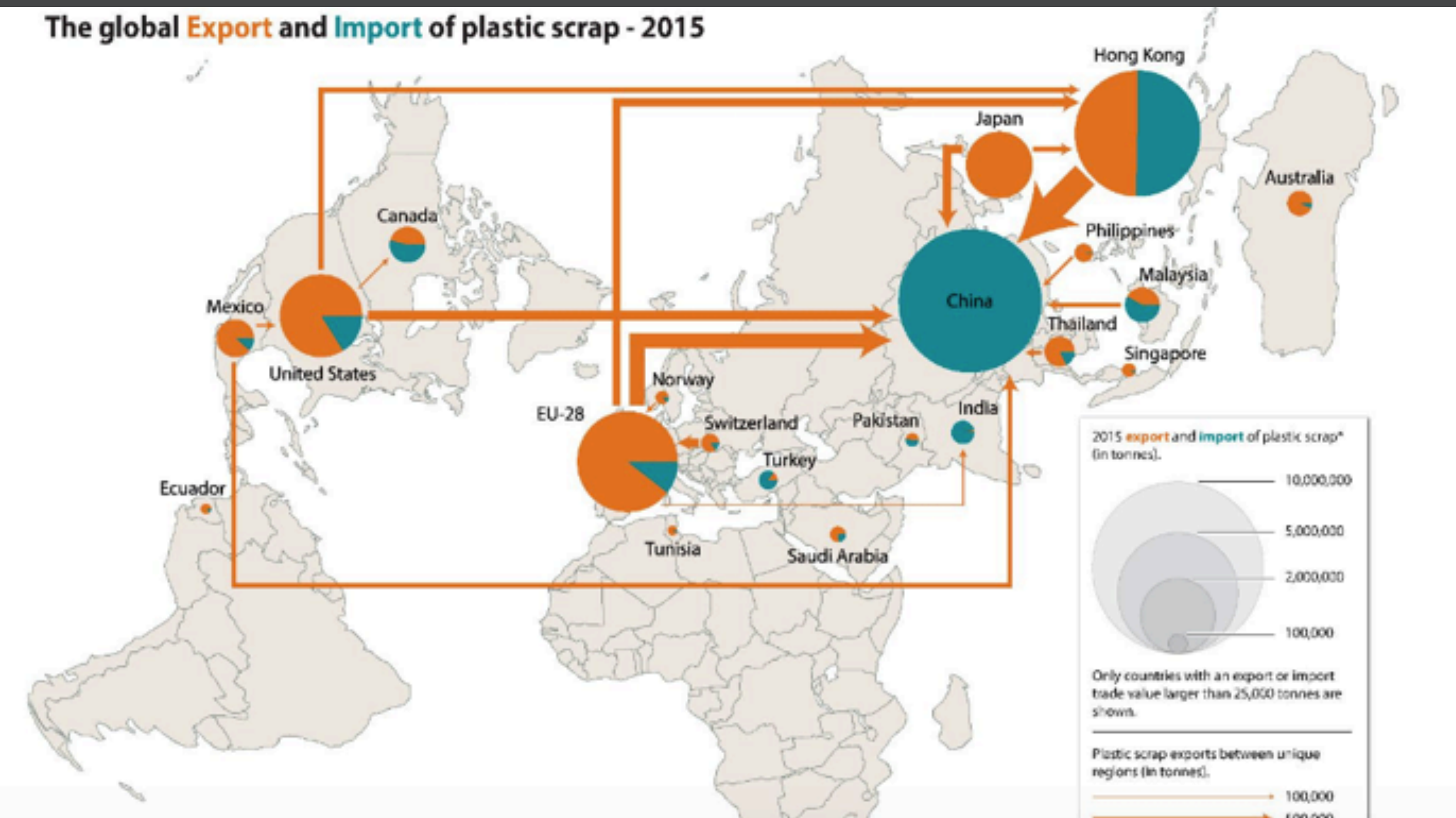


Figure 8: *The global export and Import of plastic waste. (GRID-Arnedal, 2017)*

1.5.1 THE GLOBAL TRADE

According to Plastics Europe (2018), a leading European trade agency, Asia is responsible for 50% of the world production of plastics*. Europe is second with 19%, and NAFTA coming in third with 18%. Besides being the largest producer, China is also the market leader (69%) when it comes to demand for plastic waste. The global export and import of plastic scrap is presented in figure 8.

The largest exporters are European countries (collectively), Japan and the United States; the leading importers are China and Hong Kong, of which more than 90 per cent is re-exported to China. This makes China the largest in recycling on a global scale, but the amount of waste is too large to process and ends-up at landfills, and the ecosystem.

Good news is that plastic recycling in Europe is increasing which could decrease the environmental footprint of recycling. Since 2006, many countries have banned sending plastic waste to landfills resulting in an increase in recycling and energy recovery. Also, trading plastic inside Europe has become more common, especially imports to Germany, The Netherlands and Belgium due to their advanced recycling technologies. (GRID-Arendal, 2017)

*Only thermoplastics and polyurethanes

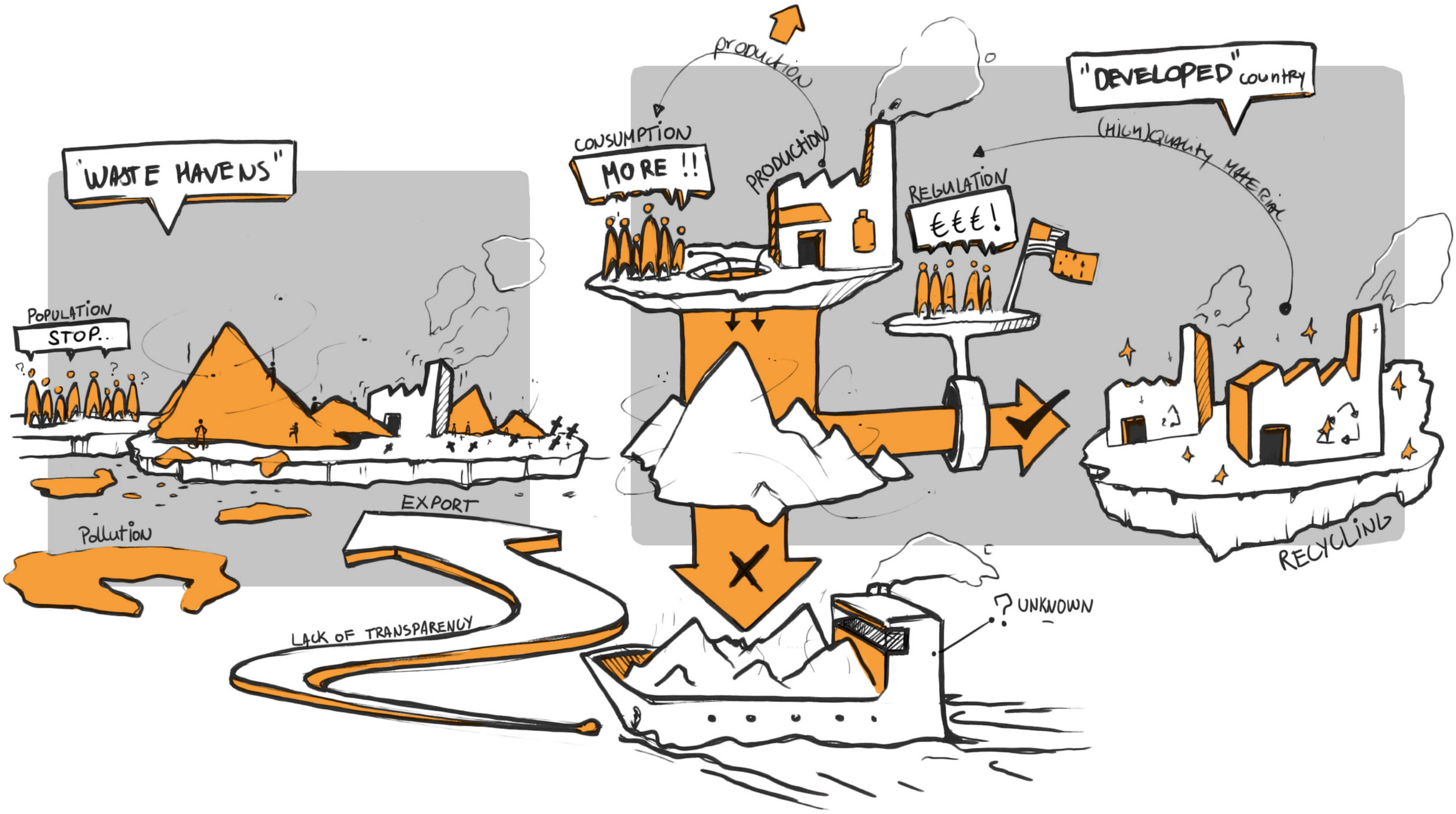


Figure 9: *Interaction with plastic waste on a global scale. (Author, 2018)*

1.5.2 A GLOBAL INTERACTION

The story in figure 9 visualizes a number of interesting results, which have been found during the analysis. First, plastic waste is being traded on a global scale and has increased due to rising production driven by increased market demand, regulations restricting the use of landfills in regions such as Europe, and higher recycling targets. The waste produced in developed countries could be captured and recycled by modern technologies, close to where the waste is produced. Instead, the waste is exported to developing countries (so-called 'waste-havens") with inadequate regulations and recycling facilities.

Another issue is the lack of transparency, which makes control of the environmental, social, and economic compliance a real challenge. The large amount of stakeholders involved in the value chain, combined with the lack of transparency leads to illegal trade of plastic waste and causes severe problems for the local population. Illegal trade of discarded plastic that has lost economic value, and cannot be traded through legitimate trading routes due to strict local regulations, is the main problem as it can contain hazardous materials.

Dumping is caused by the contamination of plastics, which cannot be recycled by the recipient countries due to the lack of proper waste management. This leads first to severe pollution of local ecosystems, after which the plastic finds a way into the ocean via different waterways. Not being able to process the contaminated material is one part of the problem, the other being the shear size of the incoming waste streams. As the burden of recycling the incoming waste streams becomes too great, the unprocessed waste ends up being dumped into the ecosystem.


(National Geographic, 2018)

1.5.3 A SUMMARY

At a global scale the problem of plastic waste is mainly found in legal issues. A lack of transparency and the ability to monitor the trading of plastic waste allows for illegal trade to flourish. Although China is the largest polluter, the waste that ends up in the ecosystem is imported from the west. Solving such an issue requires the cooperation of many different stakeholders, operating on international and local levels alike. Getting involved in the value chain at an international scale does not fit the scope of this project, but there have been a number of interesting findings.

1 Plastic waste is an internationally traded commodity, which is being traded through legal and illegal trade routes alike.

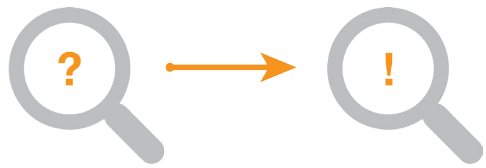
2 Illegal trade is a low-risk activity, due to the lack of transparency within the value chain.

3 Lack of transparency is caused by the large amount of different stakeholders, each operating at different levels.

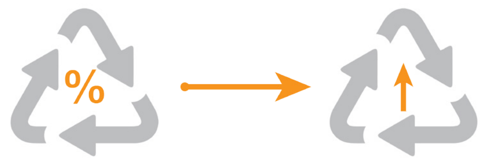
4 Plastic waste that cannot be processed by local facilities, due to contamination and strict local legislation, is shipped to primarily China.

5 If the incoming waste stream is too large and/or too contaminated to be processed, the plastic is dumped into the ecosystem.

The following directions have been formulated based on the findings:



How to make the value chain of plastic waste more transparent?



How to increase recycling of plastic waste in a developed country, focussing on a regional context?

It was assumed that addressing the first issue would involve too many stakeholders and European regulations, which doesn't fit the graduation direction of product innovation. Therefore the second issue was chosen as favourite, but further analysis was required to identify possible opportunities within a regional context.

Exporting plastic waste to developing countries needs to be reduced in order to address plastic pollution at a global scale. For this, the European influence needed to be researched further.

CHAPTER 1.6 | EUROPEAN CONTEXT

The previous sub-chapter concluded with an assumption that improving the transparency within the context of plastic recycling would involve many stakeholders and regulations. This assumption is addressed in this chapter, which presents a number of statistical insights; discusses a roadmap towards a circular economy presented by the European Commission (2018); and concludes with a defined focus for the Dutch context analysis.

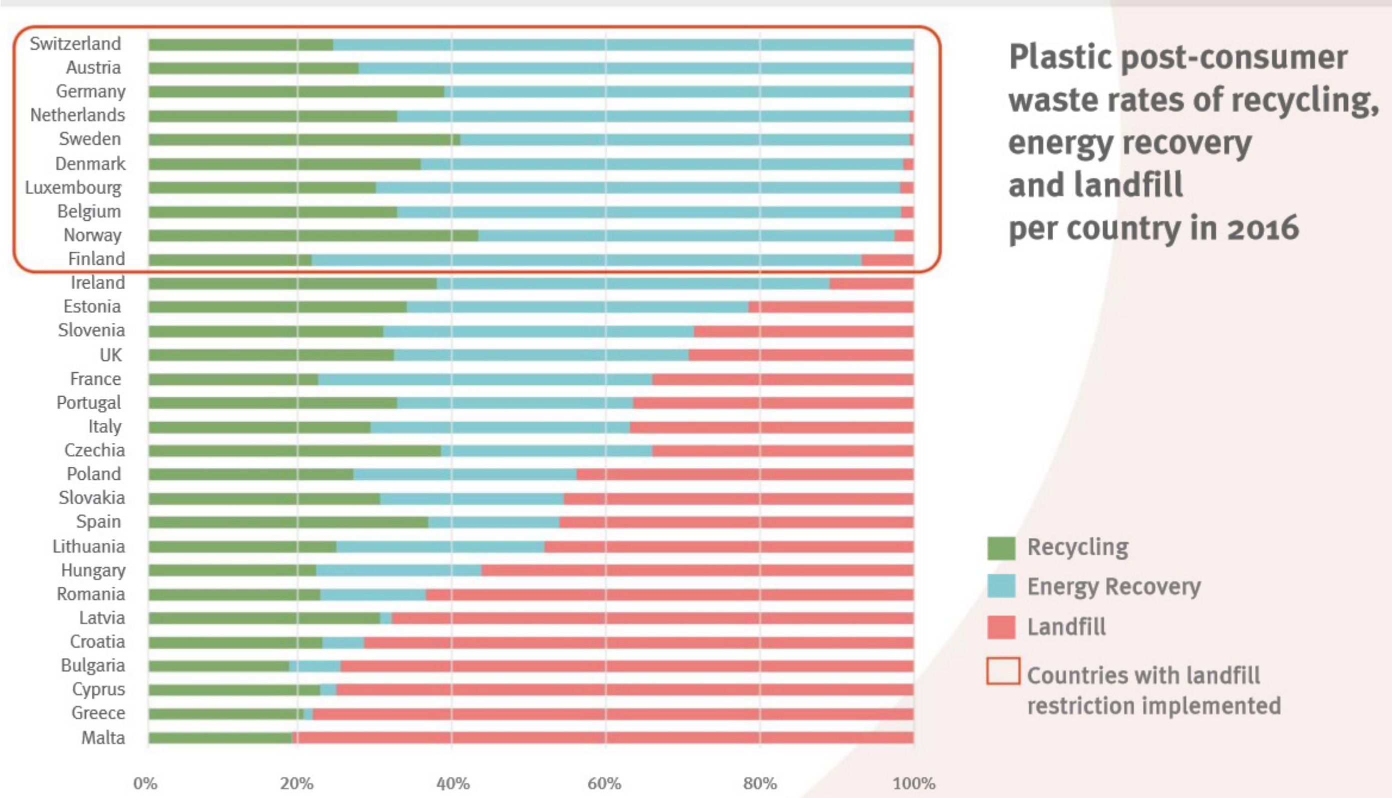


Figure 10: *European recycling, landfilling, and energy recovery rates in 2016. (Plastics Europe, 2018)*

1.6.1 EUROPE'S DEMAND

First, the demand for recycled plastics in Europe accounts for only 6%, which is caused by the EU plastic recycling sector having suffered from low commodity prices and uncertainties about market outlets. Investment in plastic recycling has been held back by the sector's prospects of low profitability.

1.6.2 EUROPE'S PRODUCTION

Approximately 25,8 million tons of plastic waste is generated in Europe every year, of which less than 30% is collected for recycling. And then a large proportion of this waste is shipped to developing countries where the plastic ends up at a landfill at best.

1.6.3 RECYCLING IN EUROPE

Landfilling (31%) and incineration (39%) rates of plastic waste remain high, and although landfilling has decreased over the past decade as regulations become stricter; incineration on the other hand has increased, a process to be avoided due to the loss of material and the production of CO_2 emissions. It has been estimated that by recycling all of the global plastic waste, an equivalent of 3.5 billion barrels of oil could be saved annually.

1.6.4 A BAN ON LANDFILL

Recycling, energy recovery, and landfill rates as presented in figure 10 show a number of interesting statistics. The amount of plastic that is stored at landfills has significantly decreased due to the implementation of landfill bans across a number of countries, the Netherlands being one of these. Unfortunately, the material is mostly incinerated instead of recycled. This supports the decision to focus on mechanical recycling and the need to increase recycling rates of post-consumer plastic waste. What role does the European Union play in this context of plastic waste management?

European legislation affects how plastic waste is being disposed, therefore it was necessary to focus further on Europe's future plans on plastic waste management.

1.6.5 A FUTURE VISION

The European Commission (2018) has just recently presented a brochure that presents a roadmap towards a circular economy, where a future vision on recycling plastics is presented.

1.6.6 THE KEY ELEMENTS

The proposed plan has been summarized in a list of key elements, focussing on elements that are relevant for this projects scope:

A common EU target for recycling 65% of municipal waste by 2030.

- The current recycling target for 2020 is 50%.

A common EU target for recycling 75% of packaging waste by 2030.

- The current recycling rate of plastic packaging is 22.5%.

A binding landfill target to reduce landfill to maximum of 10% of municipal waste by 2030.

- Out of the EU28+NO/CH countries, only 10 countries meet the target of 10%.

A ban on landfilling of separately collected waste.

- Currently each country follows their own regulation, in some cases there are even separate bans per municipality or none at all. According to CEWEP (2017) Belgium, France, and the United Kingdom are the only countries that have implemented a specific ban on separately collected waste.

The EU plans to minimize the amount of plastic that ends up at landfills, increase the recycling rates, and increase alignment between the European countries. Besides setting up stricter targets and banning certain types of waste, the plans also include economic incentives:

- Concrete measures to **promote re-use and stimulate industrial symbiosis;** turning one industry's by-product into another industry's raw material.

- **Economic incentives for producers** to put greener products on the market, support recovery and recycling schemes.

European Union has set strict targets and incentives to increase recycling rates of plastic waste.

1.6.7 REFINING THE SCOPE

The goal of this sub-chapter was to get a better understanding of recycling at a European-context level, focussing on the two directions defined previously.

It has been concluded that increasing transparency within the recycling market is difficult to achieve due to the large variety and amount of the stakeholders. Increasing the recycling rates at a regional level on the contrary was found to be discussed excessively and it was therefore decided to focus further on improving the quality of recycled material. Doing so, enabling the demand for higher quality recyclate to be reached and at the same time decreasing plastic pollution at a global scale.

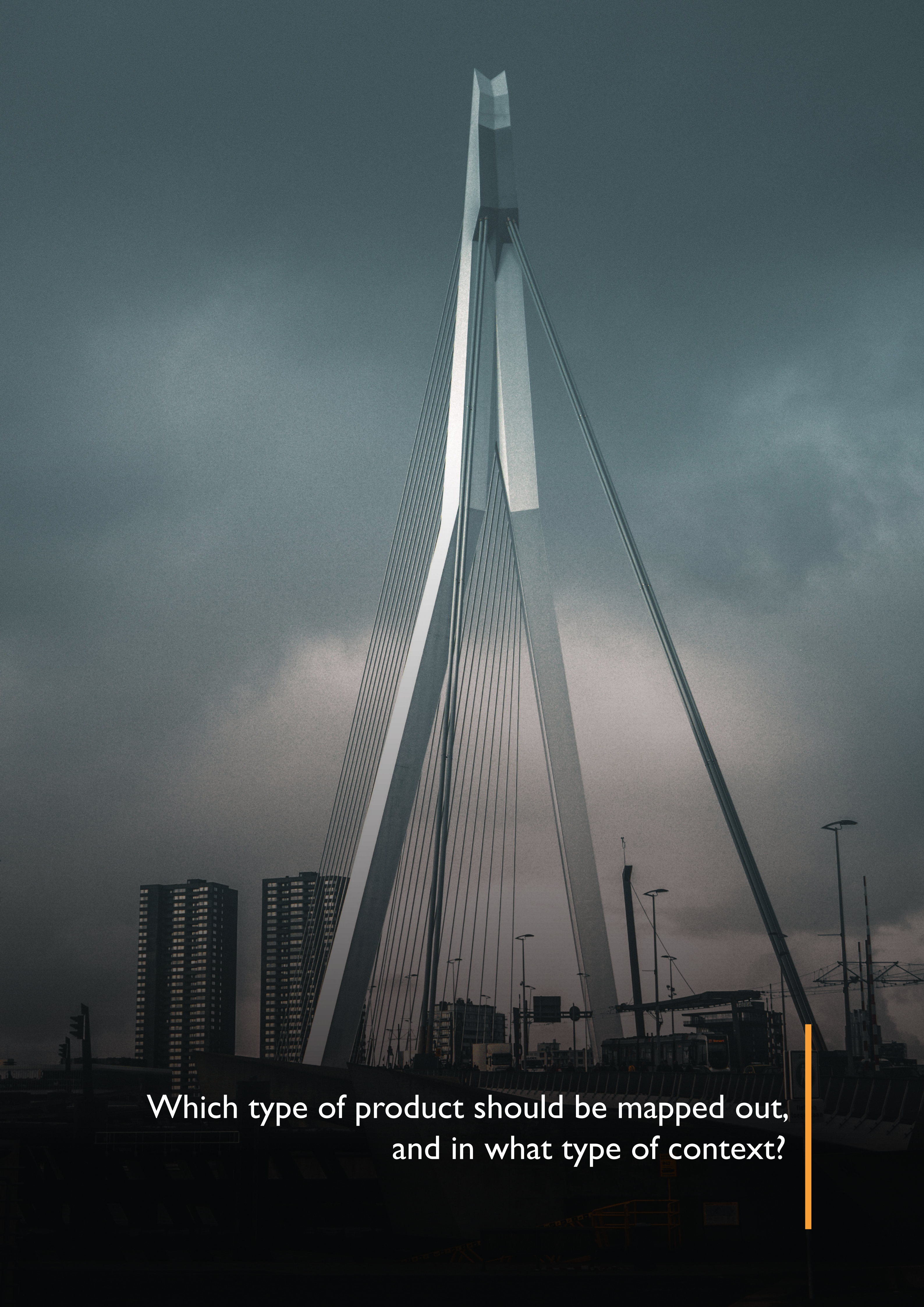
Opportunities that have been identified within the direction of improving the quality of plastic recyclate:

The two opportunities were addressed further by mapping out a product journey within a Dutch* context.

Improving the purity of post-consumer waste streams will increase the recycled material quality, as the recycling costs will be decreased and the contamination of plastics reduced.

Innovation in recycling will increase the amount of waste that can be recycled and thus decrease the waste that is landfilled or incinerated.

* Focussing on the Dutch context is primary based on the fact that this thesis report has been written in Delft, the Netherlands, which makes it easier to access the context. Secondarily, the Dutch recycling industry belongs to the top three in Europe, meaning that the outcome of this project should have a significant impact on plastic pollution.



Which type of product should be mapped out, and in what type of context?

CHAPTER 1.7 | DUTCH CONTEXT

With the global and European contexts analysed, it was time to focus on the Dutch context of plastic recycling. The results are presented in a mapped out product journey that focusses on interactions that can be found in processing plastic waste.

1.7.1 THE FOCUS

A context needed to be defined due to the large variety of different possible journeys that could have been mapped out. For this reason, the type of product and housing have been defined as followed.

Type of housing | URBAN HIGH-RISE

Collection of (sorted) plastic waste in an urban environment is much more difficult to accomplish, compared to rural areas with plenty of space for storage. The difficulty of access is also another main issue in the collection process in highly populated areas such as Rotterdam, where only 10 per cent of the collected waste is sorted (One World, 2014). This problem is also mentioned in a public report on plastic packaging, created by Nedvang (2016), where the difficulty of collection and storage of post-consumer waste in urban high-rise environments is discussed.

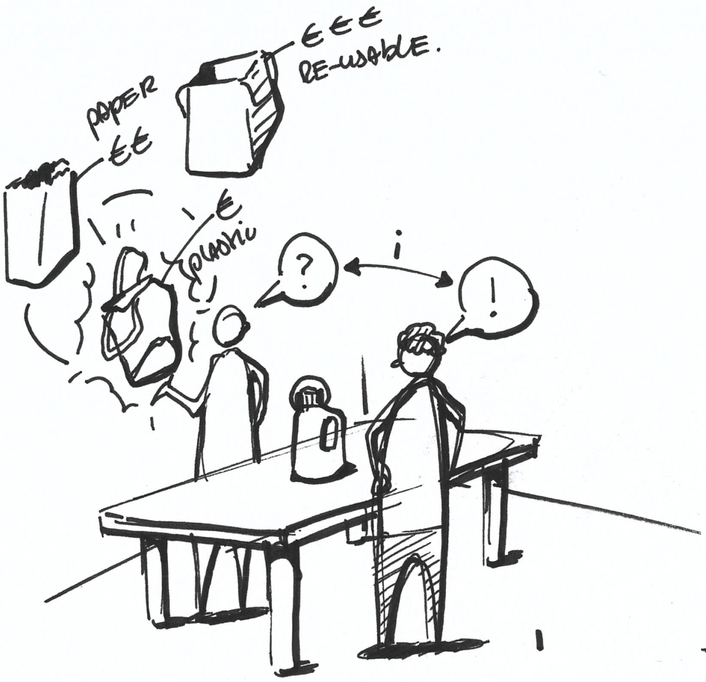
Type of product | LAUNDRY DETERGENT

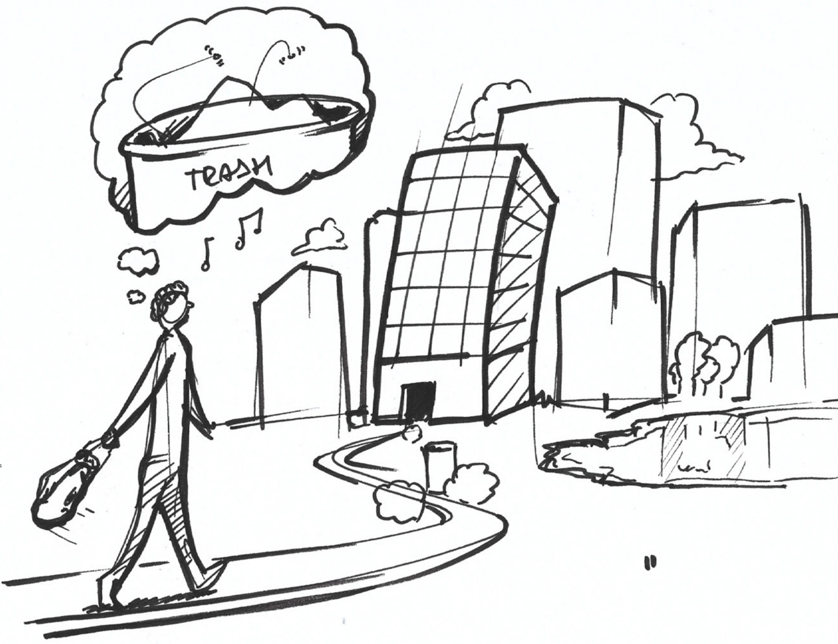
The decision to focus on laundry detergent is based on the fact that it is a product that can be found in (probably) every household. Laundry detergents are also needed for each wash cycle and are therefore considered a consumable. The packaging for Laundry detergent is generally made from a high- or low-density PE, which holds the highest share (29,1%) of the global production of any polymer type (European Commission, 2011).

1.7.2 A MAPPED OUT PRODUCT JOURNEY

The next few pages present the steps that a laundry detergent undergoes in an urban high-rise environment. Each step within the journey is presented with it’s interaction(s), followed by a short explanation of the situation, the identified opportunity, and concludes with a general reflection.

It was found that plastic waste disposal is the hardest to achieve in an urban high-rise environment.





Journey step 1
PURCHASE

Laundry detergent is purchased and the user is asked whether a plastic bag is necessary. Depending on the available choice and cost, the type of additional packaging is selected.

OPPORTUNITY I

Eliminate the need for a plastic bag during transportation of consumable products.

REFLECTION

Addressing this opportunity will require cooperation of many different stakeholders and although it could lead to less pollution, it doesn't affect the already present problem nor does it increase the quality of recycled material.

Journey step 2
TRANSPORT I

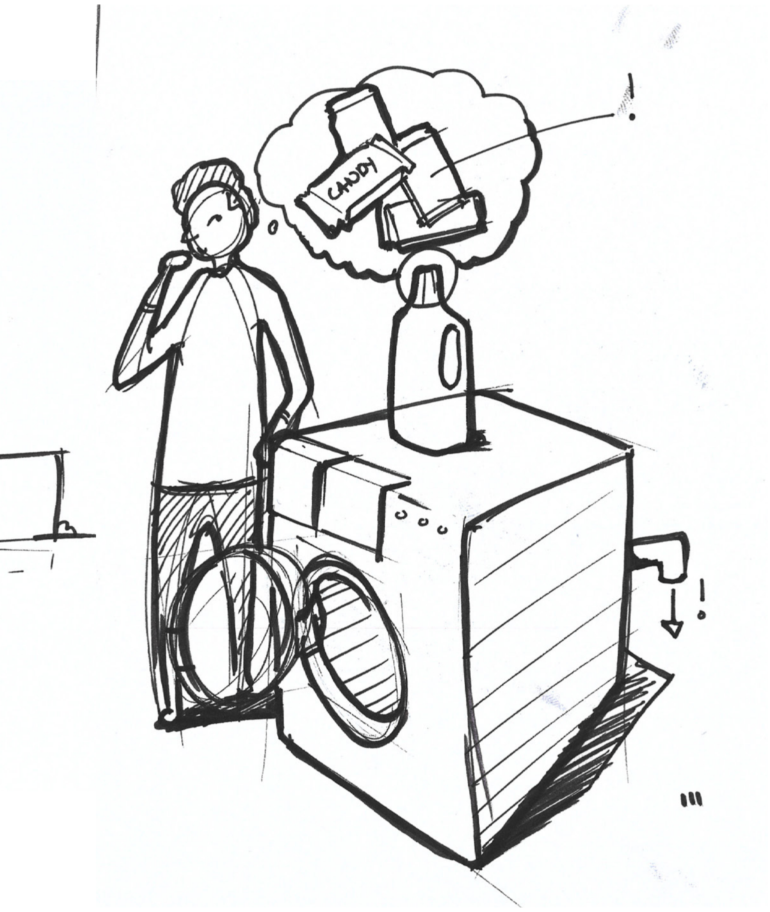
Assuming the worst-case scenario, the product is transported in a plastic bag. Arriving home, the plastic bag is either thrown away immediately or re-used and thrown away later.

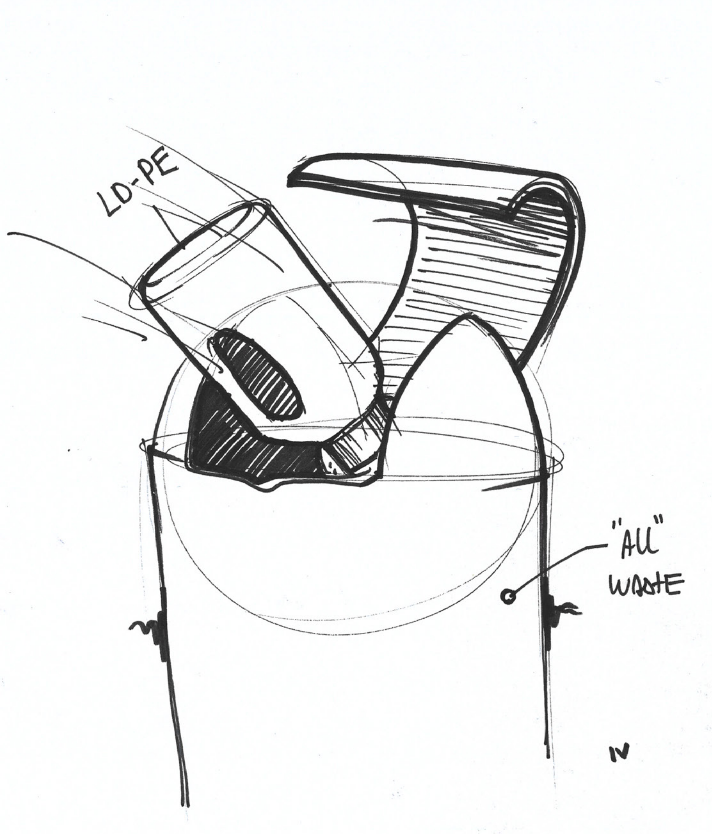
OPPORTUNITY

None

REFLECTION

Transportation of the goods was not included in the scope, and is not discussed further.





Journey step 3
CONSUMPTION

The laundry detergent is consumed and unless containing micro plastics, doesn’t produce plastic pollution during consumption. Unfortunately, there are types of packaging found in food and beverages, where each individual piece of consumable is wrapped in a separate piece of plastic.

OPPORTUNITY 2
Reduce the amount of plastic waste that is generated during consumption.

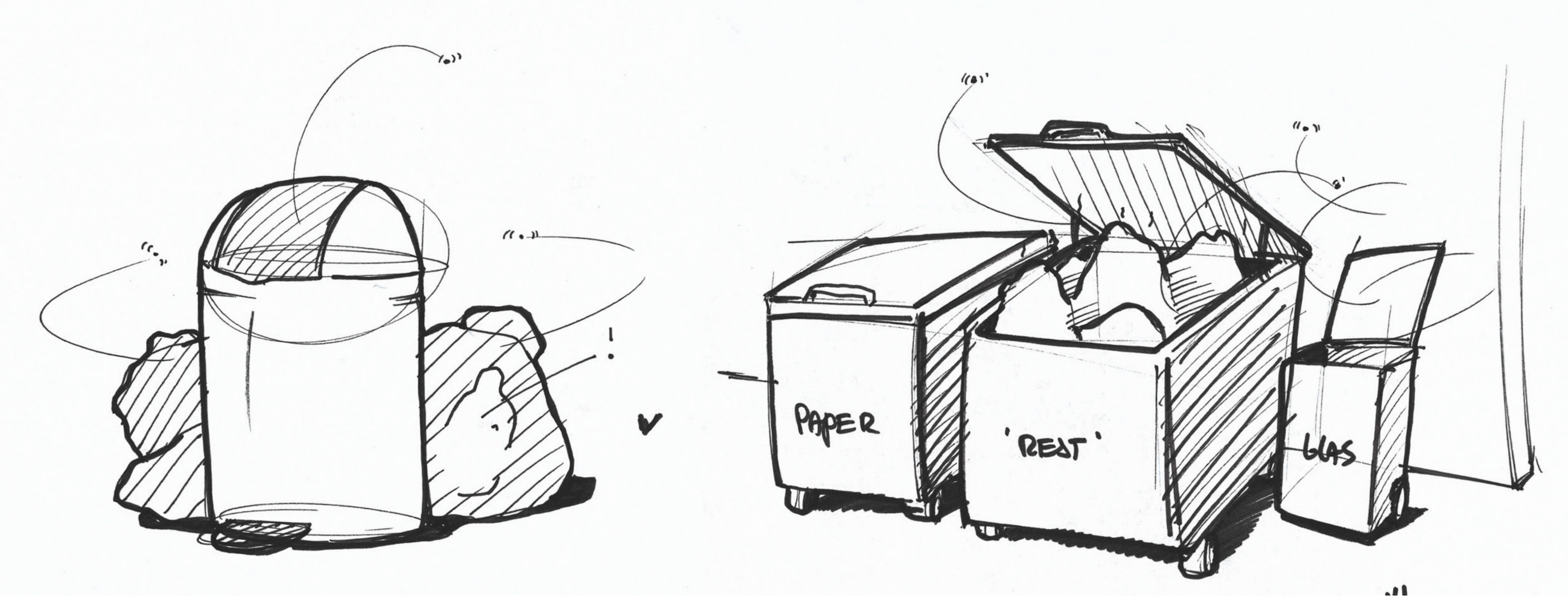
REFLECTION
Addressing this opportunity would require cooperation between many stakeholders, knowledge in food conservation, and the focus would be too specific to achieve the desired impact.

Journey step 4
DISPOSAL

The empty bottle is deposited in a regular trash-bin, together with other household waste, leading to a contaminated waste stream that is more difficult to recycle.

OPPORTUNITY 3
Stimulate (correct) separation of plastic waste at a consumer level.

REFLECTION
Properly sorting household waste requires significant amount of knowledge in recycling and space to store the different waste streams. Additionally, it was found that identifying plastic is very difficult, with 42 per cent of household plastic being unidentifiable (Appendix A). Improving consumer knowledge needs to be addressed, but will require consumers to change their rituals (habits). Disposing of waste differs per culture, and will need to be addressed accordingly per culture.



Journey step 5
STORAGE I

Waste is stored inside the house, next to the trash bin or stored outside until it is moved to the common storage area.

OPPORTUNITY 4
Enable efficient storage of separated plastic waste in an urban high-rise environment.

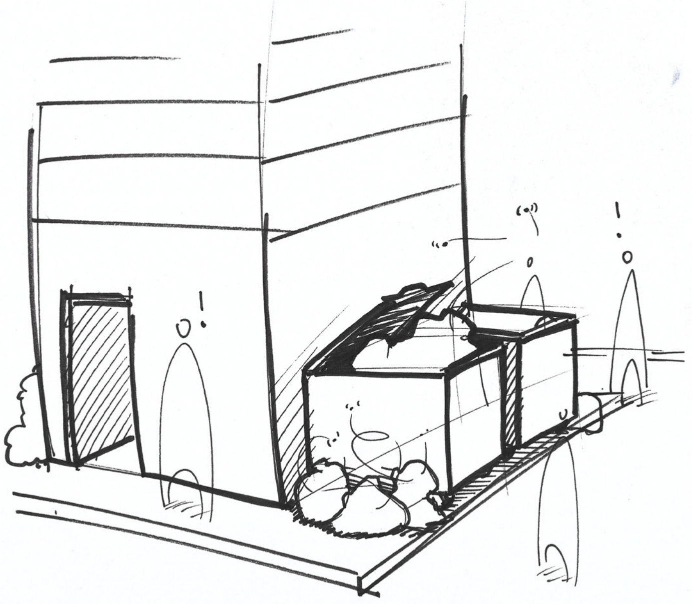
REFLECTION
The trash will accumulate and take-up a portion of the available living space, separating different waste streams will only increase the amount of space required to store the collected waste. There are already a number of trash bins available on the market that enable separate collection of household waste, but these will only have an impact if the consumer decides to purchase one.

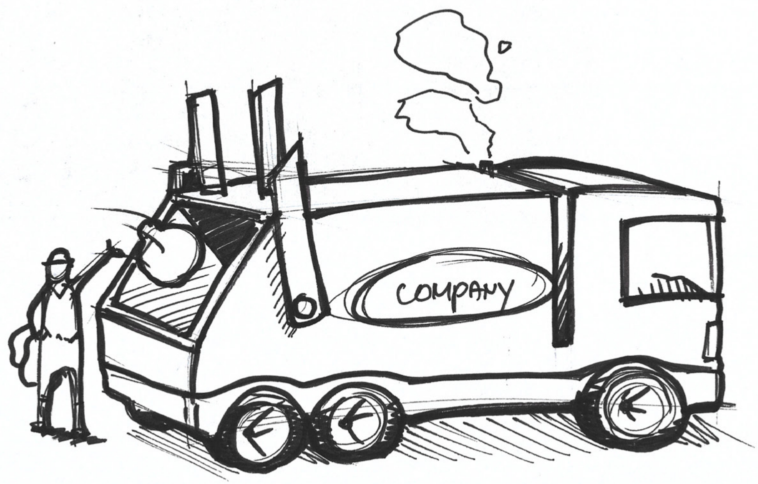
Journey step 6
STORAGE II

When the resident decides to dispose of the trash stored inside the apartment, he or she is presented with three options: glass, paper, rest.

OPPORTUNITY 5
Enable consumers that live in an urban high-rise to deposit collected plastic waste in a separate container.

REFLECTION
Currently there are only three options present in the shared container space, these are: (1) residual waste, (2) glass, and (3) paper. The separation between these three is already not being accomplished, adding a fourth option will not improve this situation. Assuming that a separate plastic container will be implemented, there is still the problem of getting the solution adopted by each residential complex.





Journey step 7
COLLECTION

Journey step 8
TRANSPORT II

Periodically, the containers are moved out of the storage space so that they can be collected by a waste management company, chosen by the municipality.

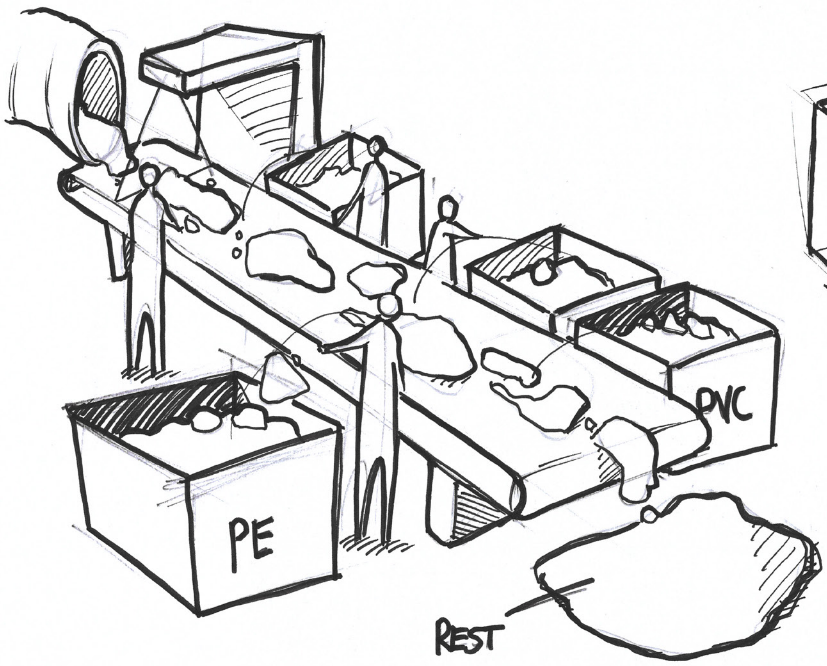
A garbage truck transports the collected waste to a transshipment facility. Here the quality and weight of the collected waste is defined to determine its destination.

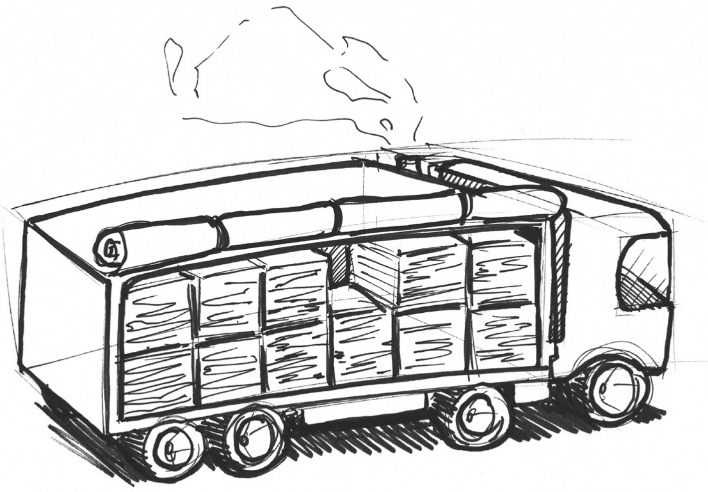
OPPORTUNITY 6
Enable separate collection of plastic waste within an urban high-rise environment.

OPPORTUNITY
None

REFLECTION
As each municipality is free to choose their own collection company it will require the cooperation of each stakeholder, to implement more vehicles and containers for the collection of plastic waste. Besides, there are already many initiatives when it comes to the collection of plastics. These are to be expanded and should address the issue of plastic collection.

REFLECTION
The process of transshipment was not included into the scope was therefore not addressed further.





Journey step 9
SORTING

Waste is sorted by the so-called NIR-technology, used to identify different plastic types so that multiple air nozzles can “blow” the identified plastics into specific containers. This process can be facilitated by human employees, depending on the facility.

OPPORTUNITY 7
Improve accuracy for the NIR-technology, enabling sorted waste to be produced with higher efficiency and purity.

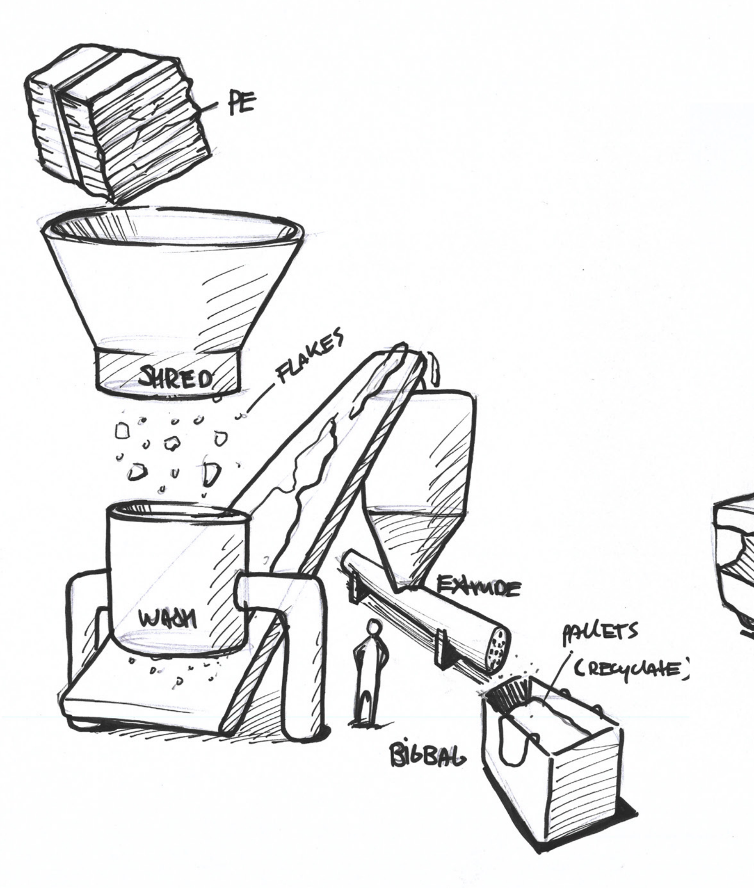
REFLECTION
Addressing the sorting efficiency requires additional technical knowledge in separation methods and especially NIR-technology.

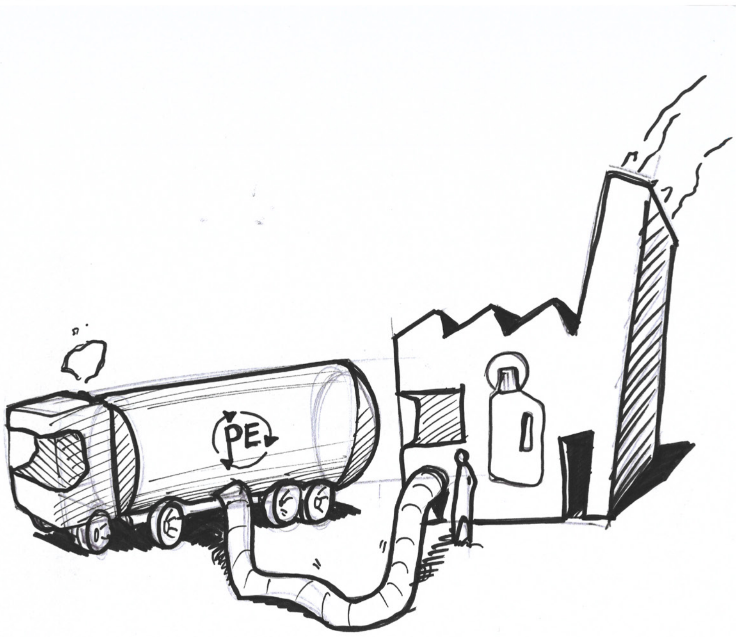
Journey step 10
TRANSPORT III

The sorted plastic is pressed and stacked into large piles, which are then transported by trucks to a recycling facility.

OPPORTUNITY
None

REFLECTION
An important takeaway is that the waste is transported again, leading to air pollution during this step.





Journey step 11
RECYCLING

Sorted waste is shredded into smaller pieces of plastic, called flakes. These are washed and dried so that the flakes can be extruded into granules. The quality of these granules (recyclate) is determined by the purity of the waste stream.

OPPORTUNITY 8
Provide necessary insights into the composition of plastic waste, enabling the production of high-quality recycled material.

REFLECTION
The processed waste has a (average) purity of 95%, which is not sufficient for the production of new packaging. This leads to production of lower quality products (down-cycling) such as flowerpots, furniture, and planks. Additional knowledge is needed to address this opportunity, but the possible impact would be significant due to the processed volumes.

Journey step 12
PRODUCTION

Recyclate is sold and transported to converters that use the recycled material to produce new products.

OPPORTUNITY
None

REFLECTION
The production of new products was not included into the scope, but it is relevant to understand that converters are the ones that require the high material quality to produce their packaging.

CHAPTER 1.8 | CONCLUSION

The mapped out product journey (chapter 1.6) focussed on different steps that a bottle of laundry detergent goes through from being purchased to being recycled, which led to the formulation of eight possible opportunities. This chapter explains the process of selecting one of these opportunities.

A list of identified opportunities within the context of mechanical recycling of plastic packaging waste, collected in urban high-rise.

1 | Eliminate the need for a plastic bag during transportation of consumable products.

2 | Reduce the amount of plastic waste that is generated during consumption.

3 | Stimulate (correct) separation of plastic waste at a consumer level.

4 | Enable efficient storage of separated plastic waste in an urban high-rise environment.

5 | Enable consumers that live in an urban high-rise to deposit collected plastic waste in a separate container.

6 | Increase separate collection of plastic waste streams that are produced in an urban high-rise environment.

7 | Improve accuracy for the NIR-technology, enabling sorted waste to be produced with higher efficiency and purity.

8 | Provide necessary insights into the composition of plastic waste, enabling the production of high-quality recycled material.

The C-Box in figure 12 was completed by applying the following criteria to the list of identified opportunities that is presented on the left. Further reading on how this reflection was conducted can be found in appendix B.

▶ The first criterion applied for reflection was that an opportunity had to **fit the defined scope** of mechanical recycling of post-consumer plastic packaging waste.

▶ Second criterion applied was **feasibility of addressing** an opportunity, which had to be completed within a time-frame of 22 weeks*.

▶ The third and final criterion was the **achievable impact** that could be expected by addressing an opportunity.

As can be seen in figure 12, opportunity 7 and 8 score the best after reflection. Opportunities 3,4, and 5, are interdependent and would require to be addressed as a set. This would make the project less feasible to complete within the project's time-frame, the possible impact that could be achieved would also not be as significant compared to the 7th and 8th opportunity. For this project, one of these two opportunities had to be selected.

A lack of knowledge in the field of mechanical recycling with the use of NIR-technology required assistance of an external party. Therefore, the outcome of the preliminary analysis was discussed with a number of industry experts to discuss and validate the findings.

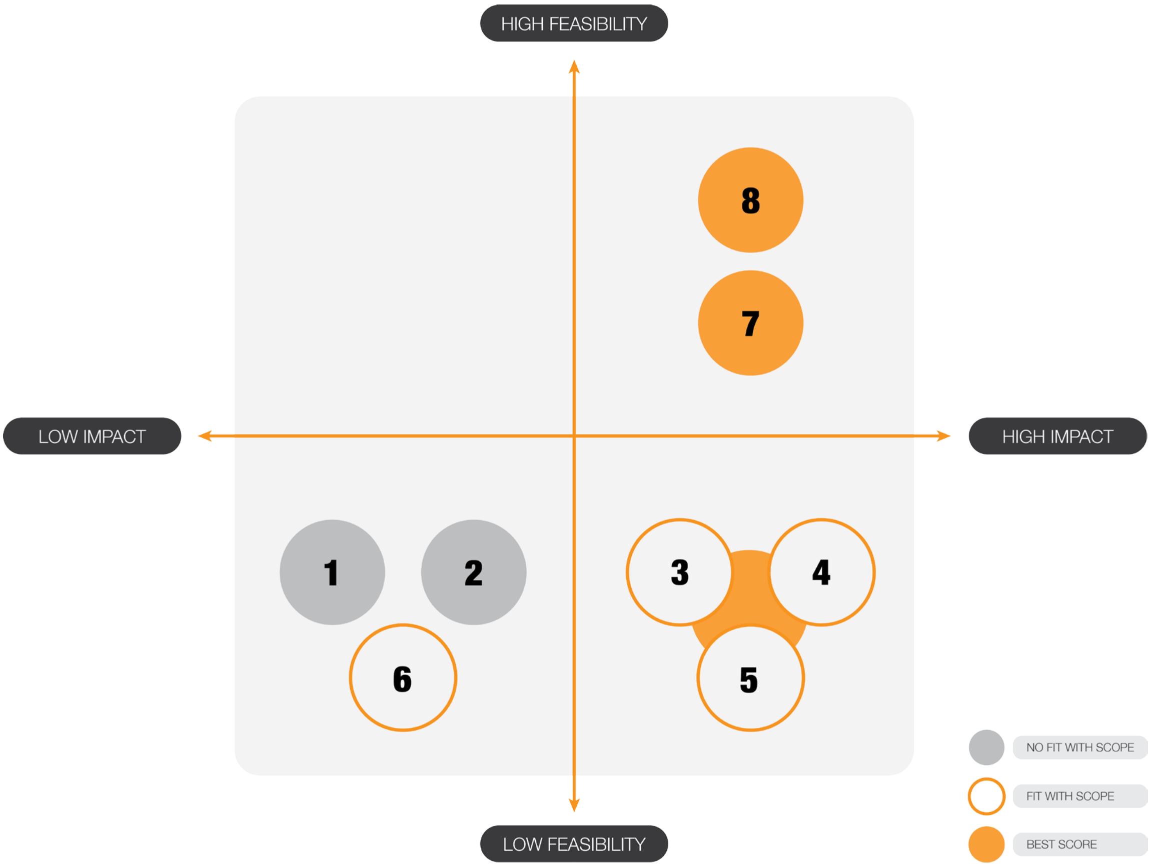


Figure 12: *Overview of the identified opportunities plotted in a C-Box matrix.*

One of the approached companies was Polytential, a start-up company working on an automated product that analyses the composition of plastic waste. Not only did was the 8th opportunity validated, but an opportunity to do an internship at Polytential was also presented.

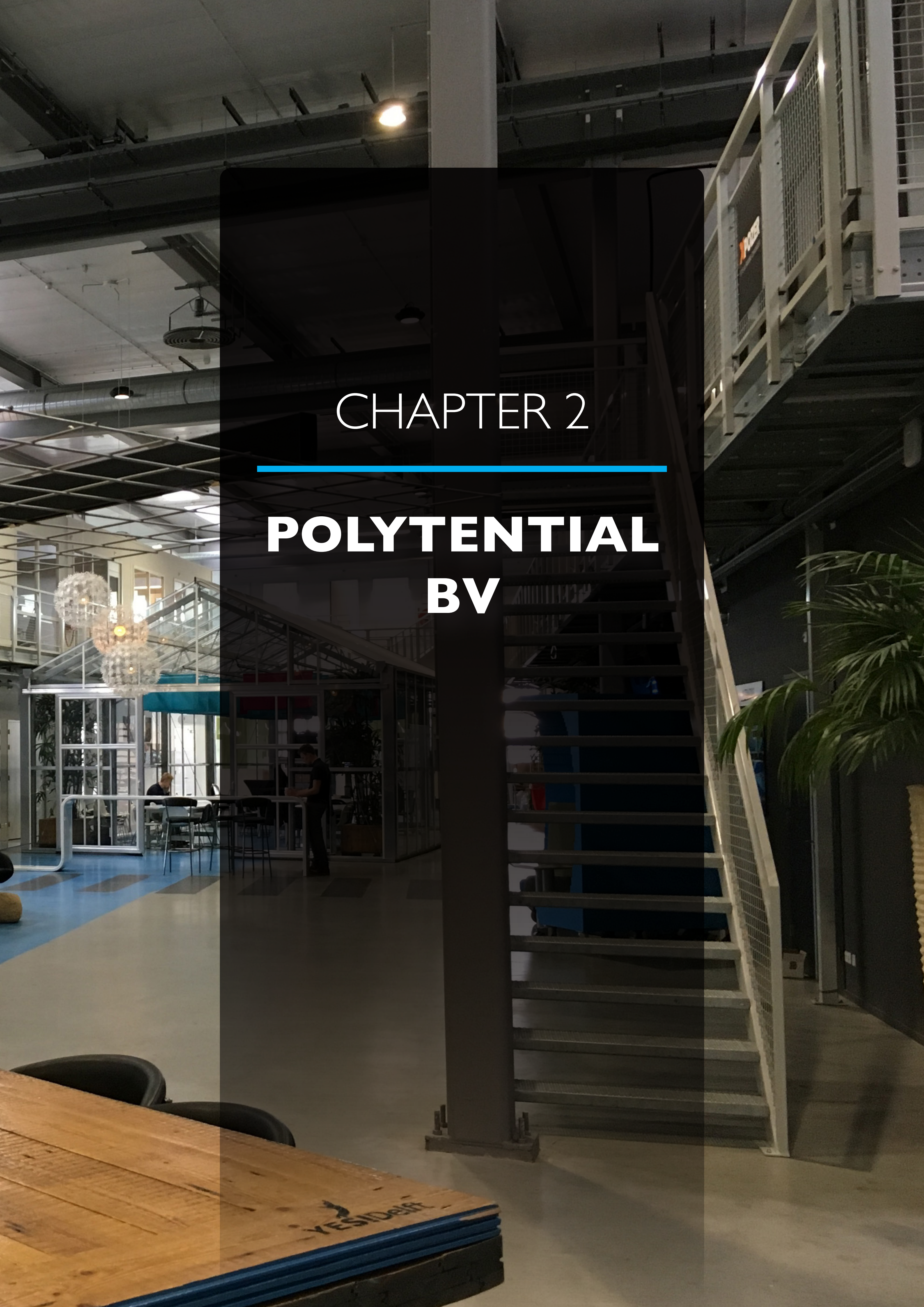
By doing an internship of 22 weeks, the lack of knowledge could be solved and it was therefore decided to involve the company with this project.

THE OPPORTUNITY

8 | Provide necessary insights into the composition of plastic waste, enabling production of high-quality recycled material.

The next chapter introduces the company in further detail, explains their mission, presents the solution and design challenge that was addressed during the internship.

*The project's time-frame was increased, but this was not known at the moment of reflection.



CHAPTER 2

POLYTENTIAL BV

CHAPTER 2.1 | A START-UP ENVIRONMENT

Polytential BV is part of the incubator program Yes!Delft that programs for tech start-ups in the areas of: Blockchain, Med-Tech, Artificial Intelligence, Aviation, Clean-Tech, Robotics and Complex Technology. This chapter shortly explains the working environment and what type of affect it had on this project.


Photograph taken at Yes!Delft, Delft. (Schetselaar, 2018)

A start-up is focused on failing, and preferably doing so as much as possible, as often as possible. Why is failing a good thing? The whole idea of a start-up is that you confirm your assumptions, and get a clear idea of what works and what doesn't. A large company on the other hand cannot permit itself to be as reckless due to the complexity and size of the business structure.

Why does the size of a company influence the ability to adapt? Let's compare a start-up with an established company and use a metaphor to explain the differences between the two. Imagine a start-up being a small car that allows you to explore, manoeuvre through obstacles, and make decisions on the spot. An established company on the other hand, should be seen as a large bus filled with different people all depending on the known route of the bus. The bus cannot make big adjustments to the route without negatively affecting its passengers.

With Polytential being a start-up that is exploring their route, it should be viewed as the car; but how does this affect this project and the design process?

2.1.1 Fail to learn

The goal is to iterate as much as possible throughout the project, so that the team knows what works and what doesn't. This means that there will be a significant focus on in-house testing, conducting demo's at different clients to gather as much insights as possible for further product development.

2.1.2 Money doesn't grow on trees

Not having an unlimited supply of resources means that the development needs to be done with easy-to-get, affordable materials and elements that can be used for the development of the Virtual Chemist.

2.1.3 Prioritizing is key

The amount of work that needs to be done never ends, therefore it is important to clearly prioritize what issues need to be solved today and which issues can wait until tomorrow.

CHAPTER 2.2 | COMPANY MISSION

Understanding the mission statement of a company is crucial in any design project, as it influences the decision making processes. This chapter explains the opportunity that the company intends to address, and is based on their understanding of the problem found in the context of plastic recycling.

After being separated from household waste, the plastic that is sorted and processed still contains an average contamination of 5 per cent. This presence of unknown plastics that remains in the recycled batches force the industry to take additional measures to mitigate the negative effects, caused by the contaminating plastics, in order to reach the required material quality.

This problem is caused by the current method of analysing plastic waste, which requires intensive (manual) labour and uses inaccurate tests to get an idea of the composition.

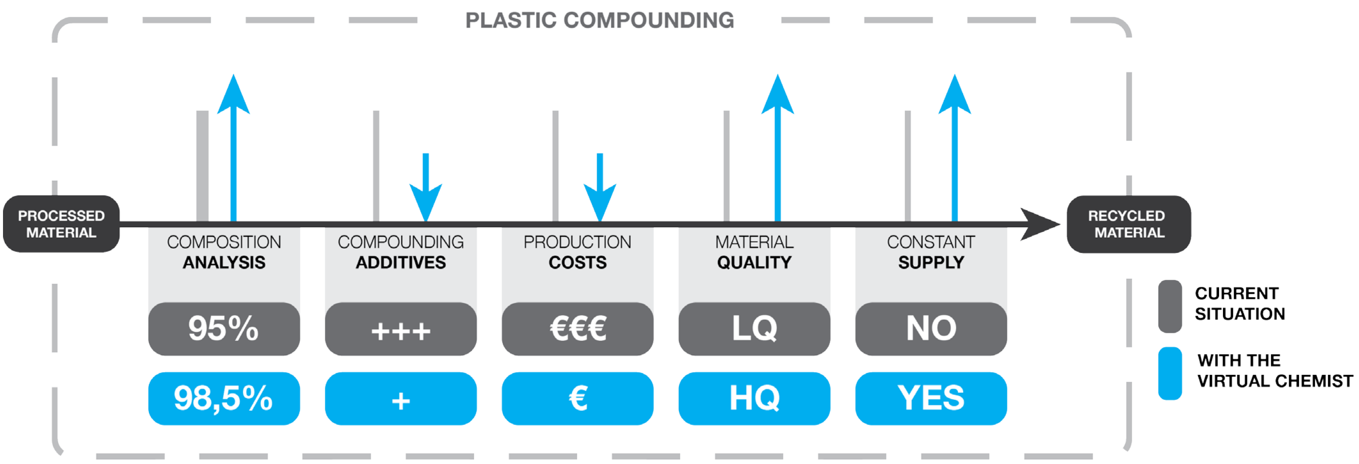
Besides the impurity, the contamination can also lead to increased malfunctioning (and downtime) of industrial machines, which leads to a loss of revenue. Another bottleneck that prevents the use of recycled plastics in high quality applications is caused by the unstable product quality.

Solving the described issues should increase the profitability of high-quality recyclate, less use of additives, and a higher demand for recycled plastic material.

Polytential intends to provide accurate and real-time insights into the material composition of recycled plastics, decreasing the uncertainty from 5 to 1,5 per cent. Addressing these factors will further increase the profitability of recycling plastic waste.

COMPANY MISSION

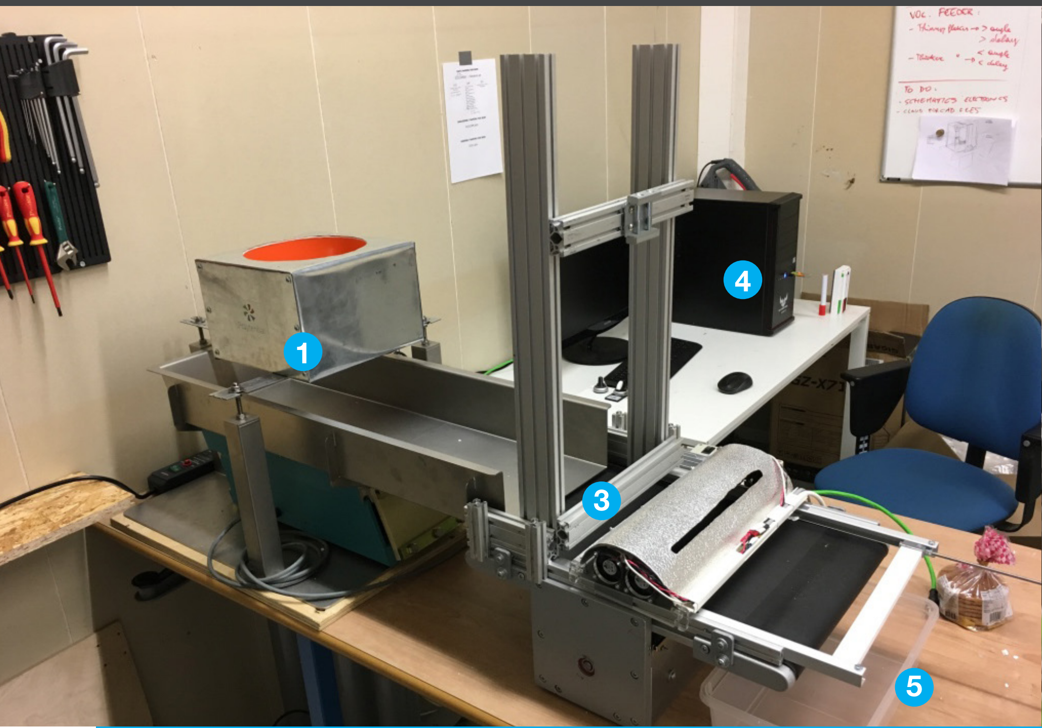
| Polytential intends to provide the recycling industry with the necessary insights into material composition, so that a stable production of high-quality recyclate can be achieved.



Visualised company mission statement. (Schetselaar, 2018)

CHAPTER 2.3 | THE SOLUTION

The version presented below is considered a MVP (Minimum Viable Product) and is used to demonstrate the functionality to clients and gain insights for further development. It was in this development stage that the internship commenced, therefore this version is used as the starting point for this report.



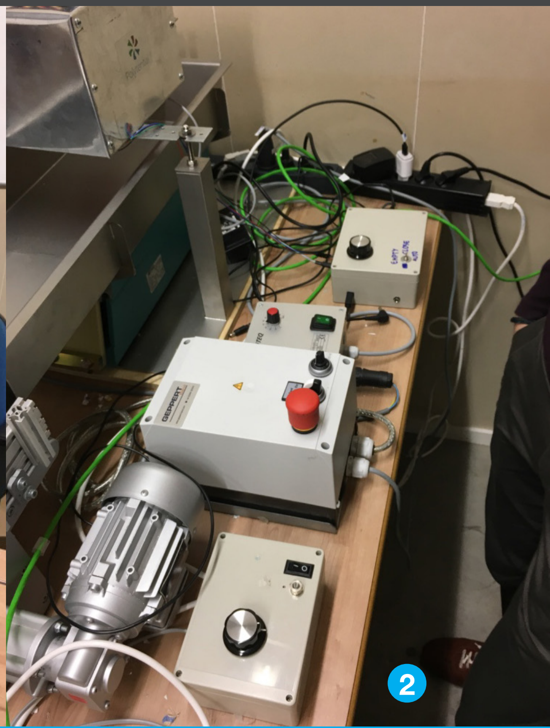


Figure 13: *Photograph of the product as a starting point.*

Figure 14: *The product's control panels.*

2.3.1 THE PRODUCT

Most important aspect of working with a MVP was that a product goes through numerous client demonstrations to identify focus-points for further development. Addressing the focus-points had a direct affect on the product's appearance and functionality throughout the project.

Such a dynamic process was difficult to match with the "standard" design process, which can be found in appendix C. How the revised design process affected this project can be found in appendix D as it is not further discussed in this report.

The main takeaway is that by the time the design brief was formulated, the product itself had undergone numerous iterations and thus leading to a different starting point.

For this reason, this chapter only discusses the main functionality and does not yet provide further information on the different sub-systems and elements that makeup the entire product.

2.3.2 MAIN FUNCTION

Provide accurate plastic waste composition results, on an industrial scale.

2.3.3 GENERAL USE

Explained with the numbers found in figures 13 and 14.

1. The sample is inserted into a feeding system.
2. The product is turned-on using multiple control boxes.
3. Flakes are transported under a hyperspectral camera, after which the hyperspectral data is uploaded to the cloud.
4. The computer is used to process the incoming data and send it to a cloud, where the data is processed by an Artificially Intelligent algorithm. Additionally, the computer's software enables a user to operate the hyperspectral camera.

5 The scanning sequence is completed by collecting all flakes in a container.

These steps explain a general overview, a more in-depth analysis and explanation of the product's functionality can be found in chapter 3.3.

2.3.4 THE PRODUCT'S NAME

Just like a real chemist, this product analyses the composition of matter where the hardware is the chemist's body and the software the mind.

2.4 WHY ME

The company's goal is to develop the product further so that it can be sold to clients as a minimum-marketable-product (MMP), which can be achieved by addresses the user needs and facilitating the right user-experience (UX).

Therefore, the goal of this internship was to analyse the current situation and design the user interaction/experience for the first sell-able version of the Virtual Chemist.

A design project should have a well-defined design brief, which includes a design goal(s), criteria, requirements, and vision. However, constructing such a brief required further analysis on a number of topics such as a defined design focus, the user, context, interactions, and user-experience. These topics have been researched prior to the formulation of the design brief, and are presented in the next chapter.

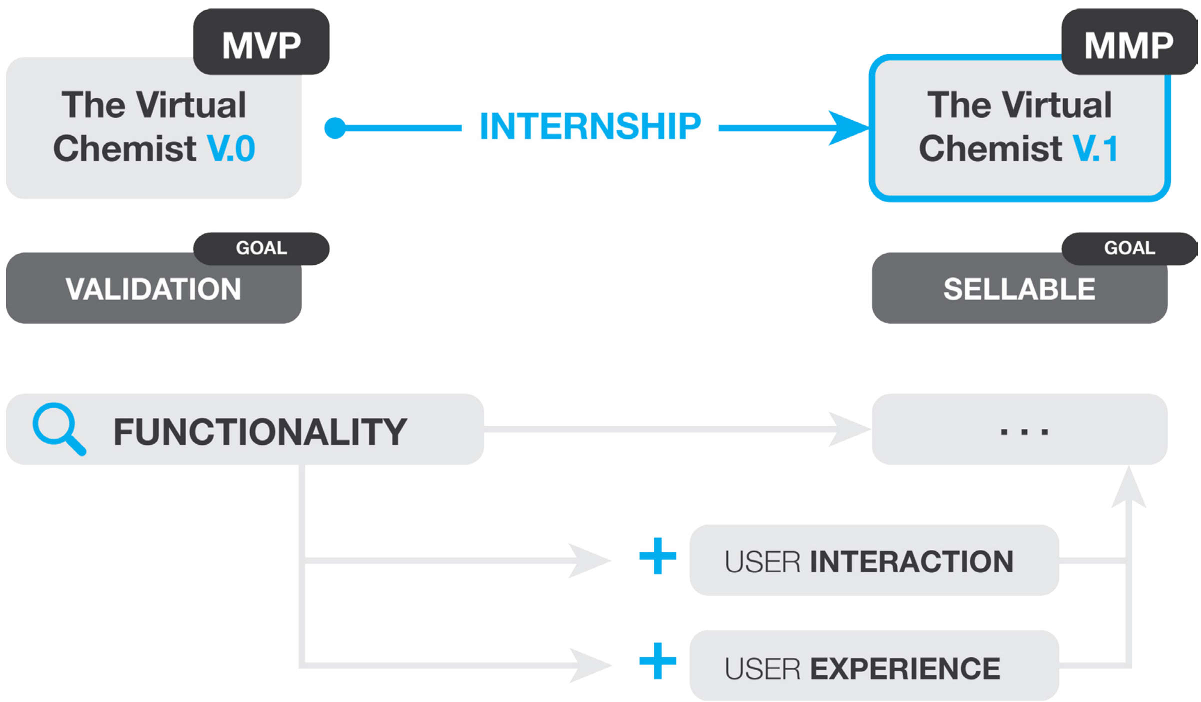
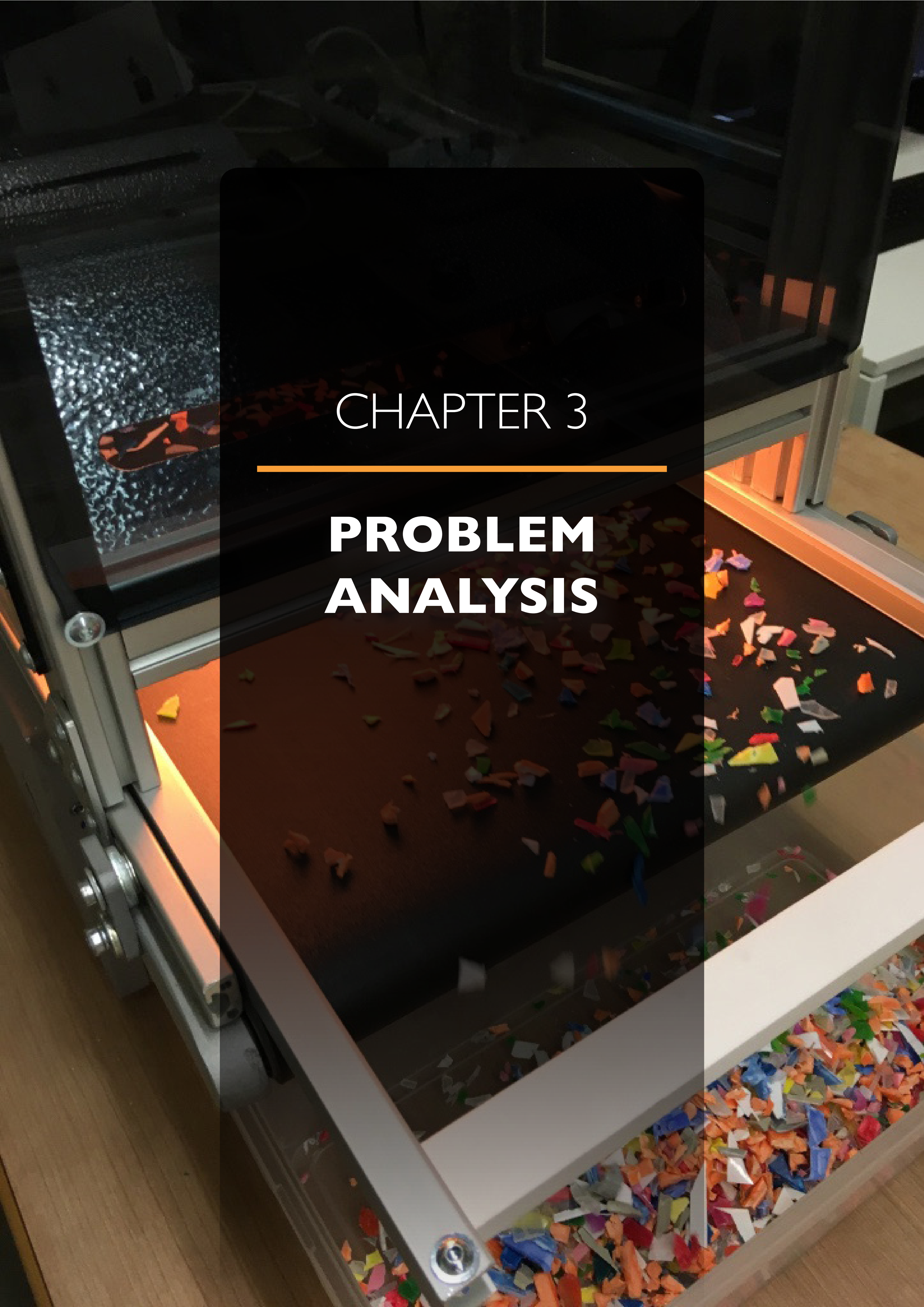


Figure 15 : *A representation of the situation and the internship goal. (Schetselaar, 2018)*



CHAPTER 3

PROBLEM ANALYSIS

CHAPTER 3.0 | INTRODUCTION

The analysis goal, defined prior to the internship, is illustrated in figure 16, and explained further below. This chapter concludes with a short summary of the findings, by reflecting back at this image.

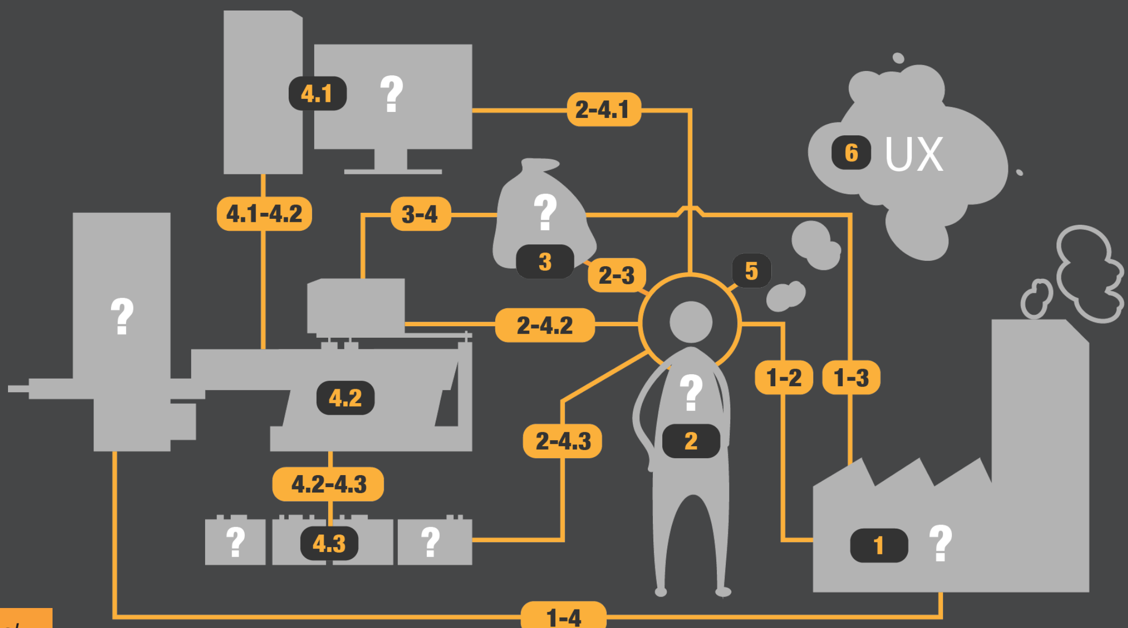


Figure 16: *Visualised analysis goal, an overview. (Author, 2018)*

3.1 THE CONTEXT I

WHAT An analysis of the context in which the Virtual Chemist version 1 will operate.

WHY To determine how the context influences the product's design.

HOW By observing the context during the client demo(s), conducting an online client analysis, and company insights.

3.2 THE USER II

WHAT An analysis of the expected user that will operate the Virtual Chemist.

WHY To determine the user's persona, needs and wishes.

HOW By interviewing clients, conducting an online analysis of comparable job vacancies, and company insights.

3.3 THE WORKFLOW III

WHAT An analysis of the workflow that needs to be completed by the user.

WHY To determine what could/should be improved in-order to provide a better user-interaction and experience.

HOW By personally completing the workflow, observation during client demo, client feedback, and company insights.

3.4 THE SYSTEM IV

WHAT An analysis of the functionality of the system, sub-systems, and elements.

WHY To prioritize which sub-system(s) should be addressed during the internship.

HOW Through an analysis of the selected sub-systems and in consultation with the company.

+ INTERACTION V

WHAT An analysis of the interactions that occur during usage.

WHY To determine which interactions should be addressed during the internship.

HOW By observing the user interactions during the demo, client feedback, and company feedback.

+ EXPERIENCE VI

WHAT An analysis of how the product is experienced by a user.

WHY To determine how the user experience can be improved.

HOW By collecting user feedback through questionnaires, company feedback, and personal experience.

CHAPTER 3.1 | THE CONTEXT

This sub-chapter presents the analysis results of the context in which the Virtual Chemist would be used. The goal was to get a better understanding of the context and how it influences the Virtual chemist. For this, the company insights have been used as orientation, this input was then used to map out the current aesthetics that can be found within the context. Additional insights have been gathered though observation of the context during client demonstrations.

Figure 17: *The facility, a mechanical recycler. (Recycling magazine, 2018)*

3.1.1 CONTEXT INSIGHTS

The following context insights have been formulated in consultation with the company.

The company's clients process primarily PET and PP/PE, as these types of plastic are the highest in demand. (Addressed in chapter 1.3)

Current composition analysis methods are highly accurate, but can only process (very) small volumes that are not highly representative.

Implementing the Virtual Chemist in the client's process will require assistance from the company to facilitate the transition from their current analysis methods.

The working environment varies between different clients, as processing different types of plastic leads to different problems.

PET | High quantity of dust | Colour purity

- **PET dust is found everywhere and it will inevitably interact with the Virtual Chemist's hardware**, negatively affecting the composition analysis results.
- **Colour purity is important when recycling PET** in-order to maintain its transparent material characteristics.

PE/PP | High level of contamination | Material diversity

- Polyolefins need to be washed more thoroughly to remove any leftover residue. This **leads to more moisture, negatively affecting the composition results.** This could be solved by further drying of the flakes, but will also lead to higher operational costs and is therefore not considered a feasible option.

- As opposed to PET, the **PE/PP waste stream is more contaminated with other materials** such as silicone, foils, and aluminium.

Other external factors that have been mentioned by the company, that will affect the functionality of the Virtual Chemist are: **variable light intensity**, **variable temperatures**, and **high humidity**.

Although **the composition analysis of plastic waste is conducted in a separate room inside a facility**, the discussed external factors should not be ignored.

3.1.2 PRODUCT INSTALLATION

As introduced above, the Virtual Chemist will not be placed inside the recycling facility (figure 17), but in a separate room inside the facility as can be seen in figure 18.

As can be seen in the image, **the workspace is crowded and filled with different types of machinery** that could affect the functionality of the Virtual Chemist (and visa versa).

According to the company, **placement of the product did not involve any major difficulties during the demo.** However, as each client does things a bit different it was necessary to observe other contexts before drawing further conclusions.

3.1.3 OBSERVATIONAL INSIGHTS

The following insights have been gathered during a client demonstration (appendix E).

The laboratory was located at a different location, and not inside the recycling facility as discussed earlier.

The system was installed on top of a table, but **used all of the available space** that could no longer be used for other activities.

In consultation with the company **it was decided to not focus further on this context**, as it did not correctly represent the context.

The observed products within the context were old-fashioned and user-unfriendly, these are discussed next.

Figure 18: *The Virtual Chemist placed inside a client's facility. (Polytential, 2018)*

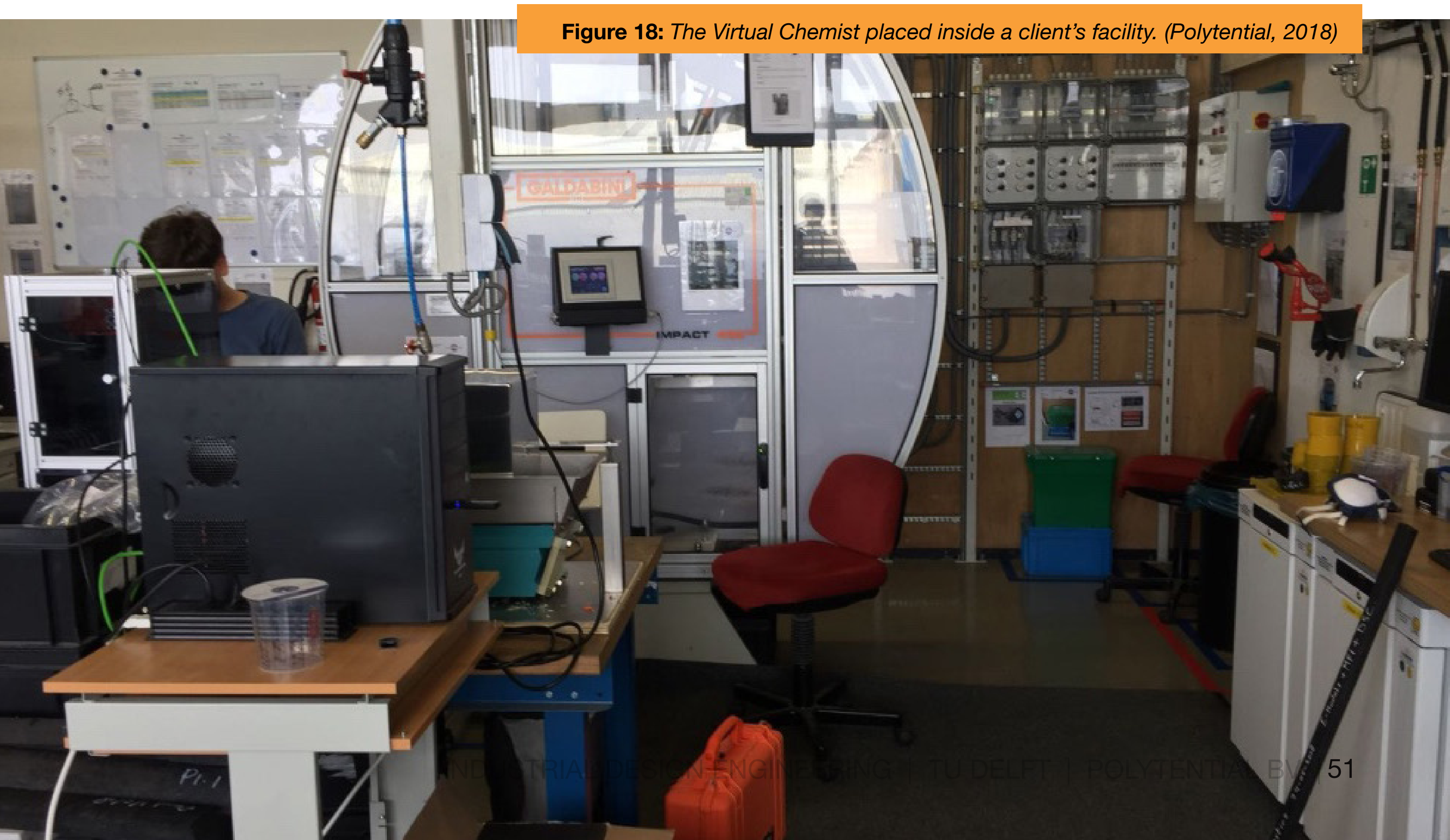


Figure 19: *Current product aesthetics, a hot wash device used for PET. (B+B, 2018)*

3.1.4 CURRENT AESTHETICS

The current aesthetics observed within the context are **very industrial** (figure 19 and 20) and **expressed a sense of robustness. The products felt cold and did not communicate an inviting personality**.

Another example of an industrial product, as observed during a client demonstration can be seen below.

Figure 20: *Photograph of a product found within the context. (Author, 2018)*

The Virtual Chemist is being developed as an innovative product that utilizes modern technologies, and should also be perceived as such. It was hypothesized that the current aesthetics observed within the context do not fit company's vision.

This hypothesis was converted into a collage that can be seen in figure 21, and was used to elaborate further on the design direction for the Virtual Chemist.

3.1.5 FUTURE AESTHETICS

The images used for the collage have been carefully selected based on a number of criteria. The product should be experienced as **modern**, **clean**, and **trustworthy**.

The collage was presented to each company member individually to ensure that the feedback was not affected by each other's feedback.

It was decided to design the Virtual Chemist to fit a modern context, compared to the current situation. However, some team members expressed that **the Virtual Chemist should feel more manly and less clinical**, compared to the collage.

| The system should be fully-enclosed to ensure that the functionality is not affected by external factors.

Figure 21: *A collage that was used to convey the intended design direction. (Author, 2018)*

Polytential
CREATED BY SERGEJ SCHETSELAAR

CHAPTER 3.2 | THE USER

The User analysis was completed by interviewing a client, conducting an online analysis of relevant job vacancies, and the company insights. The sub-chapter concludes with a collage, visually communicating a persona that represents the operator.

3.2.1 COMPANY INSIGHTS

In consultation with he company **it was decided to design the system in such a way that no prior experience is required to operate the Virtual Chemist.**

This decision was based on the assumption that **the operator's main task is to scan the samples**, and provide the scan results to a data analyst for further processing.

3.2.2 CLIENT FEEDBACK

During the demonstration at TUSTI, Jan Kolijn the company's CTO, expressed that **a machine operator would be hired to scan the samples** on a full-time/part-time basis.

Jan expressed that he is interested in real-time results, but that **the data should be able to be exported** for further processing.

In consultation with the company **it was decided to focus on the machine operator**, and to exclude the data analyst from this project's scope.

3.2.3 REPRESENTATIVE VACANCIES

The following insights have been gathered by focussing on the similarities found in different job descriptions for a machine operator, as found on Indeed (a search engine for jobs).

EDUCATION | MBO-4 (High-School)

Having analysed both the US and Dutch job vacancies for a machine operator, it was decided that the level of education of a machine operator is MBO-4, or equivalent.

Additionally, the job descriptions mentions to prefer someone with experience in the relevant field, a driving license (including forklift), and a VCA-certificate. A VCA-certificate is used in the Netherlands to ensure workspace safety.

GENDER | Undefined (Male)

Although the job descriptions do not mention a preference for male of female, the recycling industry is mostly dominated by men.

THE JOB | Operation

A machine operator's job involves operating equipment according to the standard operation procedures (SOP).

| Maintenance

A machine operator needs to maintain a clean and safe work area. Identify items requiring maintenance and report to a supervisor.

| Communication

A machine operator needs to communicate critical information to supervisor and oncoming shifts.

| Flexibility

A machine operator needs to be able to work shifts on a rotating basis, and be able to complete other duties as required.

3.2.4 THE MACHINE OPERATOR

Figures 22 and 23 depict a machine operator, based on the collected insights. Although the image represents a good idea of the type of person that will interact with the Virtual Chemist, the image was to specific for the ideation phase. For this reason, a more abstract persona was constructed and translated into a collage. The collage (presented on the next page) was created to be used as inspiration, and to conclude the user analysis phase.

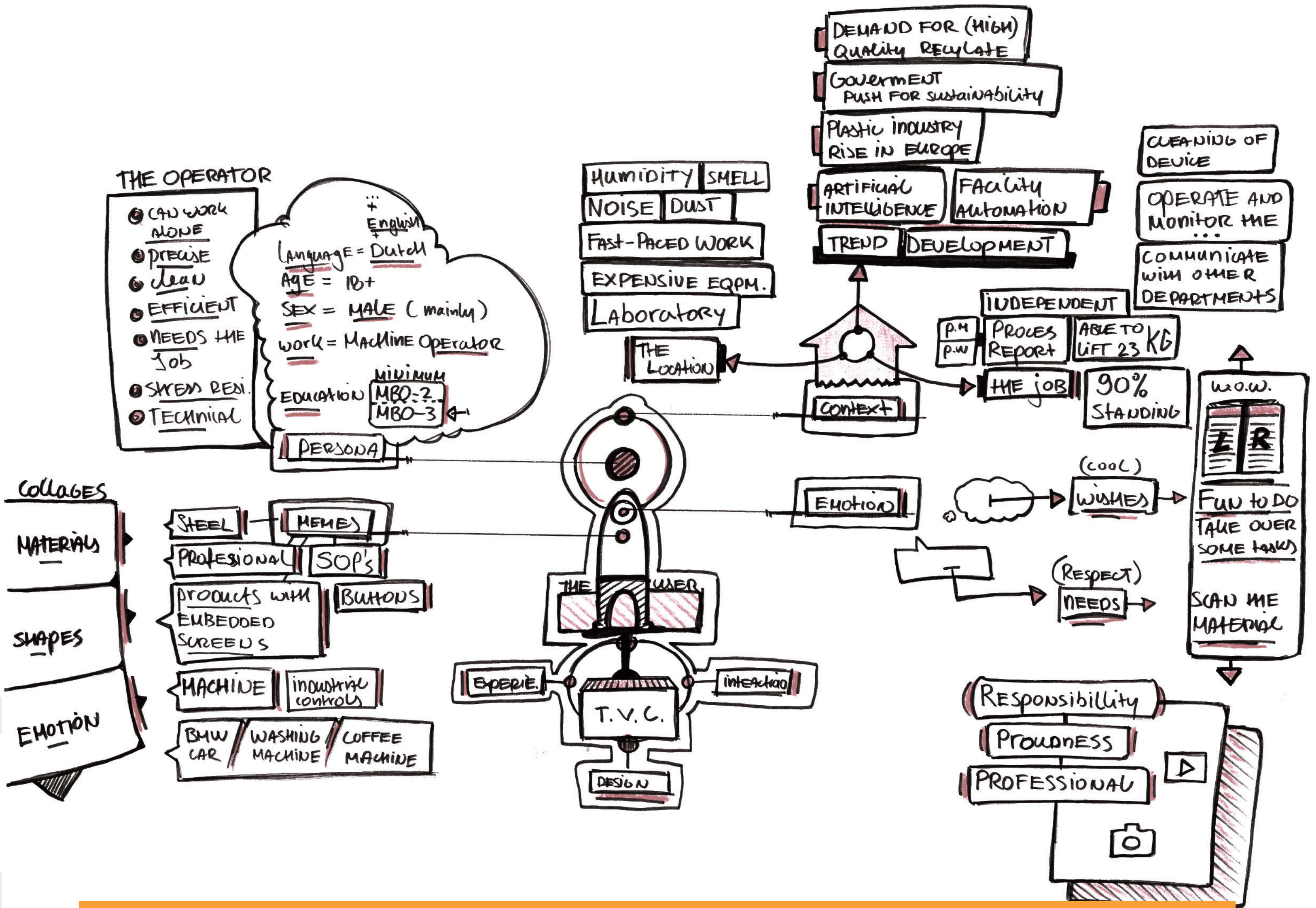


Figure 22: *Sketched-out results, based on numerous job vacancies for a machine operator. (Author, 2018)*

Figure 23: *A machine operator. (DS Smith, 2018)*

THE MACHINE OPERATOR

1 | TECHNICAL KNOW-HOW

A machine operator is someone that is familiar with industrial machinery and is able to assess the functionality of the Virtual Chemist. Although the company has stated that they will be responsible for periodic maintenance of the system, the machine operator must be able to solve hardware problems in-order to prevent process downtime.

In consultation with the company **it was decided that the machine operator should not be able to access the hardware**, as this will be done exclusively by the company.

2 | MONEY DRIVEN

A machine operator has finished his education and is focussed on making the money he needs to live his life. **He did not chose to operate the Virtual Chemist because of passion, or interest for the product itself.**

He is less interested in the design aesthetics and more interested in an efficient interaction with the system, which should enable him to complete his work accordingly.

3 | STRESS-PROOF

The operator is used to work in high-pressure environments and is able to address problems accordingly. He respects the company processes and completes these accordingly.

A machine operator is not a lone-wolf and works well within a team of professionals. He understands that he needs to complete his tasks as fast as possible, but also complete these properly so that others can rely on him.

4 | A WARRIOR

The operator is used to work long hours, complete tasks that require physical labour, and does this without complaint. **He receives tasks from his superiors and individually completes these to his best ability**, after completion **he reports back to the supervisor**. A machine operator is not a push-over and gets the job done.


1


2


3


4

CHAPTER 3.3 | THE WORKFLOW

The workflow was analysed to define with which sub-systems the operator will interact with, discussed further in the next sub-chapter. Another goal was determine what could/should be improved in order to provide a better user interaction and experience. This was done by personally completing the workflow, observation during client demonstration, client feedback, and with the company's insights.

3.3.1 IN-HOUSE TESTING

The workflow presented in figure 25 (appendix E) was constructed in consultation with the company, after having completed the workflow during a in-house test. The figure is explained further below.

| Cleaning

The Virtual Chemist needs to be kept clean to ensure that no residue is scanned again, which is crucial to ensure trustworthy data results. Cleaning can be skipped occasionally, if the same sample is scanned again.

| Sub-steps Required

The goal was to define a general workflow, so that it could be used as a reference during the client demonstration. Sub-steps required to complete certain tasks, such as naming and uploading data have been left out, as it was decided in consultation with the company that these should be redesigned into a single interaction.

| Single Scan

This path represents the workflow of scanning a single sample.

| Multiple Scans

This path represents the expected workflow, as the operator will be scanning continuously throughout his shift.

The presented workflow was converted into an observational template, used during a client demonstration (figure 24).

Figure 24: *From left to right; Jan Kolijn (CTO, TUSTI), Jeroen (Assistant, TUSTI), and Antonio Arbues (Polytential) observing the process. (Author, 2018)*

3.3.2 WORKFLOW INTERACTION

The following insights have been collected through observation and have been discussed with the client after completing the workflow.

- **The location of the screen affected to interaction** with the system, which led to an incorrect completion of the workflow.
- **The system was not cleaned during usage**, as the samples came from the same bag (20kg) and would not affect the results.
- The system was turned off during discussions, as **the noise made it difficult to communicate**.
- **The client was more focussed on the data**, compared to the system operation and maintenance.

The amount of interactions need to be reduced and redesigned to be more intuitive, so that a higher workflow efficiency can be achieved.

The user interface should assist the client in completing the workflow as intended, as the current workflow is too ambiguous.

APPENDIX XX

Figure 25: *The workflow represented by a task-flow, based on in-house testing and company insights. (Author, 2018)*

3.3.3 WORKFLOW EXPERIENCE

The following experience insights have been gathered by interviewing the client after a full day of using the system.

- **The workflow was experienced as CLEAN.**
The client elaborated further on his response by stating that: “Working with flakes is a messy process, it’s part of the job”. Furthermore, optimizing the container and having more space to work with should decrease the amount flakes being dropped.

- **The workflow was experienced as FUN.**
The client elaborated further on his response by stating that: “I think it is fun for now, but I don’t think that it will remain fun after a while”.

- **The workflow was experienced as FAMILIAR.**
The client elaborated further on his response by stating that: “The workflow is easy to understand, and feels familiar to me”.

The container should be optimized to reduce the amount of flakes that are dropped during transfer.

3.3.4 WORKFLOW OPPORTUNITIES

The workflow analysis was concluded by focussing on possible opportunities within the workflow, the outcome is presented on the next page.

Opportunities that have been selected to be used as input during the ideation phase are presented below.

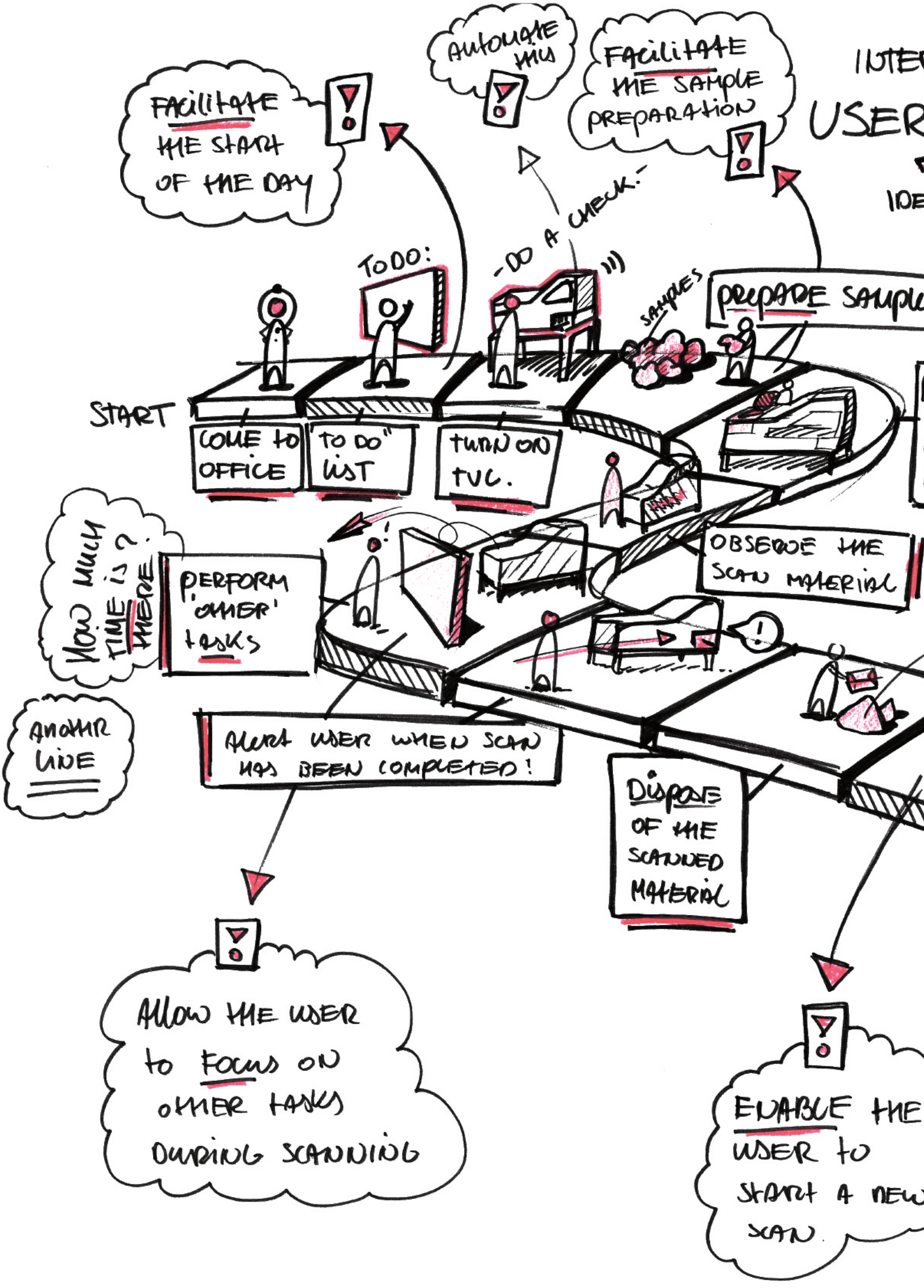
! | **The Virtual Chemist could assist the operator in constructing a process report,** enabling the operator to focus on other tasks.

! | **The amount of interactions could be reduced by inserting multiple samples at once.**

! | **Observing the process could be done from a distance,** enabling the operator to move more freely during scanning.

! | **The setup could be designed to be more efficient,** by automating certain user-software interactions.

! | **Scanning another sample could be accomplished with fewer interactions.**


FACILITATE THE START OF THE DAY
AUTOMATE THIS
FACILITATE THE SAMPLE PREPARATION
INTER
USER
IDE
TODO:
-DO A CHECK:
SAMPLES
PREPARE SAMPLE
START
COME TO OFFICE
"TO DO" LIST
TURN ON TVC.
HOW MUCH TIME IS THERE?
PERFORM 'OTHER' TASKS
OBSERVE THE SCAN MATERIAL
ANOTHER LINE
ALERT USER WHEN SCAN HAS BEEN COMPLETED!
DISPOSE OF THE SCANNED MATERIAL
ALLOW THE USER TO FOCUS ON OTHER TASKS DURING SCANNING
ENABLE THE USER TO START A NEW SCAN.

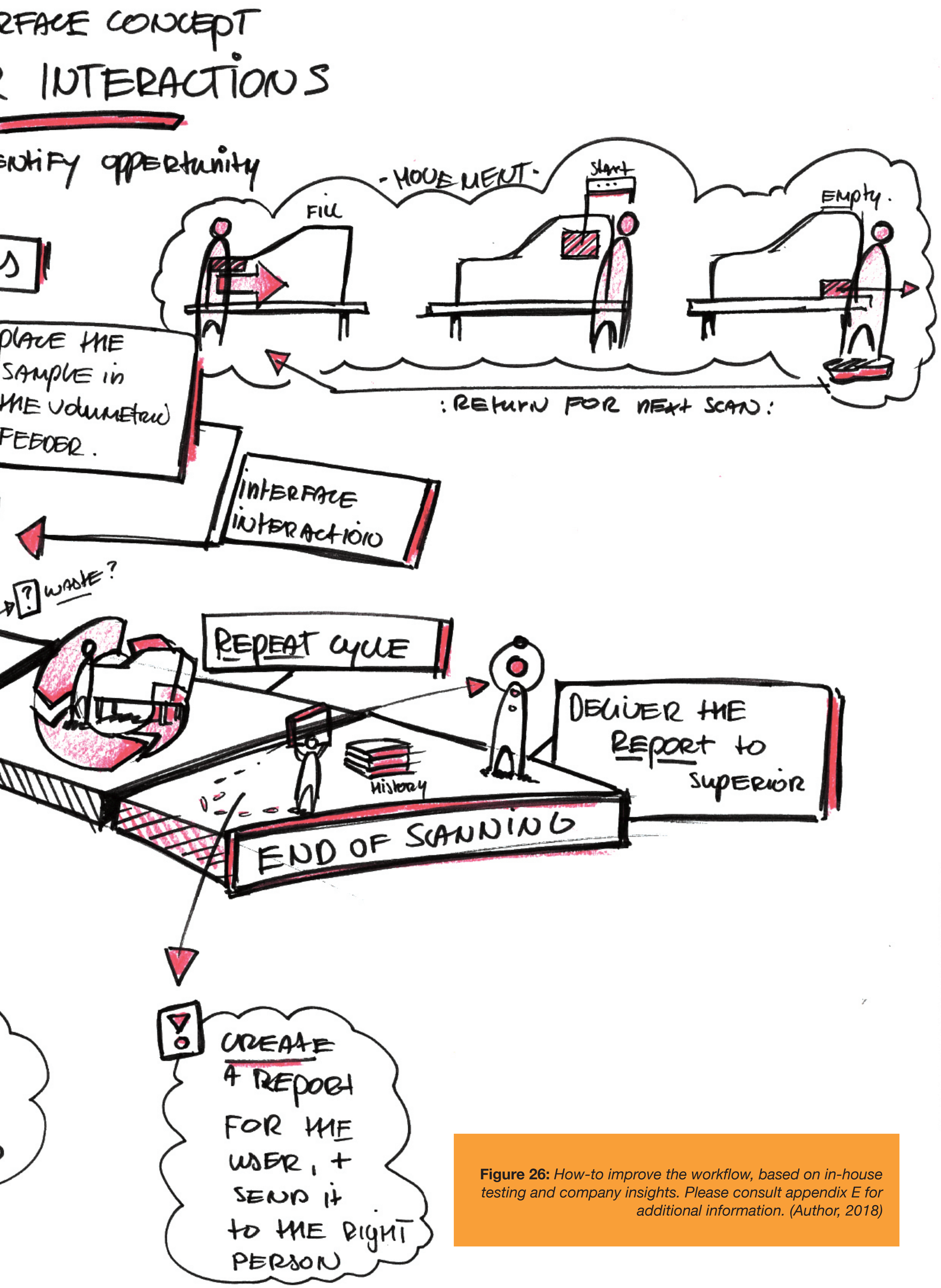


Figure 26: *How-to improve the workflow, based on in-house testing and company insights. Please consult appendix E for additional information. (Author, 2018)*

CHAPTER 3.4 | THE SYSTEM

This chapter presents the analysis results of the functionality of the system, sub-systems, and elements. For this, each sub-system was analysed and in consultation with the company. to prioritize which sub-system(s) should be addressed during the internship.

Through an analysis of each sub-system and in consultation with the company.

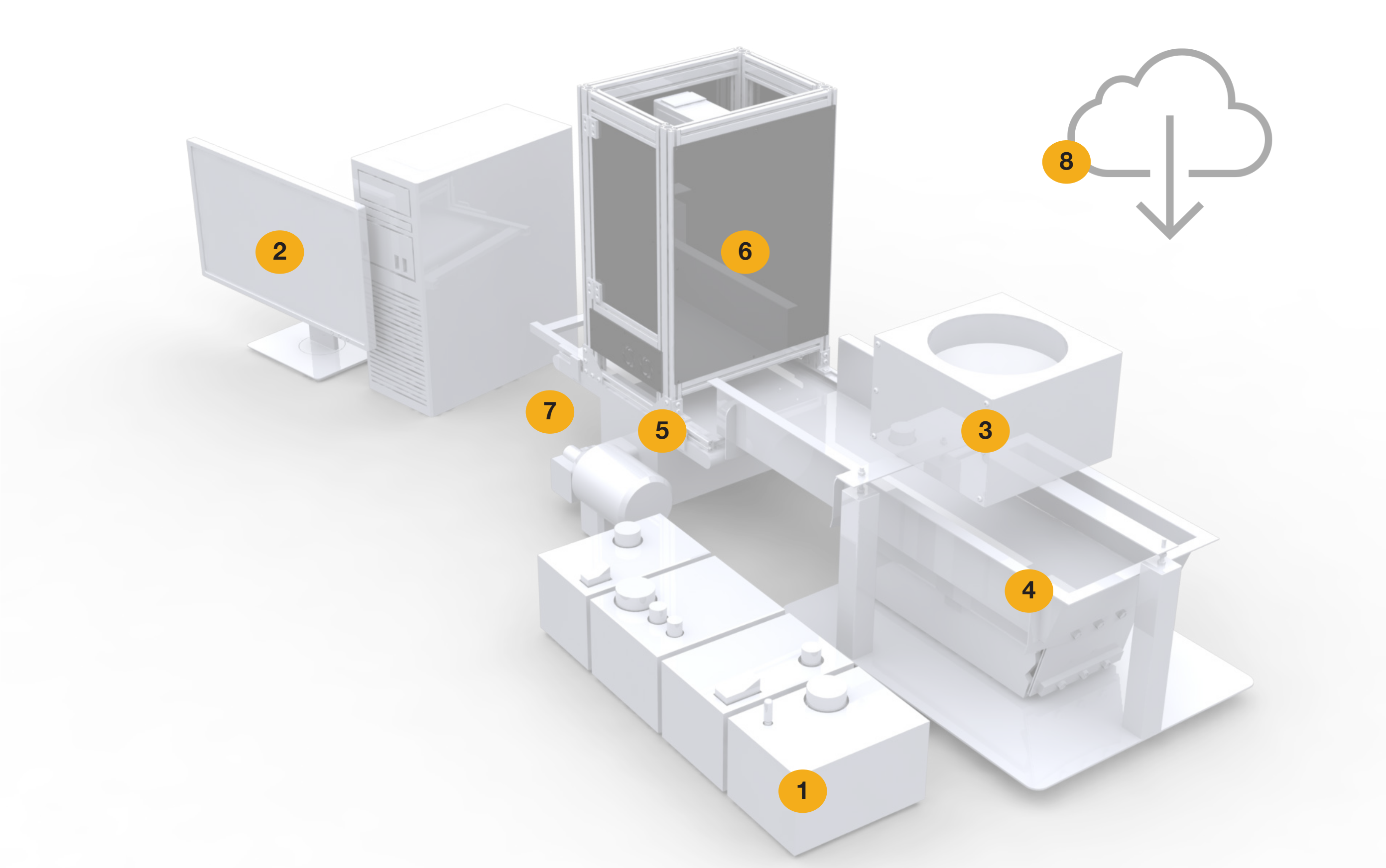


Figure 27: *The Virtual Chemist V.0.2 (Author, 2018)*

The version presented in figure 27 was chosen as the starting point for this project.

An overview of the system functionality analysis can be found in figure 28, where the numbers correlate with the numbers in figure 27. Please consult appendix F for the complete overview.

This analysis was conducted to gain a complete understanding of the system and to define an internship focus. This was done by including only the sub-systems that will have a direct interaction with the user, the selected sub-systems are marked with a star in figure 28. The selection of the sub-systems was done based on the workflow analysis presented in chapter 3.5, and in consultation with the company.

3.4.1 | CONTROL BOX

FUNCTION **To operate the (hardware) sub-systems**, and to enable a user to make adjustments to these.

ANALYSIS During the internship **it was decided to automate to functionality** of the control boxes.

CONCLUSION **Automation of this sub-system was not included into the initial project scope** and is therefore excluded from this project's scope.

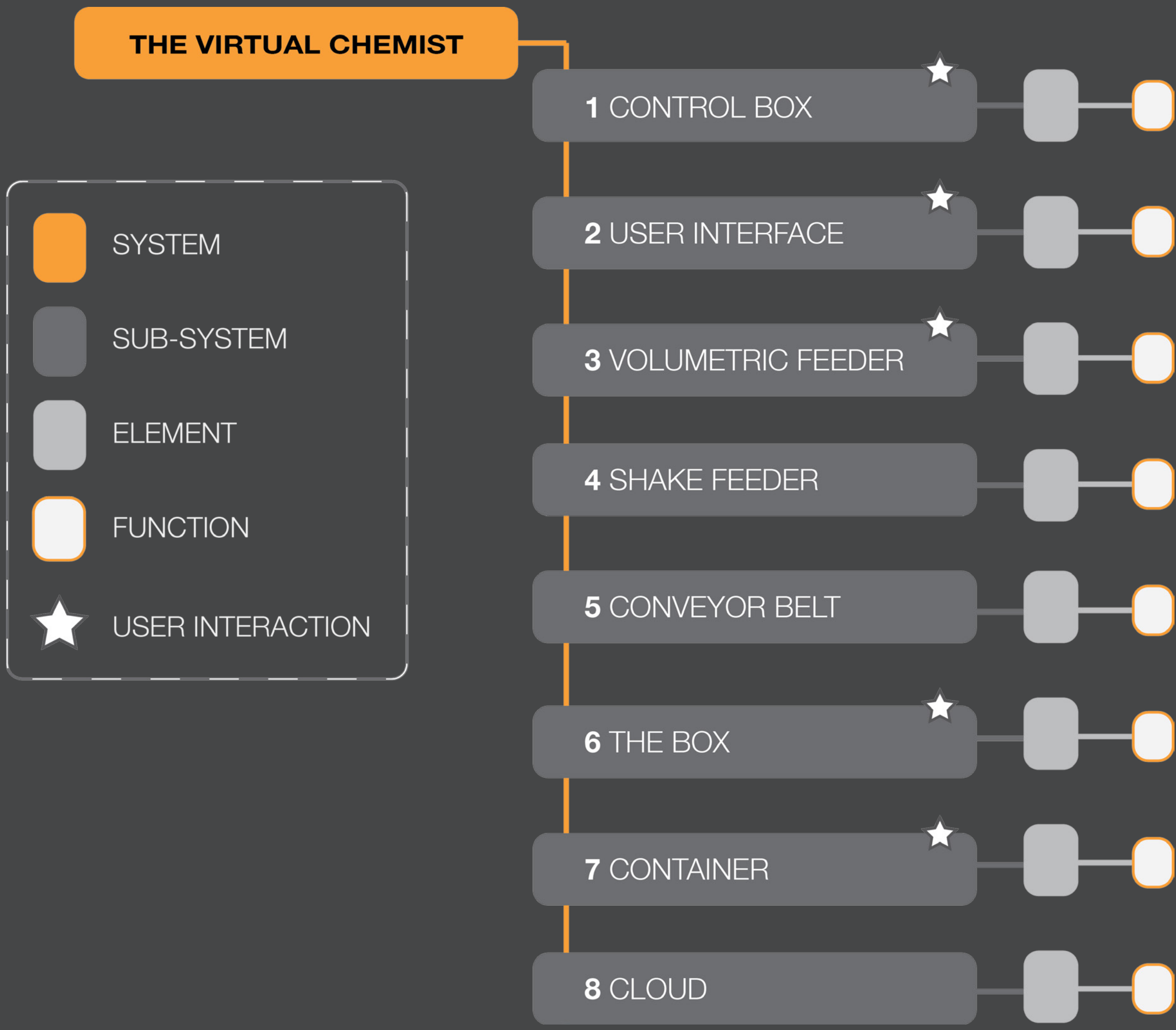


Figure 28: *The functionality of the Virtual Chemist V.0.2 (Author, 2018)*

3.4.2 | USER INTERFACE

FUNCTION **To communicate with the user** and to enable the user **to operate the system**.

ANALYSIS The following insights have been gathered through observation and during a client demonstration.

- **The time required to setup a scan should be lowered** to increase efficiency.
- **The software is over-complicated and presents unnecessary information** for the completion of the workflow.
- **User interface should be integrated with the product** to reduce the product's dimensions.
- **The (interface) workflow involves repetitive interactions** and should be automated to enable higher efficiency and a better user experience.
- **An operator will be hired to operate the product**, the data analysis will be done by another individual.
- The client mentioned to be interested in only plastic types that are significantly present in the sample, mentioning that **a top three expressed in a single decimal would be sufficient**.

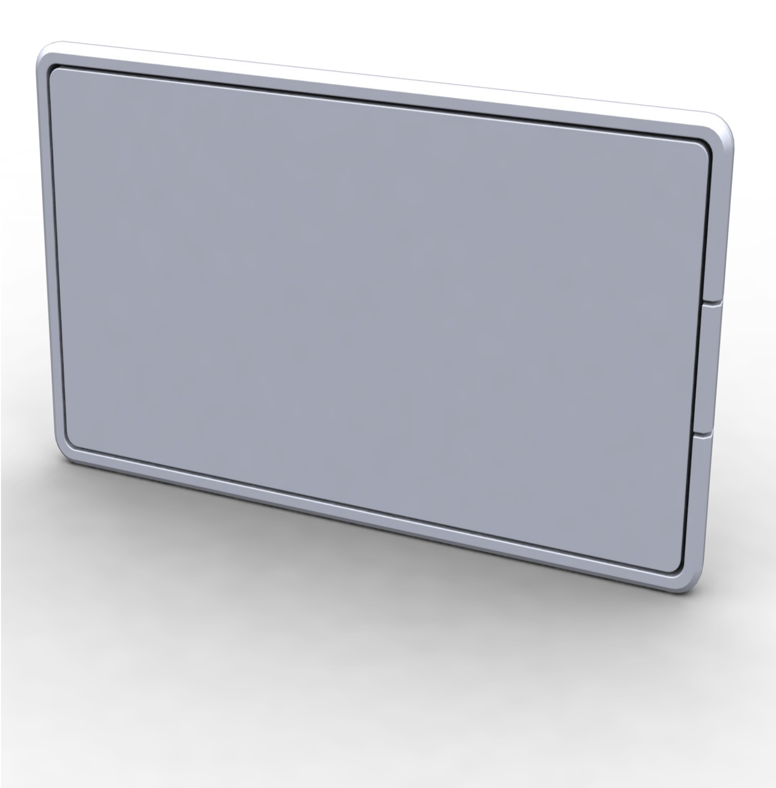
The software was analysed further so that a baseline could be formulated for the ideation phase, presented in chapter 5. For this, **a user flow diagram was created** and can be found in appendix G for confidentiality purposes.

Polyscan (display of results) was not further analysed, as this functionality would be designed according to the analysed user needs.

The setup time was analysed by completing a number of scan sequences using current software, Polyscan was excluded as the results would be presented within the same interface and preferably real-time. **User interaction with the interface was measured and averaged at 60 seconds**.

Based on similar product examples (appendix H) and in consultation with the company, it was decided to design for a 13 inch touch-screen.

CONCLUSION The user interface has been chosen as **the primary focus for this project**, as this sub-system holds the biggest opportunity in regard to user interaction and experience with the Virtual Chemist.



3.4.3 | THE VOLUMETRIC FEEDER

FUNCTION **To contain and regulate the throughput of flakes** and **to identify the presence of material**, with which further (workflow) automation can be realized.

ANALYSIS The volumetric feeder has been analysed to identify possible challenges in-regard to user interaction and experience, for a detail overview please consult appendix I.

CONCLUSION Having discussed the findings with the company, it was decided to **focus primarily on accessibility and cleaning of the volumetric feeder.**

3.4.4 | THE ENCLOSURE (BOX)

FUNCTION

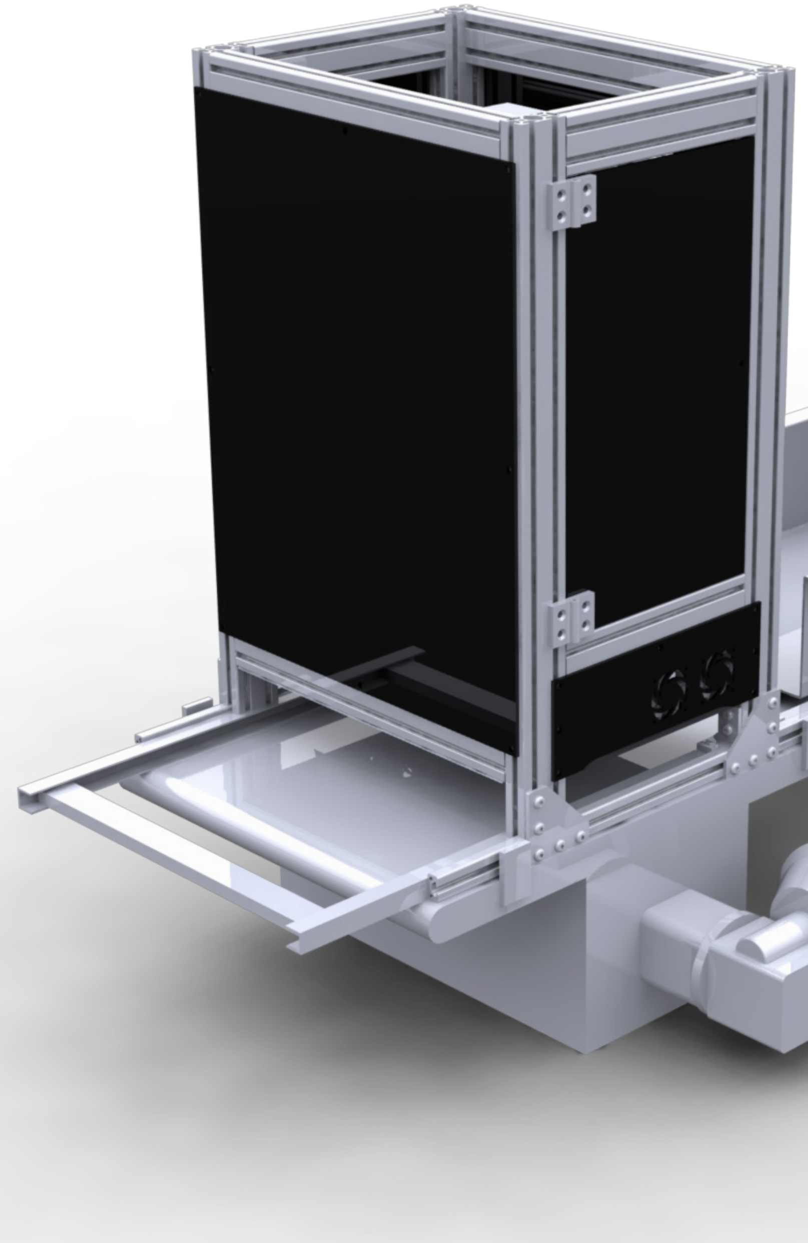
To ensure that the scanning sequence is not affected by external factors (dust, humidity and light) and **to protect the scanning hardware elements**, with which the user should not interact with.

ANALYSIS

In consultation with the company **it was decided to enclose the entire system**, complicating the current access making cleaning and maintenance more complicated.

CONCLUSION

It was decided to work closely with the development during further development of the system, focussing on the user interaction, experience, and product aesthetics.



3.4.5 | THE CONTAINER

FUNCTION

To contain all flakes that have been scanned and **to enable the user to transfer the collected flakes** into another container for storage.

ANALYSIS

The container has been analysed during the internship, focussing on ergonomics and the ability to transfer flakes from one container to another. The results can be found in appendix J.

CONCLUSION

In consultation with the company **it was decided to focus first on the enclosure, as this sub-system would depend on the enclosure's design. Additionally it was decided to focus on improving the ergonomics during usage.**

| The collected analysis insights were combined to formulate a conclusion that explains the internship goals and approach, presented on the next page.

CHAPTER 3.5 | CONCLUSION

This chapter concludes by reflecting back at the initial goal defined in chapter 3.0, below the summary of findings which define a baseline for this project.

3.5.1 THE CONTEXT I

As the company already had experience in the field of mechanical recycling, their knowledge was first used to gain a basic idea of the context. It was found that there are different types of clients, with different processes and material that are being processed, which was also found during the preliminary analysis (chapter 1.4).

A client demonstration was planned and used to collect further insights, unfortunately the client's laboratory location was not the same as the recycling facility that processes the waste, further illustrating the complexity of the context.

The context analysis was addressed further with a literature study, focussing on the recycling process in general, followed by a focus on current aesthetics.

It was found that **the system needs to be fully enclosed to protect the functionality form any external influence and contamination**, which as mentioned is not to be expected due to the complexity of the context. Furthermore, it was found that the current context aesthetics did not match the vision for the Virtual Chemist.

The collage presented in chapter 3.1 would be used as inspiration to **design the Virtual Chemist to be perceived as modern, clean, manly, and trustworthy.**

3.5.2 THE USER II

The user was analysed similarly to the context, by discussing the company's and client's idea of the future user. Based on their feedback it was decided to focus on a machine operator as the main user, who would be hired to operate the Virtual Chemist on a full-/part-time basis.

Numerous job vacancies (Dutch and American) were consulted to define relevant memes for a machine operator, which was done by focussing on reoccurring elements throughout the different vacancies.

Collected insights were used to construct **a collage that expressed the machine operator's persona as being technical, money driven, stress-proof, and a warrior.**

3.5.3 THE WORKFLOW III

With an operational Virtual Chemist, the workflow could be mapped out through in-house testing and led to the creation of a user flow diagram, representing the intended workflow. This predefined workflow was then used to design a template for the client demonstration, used to observe and document the workflow completion. Observed interactions that did not fit the predefine workflow were discussed afterwards with the client and company to define focus-points for further development of the Virtual Chemist.

The workflow analysis was concluded by mapping out the workflow, based on the collected insights, focussed on identifying possible opportunities to improve efficiency and to provide additional value during use.

Several opportunities found:

- **Facilitate** efficient preparation of samples.
- **Enable** efficient placement of samples.
- **Enable** completion of other tasks during scanning.
- **Decrease** the amount of workflow interactions.
- **Assist** the user in competing reporting tasks.

3.5.4 THE SYSTEM IV

The Virtual Chemist, as a system, was analysed by discussing all sub-systems and element with the company to define their functionality. Selecting the sub-systems and elements which would be addressed during the internship was done during the workflow analysis.

Selected sub-systems were analysed further during the internship to conclude each by defining the goal(s), requirements, and approach towards addressing these.

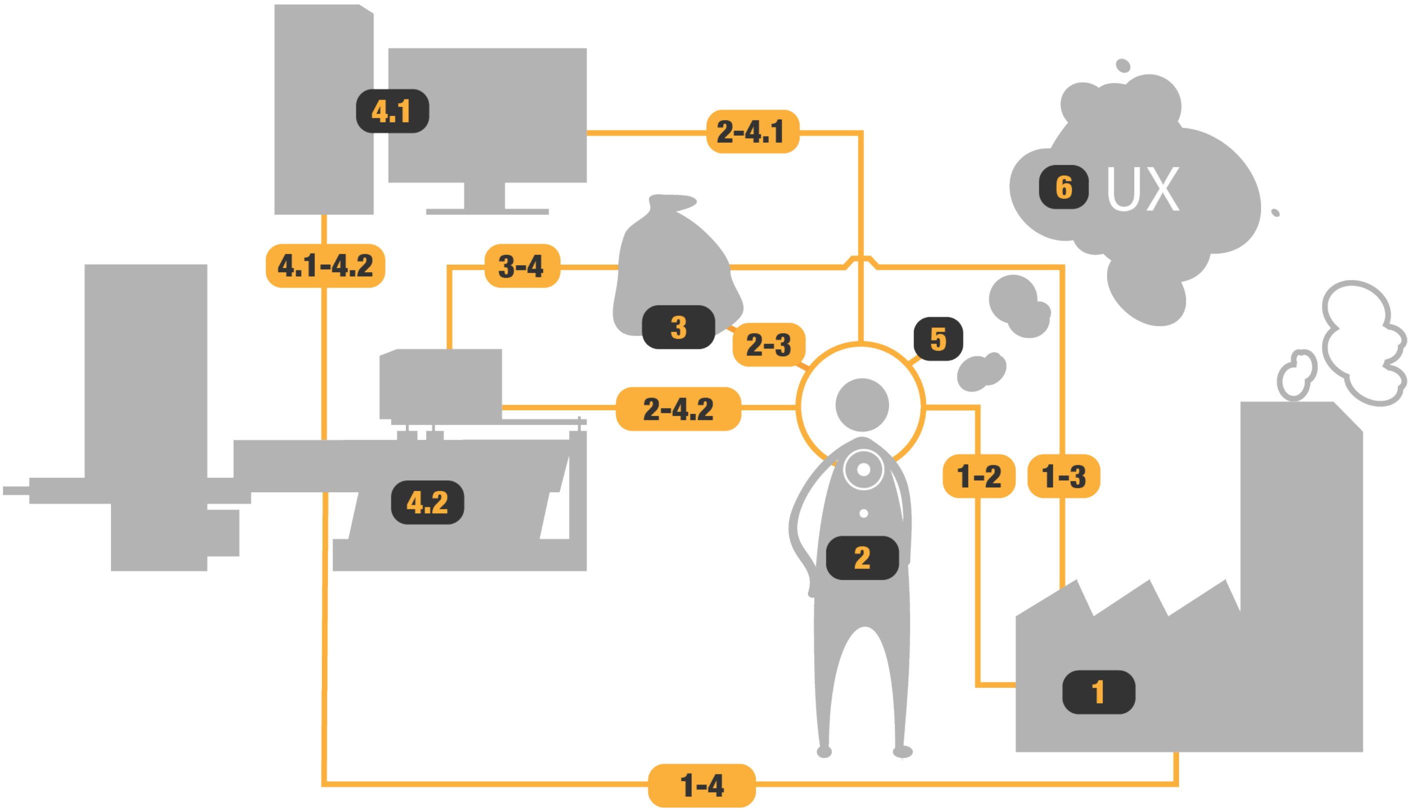


Figure 29: *Visualised analysis goal, an overview as presented in chapter 3.0. (Author, 2018)*

- **Designing the user interface would be the main priority,** as operating the system will revolve around the user interface, which would also provide the composition results.

- **Second priority would be to design the enclosure,** working closely with the development team to deliver the desired system interaction and experience, focussing on product aesthetics.

- **Furthermore it was decided to focus on improving ergonomics for the container,** which would be designed to fit the enclosure.

- **And it was decided to include accessibility and cleaning of the volumetric feeder** to the design brief, presented in the next chapter.

3.5.5 INTERACTION V

Interactions presented in figure 29 have been analysed to define the context, user, workflow, system, and how these interact with each other. The gathered insights were applied during the ideation and conceptualisation phase of the Virtual Chemist, ensuring that this project's outcome would address the entire situation accordingly. The control panel has been removed from the image, as it is not addressed further in this report.

- The main takeaway is that **the amount of interactions should be reduced and designed to be more efficient**. **The system should facilitate intuitive use**, as it was found that completing the workflow required assistance, enabling **the system to be operated by anyone**.

3.5.6 EXPERIENCE VI

Interactions described are a part of the user experience, but there many more factors that need to be addressed in order to define and design an user experience. As shown in figure 29, the user experience (UX) is depicted as an abstract element specific to a (living) being such as humans. Designing a UX requires an understanding of emotions and memes that are provoked by product aesthetics for example.

Current context and product aesthetics were analysed and compared with the company's vision to define a design direction for the Virtual Chemist. This direction was defined further by creating a collage for the machine operator's persona and gathering client feedback on the system and workflow experience.

- Based on the collected insights it was decided **to design the Virtual Chemist to be experienced as a modern, clean, and trustworthy assistant** that enables the intuitive and efficient workflow without making the user feel redundant.

CHAPTER 4

DESIGN BRIEF

CHAPTER 4.0 | RECAP

It was decided to do an internship with Polytential BV, as this company addresses the opportunity identified in chapter 1.8, which is to enable high-quality recycling of plastic waste. The internship goal was to design the user-interaction for the Virtual Chemist and to provide the right user experience so that it can be sold to clients as a MMP type of product. The following sub-chapter first provides a recap prior to presenting the design brief 4.1, criteria 4.2, requirements 4.3, and vision 4.4.

4.0.1 WHAT IS THE PROBLEM?

Inability to properly identify the composition of plastic waste, which leads to an unknown material quality that is difficult to recycle in a closed-loop.

4.0.2 WHY IS THIS A PROBLEM?

▷ The recycled plastic material is down-cycled if the material composition is unknown, which leads to a **loss of valuable resources**.

▷ Low-quality recycled material is **not economically attractive** to converters, as it doesn't reach the industry's quality demand.

▷ Expensive additives need to be added during compounding in-order to achieve the desired material quality, which leads to **higher compounding costs**.

▷ Industrial machinery can be damaged due to the presence of certain contaminants, leading to a **loss in revenue and high maintenance costs**.

▷ Plastic waste with an unknown composition is incinerated, which **leads to air pollution**.

▷ A low economical feasibility in recycling leads to **higher export rates** of plastic waste, where the waste ends-up **polluting the ecosystem** on a global scale.

4.0.3 WHO HAS THE PROBLEM?

A plastic compounder; the composition of the incoming plastic material needs to be known in-order to produce high-quality recycled material.

A mechanical recycler; unknown material composition can lead to machinery malfunction and high maintenance costs.

A sorting facility; although this client is not included into the project scope, they could use an analysis tool to gain insights into their sorting processes in-order to increase the material purity.

Anyone interested in the composition of plastic waste; although this type of client is not included in the design scope for this project, as it is too vague to address, it is an interesting opportunity that should be mentioned. *Example:* Many initiatives have started collecting plastic waste, such as Plastic Whale, but not knowing the composition of the collected waste limits their options of processing the resource.

4.0.4 WHEN DOES THIS PROBLEM OCCUR?

The problem occurs during plastic waste analysis, which is conducted **before, during, and after the recycling process**.

4.0.5 WHERE DOES THE PROBLEM OCCUR?

The problem occurs during analysis of the plastic waste, which can be done at different locations depending on the type of client. The most common location however was found to be **the laboratory**, which can be found within most recycling facilities.

Employees sorting waste in a sorting facility before being mechanically processed. (Clean Malaysia, 2018)

4.0.6 WHAT IS BEING DONE TO SOLVE THE PROBLEM?

The European Union has presented a roadmap towards a circular economy, for the year 2050. For more information please consult chapter 1.6.

The target for recycling post-consumer waste is increase to 65%. (Current target is 50%)

The target for recycling plastic packaging is increased to 75%. (Current target is 22,5%)

A ban on landfilling of separately collected waste. (Currently only implemented by Belgium, France, and the UK)

And plans to,

Promote re-use and stimulate industrial symbiosis; turning one industry's by-product into another industry's raw material.

Provide economic incentives for producers to put greener products on the market, support recovery and recycling schemes.

Although these are only a few of the mentioned focus-points that the EU has presented, it does illustrate the seriousness of addressing the problem of plastic pollution. These decisions should positively affect the economic feasibility and volume of plastic recycling, which increases the need for the Virtual Chemist to analyse the plastic waste.

4.0.7 WHY HAS THE PROBLEM NOT YET BEEN ADDRESSED?

The recycling industry is stuck in their ways, which is partly to blame by **a lack of incentive from strict regulation and guidelines** for recycling.

Recycling plastic is **a complex and internationally connected context** that requires the cooperation of many different stakeholders and governments alike.

Another reason is that innovation in recycling has only recently started to gain momentum, which could be caused by the **difficulty of analysing large and contaminated plastic waste streams**.

Assumption: **Processing waste is not** a **sexy** occupation that people want to do.

4.0.8 HOW CAN THE PROBLEM BE SOLVED?

The problem can be solved with the Virtual Chemist, a tool that analyses the composition of plastic waste with an accuracy of 98,5%.

4.0.9 WHAT NEEDS TO BE DONE TO REALISE THIS SOLUTION?

The Virtual Chemist needs to be further developed so that it can be sold to early adaptors.

4.0.10 HOW WILL THIS BE ACHIEVED?

The user-interface will be designed so that the product can be intuitively controlled.

The interaction with the product will be designed in such a way that every scan-cycle is completed successfully.

The user-interface will clearly present the composition-results, and enable the user to access the data at all times.

And, **the product will be designed to address the user needs** and **provide the right user experience**.

CHAPTER 4.1 | DESIGN GOAL

The analysis in chapter 1 led to the formulation of an opportunity to increase the quality of recycled plastic material. In-order to address this opportunity it was decided to do an internship at Polytential, which is a start-up company that is working on a product that enables high-quality plastic recycling. The main objective up to this point was to present the problem definition and what should be done to address it. From here on out the focus is on 'how' the problem should be addressed and define the intended outcome for this project.

TO DESIGN AN **EFFICIENT** AND **INTUITIVE INTERACTION**[1] THAT ENABLES **ANYONE**[2] TO **CORRECTLY OPERATE**[3] THE VIRTUAL CHEMIST, AND PROVOKE AN **ASSISTANT-LIKE USER EXPERIENCE**[4].

[1] EFFICIENT AND INTUITIVE INTERACTION
During the analysis phase (chapter 3) it was concluded that the workflow itself was acceptable, but the quantity of interactions and the ambiguity of these should be addressed.

[2] ANYONE
A machine operator is still to be considered as the user, but it was decided to design for anyone (an individual with no experience with industrial machinery). This decision was based on the observed ease in which the clients learned to operate the Virtual Chemist.

[3] CORRECT OPERATION
During the analysis phase it became clear that completing standard operation procedures is a significant part of the job, to ensure that a constant quality is achieved.

[4] ASSISTANT-LIKE USER EXPERIENCE
As the company's goal is to automate the system as much as possible, it is important to ensure that the operator does not feel unnecessary while using the Virtual Chemist.

CHAPTER 4.2 | DESIGN CRITERIA

Although it was decided to focus on a number of sub-systems, these criteria have been formulated with the entire system in mind.

4.2.1 VALUES

-principles or standards of behaviour.

CONTINUITY

-the unbroken and consistent existence or operation of something over time.

The Virtual Chemist should value the continuity of operation, and **strive to ensure that the functionality remains at all times.**

How to ensure that scanning process can continue without an internet connection?

DUALITY

-an instance of opposition or contrast between two concepts or two aspects of something; a dualism.

The Virtual Chemist should value the duality of automation and operation, and **strive to utilize the strengths of both the software and hardware.**

What can be automated? And what shouldn't?

MATERIALITY

-the quality of being composed of matter.

The Virtual Chemist should value the materiality of the system, and **strive to aesthetically connect the hardware with the software.**

How to aesthetically connect an interface to the hardware?

SPIRITUALITY

-the quality of being concerned with the human spirit or soul as opposed to material or physical things.

The Virtual Chemist should value the spirituality of the operator, and **strive to ensure that no unnecessary interactions are required.**

What can be done to make a task easier for an operator when automation is not an option?

PURITY/CLARITY

-freedom from contamination; the quality of being easy to see or hear; sharpness of image or sound.

The Virtual Chemist should value the need for clarity/ purity in processing the plastic samples, and **strive to assists in maintaining cleanliness at all times.**

How to minimize the need for maintenance when the contamination becomes significant?

HONESTY

-the quality of being honest.

The Virtual Chemist should value the honesty of business, and **strive to ensure that client's data is properly managed and protected.**

How to communicate if the presented data is real-time or not?

SINGULARITY

-the state, fact, quality, or condition of being singular.

The Virtual Chemist should value the singularity of belonging to a larger system, and **strive to fit within the client's context.**

How to involve the Virtual Chemist with the clients processes?

4.2.2 QUALITIES

-are distinctive attributes or characteristics possessed by someone or something.

MASCULINE

-having qualities or appearance traditionally associated with men.

The Virtual Chemist should be experienced as masculine, and **strive to focus on a male operator.**

How to make a design masculine?

HELPFUL

-giving or ready to give help.

The Virtual Chemist should enable helpful interactions with its context, and **strive to increase the provided value offered to client(s).**

How to add additional value to the Virtual Chemist?

MODERN

-characteristic of a period extending from a relevant remote past to the present time.

The Virtual Chemist should be experienced as a modern device, and **strive to provide both the hard- and software with a modern appearance.**

How to design a modern interface that fits an outdated context?

EFFICIENT

-capable of producing desired results with little or no waste (as of time or materials).

The Virtual Chemist should have an efficient workflow, and **strive to interact with the operator only if necessary.**

How to increase workflow efficiency?

ACCESSIBLE

-able to be reached or entered.

The Virtual Chemist should be accessible to any type of user, and **strive to ensure that the interface is inviting and intuitive.**

How to make an interface inviting and intuitive?

TRUSTWORTHY

-able to be relied on as honest or truthful.

The Virtual Chemist should be experienced as trustworthy, and **strive to ensure that interacting with the system is safe.**

How to communicate trust?

PROFESSIONAL

-relating to or belonging to a profession.

The Virtual Chemist should be experienced as a professional device, and **strive to interact accordingly with its professional context.**

How to present sample-results in a professional manner?

CALM

-the absence of strong emotions.

The Virtual Chemist should interact with the user in a calm manner, and **strive to achieve balance within a hectic environment.**

How to provoke a calm user experience?

4.2.3 FUNCTION

-an activity that is natural to or the purpose of a person or thing.

COMMUNICATE

-share or exchange information, news, or ideas.

The Virtual Chemist must be able **to communicate the scanned data** through the interface.

OPERATE

-control the functioning of (a machine, process, or system).

The Virtual Chemist must enable a user **to operate the system** through the interface.

MONITOR

-observe and check the progress or quality of (something) over a period of time; keep under systematic review.

The Virtual Chemist must enable the user **to monitor the scanning process** through the interface.

SUPPORT

-bear all or part of the weight of; hold up.

The Virtual Chemist must be able **to support the user** during the scanning process.

PROTECT

-keep safe from harm or injury.

The Virtual Chemist must be able **to protect the client and client data at all times.**

INNOVATE

-make changes in something established, especially by introducing new methods, ideas, or products.

The Virtual Chemist must enable the client **to innovate the recycling/compounding process**.

INFORM

-give (someone) facts or information; tell.

The Virtual Chemist must be able **to inform the operator** when necessary.

APPENDIX K

CHAPTER 4.4 | CONTEXT VISION

This collage was created based on the gathered analysis results (chapter 1 and 3) and the criteria presented earlier in this chapter. The collage was used as inspiration during the ideation phase, presented in chapter 5.

1 | CLEAN

The interaction with the Virtual Chemist will be much cleaner than generally expected within the current context, where spillage of flakes is considered as part of the job. With innovation within the context of plastic waste composition it is expected that the working environment will become cleaner, by introducing the Virtual Chemist.

2 | DIRTY

However, processing plastic waste means that the presence of dirt is inevitable and should not be ignored. The Virtual Chemist will need to be designed accordingly to function properly under these conditions and ensure that the data is reliable.

3 | EXPLORING

The shoes shown in the collage enable the hiker to reach new places and goals, with much more ease than using sneakers for example. The Virtual Chemist will enable the clients to explore new possibilities in plastic waste composition analysis.

4 | SECURITY CHECKPOINT

The Virtual Chemist will enable clients to explore new possibilities in composition analysis, enabling them to analyse the quality with much higher precision and ease. The context will resemble a modern security checkpoint where nothing passes unnoticed.

5 | REPORTING

Installing the Virtual Chemist will enable a client to produce a constant flow of high-quality recycled plastic, which will require reporting to ensure that procedures are being completed accordingly. These reports will be used to ensure that the required quality is achieved, every time.

6 | FAST-PACED

Current analysis methods cannot keep up with the production of plastic recyclate, but this will change once the Virtual Chemist is installed. Enabling clients to process much larger volumes will lead to a fast-paced working environment, as ”time is money”.


1


2


3


4
Staff route


5
DAILY REPORT
PATIENT NAME
TIME


6

CHAPTER 4.5 | INTERACTION VISION

The interaction vision presented on the right was used to visually communicate the intended user interaction, and served as a reference during the ideation phase. The images, explained below, were used as inspiration and not as a requirement.

1 | EFFICIENT

Interacting with The Virtual Chemist should resemble traveling on an underground system (metro or subway), which transports thousands of passengers from one location to another with the highest possible efficiency. In this context it is important that the passengers can intuitively navigate through the system, which is accomplished by (clear) navigation and human assistance if necessary. Furthermore it is important that continuity of the system is ensured, as people depend on the functionality of the service.

2 | HELPFUL

Interacting with The Virtual Chemist should resemble a person using reading glasses, which immediately enables the individual to read. These glasses are made for each person to meet their specific needs, which makes the interactions with the product not only helpful but also personal.

3 | DUALITY

Interacting with The Virtual Chemist should resemble the operation of an aircraft, which enables and assists a pilot to operate a highly complex system. This system (plane) requires both to function and is designed accordingly to facilitate this duality between the two.

4 | PROFESSIONAL

Interacting with The Virtual Chemist should resemble the use of professional lab equipment, which enables researchers to complete their tasks with the needed precision. Interacting with lab equipment is done by following protocols that describe how procedures need to be completed. A researcher needs the collected results to be trustworthy and reliable in order to draw useful conclusions.


1
Northern line

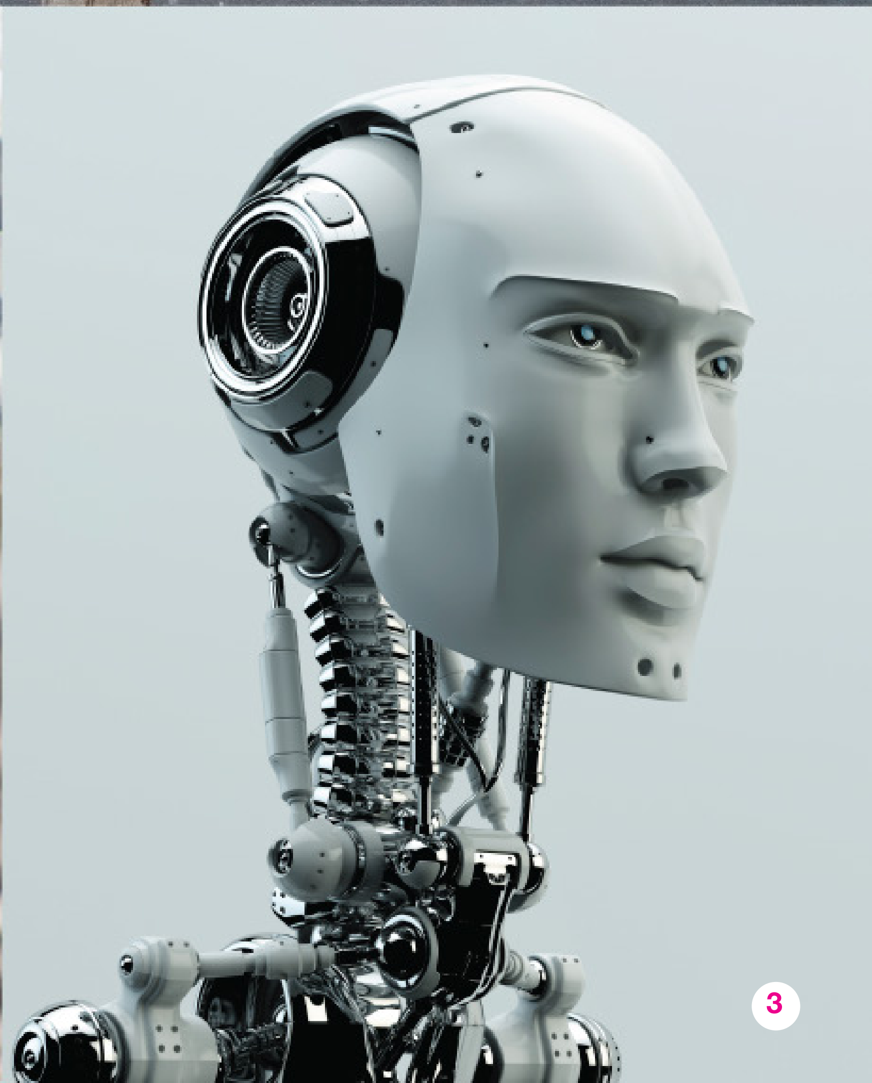

2


3


4
Polytential
CREATED BY SERGEI SCHSTELAAR


1


2


3

CHAPTER 4.6 | INTERFACE-PERSONA VISION

During the analysis phase (chapter 3) it was concluded that the current interface did not depict any type of character. With this in mind it was decided to design an assistant-like user experience, the following collage was created to be used as inspiration during the analysis phase (chapter 5).

1 | A GUIDE
-a person who advises others, especially in matters of behaviour or belief.

The interface-persona will guide the user in completing the correct workflow and ensure that the system is operated accordingly. The communication will be done directly and through usecues, enabling an intuitive interaction while maintaining clarity.

2 | CALM
-not showing or feeling nervousness, anger, or other strong emotions.

The interface-persona will act as a counter force to a fast-paced and possibly chaotic environment, making sure that the user maintains focus. Although fast completion of the workflow is desired, it is important to complete it correctly without mistakes.

3 | INTELLIGENT
-able to vary its state or action in response to varying situations and past experience.

The interface-persona will be experienced as intelligent and (possibly) apply data to increase the system value. Intelligence will be found in the way the software communicates with the user and supports the scanning process.

CHAPTER 4.7 | EXPERIENCE VISION

Interactions can occur anywhere, between anything. Experience is something that happens after an interaction. The collage presented in this sub-chapter was created in order to communicate the desired user experience and to guide the ideation phase towards this goal.

1 | EMPOWERING

-give (someone) the authority or power to do something.

Using the Virtual Chemist will be experienced as if conducting a security check, as the client will be enabled to analyse a sample and draw a conclusion based on the results. Just as the guard is empowered by the scanning device, enabling him to identify metal objects within a matter of seconds.

2 | GROOMING

-to maintain the beauty of a certain product or service.

Interactions that involve maintenance and cleaning will be experienced as if cleaning your vintage automobile, called grooming. The person in the image takes good care of the machine to maintain its beauty. The Virtual Chemist will be a device that the clients want to show to their customers, friends, colleagues, and even competitors.

3 | HACKER

-a person who uses computers to gain access to data.

The user will interact with a device that uses artificial intelligence to analyse the composition of plastic waste. Interacting with the Virtual Chemist will be experienced as if being a professional hacker, controlling and observing a digital stream of information.

4 | TEAMWORK

-the combined action of a group, especially when effective and efficient.

The operator will feel a strong connection to the process and the people involved. He depends on others just as much as others depend on him. The Virtual Chemist will ensure that the user understands this and will provoke

1

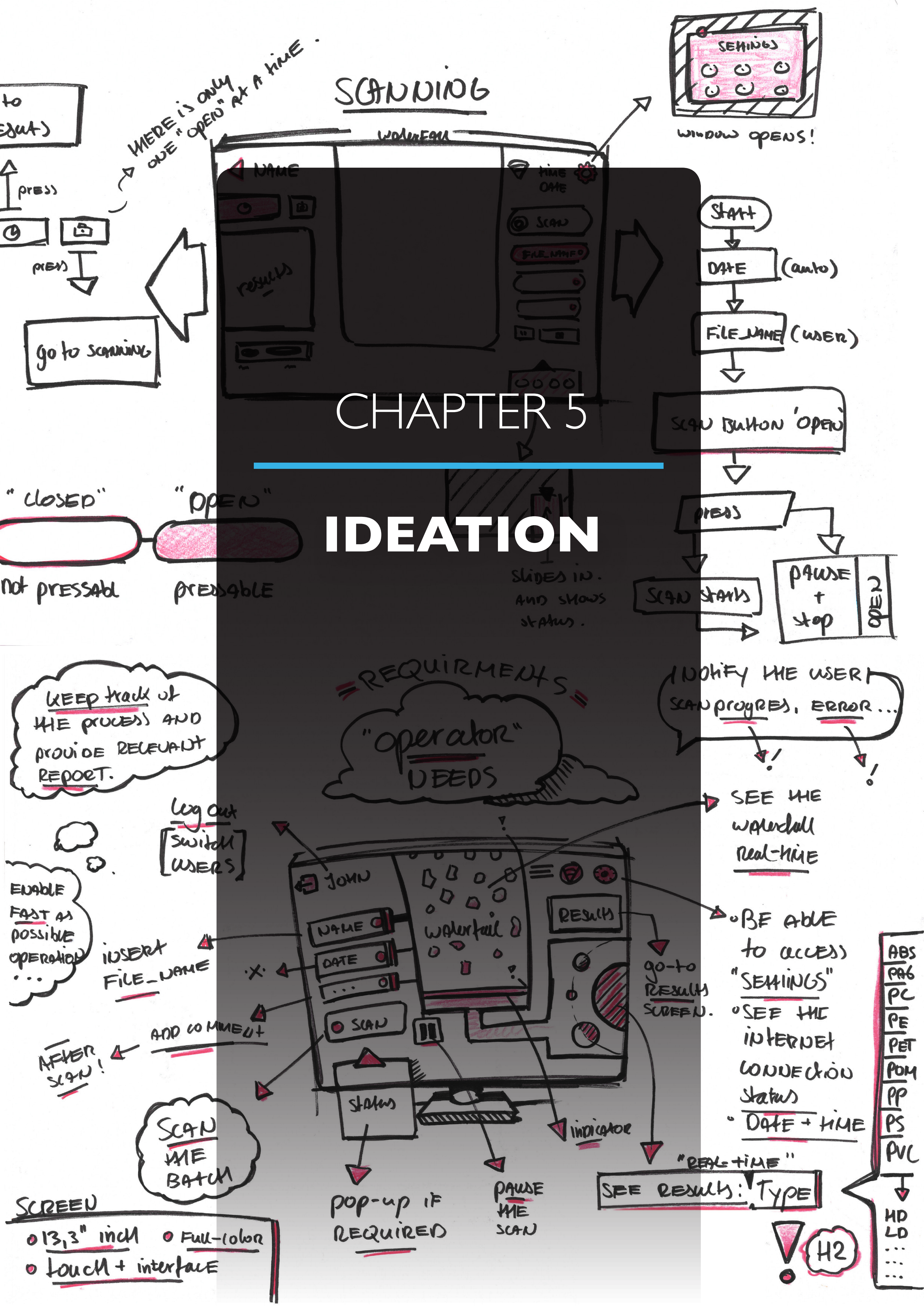
2

3

4

CHAPTER 5

IDEATION



CHAPTER 5.0 | INTRODUCTION

The gathered analysis results have been translated into a design brief, presented in the previous chapters. This chapter presents the ideation process, which was completed by combining design thinking, visual thinking, and an agile method called scrum. This sub-chapter provides a general overview of the process that was completed during the internship, focussing on ideation of the interface, and enclosure.

5.1 | INTERFACE V.0.1
As discussed in chapter 3, the main goal during the internship was to design the user interface for the Virtual Chemist V.1. For this, the first interface was constructed based on the gathered insights so that it could be presented to the company for reflection.

5.2 | REFLECTION INTERFACE V.0.1
As the company's vision on aesthetics was not yet known, it was decides to design the wireframes in such a way that a direction could be discussed.

The reflection results have been used to improve the interface design, and also inspired the creation of an assistant-like user experience to increase the workflow efficiency.

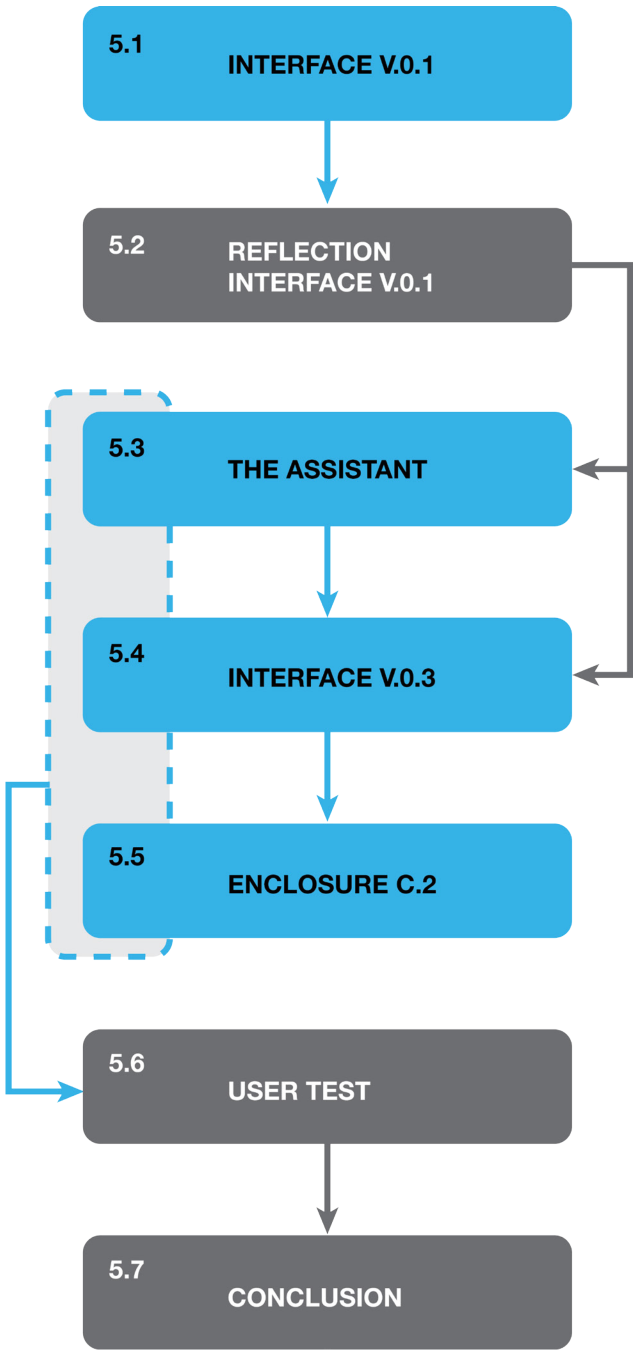
5.3 | THE ASSISTANT
The assistant function was researched and sketched out, so that it could be implemented into the next interface design iteration.

5.4 | INTERFACE V.0.3
Throughout the project there have been numerous iterations, only redesigns that have been significantly changed are discussed in order to keep the report concise.

5.5 | ENCLOSURE C.2
As further development of the Virtual Chemist was being conducted during the internship, it was decided to design a conceptual design so that it could be used during a user test.

5.6 | USER TEST
The goal of the user test was to determine the aesthetically direction for the enclosure, to test the assistant function implemented into the wireframes, and to test the workflow to name a few.

5.7 | CONCLUSION
The ideation phase was concluded by defining the goals for the conceptualisation phase, based on the ideation results.



CHAPTER 5.1 | USER INTERFACE V.0.1

The goal of this ideation step was to translate the design requirements (chapter 4.3) into a user interface that could be presented to the company for reflection, which is presented in the next sub-chapter.

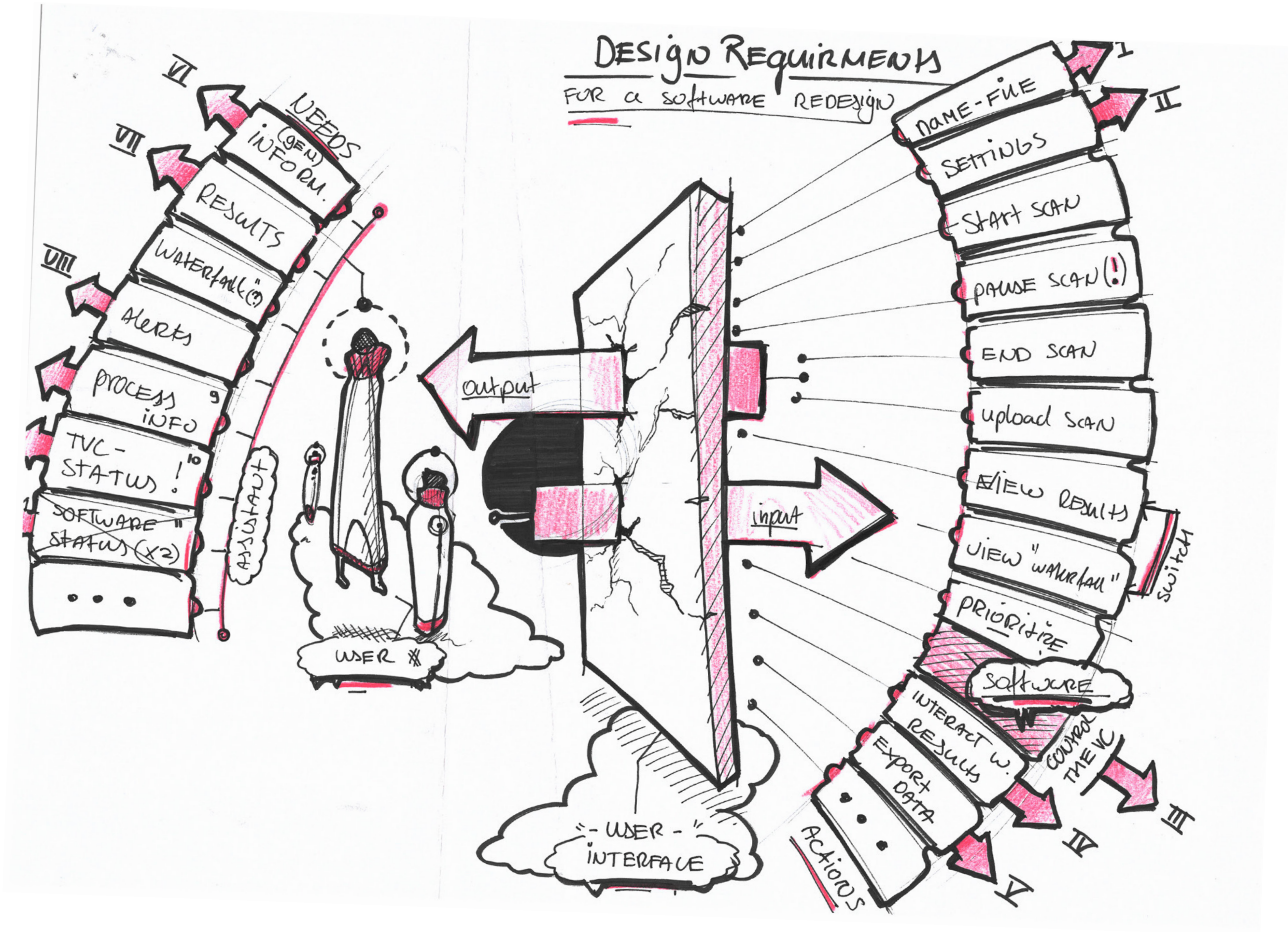


Figure 29: *A sketched-out representation of the design requirements; please note that these can differ from the final design requirements presented in chapter 4, as the requirements have been adjusted accordingly to the collected insights. (Author, 2018)*

The design goal, as presented in chapter 4.1:

> To design an efficient and intuitive interaction that enables anyone to correctly operate The Virtual Chemist, and provide an assistant-like user experience.

Having concluded the problem analysis (chapter 3.5) it was decided to focus primarily on the user interface during the duration of the internship, while working simultaneously with the development team on the selected sub-systems. These sub-systems are addressed in chapter 5.5, and were left out of this first ideation phase.

First, the design requirements were translated into a sketched out representation of the user-interface interaction, as depicted in figure 29.

5.1.1 DESIGN REQUIREMENTS

The wall, as seen in the image, represents the (virtual) space between the user and the system's functionality. This "wall" is present in every user interface, and represents the ambiguity of interacting with an interface. To explain, a loading screen can be communicated with a process bar that fills up over time. But without communicating percentages or an estimated time to completion with the user, the interaction is commonly experienced as ambiguous.

Not knowing what is happening behind this wall doesn't fit the assistant-like experience, which was addressed in the image above by drawing an assistant next to the user (machine operator). This idea to draw out the assistant came forth from the design goal, stating that the interaction should be experienced as if working with an assistant. Although it was not addressed directly during this ideation phase, it was used as inspiration to ensure that the desired experience could be achieved.

The input and output was mapped out further (appendix L) and used as input to design the user flow diagram, presented next.

5.1.2 USER FLOW DIAGRAM

The task flow diagram presented in chapter 3.3 was used to describe the current workflow, excluding the user interaction with the composition results. It was decided that the composition results needed to be accessible and integrated into the user interface. For this, a user flow diagram (figure 30) was created with an enlarged version presented in appendix M. Together with the company it was decided to focus on / include the following elements:

APPENDIX N

Figure 30: *A User Flow Diagram, used to determine the user interface interactions prior to the creation of the screens. (Author, 2018)*

-a login function.
The company admin needs to be able to login so that he/she can access the Virtual Chemist. It was hypothesised that clients would want to restrict an operator from accessing some functionalities.

-separate scanning/results screens.
At the time it was assumed that there would be two types of users, one who would scan the plastic samples and the second would be interested in the composition results.

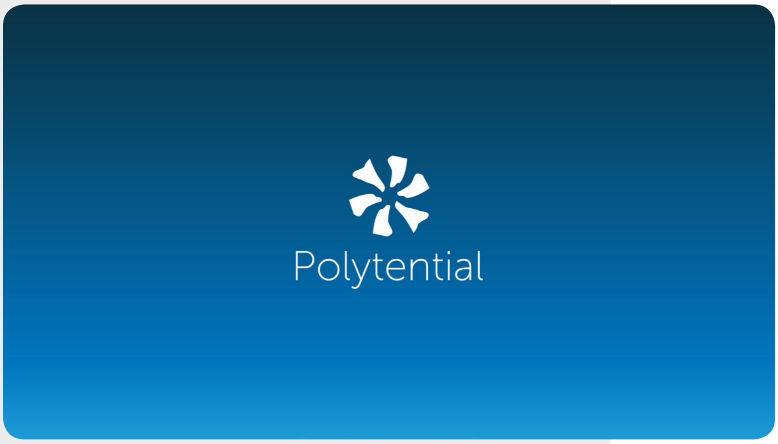
-workflow improvement.
As discussed in chapter 3, the internship goal was to increase the workflow efficiency and to enable an assistant-like experience.

-interface interaction.
The reference software required many interactions in order to complete a task. For this ideation phase it was decided to focus only on screens that are relevant for scanning.

-interface experience.
To improve the user experience it was decided to include better communication with the user by enabling a troubleshooting option, which was absent in the reference software.

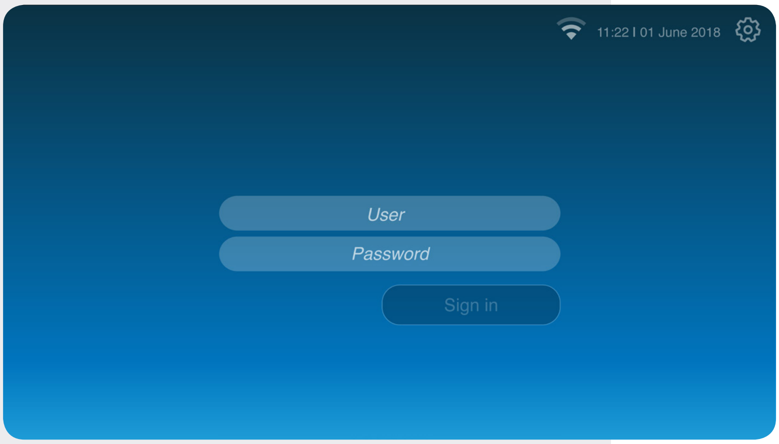
-interface aesthetics.
Without any sort of baseline in terms of aesthetics, it wad decided to design the interface graphics so that these could be discussed with the company to define their preference.

The user flow diagram was presented to and discussed with the company to define what needed to be translated into the interface-screen designs, presented next.



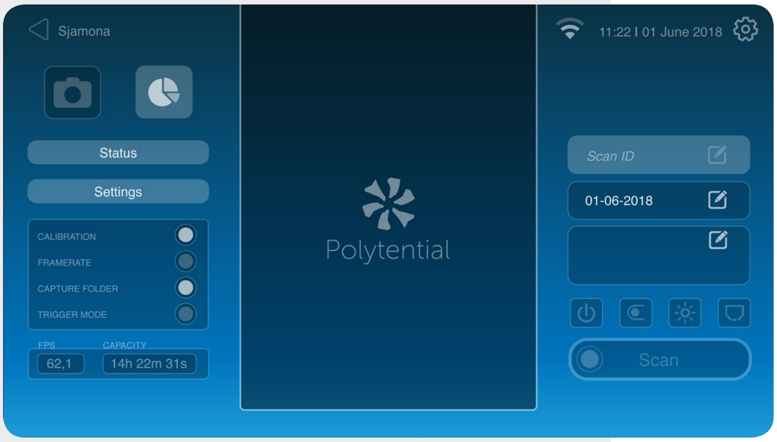
WELCOME SCREEN

The interface will be turned on automatically after turning ON the Virtual Chemist's hardware and present the Polytential logo. This animation should not take more than 3 seconds, to ensure that the efficiency is not compromised.



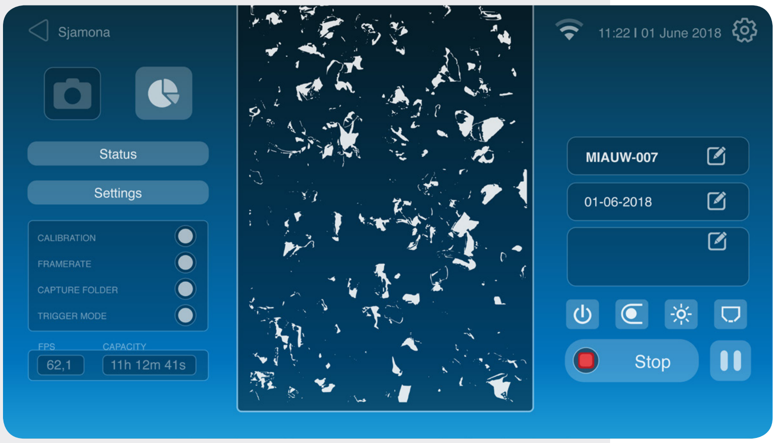
LOGIN SCREEN

Immediately after the welcome screen, the user is presented with the login option requesting a user-name and password. The "Sign-in button" will only become press-able after providing correct user credentials.



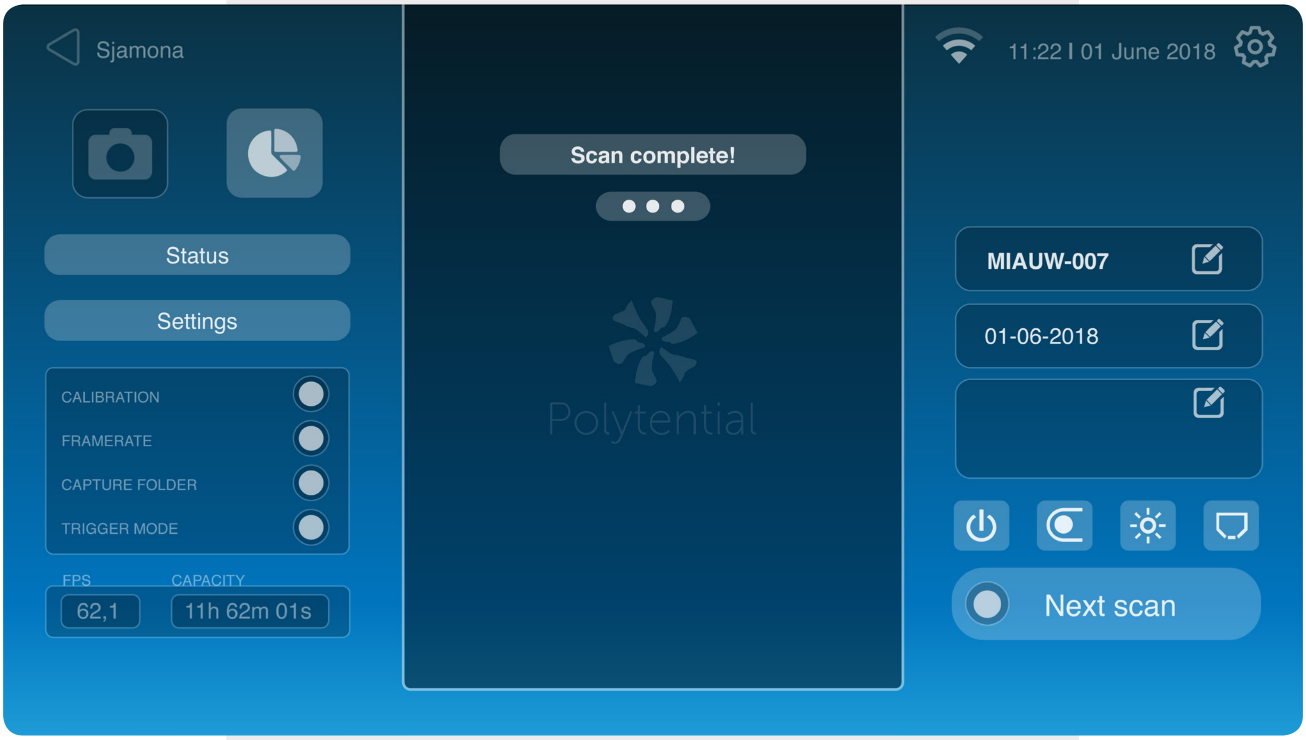
SETUP SCREEN

The user is recognized and the interface opens the scanning screen (relevant to the operator). Press-able buttons are highlighted to assist the user in correctly completing the workflow. The "Scan-button" lights up once the user provides a valid Scan_ID, date, optionally a comment, if all hardware sub-systems have been turned ON, and the sample has been provided.



SCANNING SCREEN

The user activates the volumetric feeder (control box), observes the Waterfall (centre element), and activates the scan once the first flakes are deposited on-top of the conveyor belt. After which the "Scan-button" changes to a "Stop-button", pressed after the user has observed that all flakes have been processed.



FINAL SCREEN

A message is displayed on-top of the waterfall element, clearly stating that the scan was completed successfully. At this moment the “Stop-button” changes to “Next scan”, which when pressed deletes the current Scan_ID forcing the user to enter a new name. Another option would be to press the results button (top left, pie-chart) to access the composition results. Or, logout by pressing the user-name in the top left corner.

These screens have been presented to the company for reflection to gather input for the redesign.

CHAPTER 5.2 | REFLECTION INTERFACE V.0.1

The interface screens, presented on the previous pages, have been discussed with the company in order to define the design direction for the next iteration phase. This sub-chapter presents the company feedback concerning the defined elements that have been discussed in chapter 5.1.2, and concludes with more general remarks for further improvement.

5.2.1 IMPLEMENTED ELEMENTS

-a login function.
A user needs to be enabled to recover, access, change, or delete personal information. Furthermore it was discussed to focus on the user and client needs concerning the login function, as it involves multiple interactions making the workflow less efficient.
H2: *enable a login function with fewer interactions required?*

-separate scanning/results screens.
Composition results need to be communicated as quickly as possible, preferably real-time. The need for a separate screen in which a user can interact with the results had to be researched further. Icons used in the buttons that enable a user to switch between scanning and results were too ambiguous and needed to be addressed.
H2: *display the composition results while scanning?*

-workflow improvement.
Use of interactive buttons and highlights to navigate a user through the workflow was appreciated and should be explored further. However, the highlighted buttons “status” and “settings” were experienced as confusing.
H2: *navigate a user through the workflow, with the use of highlighted buttons and/or other means?*

-interface interaction.
As it was decided to design for a 13 inch touch-screen display (chapter 3.4.2), it was necessary to enable each operation to be completed though a touch-based interaction. No significant bottlenecks were found during this time. But, it was discussed to not exclude the use of a keyboard and mouse.
H2: *enable a user to interact with the interface though both touch and keyboard with the least amount of interactions?*

-interface experience.
The user interface needed to be refined further, by decreasing the amount of information and increasing the assistant-like function. Communicating the status, connectivity, hardware connection, and other elements should be explored further and implemented more efficiently.
H2: *provide a clearer and more useful assistant-like experience?*

-interface aesthetics.
The current interface displayed a (more) modern look and feel, compared to the conventional software interfaces found within the context. It was decided to explore this direction further, as the team agreed on the modern direction.
H2: *communicate a “modern” look and feel?*

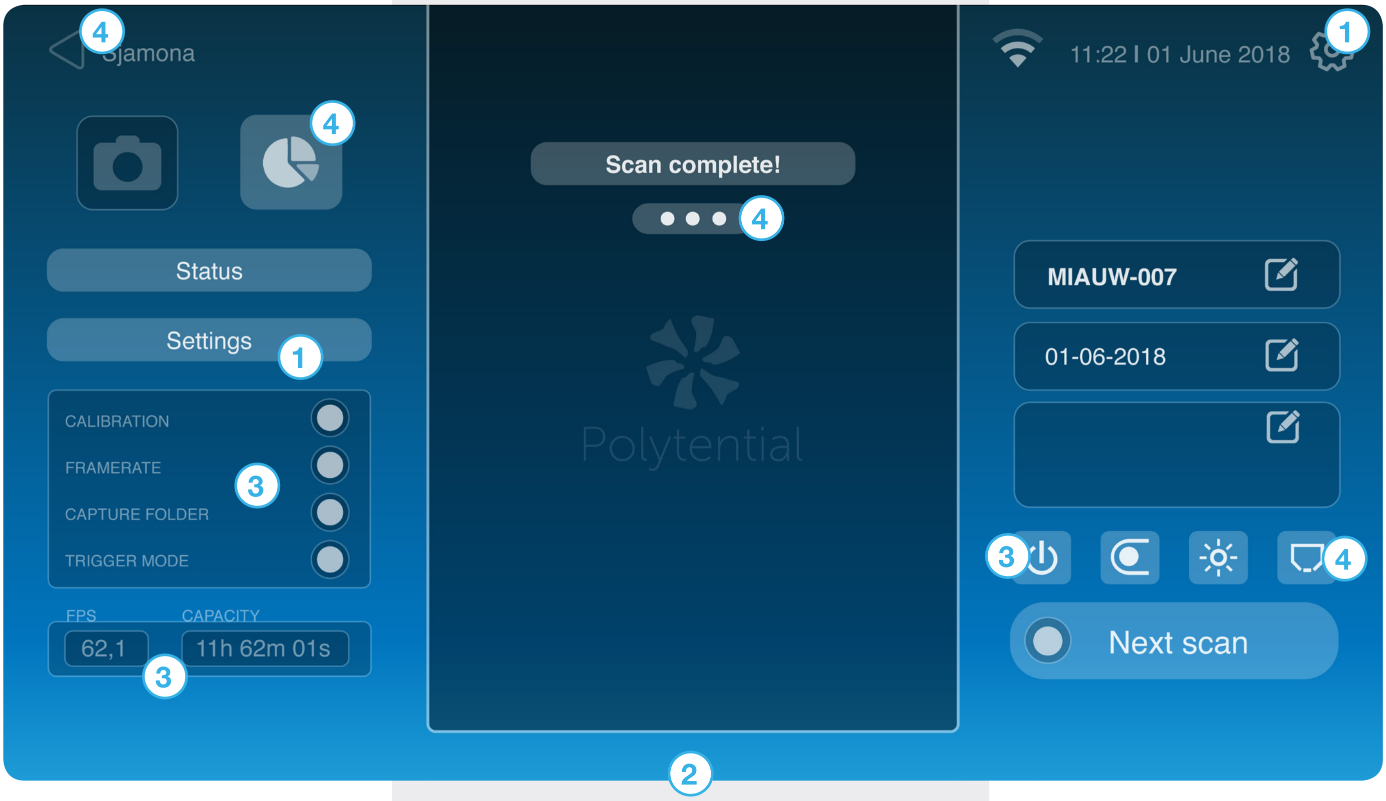
5.2.2 GENERAL REMARKS

Although the feedback was mostly positive, a number of topics have been discussed for further improvement. Most important focus-points discussed are presented below:

1 SETTINGS
The use of a button called “settings” in combination with a icon representing settings should be addressed as it was not experienced as intuitive.

2 LAYOUT
The layout should be revised to improve intuitive use and enable the implementation of a results window, which would present (real-time) results. The overall hierarchy in which the information is presented should be addressed.

3 INFORMATION
The hardware status icons located above the start/stop-button and the software information were not considered as a necessity and should be removed to improve interface clarity.



The FPS (frames per second) and CAPACITY should not be removed for the next redesign, but the need for this element should be addressed.

4 ICONS
A number of icons need to be revised to enable an intuitive interaction, as these were not understood during discussion.

. RESULTS
Composition results need to be implemented within the scanning screen, reducing the amount of interactions needed to access the data.

. WIREFRAMES
Future wireframes should focus on addressing the discussed focus-points first, prior to the graphical design.

It was decided to first focus on increasing the assistant-like experience, and then secondly address any remaining focus-points discussed in this sub-chapter.

CHAPTER 5.3 | THE ASSISTANT

The idea of introducing an assistant to the user interface was inspired based on the collage presented in chapter 4.6. This chapter first briefly introduces the reasoning behind an interface-persona, followed by a summary of how this was achieved, and concludes by translating the results into the next interface iteration.

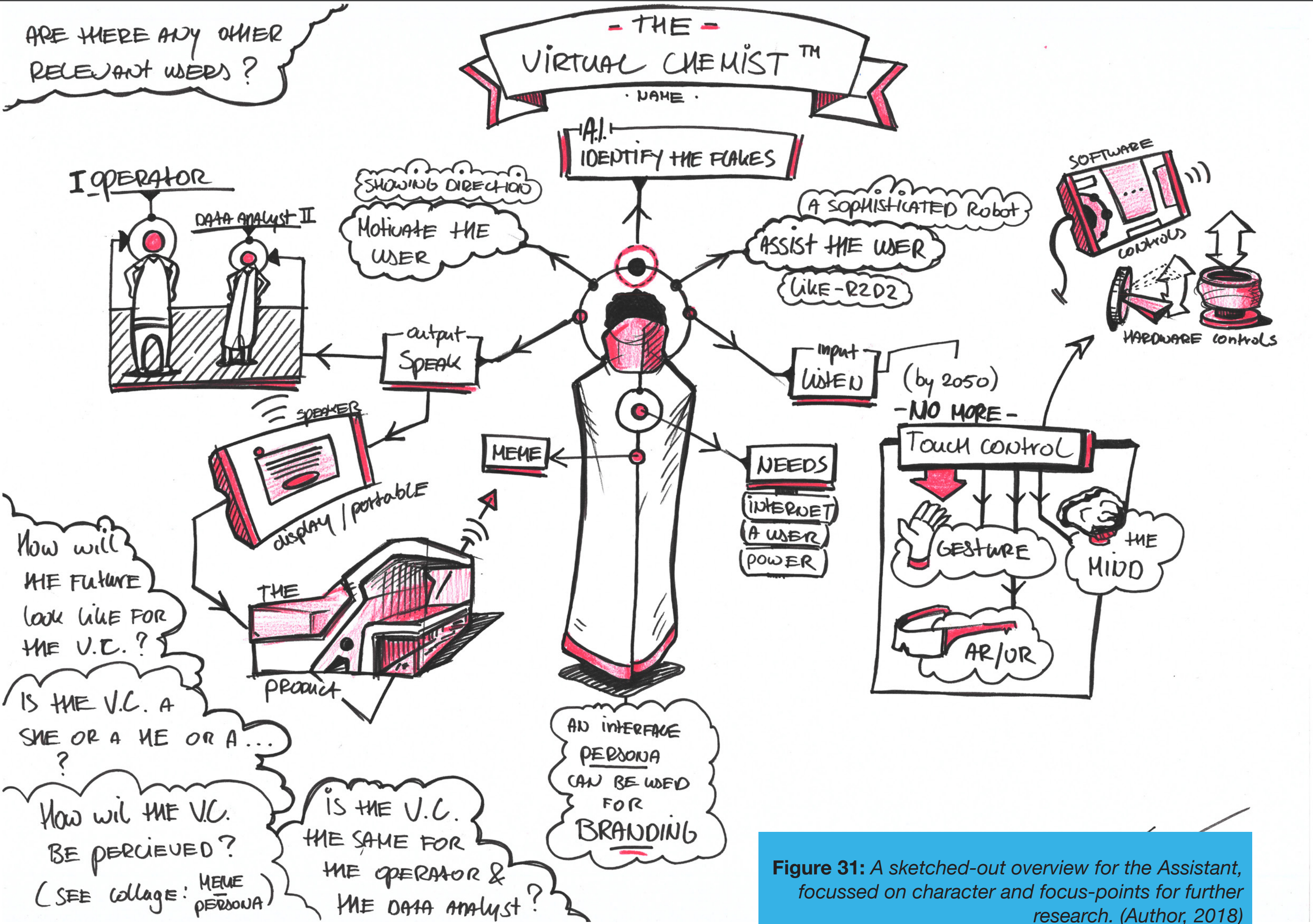


Figure 31: *A sketched-out overview for the Assistant, focussed on character and focus-points for further research. (Author, 2018)*

5.3.1 WHY AN INTERFACE-PERSONA

During the context analysis it was found that the current product aesthetics did not fit the company's vision for the Virtual Chemist (chapter 3.1).

With this in-mind it was decided to design an experience that resembles working with an assistant, with the assistant completing predefined tasks to increase workflow efficiency for the operator.

However, it was important to achieve this type of experience while maintaining the machine operator's sense of control and importance (chapter 3.2).

5.3.2 VALUES AND QUALITIES

An assistant-like experience was included in the design goal (chapter 4.1) and defined further with a list of design criteria (chapter 4.2). The following criteria were used during this ideation phase to increase the probability of realising the desired user experience for the Virtual Chemist.

4.2.1 DUALITY | SPIRITUALITY

4.2.2 HELPFUL | MODERN | EFFICIENT | CALM

5.3.3 IDEATION: THE VIRTUAL ASSISTANT

As mentioned earlier in the report, the Virtual Chemist as a name already provoked a certain type of a character. This character can be seen throughout the sketches presented on these pages, and was used as a starting point for further ideation.

This “Virtual Assistant” (figure 31) was further defined by focussing on relevant memes, needs, wishes, and context.

The fictional assistant-robot R2-D2 (appendix O), from the STAR WARS franchise, was used as inspiration to define the type of interaction the Virtual Assistant should have with the operator.

This example was chosen because it fits the interaction and experience vision presented in chapter 4. This robot enables the owner to complete tasks that would otherwise be impossible to do, intervenes if necessary, and has a strong personality presence.

The Virtual Assistant was further defined through a number of mind maps, **inspired by the R2D2- interaction meme**.

- **Figure 32:** Functionality
A mind map of the possible functionalities that the Assistant could complete to assist the operator.

- **Figure 33:** Tasks
Next, the possible tasks that the assistant could complete had been mapped out.

- **Figure 34:** Problems
Possible problems that could occur were mapped out to decide which of these could/should be addressed by the assistant.

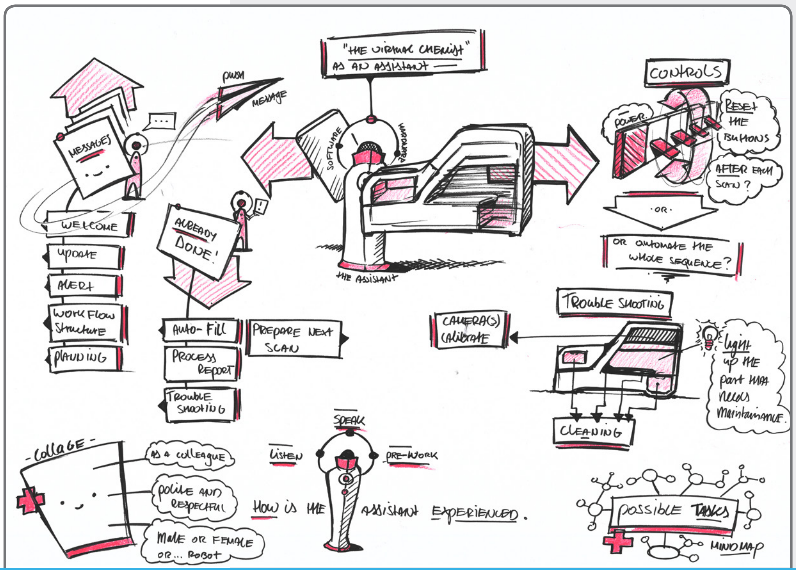


Figure 32: *Sketch, mapping-out the Assistant’s functionality. (Author, 2018)*

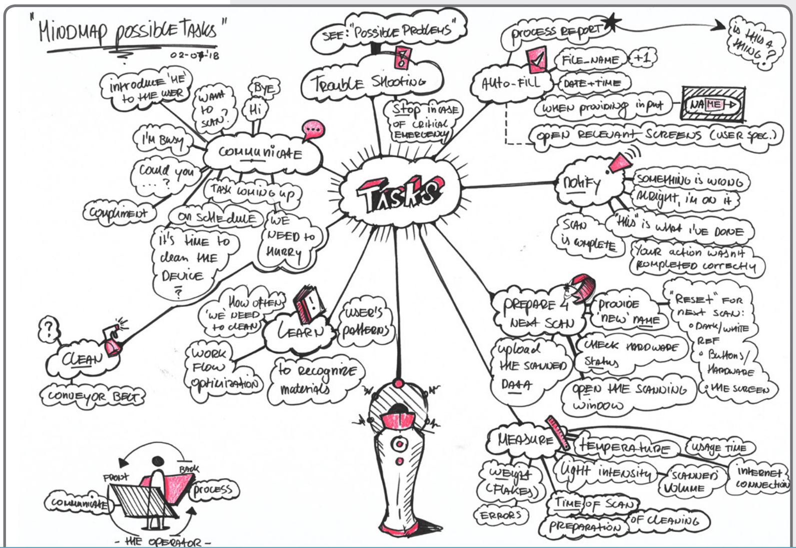


Figure 33: *A mind-map of the Assistant’s tasks. (Author, 2018)*

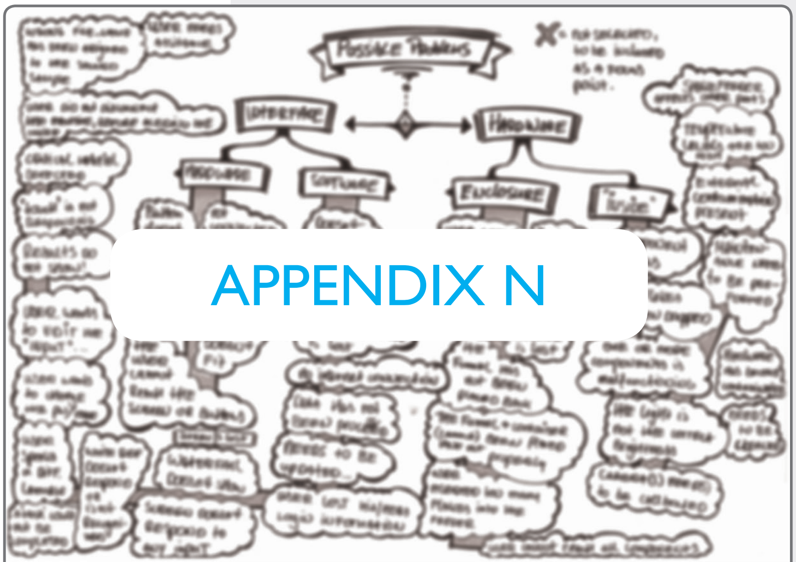


Figure 34: *A mind-map of possible problems that can occur. (Author, 2018)*

The previous page introduces “The Virtual Assistant”, an idea that enables any user to correctly operate the system. This page concludes this ideation phase by presenting the Virtual Assistant’s functionality, user interaction, and how it should be implemented into the user interface.

5.3.4 FUNCTIONALITY

- The Virtual Assistant will **navigate the operator through the workflow**, ensuring a correct completion.

- The Virtual Assistant will **inform the operator accordingly while completing tasks** such as: loading, connecting systems, exporting, and saving.

- The Virtual Assistant will **track the operators workflow and interactions** in-order to produce the necessary report(s).

5.3.5 INTERACTION

The Virtual Assistant will primarily interact with the operator through the interface, as observed during a client demonstration (chapter 3.3). During which the client focussed more on the user interface, compared to the system’s hardware. The assistant will communicate through a “message box”, initially in English. The type of messages, and nuance have been researched and can be read in appendix P.

However, **the system’s hardware should also be considered as a medium for communication.** With a lighting sub-system already in-place it could be used as an extension for the interface, enabling new possibilities to interact with its context. The human peripheral sight could be triggered by a flickering light, representing the end of a scan.

5.3.6 IMPLEMENTATION

The idea to use the system’s lighting element(s) to communicate with an operator was discussed with the company, and it was decided to address this in a later development stage.

Figure 35: *The F-Reading Pattern. (UX Planet, 2017)*

The message box, through which the Virtual Assistant will communicate has been placed in the top left corner. This decision is based on the so-called “F and Z shaped Patterns of Reading”.

The Z Pattern | Designs with *less* text, the eyes start scanning from top left to top right, then diagonally down to bottom left, and stop at the bottom right. (Figure 35)

The F Pattern | Designs with *more* text, the eyes scan across the top, from left to right, then down the left, searching for clues. If one is found, the eyes scan across to the right.

Figure 36 Based on these two reading patterns it was decided to place the Virtual Assistant’s message box (**1**) in the top left corner, being the first element with which an operator interacts. Next element is the setup field (**2**), start/stop button (**3**), followed by the waterfall (**4**), and ends with the results (**5**).

The ideation results were used as input to redesign the user interface V.0.3, presented in the next sub-chapter.

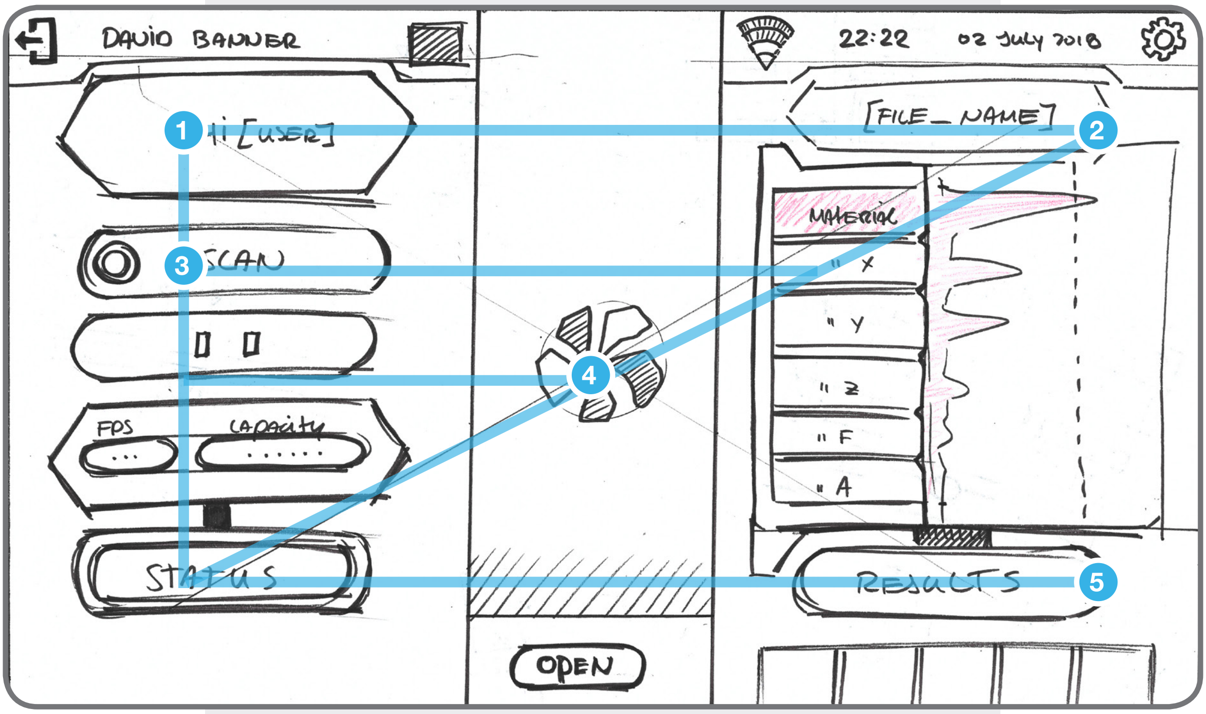


Figure 36: (Above) *Sketching ideas for the user interface V.0.2, with an integrated Virtual Assistant. The Z- and F-pattern placed over the interface.*

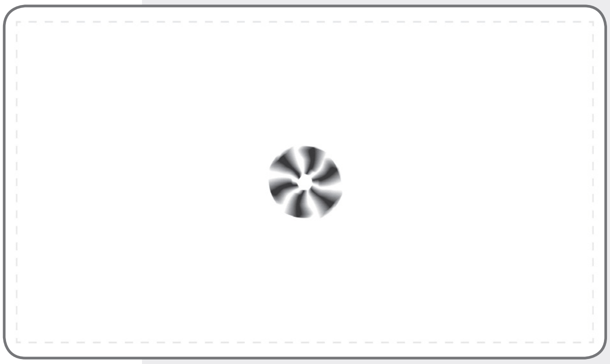
(Below) *Example of further ideation, focussing on interaction with the interface layout, enabling a user to customize the layout.*
(Author, 2018)

CHAPTER 5.4 | **USER INTERFACE V.0.3**

The reflection (chapter 5.2) and ideation results presented in chapter 5.3 were used to design the following user-interface wireframes. This sub-chapter briefly introduces the most important changes, added functionality, and reasoning behind the decision made.

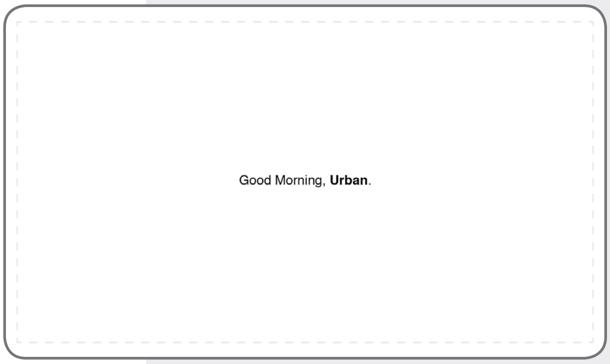
LOADING SCREEN

The company logo (without text) has been used to animate a rotating motion, so that the user can be informed that the software is busy (loading, processing). Embedding such an interaction ensures that the user experience is not negatively affected by the software's loading times.



WELCOME SCREEN

To provoke the assistant-like user experience it was decided to include a welcome message right after logging in, instead of displaying the loading animation.

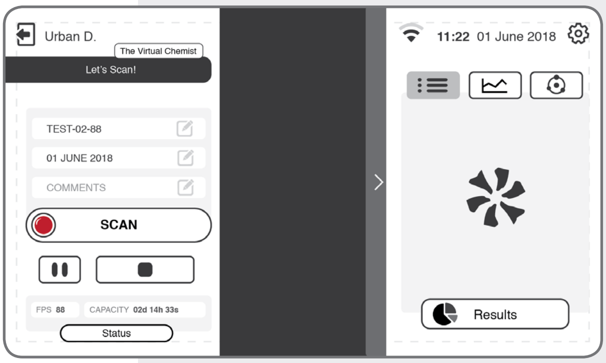


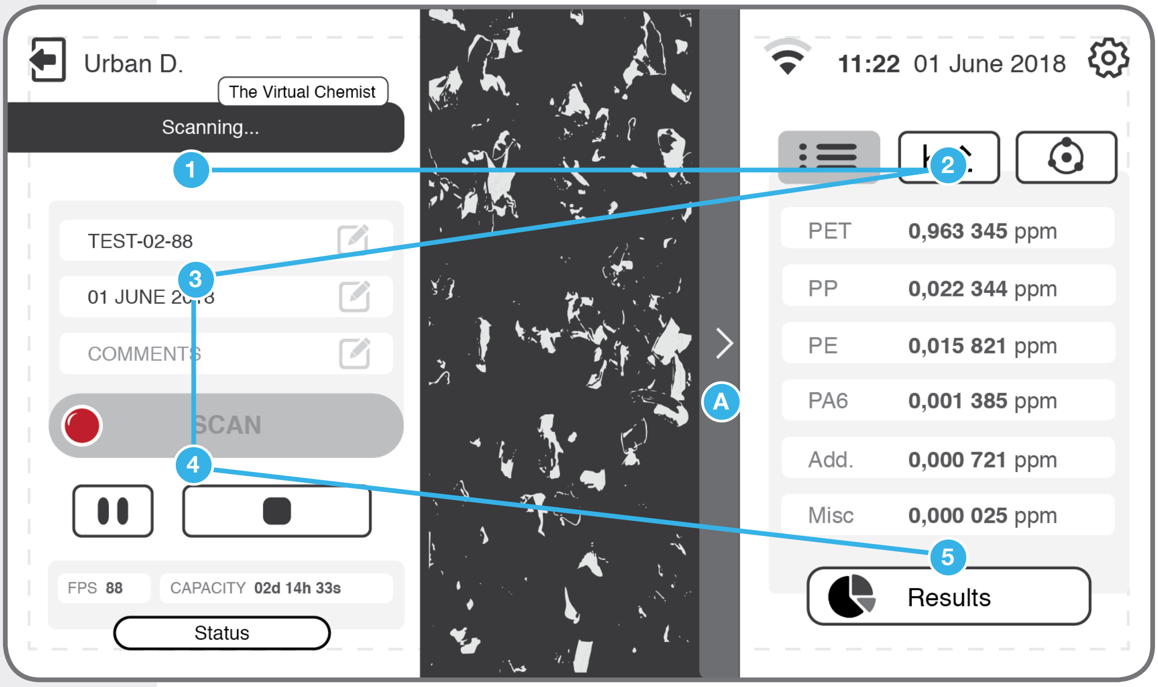
SETUP SCREEN I

The Virtual Assistant (Virtual Chemist) immediately starts preparing for a scan, communicating each step through the embedded message box. During this time the user is disabled from setting up a scan, but is able to access previous composition results.

SETUP SCREEN II

The setup is enabled once the Virtual Assistant has completed all tasks, this too is communicated though the message box. The SCAN-button can only be pressed if all setup fields have been correctly completed by the operator.

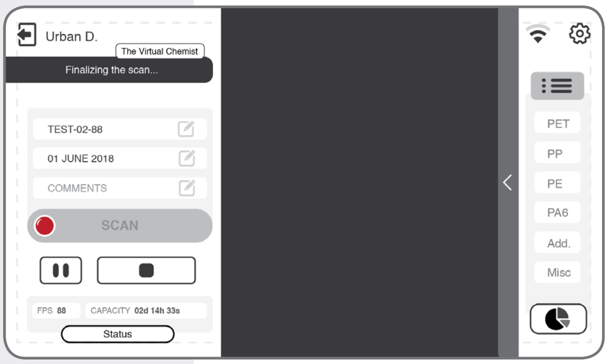




SCANNING SCREEN

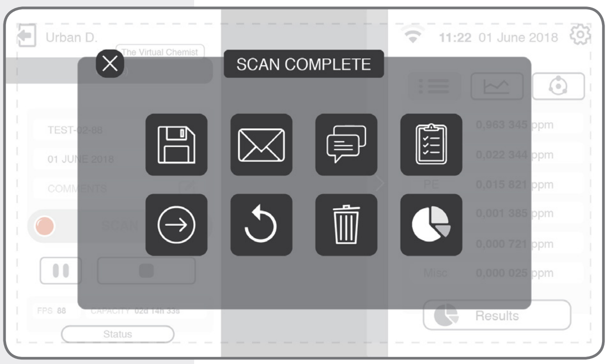
The reading pattern, presented in chapter 5.3, was applied to provoke an intuitive user interaction while operating the Virtual Chemist. Number 1 represents the start of the workflow (software) and number 5 the end. The composition results can be viewed in three different styles (**2**): pie chart (adjusted), graph, and numeric. Pressing the Results-button will open the results-screen, which was excluded from this ideation phase.

Another new function that has been added is the slider (**A**), which enables the operator to adjust the size of the waterfall to better suit his needs. This only affects the results-section, as can be seen in the wire-fame below.



END OF SCAN SCREEN

Once the operator observes the last flakes being processed, the stop buttons needs to be pressed to conclude the scanning workflow. At this time, the Virtual Assistant informs the operator that the data is being processed. Interacting with the results section is possible during this time, compared to the disabled scanning section.



SCAN COMPLETE WINDOW

The SCAN COMPLETE window is automatically opened after the Virtual Assistant has processed the data. This window presents the user with a number of possible actions: Save As, Mail To, Message, Generate Report, Next Scan, Scan Again, Delete Scan, and Results.

CHAPTER 5.5 | ENCLOSURE C.2

A conceptual (C) design of the enclosure needed to be designed, so that it could be presented during the user test (chapter 5.6) in-order to collect insights for further development. It was also necessary to take a step back from focussing solely on the user interface, and to focus on the interaction and experience for the entire system (as defined in chapter 3.5).

An earlier version (C.1) was designed during the first week of the internship. Designing this version helped in understanding the system in its early development stage, the mentioned version can be seen in appendix Q and is not discussed further.

5.5.1 THE GOAL

In consultation with the company **it was decided to design a conceptual design for the Virtual Chemist version 2**, which would be used as inspiration for the development of the first version (presented in chapter 7).

5.5.2 FOCUS

For this ideation **it was decided to focus on designing the complete system, but focussing only on the selected sub-systems** (chapter 3.5): *Volumetric feeder, Container, User Interface,* and *Enclosure*.

The following design criteria were selected as focus-points for this step in the ideation process:

4.2.1 DUALITY | MATERIALITY | PURITY

4.2.2 HELPFUL | MODERN | EFFICIENT

This concept was designed to communicate the desired direction to the user test participants, in order to collect their feedback for further development. Therefore the detailed workings and materials of each sub-system were excluded from this ideation phase.

5.5.3 SKETCHING

The direction of the sketches was defined together with the company, as the frame for the Virtual Chemist was being designed at that time. This frame (figure 38) was designed to enclose the entire system and thus defined the shape of the Virtual Chemist.

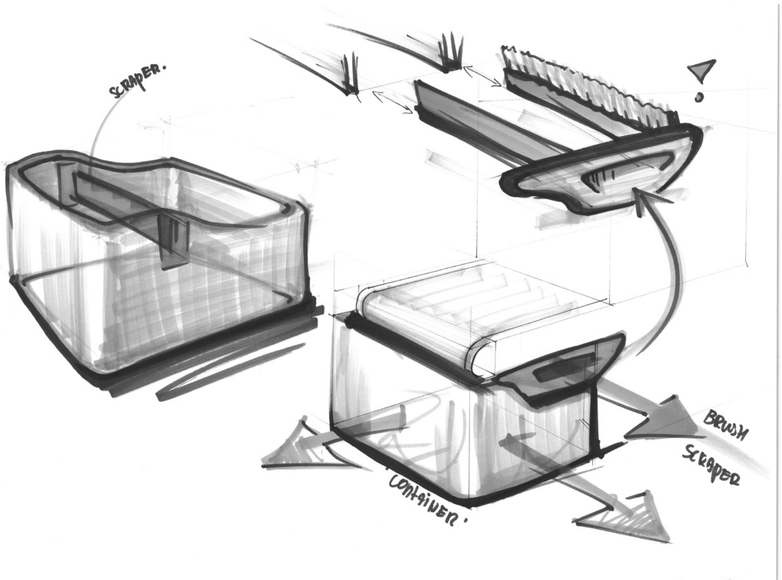


Figure 37: (Above) *Sketching the Container, with an integrated "scraper" to clean the conveyor belt.*

(Right) *Sketches made during the ideation phase, exploring the interactions with the enclosure and opportunities to address the selected design criteria. (Author, 2018)*

The sketches presented in figure 37 represent only a small portion of the ideation and are primarily used to provide an idea of the process.

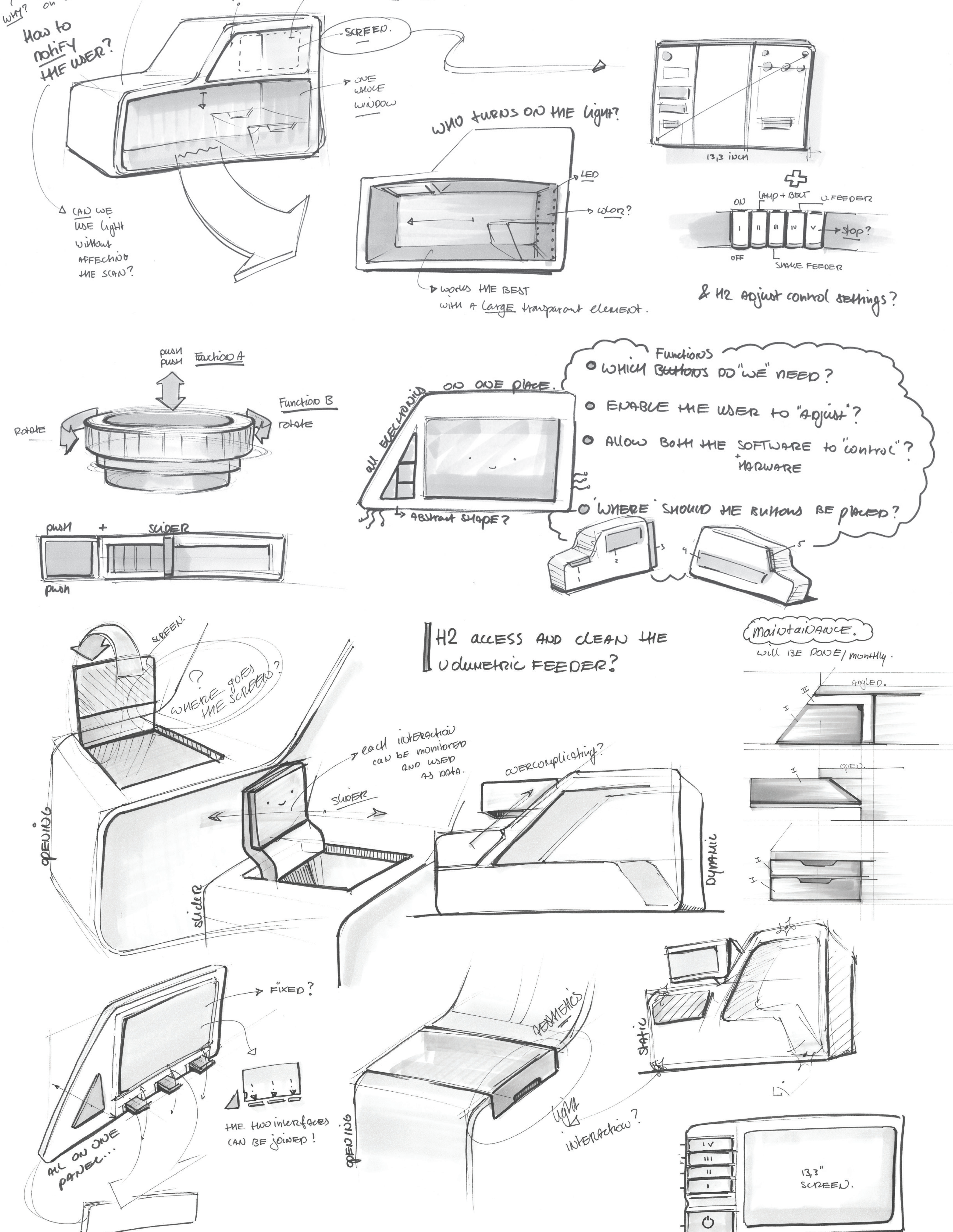
These sketches were then used as a reference for a digital model that was created next.

5.5.4 MODELLING

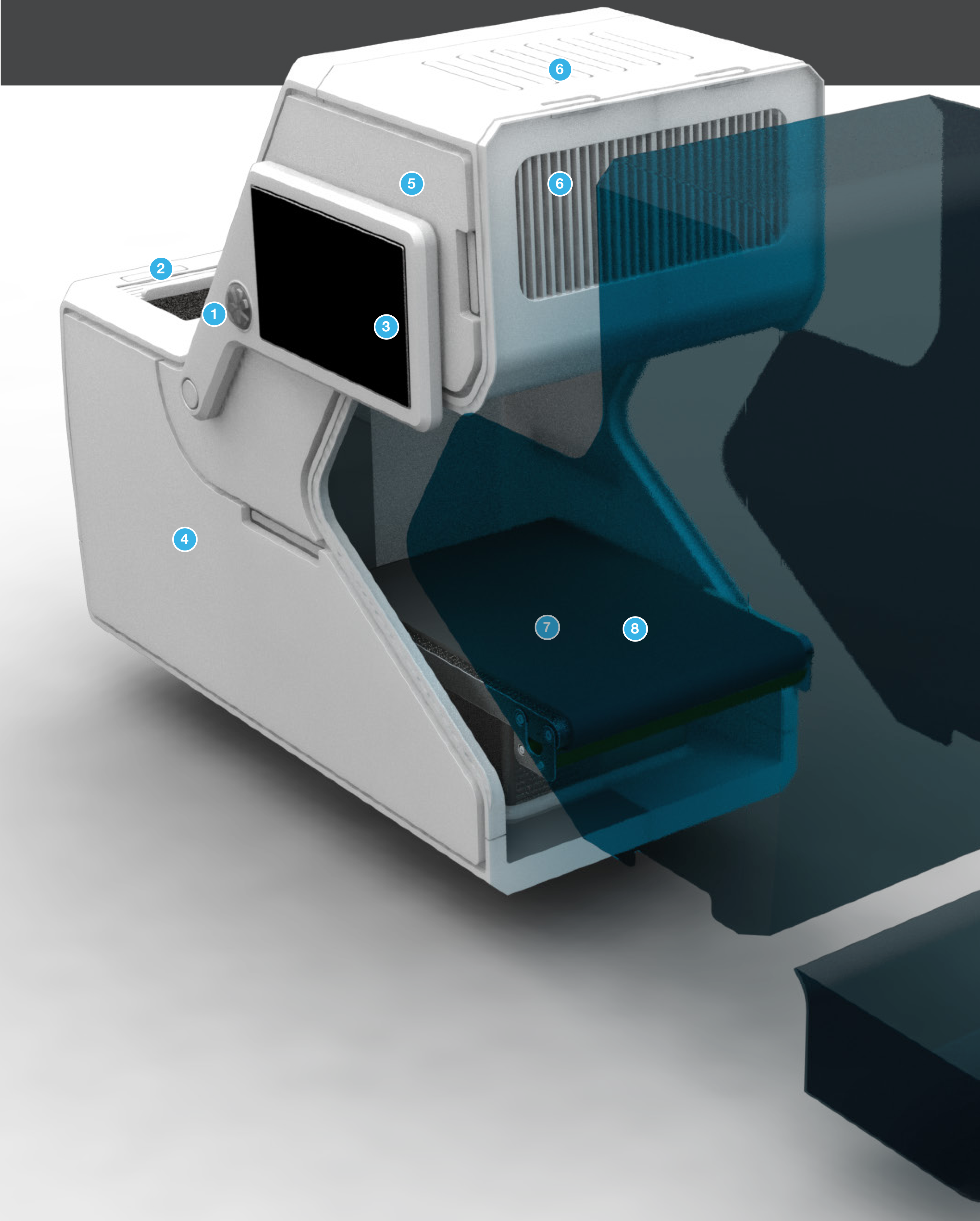
Modelling an idea in SolidWorks this early on is usually not feasible as there are too many unknowns, but as the goal was to convey the future vision it was a very useful tool. Sketching is namely dangerous as everything seems to work properly on paper, but not in reality. Therefore, SolidWorks was used to turn an idea into a concept in-order to gather more relevant user feedback.

The conceptual model is presented and explained further on the next pages.

INTERACTIONS



FOR WHO IS THIS MOST RELEVANT? THE USER (client) OR US (MAINTAINANCE)?


6
5
6
2
1
3
4
7
8

ELEMENTS

1 | Power button
2 | Volumetric Feeder
3 | Touch-screen (UI)
4 | Maintenance panel
5 | Camera panel (Accessible only to the company)
6 | Ventilation system
7 | Conveyor Belt
8 | Removable Cover
9 | Container

FUNCTIONALITY

The system is turned on by pressing the power button (1) which activates both the hardware and user interface.

The Volumetric Feeder (2) is equipped with a hatch that slides into the enclosure, as seen in figure 41.

The touch screen (3) is embedded into the arm element and is placed over the camera panel (5) to disable a user from accessing the camera.

Maintenance and cleaning is done by accessing the maintenance panel (4) is first released from the enclosure by pressing the panel-button, after which it is entirely detached from the enclosure for easier access.

Internal temperature is regulated through the ventilation system (6), which transports the heat from inside to outside through the grid located at the top. This grid is designed to allow heat to escape, but prohibit dust from entering to prevent sample contamination.

Inspired by the collage (figure 20), it was decided to design a large semitransparent cover (8), enabling the operator to easily observe the scanning process from different directions. The cover can be removed by pressing the two buttons at the top, and is held in-place by a protruding edge.

The container (9) was designed to be asymmetrical to facilitate proper placement and to assist an operator during interaction with the flakes.

The design is explained in further detail on the next page.

CHAPTER 5.5 | ENCLOSURE C.2

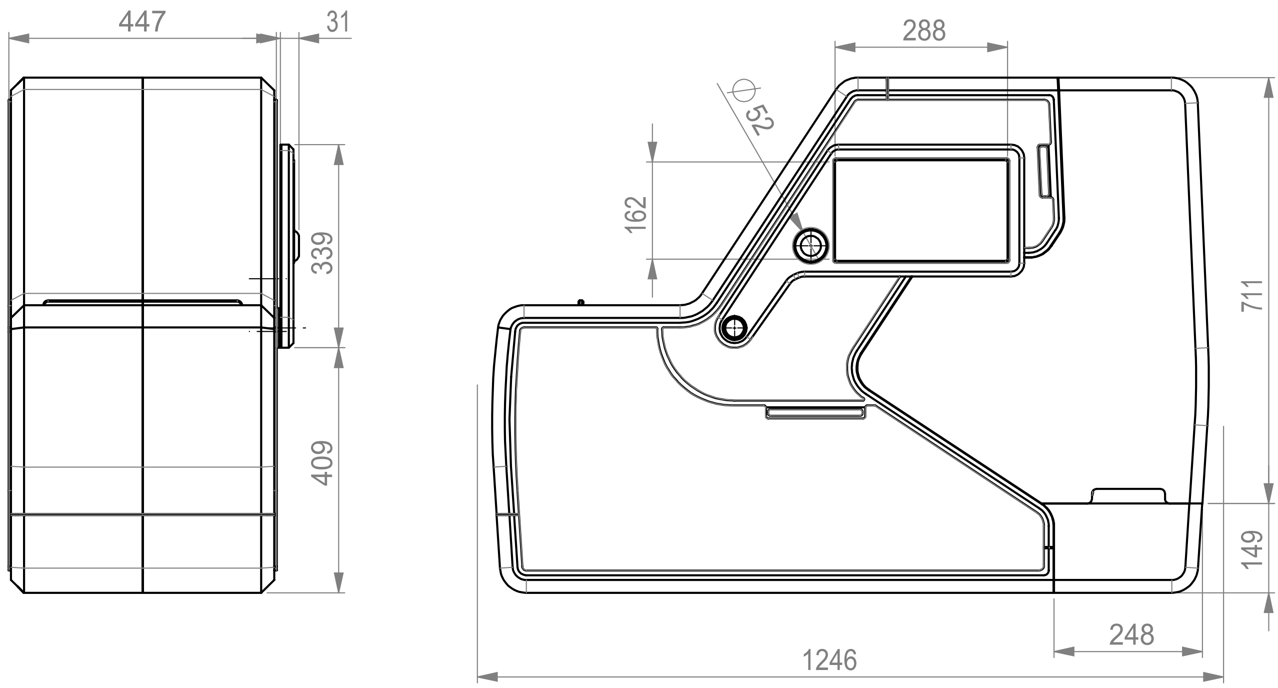


Figure 38: *A 3D model representation of the Virtual Chemist C.2, including product dimensions expressed in mm. (Author, 2018)*

5.5.5 THE SYSTEM

The system's appearance was inspired by the collage presented in chapter 3.1 (figure 20) with the goal of expressing a modern and clean look and feel. The product's dimensions (figure 38) were defined by the enclosed hardware elements, which were being developed at the time and are therefore not discussed further in this sub-chapter.

5.5.6 ENCLOSURE

The enclosure was found to be a crucial part of the system as **it provides protection from external contamination, and ensures reliable composition results** by maintaining a constant internal environment (temperature, humidity, light intensity).

The container and interface have been integrated into the enclosure, streamlining the product so that it is experienced as a single system. Addressing the focus-points stated in the problem analyses phase (chapter 3.3 and 3.4).

Over-dimensioning the enclosure's elements was done deliberately to express a sense of robustness and reliability, which was done to address the product quality of being masculine (chapter 4.2).

Accessibility was addressed by designing three panels, which are fully removable to enable an operator to preform maintenance and clean the sub-systems. The fourth panel (behind the screen-element) was designed explicitly for the company to access the hyperspectral camera, and is therefore made inaccessible from the front.

5.5.7 OTHER SUB-SYSTEMS

- THE CONTAINER

This sub-system was designed according to the sketch presented in figure 37, which can be removed in three directions (in the horizontal plane). The container is made from a semitransparent-blue plastic, enabling the operator to observe the process.

- THE VOLUMETRIC FEEDER

Accessibility to clean the sub-system, as concluded in chapter 3.4, was addressed by introducing a sliding lid (figure 41). Opening the front panel enables the operator to access the volumetric feeder for further cleaning.

Figure 39: *A 3D model representation of the Virtual Chemist C.2, the backside. (Author, 2018)*

Figure 40: *A 3D model representation of the Virtual Chemist C.2, the volumetric feeder. (Author, 2018)*

- THE USER INTERFACE

The user interface (chapter 5.4), designed for a 13" touch screen, was embedded into the enclosure by designing a removable arm-element in which the screen could be placed (figure 38). **A removable element made it easier to make adjustments during further concept development**, as it can be removed without affecting other system elements.

A single button was designed to activate the system, as it was concluded that the control panels would be automated and integrated into the user software (chapter 3.4).

5.5.8 SYSTEM INTERACTION

The initial system could be used from both the front and back side, as it did not have a predefined workflow interaction. In order to design an intuitive and efficient interaction **it was decided to design the system to be used from left to right,** inspired by the user interface's reading direction.

The system is setup by connecting the necessary cables, located on the back (figure 39), enabling **a plug-and-play interaction**.

Each panel can be opened individually by pressing a button, which unlocks the panel and pushes it towards to operator. **The panels are hold in-place by magnets to ensure safe removal by the operator**, and also facilitate proper placement after maintenance.

5.5.9 USER EXPERIENCE

This system was designed to be experienced as modern, robust, professional, and masculine.

The workflow was designed to be experienced as simple, efficient (fast), familiar, and confident.

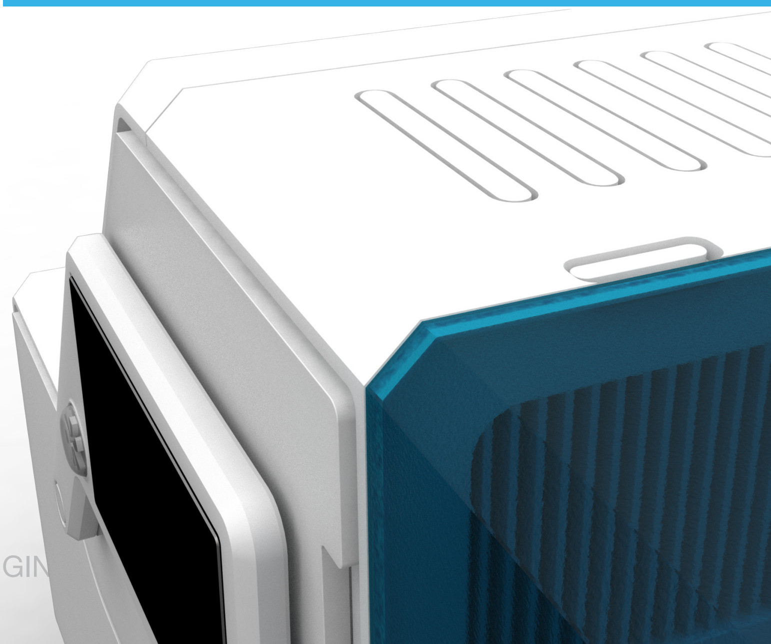
5.5.10 INSIGHTS

To maintain a constant temperature **it was decided to embed a ventilation system into the enclosure**, as can be seen in figure 41.

Interaction with the system needed to be researched further, as the size and weight of the product could lead to transportation and placement problems.

Vibrations caused by the shake feeder should be researched further, as it could negatively affect other sub-systems.

Figure 41: *A 3D model representation of the Virtual Chemist C.2, a close-up of the ventilation. (Author, 2018)*



CHAPTER 5.6 | USER TEST

The user interface (chapter 5.5) was presented and discussed with the company to make final adjustments prior to the user test, for further reading please consult appendix R. This sub-chapter briefly introduces the setup, presents the results, and concludes with insights for further development.

5.7.1 INTRODUCTION

This user test was conducted to gather insights for further development of the user interface and enclosure. Focussing on interaction and experience feedback for the workflow (software), Virtual Assistant, and Enclosure C.2.

5.7.2 METHOD

| Faculty of Industrial Design Engineering
| Delft, Netherlands

| Qualitative > Quantitative Approach

| 1 Observer

| 5 Participants
| Ages 20 to 40
| 4 Male, 1 Female
| No prior experience

Each participant was first individually introduced to the system, explaining the functionality and their role as a machine operator. During this time the participants were able to ask questions about the system, as it was decided to exclude further interaction during the user test. This decision was made due tot he nature of the user test, which was performed using wireframes (chapter 5.4), where each interaction with the software was simulated by hand (observer).

The participants were asked to complete a list of tasks, without input from the observer: (1) Login, (2) Scan Setup, (3) Start Scan, (4) Stop Scan, and (5) Export Data.

The participants were navigated through the workflow with the Virtual Assistant (chapter 5.3), using predefined messages (figure 42).

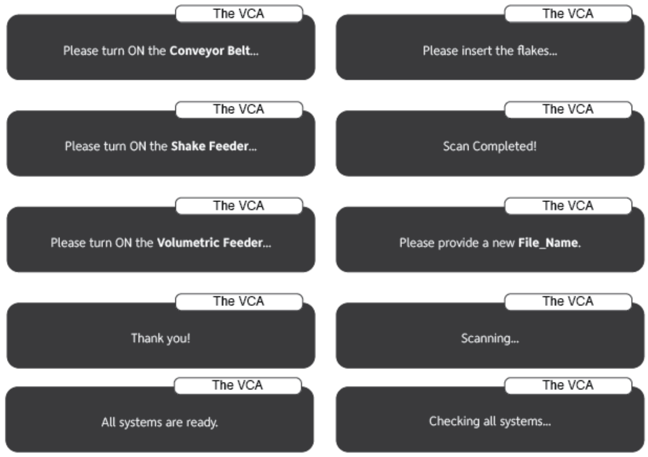


Figure 42: *Example: Virtual Assistant messages used during the user test.*

Observed participant's interactions and unexpected moments were documented during the user test (including video footage) and addressed further during the interview. Prior to this interview, each participant was asked to describe the workflow, the Virtual Assistant, and the enclosure (C.2) by answering a short questionnaire.

This questionnaire presented two opposite options, from which the participants had to choose one within 5 seconds. The interview was used to discuss the observed interactions, questionnaire results, and was used as an informal moment to conclude the session.

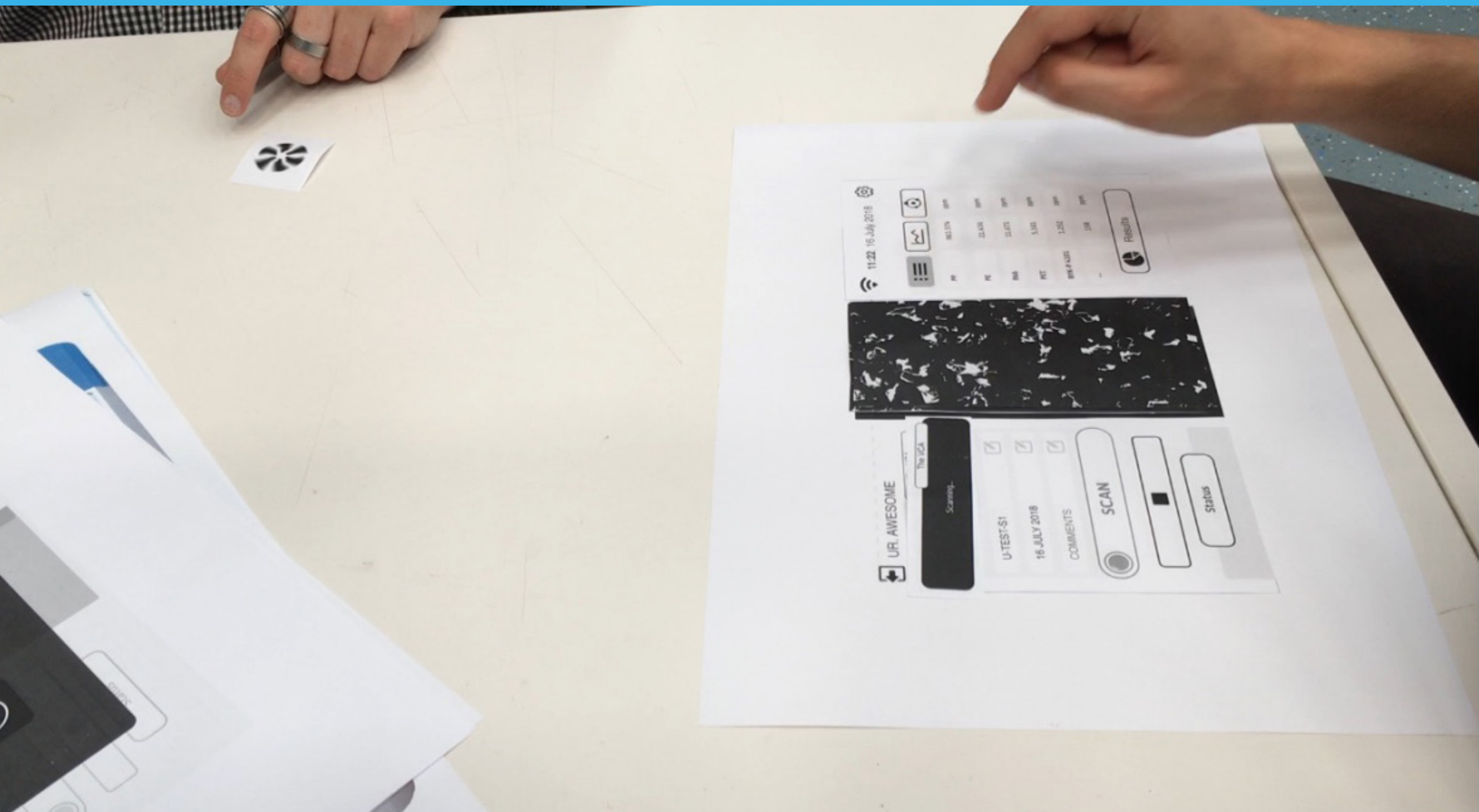
5.7.3 OBSERVATION RESULTS

The following interaction results were observed during the user test and discussed during the interview:

- **Interaction with the SCAN COMPLETE window was not intuitive**, as it was observed that participants pressed incorrect buttons to complete the given task. Participants explained that the used icons were not clear to them.

- **The RESULTS-button was not understood**, as it was incorrectly pressed a number of times during the user test. Participants explained that they did not understand the function of this button.

Figure 43: *Conducting the user test, (above) the materials used and (below) a participant interacting with the user interface V.0.3.*



- **The keyboard used to input text was not understood**, as the participants pressed the CLOSE-button instead of ENTER to confirm their input. Participants explained that they are used to pressing a similar button on their mobile phone to confirm the message input, located at the same place as the CLOSE-button.

- **Interface navigation was not misunderstood**, as participants tried to navigate though the user interface by scrolling (and other hand gestures). During the interview participants explained that they are used to this type of navigation.

- **The RESULTS-window(s) were not understood**, as the participants interacted with the results in a very ambiguous manner (random interactions). Participants expressed that they are not familiar with the context and the results presented. One participant mentioned that the Virtual Assistant should ensure that important results cannot be missed, as he mentioned that: “there is too much room for error”.

5.7.4 EXPERIENCE RESULTS

The cumulated experience results are presented in figures 44-46, in which the desired responses (+) are located on the right. Unexpected/unwanted responses were discussed further during the interviews to define whether the outcome should be addressed during further development. Experience results which should be addressed are presented below.

- **The Workflow was experienced as boring by 4 out of 5 participants,** and expressed that it had little to do with the interface and more with the work itself.

- **The Workflow was experienced as unusual by 4 out of 5 participants,** and expressed that they found it unusual that a touch screen did not facilitate touch-gestures.

- **The Virtual Assistant was experienced as robotic by 5 out of 5 participants,** and expressed that they did not experience the assistant as being human and that it could be caused by the use of a low-fidelity prototype.

- **The Virtual Assistant was experienced as chaotic by 2 out of 5 participants,** and expressed that the large amount of screens and windows that needed to be changed caused them to feel this way. Furthermore, participants also mentioned that the messages presented should be connected with the relevant system elements.

- **The Virtual Assistant was experienced as confusing by 2 out of 5 participants,** and expressed that they did not understand messages that included names of sub-systems (which they were not familiar with).

- **The Enclosure was perceived as feminine by 2 out of 5 participants,** and expressed that the softness of the shapes and the colour white made them experience it as such.

5.7.5 USER TEST CONCLUSION

The Software workflow was completed with less difficulty then initially anticipated and proved that the ambition to enable anyone (chapter 4.1) to operate the Virtual Chemist is to be considered as feasible.

The Virtual Assistant enabled the participants to successfully complete the workflow, but needs further development to ensure that the displayed messages are understood by a broader audience.

The Enclosure needs to be addressed as it was perceived as feminine, which goes directly against the defined product quality of being masculine (chapter 4.2). However, as the overall perception of the concept was highly positive it will be used as inspiration for further development of the system.

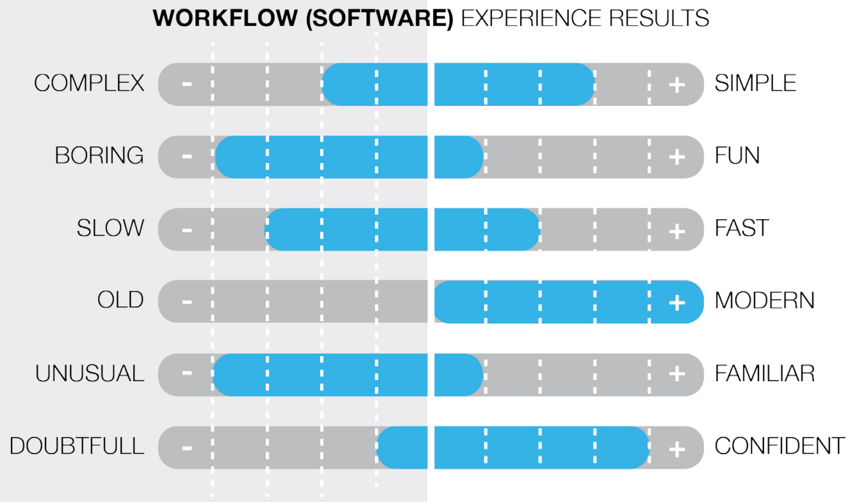


Figure 44: *User experience results: Software Workflow. (Author, 2018)*

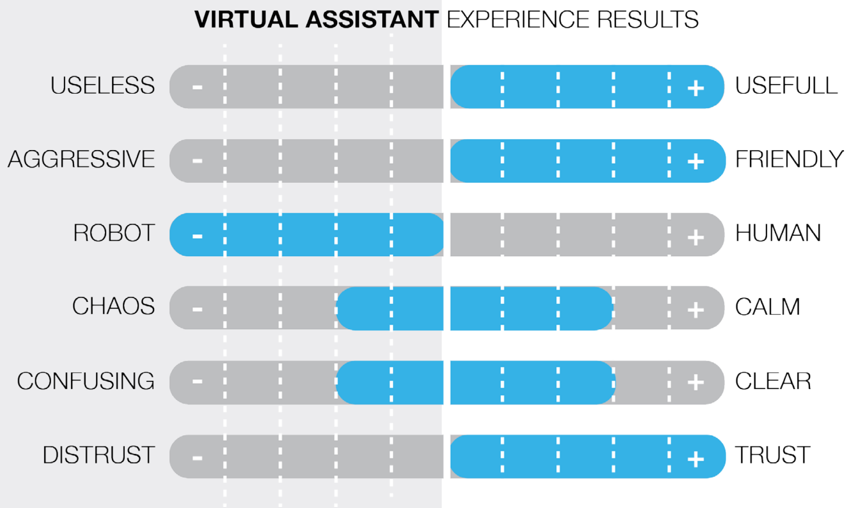


Figure 45: *User experience results: Virtual Assistant. (Author, 2018)*

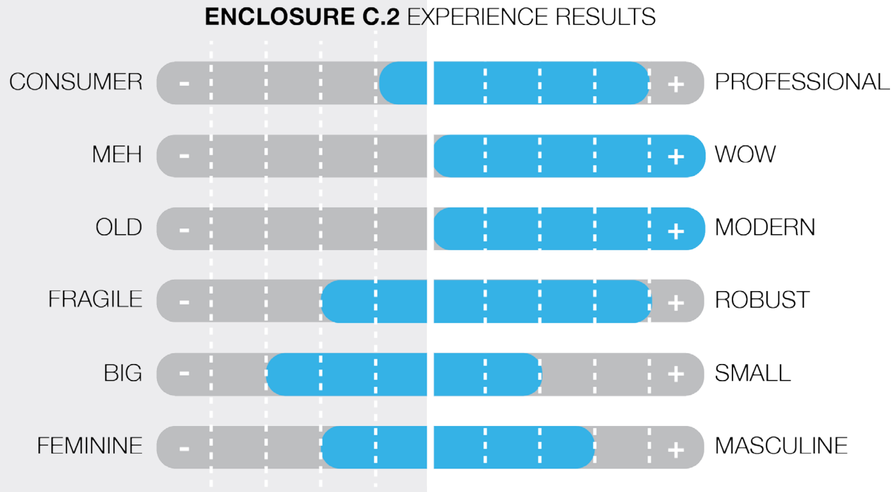


Figure 46: *User experience (perception) results: Enclosure C.2. (Author, 2018)*

CHAPTER 5.7 | CONCLUSION

This sub-chapter concludes weeks of developing and testing of ideas, by reflecting back at the design brief (chapter 4) in order to identify focus-points for further development.

5.8.1 DESIGN GOAL

TO DESIGN AN **EFFICIENT** AND **INTUITIVE INTERACTION** THAT ENABLES **ANYONE** TO **CORRECTLY OPERATE** THE VIRTUAL CHEMIST, AND TO PROVOKE AN **ASSISTANT-LIKE USER EXPERIENCE**.

An efficient and intuitive interaction was addressed thoroughly throughout the ideation phase, by reducing the amount of interactions and designing the user interface (and enclosure) in such a way that it is intuitive to use.

The results from the user test indicate that anyone can operate the Virtual Chemist through the use of the designed user interface which assists users in correctly completing the scanning sequence.

An assistant-like user experience has been addressed by designing the Virtual Assistant and embedding the functionality into the user interface. The idea enabled the possibility to automate the process further, improving (software) workflow efficiency without making the operator feel unnecessary. This experience has not been verified yet however, and should be addressed during further development.

5.8.2 DESIGN CRITERIA

Criteria that have **not** been addressed during the ideation phase:

4.2.1 CONTINUITY | HONESTY | SINGULARITY

4.2.2 HELPFUL | TRUSTWORTHY

4.2.3 COMMUNICATE | PROTECT | INNOVATE

5.8.3 DESIGN REQUIREMENTS

Requirements that have **not** been achieved during the ideation phase:

System requirements
0.3 | 0.8 | 0.11 | 0.17 | A.2 | A.5 | A.9 | A.11

Volumetric Feeder requirements
1.5 | B.2

Container requirements
2.5 | 2.6 | C.5

Enclosure requirements
3.3 | 3.8 | D.3 | D.4

User Interface requirements
4.1 | 4.5 | 4.11 | 4.15 | E.2 | E.5 | E.6 | E.7 | E.8

5.8.4 CONTEXT VISION

The following collage elements should be addressed further:

4.4 EXPLORING | REPORTING

The client's needs and wishes in regard to data processing should be researched further to identify additional value the Virtual Chemist can offer to its clients. Although it was found that operators are often requested to produce process reports to their superiors, this element should be researched further during conceptualisation.

5.8.4 INTERACTION VISION

The following collage elements should be addressed further:

4.5 HELPFUL | PROFESSIONAL

Although the composition results have been addressed during the ideation phase, the interaction with the results needs to be designed in further detail to increase their helpfulness. The ideation focussed primarily on designing efficient and intuitive interactions, for the conceptualisation the focus should be to make these professional.

5.8.5 INTERFACE-PERSONA VISION

The following collage elements should be addressed further:

4. 6 CALM | INTELLIGENT

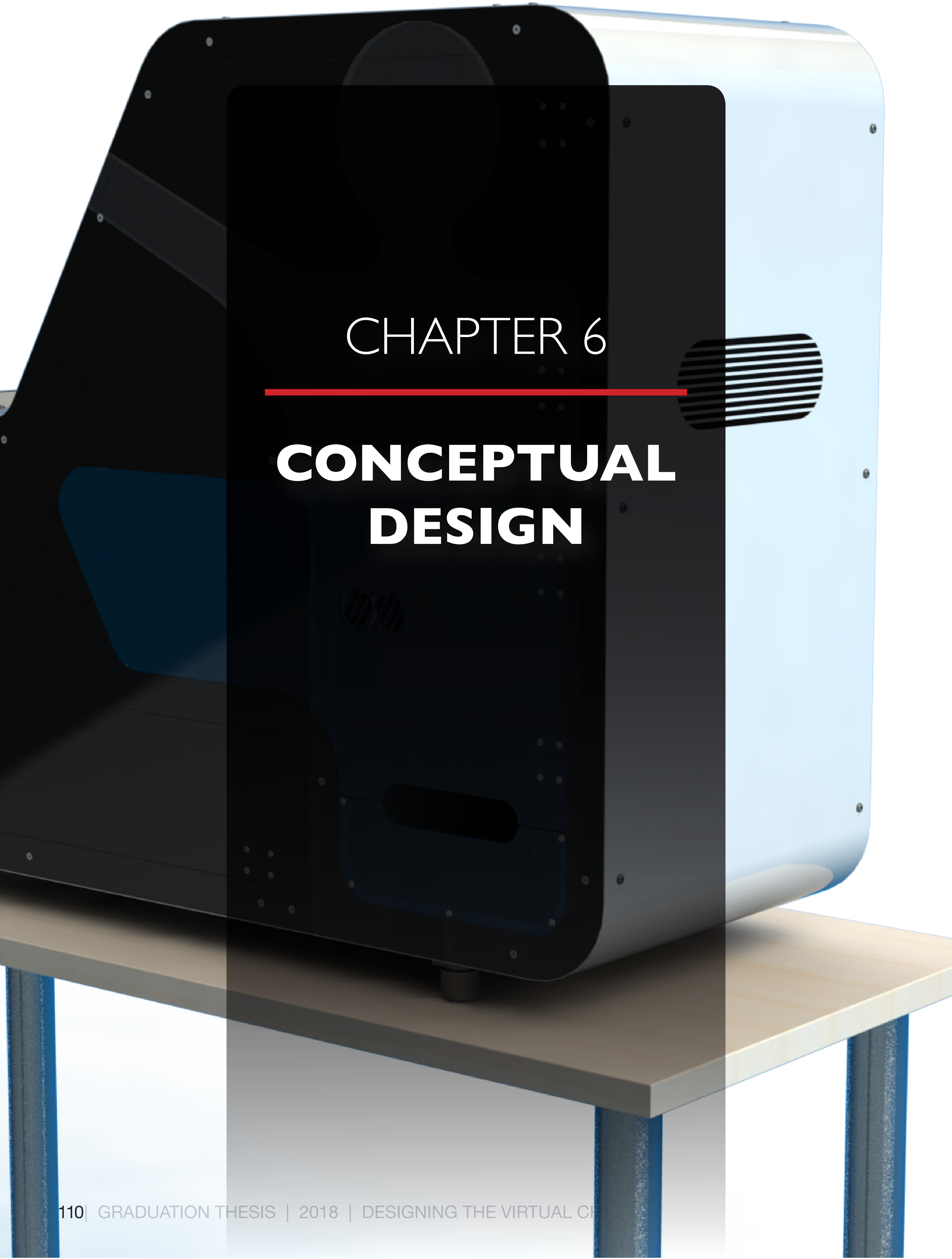
The Virtual Assistant was experienced as confusing and chaotic by several participants during the user test, therefore it needed to be addressed again during conceptualisation. Whether the assistant was experienced/perceived as intelligent was not addressed during the user test and was therefore also included in the next reflection.

5.8.6 EXPERIENCE VISION

The following collage elements should be addressed further:

4. 7 EMPOWERING | GROOMING | HACKER | TEAMWORK

The experience vision was reassessed after the user test, which is why none of the elements could have been addressed at the time.



CHAPTER 6

CONCEPTUAL DESIGN

CHAPTER 6.0 | INTRODUCTION

The Virtual Chemist was designed during the ideation by simultaneously focussing on several sub-systems and could not be validated as a complete concept. This chapter first presents the conceptualisation of the concept, followed by a validation, and concludes with a final list of focus-points.

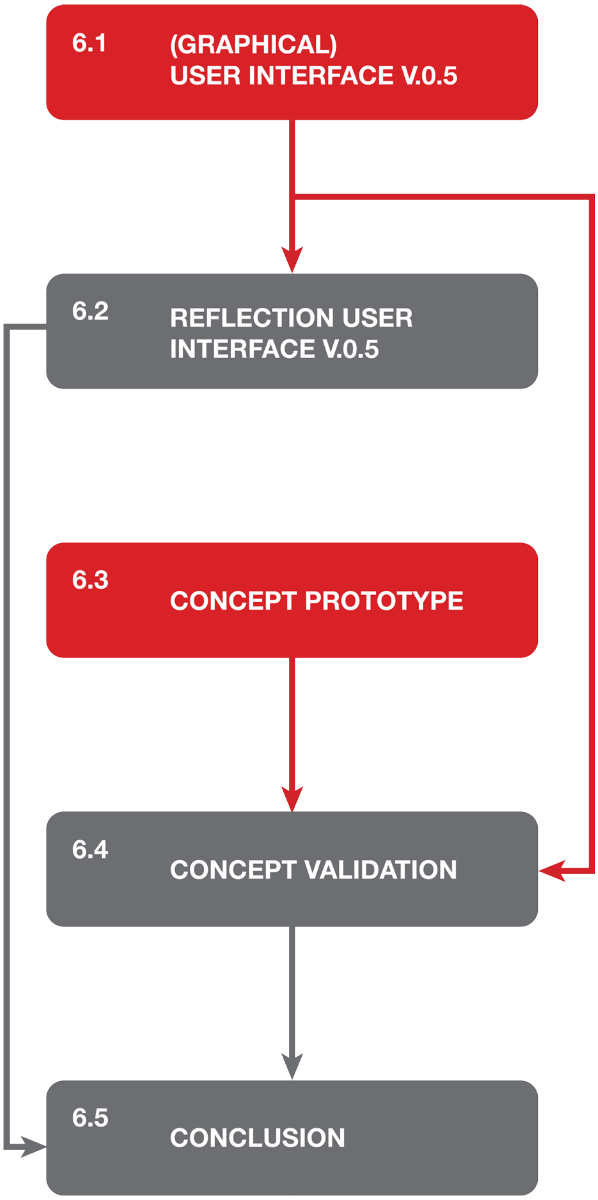
6.1 | GRAPHICAL USER INTERFACE V.0.5
The focus-points discussed in chapter 5.7 were addressed and translated into a graphical user interface (GUI).

6.2 | EVALUATION UI V.0.5
As the internship was coming to an end, the user interface needed to be finalised in order to be implemented into the Virtual Chemist. For this, the GUI screens were presented and discussed with the company to collect feedback for a final iteration, and used during the concept validation.

6.3 | CONCEPT PROTOTYPE
The selected sub-systems were prototyped so that these could be used during concept validation. The enclosure and user interface were rapid prototyped using leftover cardboard and other materials, the container was built through thermoforming a CNC milled mould.

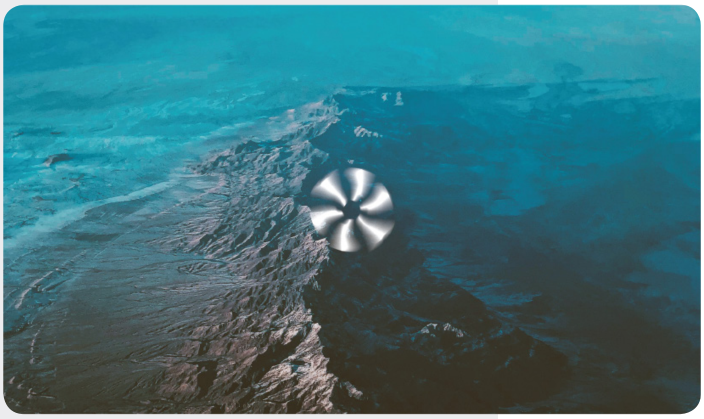
6.4 | CONCEPT VALIDATION
With the physical prototypes it was possible to complete the designed workflow, interact with the panels to simulate cleaning, maintenance, and collect final insights prior to the actual development of the Virtual Chemist.

6.5 | CONCLUSION
This chapter concludes with an overview of focus-points that needed to be addressed during the final iteration phase, based on the GUI feedback and prototype validation results.



CHAPTER 6.1 | USER INTERFACE V.0.5

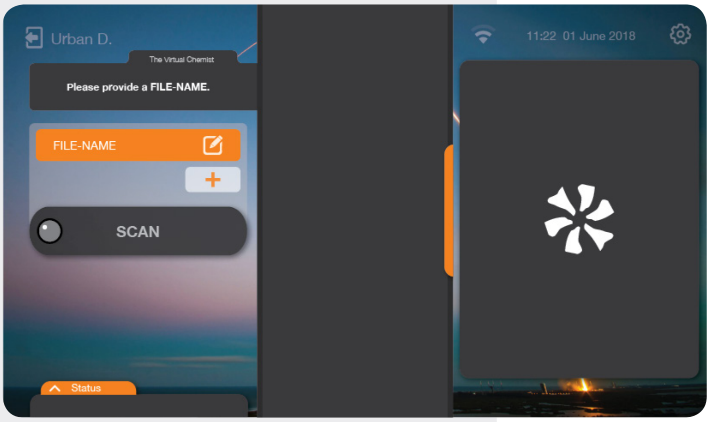
Up to this point, the user interface was designed primarily to facilitate an intuitive and efficiency completion of the scanning sequence. These screens were validated during the user test to identify focus-points that have been addressed during the conceptualisation phase, during which the screens were also designed further by addressing their aesthetic appearance. This process led to the following graphical user interface (GUI) screens.



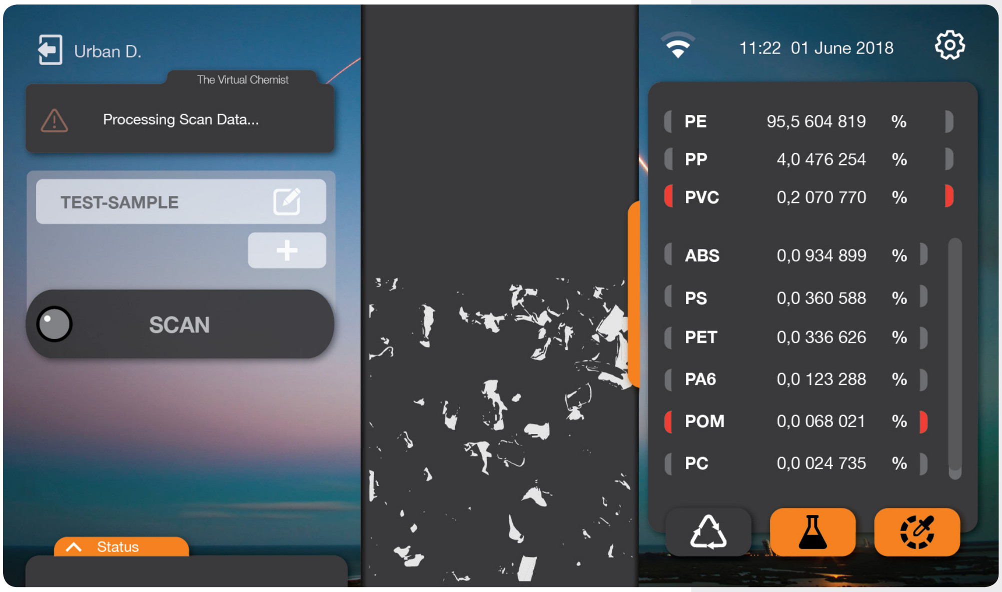
LOADING SCREEN
Within the field of UX design, the use of images is considered a tool to communicate a company's brand image. (Babich, 2018)

The image on the left was chosen to communicate a feeling of a modern and calm user interface, focussing on the duality within the context as described in chapter 4.4.

LOGIN SCREEN
An operator selects his profile, which opens a window that enables customisation of the profile, this profile can also be deleted but requires a supervisor password. The operator confirms the login by pressing the profile once again, which leads to the password screen. The password screen opens the keyboard automatically to reduce unnecessary interactions, additionally the screen also presents the "forgot password"-option. Once a correct password has been provided the user's preferences are loaded.



SETUP SCREEN
As can be seen on the left, the background has changed according to the user's preferences, this option has been implemented to provoke the grooming experience described in the experience vision (chapter 4.7). The use of custom backgrounds for different users is a common meme, which has been addressed to facilitate a stronger connection between the operator and the Virtual Chemist.

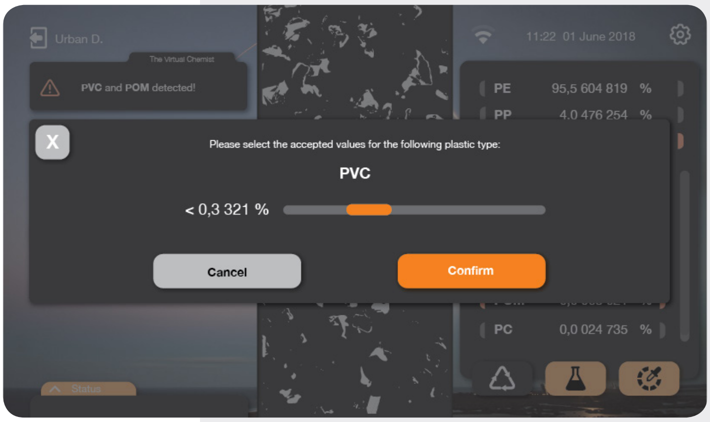


SCANNING SCREEN

It was found that there is no need for a separate results-screen, as the results window shown above is sufficient to address the client’s needs. Scanned data is exported to a data analyst, who was not included in this development phase of the system.

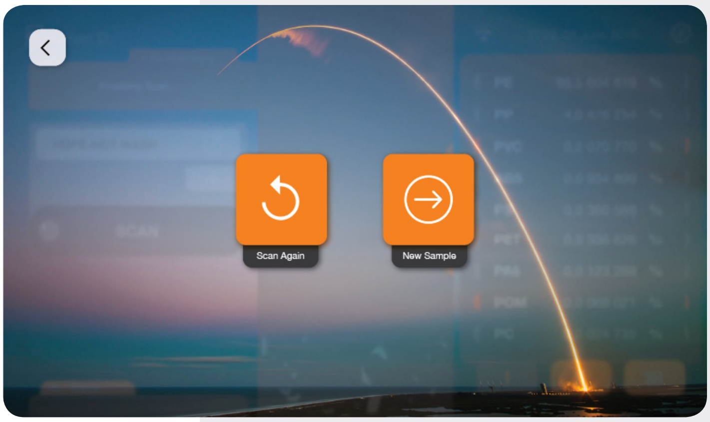
The stop-button was integrated with the scan button, the pause-button was removed.

The user interface notifies an operator if the contamination (and/or additives) threshold has been exceeded, indicated by a red colour in the results window and through the Virtual Assistant.



THRESHOLD WINDOW

As mentioned above, the user can setup the Virtual Chemist accordingly by moving a sliding-button to increase or decrease the threshold. Interaction is limited to this window upon opening, ensuring that the process is not affected.



SCAN COMPLETE WINDOW

During conceptualisation it was discussed with the company to drastically reduce the complexity of the SCAN COMPLETE-window, therefore this version offers two options: SCAN AGAIN and NEW SAMPLE.

Selecting the “scan again” option will scan the same sample again, with a new time stamp. Based on new insights it was decided to disable the operator from deleting scan results (without permission of a superior).

CHAPTER 6.2 | REFLECTION INTERFACE V.0.5

The GUI was presented to and discussed with the company to gather feedback, applied in the final few iterations leading up to the final design presented in chapter 7.

- The software **needs to load a number of protocols and should communicate these with the user during the loading animation** (figure 47) to prevent a negative user experience. (Nielsen, 1993)

- **Login doesn't need to facilitate the creation of a new user**; the number of users will be discussed with the company and provided to the clients accordingly.

- **An operator will only be asked to login once to validate the account**, after which the password is not required and thus reducing the amount of interactions. (Figure 48)

- **The function of alarming the operator** if contamination threshold has been reached **will not be implemented for the first version of the Virtual Chemist**, but will be considered during later development. (Figure 49)

- **The scanning screen should be revised by relocating the waterfall**, which should be less prominent compared to the results section.

- **The colour orange should be revised,** as it did not fit the company's vision for the graphical user interface.

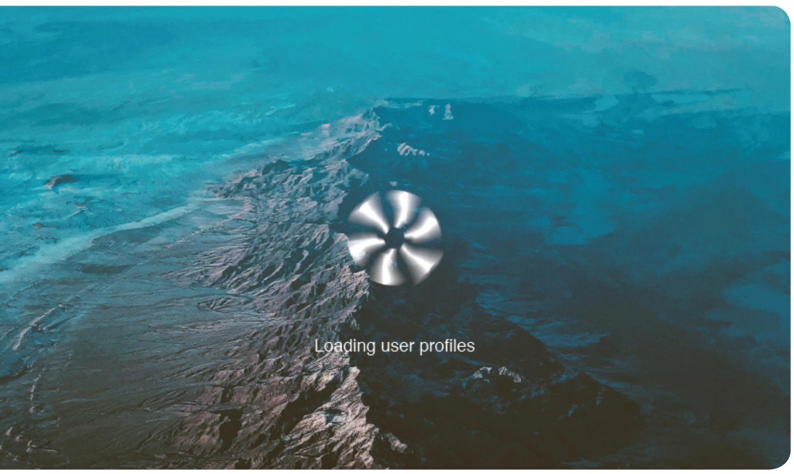


Figure 47: *Loading screen.*

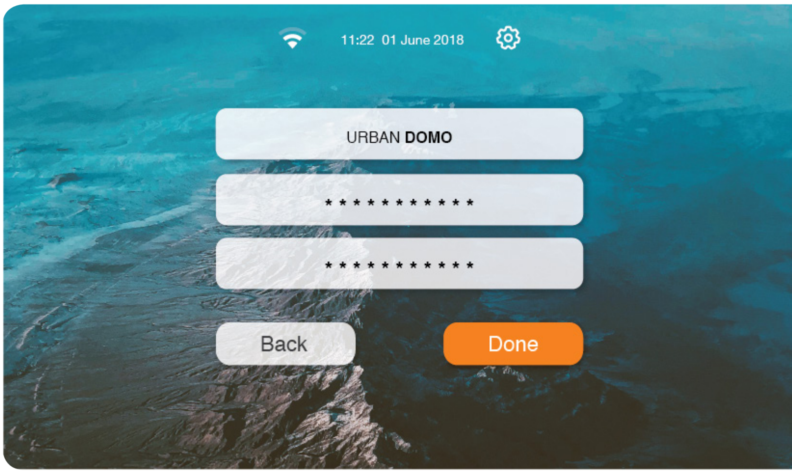


Figure 48: *Login screen.*

- **The STATUS-window should be removed from the user interface**, as this information is not necessary and can be implemented in a later development stage if required. (Figure 50)

- It was decided that **the results section should focus solely on presenting the plastic types**, the composition results concerning additives and colour will be addressed during a later development stage.

- **A search function needs to be implemented**, which will allow a user to view previous scan results.

- **The user interface should enable a user to compare different composition results**, but the need for such a function needed to be researched further.

- **It was decided to remove the functionality of adjusting the threshold**, as the company expressed to not allow an operator to complete such a task nor will this function be implemented at this stage.

- **The GUI was perceived as "too flashy"** and should be revised during the final iteration.

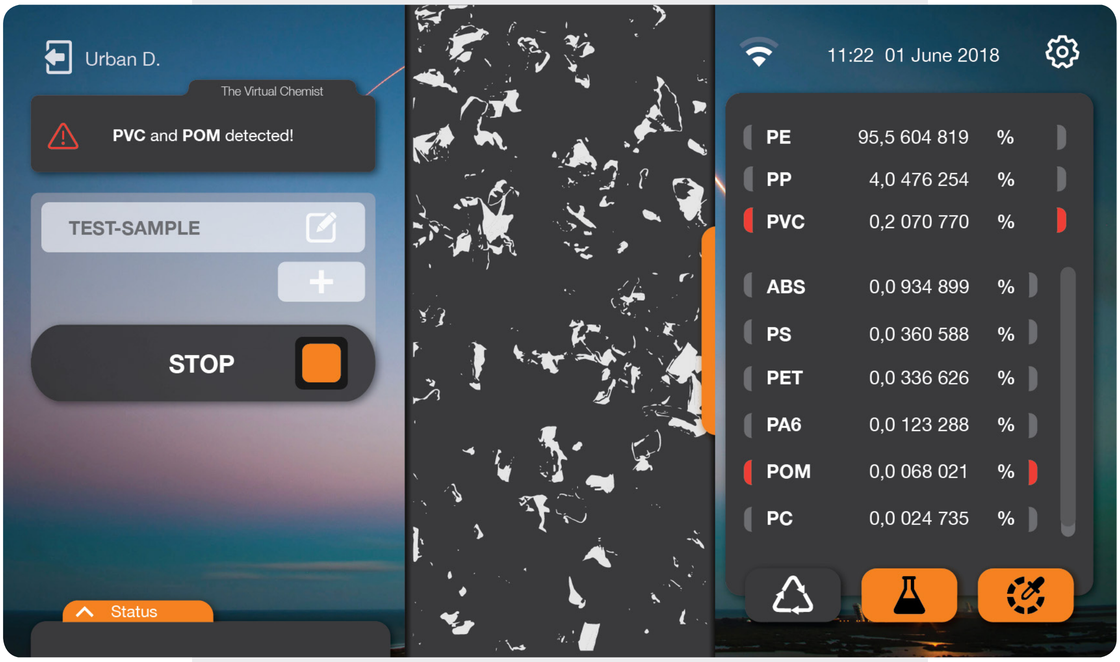


Figure 49: *Scanning screen.*

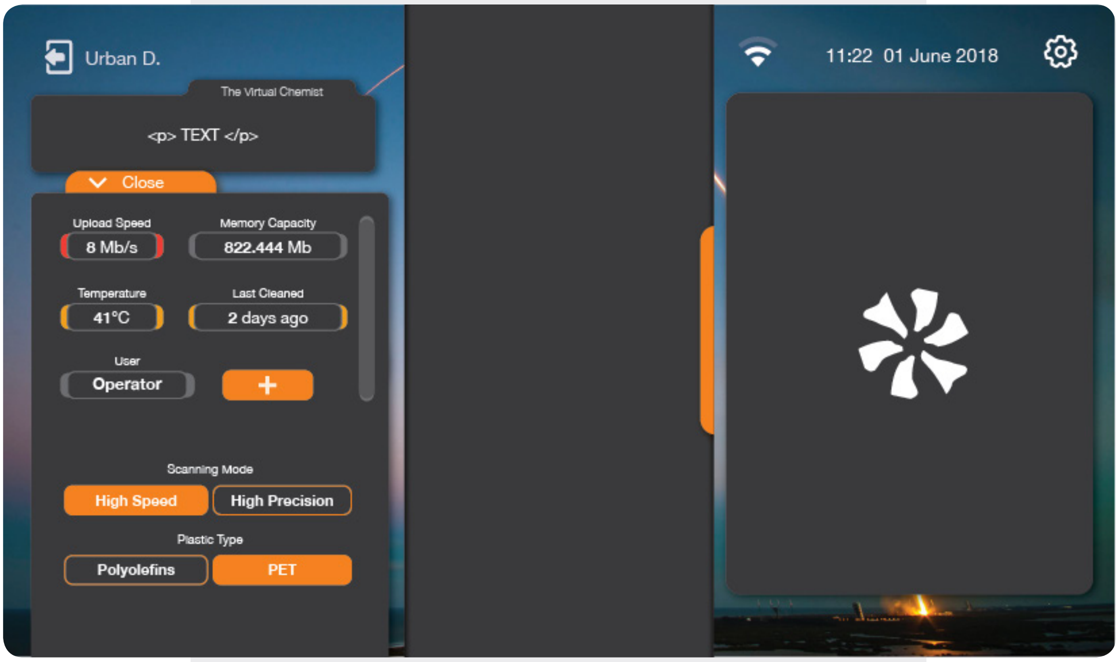


Figure 50: *Status window, when pressed.*

CHAPTER 6.3 | CONCEPT PROTOTYPE

The CAD-model below was designed by the company after addressing the user test findings presented in chapter 5.6 and was prototyped to validate the concept.

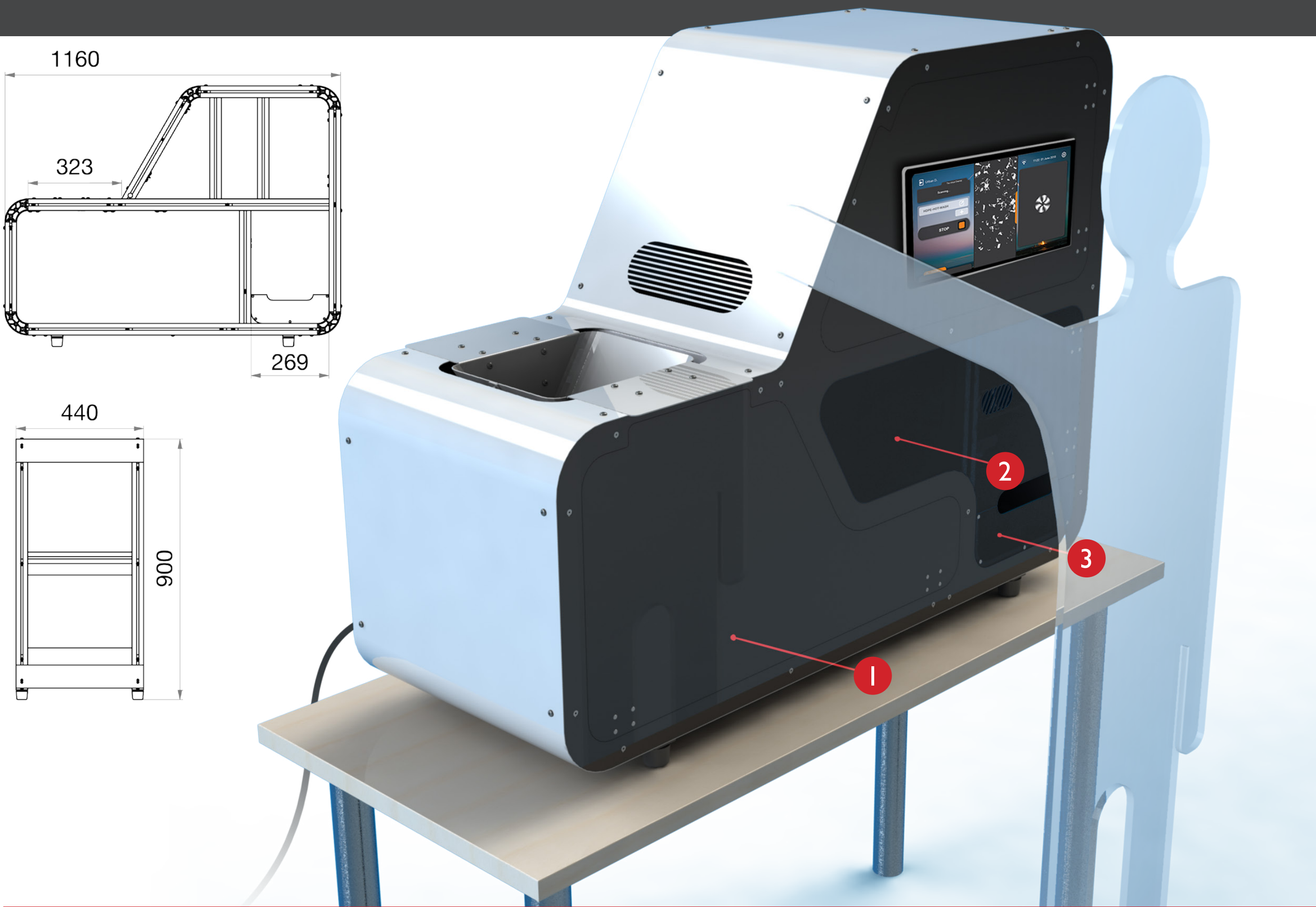


Figure 51: The Virtual Chemist, dimensions and CAD-model front-view, including a male model representing an operator with an height of 1680mm. Dimensions are expressed in milimeters. *(Polytential BV and Author, 2018)*

6.3.1 THE MODEL

The model presented in figure 51 was designed by the company during the conceptualisation phase of the user interface and was finalised based on the user test insights, presented in chapter 5.6.

Contrary to this model, the conceptual design C.2 was designed with little regard for manufacturing, as the primary goal was to focus on product aesthetics.

Unfortunately, this model would not be built until the end of the internship and could therefore not be used for validation. Therefore, **it was decided to built a representative rapid prototype that could be used to test the user interaction and experience while completing the workflow.**

This sub-chapter introduces the Virtual Chemist briefly as it is discussed in further detail in chapter 7.

6.3.2 VALIDATING THE MODEL

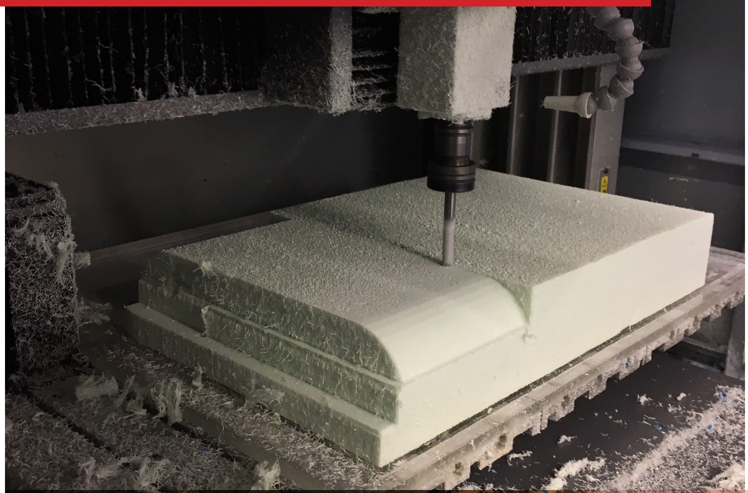
During the user test it was found that user interaction and experience is difficult to test without a physical model. Therefore, it was decided to rapid prototype the model using the frame available at that time, presented in figure 52.

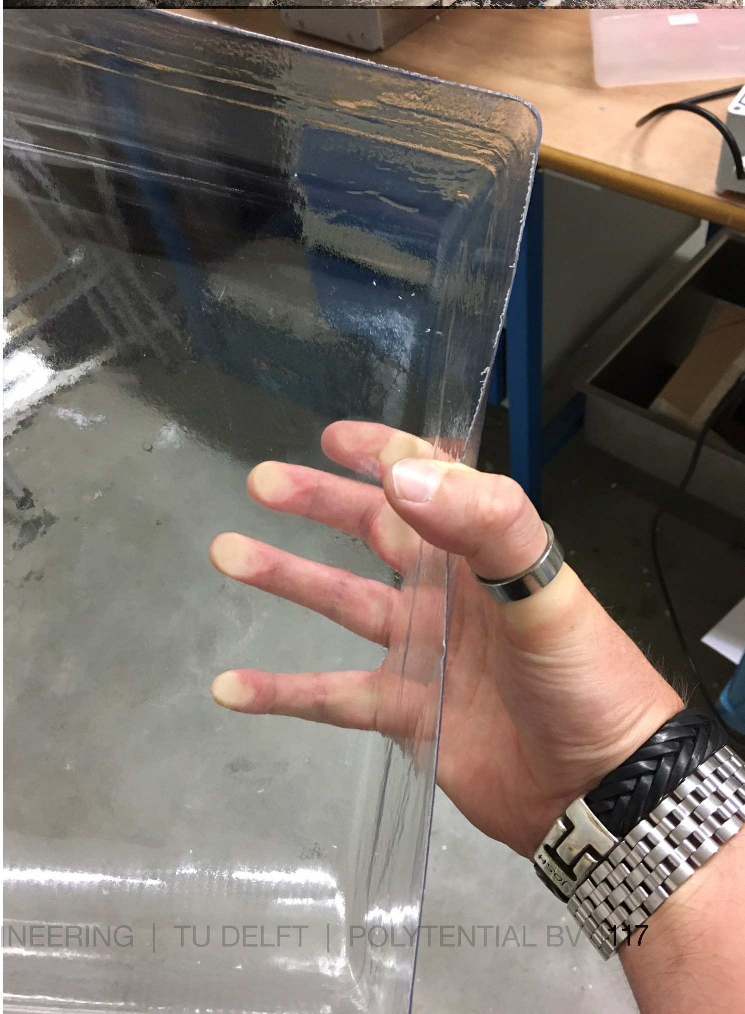
Additionally, as shown in figure 51, a P5-male (DINED, 2018) was modelled to observe how the product's dimensions compare to an operator, including acceptable ergonomic reach.

6.3.3 PROTOTYPING

▷ **The enclosure** was built by using cardboard, the panels indicated in figure 51 (1 and 2) were cut out to enable interaction with the panels as intended. A single back-panel (figure 52) was addressed during

Figure 52: *A digital model of the frame (left) and prototyping of the enclosure and container (right). (Author 2018)*





the built to test accessibility during maintenance, exclusive to Polytential. The semitransparent panel (2) was prototyped by reusing the leftover material found in the workspace.

▷ **The user interface** was prototyped according to the 13 inch design requirement to test user interaction, readability, and positioning. Including the power-button used to turn on the system.

▷ **The container** was prototyped by using CNC machine to mill a mould out of foam, followed by thermoforming a PET-G sheet in to the desired shape (Appendix S). This was necessary to test the ergonomics during use, as it was assumed that using the container to transfer flakes could lead to repetitive stress injury (figure 52).

6.3.4 PRODUCT EXPERIENCE

The workflow was re-enacted to determine if the conceptualised ideas work accordingly, and consciously focussing on any unexpected issues or opportunities that occurred during validation.

The use of images during the user test made it difficult to collect representative user experience feedback concerning certain aspects such as size and robustness. These were therefore also addressed during this validation.

The prototyped model is presented on the next page, including the validation results.

CHAPTER 6.4 | VALIDATION RESULTS

On the right, an impression of the test with the rapid prototype as introduced in the previous sub-chapter. This sub-chapter presents the validation results that have been found during the test.

6.4.1 ACCESSIBILITY

- **Accessing the volumetric feeder showed little difficulty**, as the frame blocks a user's view of the sub-system.

- **The shake feeder was accessible and relatively easy to clean** with one hand, although it was difficult to observe the cleaning process.

- **The conveyor belt accessibility should not be a problem,** based on current insights. It was decided to exclude conveyor belt accessibility, meaning that the operator should not directly interact with this sub-system.

- **The user interface should be placed in-front of the camera-panel**, as none of the other options worked as intuitive and efficient.

6.4.2 WORKFLOW

- **Working from left to right was efficient and intuitively guided by the product's design**, and should not be addressed further.

- **The Virtual Assistant is observed as the first element after moving sideways**, which was correctly assumed.

- **Standing in front of the user interface enables an operator to observe the process without further movement,** enabling the desired workflow efficiency.

- **The prototyped container** (appendix T) **is ergonomically not feasible,** as it is too large to enable proper handling and doesn't enable an efficient transfer of flakes.

- **Storage for scanned samples should be considered**, as it became difficult to maintain a clean workspace without a predefined system.

6.4.3 EXPERIENCE

- The perception of size was significantly affected by a fully enclosed system, as **the product was experienced as very robust and solid.**

- **Implementing the panels and other elements distributed the observer's focus** and reduced the perception of working with a solid and (very) large product.

- **The dark-coloured semitransparent panel reflects the surrounding light to the point that it blocks the user's view of the conveyor belt**, but as soon as the light is turned on (which is necessary for scanning) it changes completely and **results in a fascinating experience that should be explored further.**

6.4.4 ADDITIONAL INSIGHTS

- **Implementing a single back panel can only be achieved by removing the entire panel**, as the depth of 840mm disabled accessibility by using hinges.

- **It was found that transporting the system will require multiple individuals**, due to the product's size and weight (>100 kilograms).

- **Placing the product on top of a table with wheels enabled easy accessibility to the back-panel and overall product handling**, the idea of integrating a table should be considered during future development.

- **Interaction with the flakes needs to be addressed further to prevent repetitive stress injury** (RSI), as an operator who works an 8 hour shift will have at least 50 interactions (involving transfer of flakes) a day.


ERIC
SCAN
COLD-WASH-12
POWER

CHAPTER 6.5 | CONCLUSION

This sub-chapter concludes the conceptualisation phase by discussing the GUI feedback, concept validation results, and reflects back at chapter 5.7 to determine whether the mentioned focus-points have been addressed. This chapter concludes by providing an approach towards the end of the internship.

6.5.1 GRAPHICAL USER INTERFACE

The GUI screens were positively received by the company but needed to be simplified further by removing the status-window and thus enabling the waterfall to be relocated to prioritize the results window. The results window should focus only on presenting the composition results, thus excluding colour and degradation.

Although the use of images to convey a sense of personalisation was understood, it was not perceived as an element that should be introduced within the context, and should be redesigned to be less-fancy.

It was hypothesised that a client will only have a limited amount of operators conducting the composition analysis, which means that providing a password each time an operator logs in would be unnecessary. Therefore it was decided to ask a new user to validate their account once only, log in the user automatically after pressing their profile icon twice, thus skipping the entire login screen.

Additionally, it was decided by the company to remove the “add new user”-function as the amount of accounts will be defined in consultation with each client individually.

During the demonstrations it was observed that there is a need to access the composition results through a search function, enabling efficient access to previous scan results.

6.5.2 CONCEPT VALIDATION

Being able to re-enact the entire workflow with a physical model proved vary valuable and led to many new insights.

The Virtual Chemist was perceived as large and robust by enclosing the sub-systems, but also led to a significant increase in the product’s weight making it more difficult to transport. Which will need to be addressed as cardboard was used to built the panels, instead of aluminium.

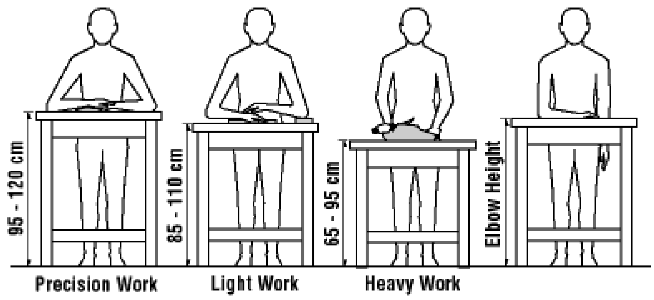


Figure 53: *Table height that should be used while performing different types of work. (CCOHS, 2018)*

It was found that interacting with the system on a full-time basis could lead to a so-called repetitive strain injury (RSI), as pouring the flakes was physically demanding due to the shape and weight (including flakes) of the container.

Ergonomics were researched further, to ensure that RSI would not become an issue, as the table height can vary across different clients. This was addressed by consulting a guideline presented by the Canadian Centre for Occupational Health and Safety (CCOHS), figure 53. During the demonstration at TUSTI, the table height was 75cm, which leads to an unwanted reach envelope result (figure 54). As can be seen in figure 53, this table height fits the advised height for heavy work. Operating the Virtual Chemist at a higher height of 95cm is advised, as this height is considered ergonomically acceptable (figure 55).

Additional findings that were observed during the validation of the model:

- Maintaining a clean workspace could be facilitated by integrating the table for storage, which could also solve the earlier described weight issue.
- Using reflective semitransparent panels provokes a fascinating and dynamic experience as the inside cannot be observed while the lamp is turned off. Contrary to the lamp being turned on, which then enables the observer to see the inside of the machine.

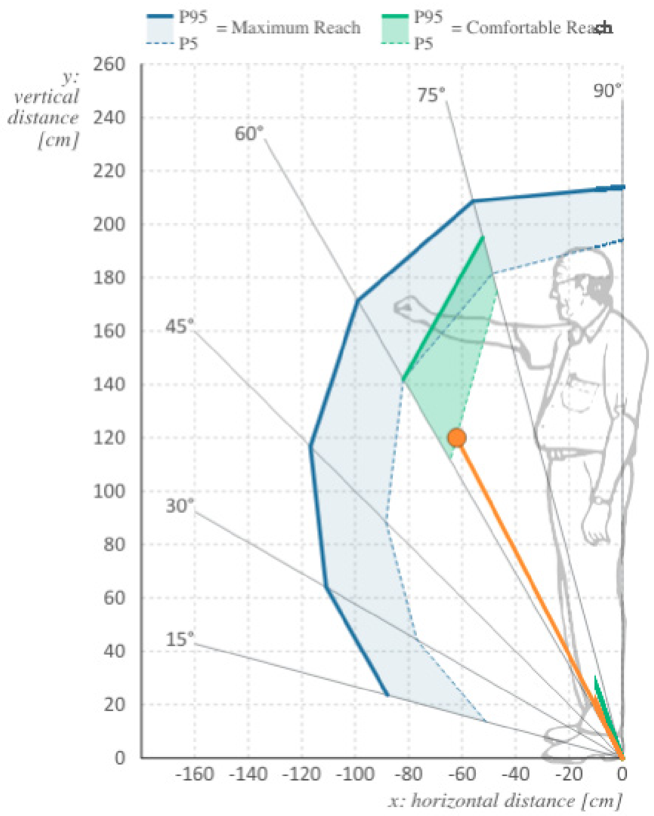


Figure 54: *A reach envelope for a male user between 20-30 years and shorter than 175 cm, using a table with a height of 75cm. (DINED, 2018)*

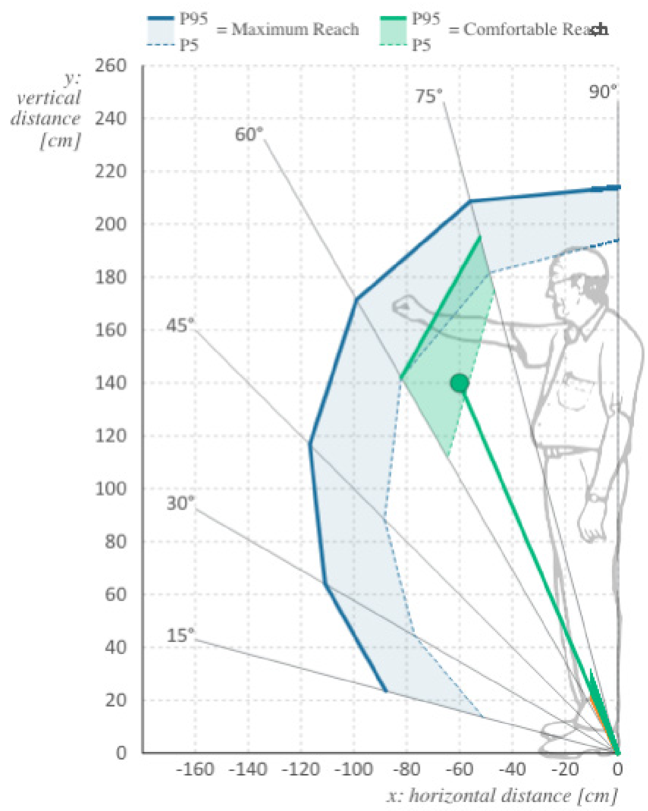


Figure 55: *A reach envelope for a male user between 20-30 years and shorter than 175 cm, using a table with a height of 95cm. (DINED, 2018)*

6.5.3 REFLECTION CHAPTER 5.7

The following design criteria, mentioned in chapter 5.7, have **not** been addressed during conceptualisation.

4.2.1 HONESTY

4.2.2 HELPFUL

4.2.3 INNOVATE

CONTINUITY was addressed by the company through extensive stress testing of all sub-systems prior to each client demonstration.

SINGULARITY will need to be addressed further as the GUI was experienced as too flashy for the context, although it has been addressed by focussing on the Virtual Chemist's aesthetics.

The quality of being HELPFUL should be addressed further by considering the integration of a table, as discussed earlier.

The function to COMMUNICATING and to PROTECT the composition data (and user) have both been addressed during the conceptualisation by designing the results window, creating user profiles that require an operator to login, and by limiting the access to the hardware elements.

Requirements that have **not** been addressed during the conceptualisation phase.

System requirements
0.11 | 0.17 | A.5

Volumetric Feeder requirements
B.2

Container requirements
2.5 | 2.6

Enclosure requirements
3.8 | D.3 | D.4

User Interface requirements
4.5 | 4.11 | E.2 | E.8

The following collage elements need to be addressed further.

4.4 EXPLORING

It was observed during a demonstration that a client started experimenting by rescanning a sample with moisture multiple times to see whether the composition results would change (moisture affects the results). This inspired the vision of a context that enables a user to experiment during scanning, which was not yet addressed nor observed.

4.5 PROFESSIONAL

The precision of using lab equipment could not be addressed during the validation test, nor could it be tested using the digital CAD-model. Therefore, this element should be addressed during the final iteration.

4.6 CALM

Although this element was addressed, the GUI turned out to be perceived as too flashy and needed to be revised again during the final iteration.

4.7 HACKER

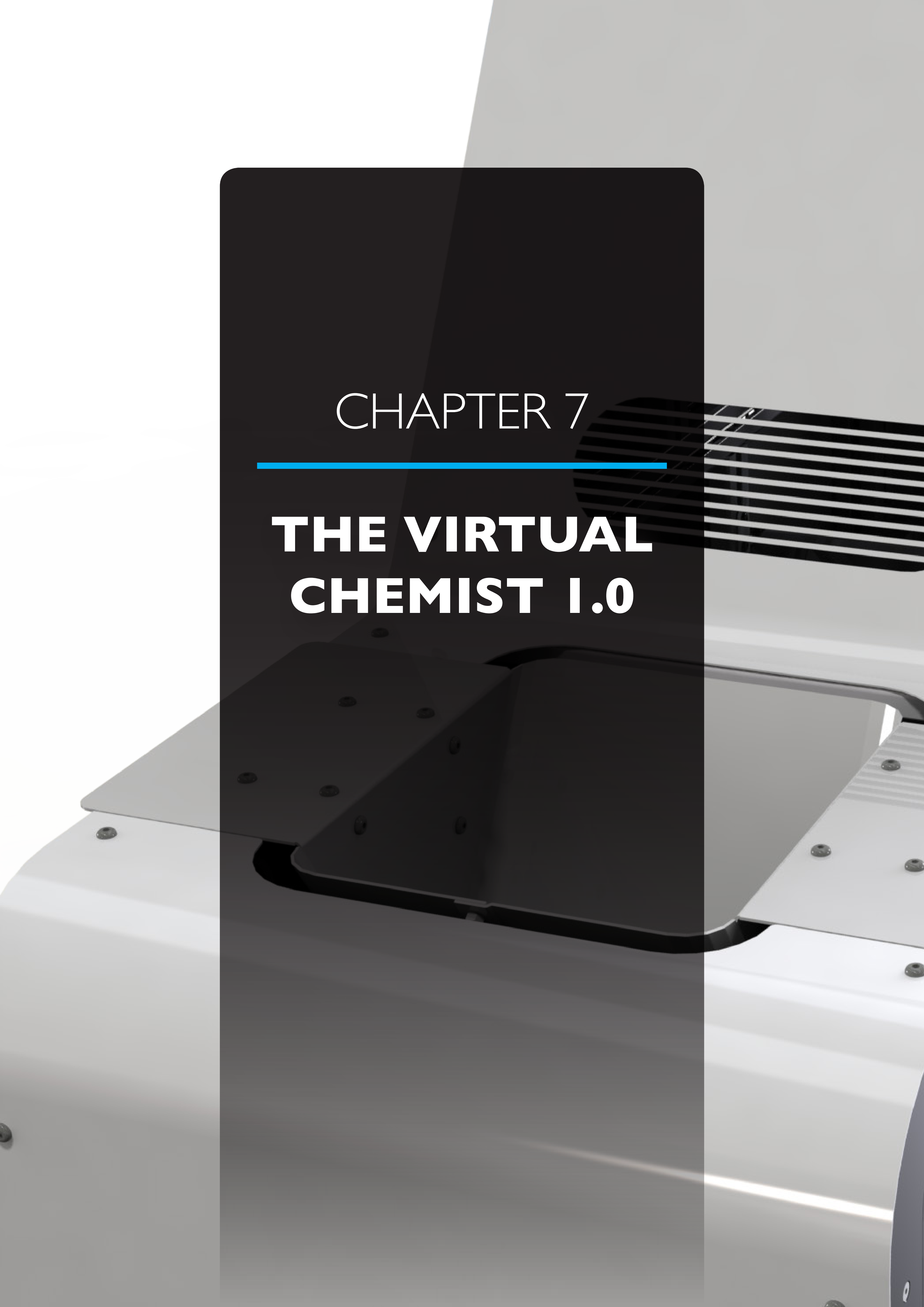
The way the results were being presented did not yet provoke the desired experience of interacting with an intelligent program and needed to be addressed.

6.5.4 NEXT STEPS

While the internship was coming to an end, and with little time left to implement the collected insights it was decided focus on redesigning the GUI. During this time the company would finalise the Virtual Chemist, as it needed to be ready for another client demonstration.

In consultation with the company it was decided that the model shown in chapter 4.3 would be used to present the final concept, as the collected insights could not be implemented before the end of the internship.

| The topics discussed during this reflection were addressed during the final iteration of the Virtual Chemist, presented in the next chapter.



CHAPTER 7

THE VIRTUAL CHEMIST 1.0

CHAPTER 7.1 | THE VIRTUAL CHEMIST 1.0

This sub-chapter concludes the conceptualisation phase by discussing the GUI feedback, concept validation results, and reflects back at chapter 5.7 to determine whether the mentioned focus-points have been addressed. This chapter concludes by providing an approach towards the end of the internship.

7.1.1 SPECIFICATIONS

DIMENSIONS	W1160mm x H900mm x D440mm
WEIGHT	>100kg
MAXIMUM THROUGHPUT	up to 20kg/hour
PLASTIC TYPES	10+
ACCURACY	98,5%

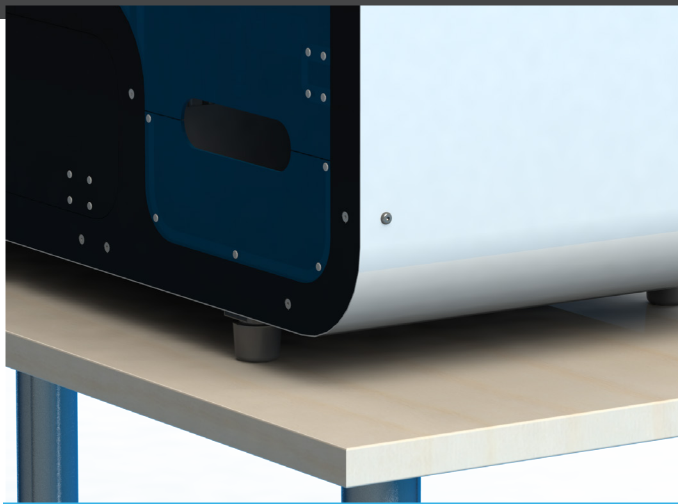


Figure 56: *Close-up of the container and legs. (Author, 2018)*

7.1.2 MATERIAL

FRAME	Aluminium
PANELS	Aluminium (Painted)
PANEL	Semitransparent Plastic (PP)
VOL. FEEDER	Aluminium
CONTAINER	Aluminium and Plastic (PP)
FEET	Rubber

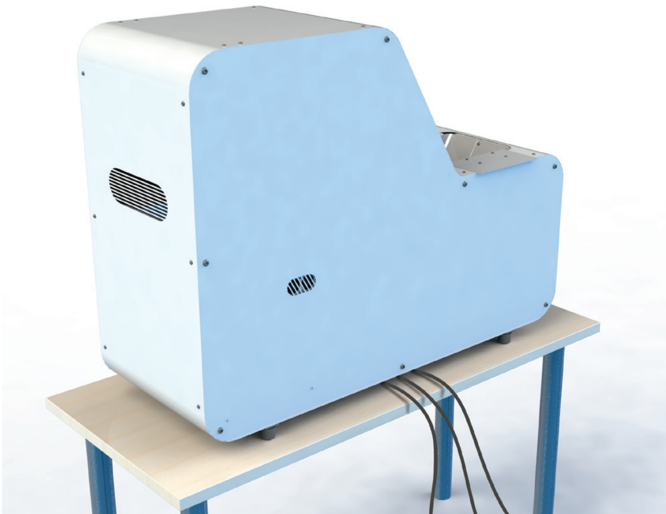


Figure 57: *(Top) The back panel, used for maintenance.*

(Below) A P5 male user reaching above the volumetric feeder. (Author, 2018)

7.1.3 SETUP

The Virtual Chemist is installed by the company, calibrated, and tested to ensure that the system operates properly. Setting up the system requires a power socket, internet cable, and a desktop computer which can be seen in figure 58. These cables run through the bottom(figure 57), enabling the back panel to be removed as a whole.

Setup requires at least two individuals due to the product's weight, which also affects the type of table that is required to ensure that user safety is not jeopardised.

Figure 58: *A representation of The Virtual Chemist being used in context, using a desktop computer instead of a touch-screen. (Author, 2018)*

7.1.4 OPERATION

Once the system has been setup, tested, and is functioning, the client is briefly introduced to the standard operating procedure and the Virtual Assistant.

The user interface has been designed in such a way that no further explanation is required, as the Virtual Assistant navigates the user through the workflow.

System operation is explained further in chapter 7.2.

7.1.5 INTERACTION

The company decided to enable a user to interact exclusively with the user interface, volumetric feeder, container, and external cables.

However, an operator is able to access the shake feeder and conveyor belt through the semitransparent panel, located above the container (figure 59).

7.1.6 CLEANING

Cleaning of the internal sub-systems was automated and does not require further effort from an operator. However, working with flakes will lead to spillage as can be seen in figure 58, this was defined as inevitable and was left out of this project's scope.

7.1.7 MAINTENANCE

The company will be responsible for maintenance, as part of the service that is offered with the Virtual Chemist. Software maintenance through updates was not addressed during this project.

7.1.8 CLIENT SPECIFIC NEEDS

The Virtual Chemist is an expensive analysis tool that will be tailored to meet specific client needs, if found feasible.

CHAPTER 7.2 | THE WORKFLOW

The flow diagram presented in this chapter was created in order to be compared with the initial workflow (chapter 3.3), by comparing the two it was possible to determine whether the design requirements had been met.

7.2.1 INTRODUCTION

The flow diagram illustrates how a user will complete a single workflow, starting at the moment that the system is turned on and is concluded when the system has been turned off again.

Additionally, the flow diagram also illustrates a more realistic situation where multiple samples are scanned and processed, communicated by the dashed lines.

7.2.2 INTERACTIONS

As can be seen in figure 60, a user will interact eleven times with the system in order to complete a single workflow. However, some of these interactions demand additional steps:

2 | LOGIN

As concluded in chapter 6.2, the user will be requested to login once to validate their profile. Although this would require more than one interaction to complete this step, it has been left out of the flow diagram because it will occur only once.

3 | SETUP SCAN

Setting up a scan requires the user to provide a sample name and to insert the flakes, which was also excluded due to the user being able to insert the flakes at any given moment, as long as it is before pressing the start button.

5 | OBSERVE SCAN

The operator is required to observe the scanning process to determine when all flakes have been processed, as this step could not yet be automated. During scanning the user is however free to interact with other devices, or the results. As it cannot be predicted how a user will interact with the system during this time, it was decided to depict this step as a single interaction.

7 | EMPTY CONTAINER

This step could be seen as a three-part step, as the operator will need to take the container out of the enclosure, empty its content, and place it back into the enclosure. Interaction with the container is defined as a single interaction because it is completed without interruption.

8 | EXPORT RESULTS

The exporting of results was introduced at the end of the conceptualisation phase, and had not been addressed nor validated prior to the construction of this flow diagram. However, in order to export a dataset, the operator will need to open the export window (first interaction) and interact with it to select and send the dataset to a data analyst (step 9).

10 | LOGOUT USER

Before a user is logged out, it is common that the software provides an option to cancel or confirm this action. This should be introduced to prevent an accidental logout, but is counted as a single interaction.

11 | TURN OFF SYSTEM

This step has not addressed during the internship and is therefore counted as a single interaction.

The additional interactions, explained above, need to be considered when calculating the number of interaction required to complete a single workflow.

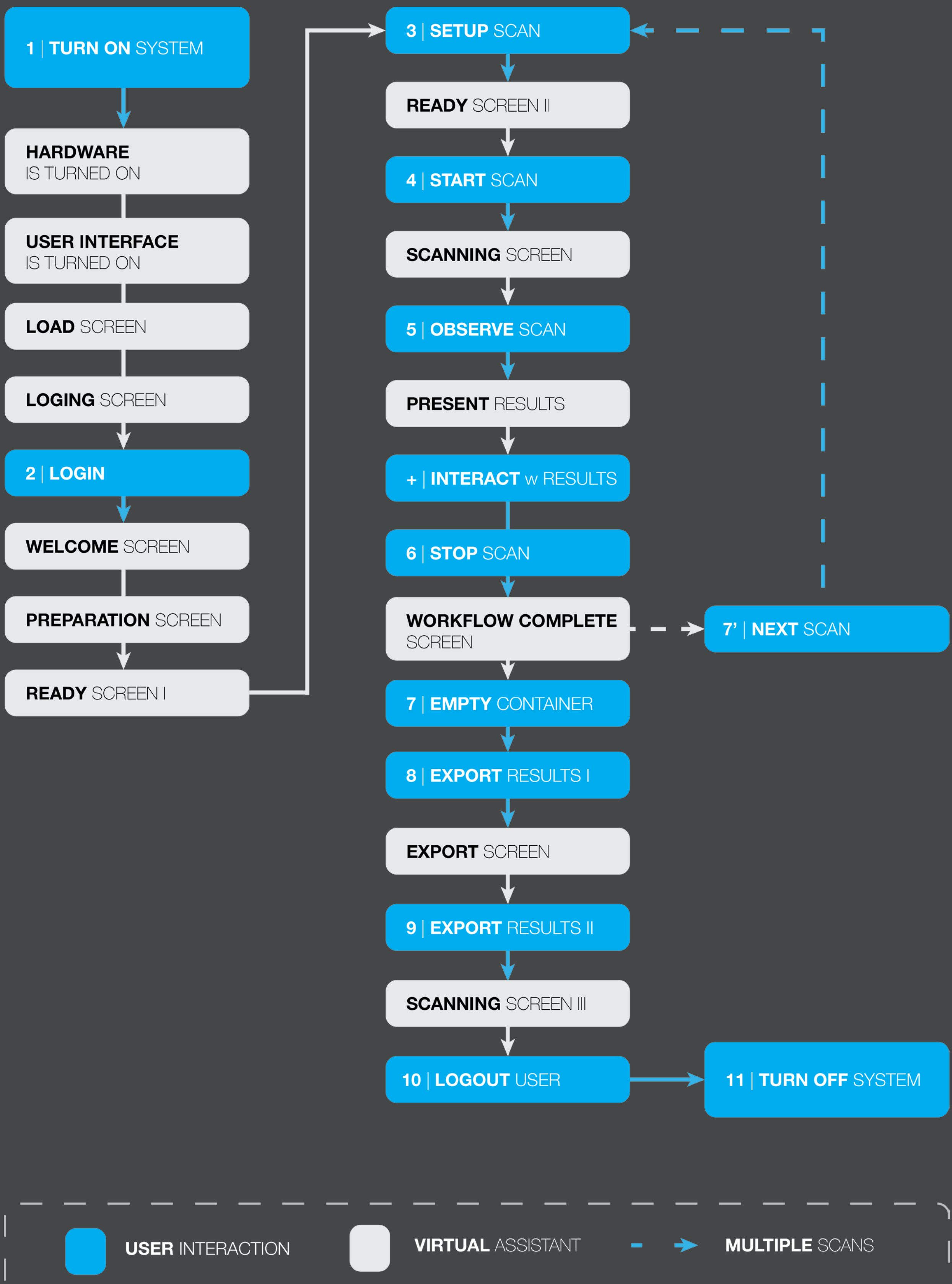
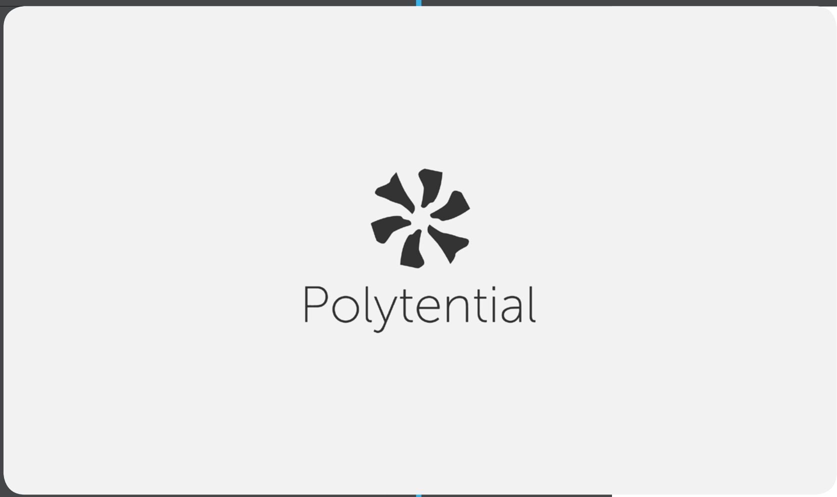


Figure 60: *Flow Chart, the workflow for the Virtual Chemist. (Author, 2018)*

CHAPTER 7.3 | **USER INTERFACE 1.0**

These GUI screens are to be seen as the final designs for the Virtual Chemist version 1. Only new elements and or functionalities are explained, as some screens have already been explained thoroughly in the previous chapters.

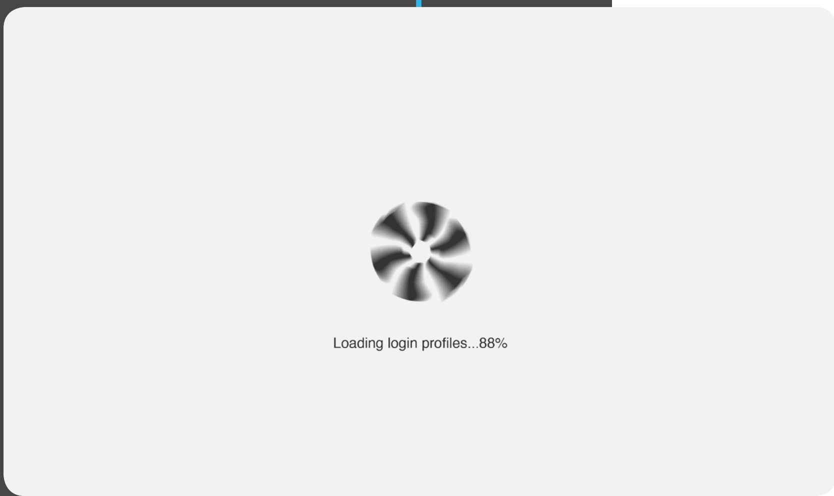
SCREEN ON



0 POWER-ON SCREEN

Communicate the company logo for branding purposes, and to clearly associate Polytential with plastic composition analysis.

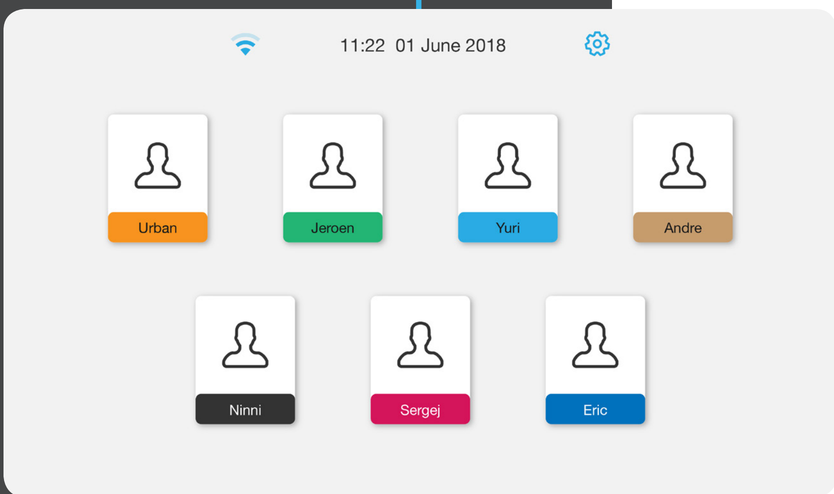
USER INTERACTION
None



1 LOADING SCREEN

The user is informed through a rotating company logo that the software is loading a number of protocols, which are presented below the icon. Additionally, a percentage is shown to illustrate the progress.

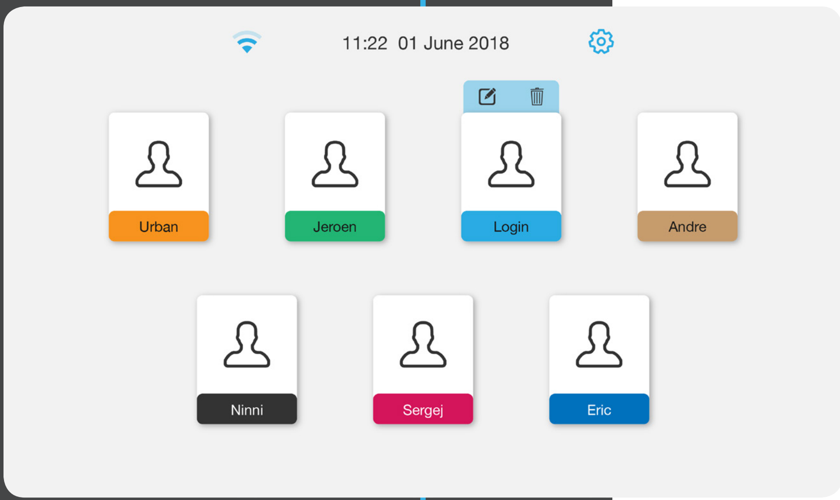
USER INTERACTION
None



2 LOGIN SCREEN I

The use of different colours should facilitate faster user selection and provokes a grooming experience by enabling users to change the colour to their liking.

USER INTERACTION
| Select a profile.

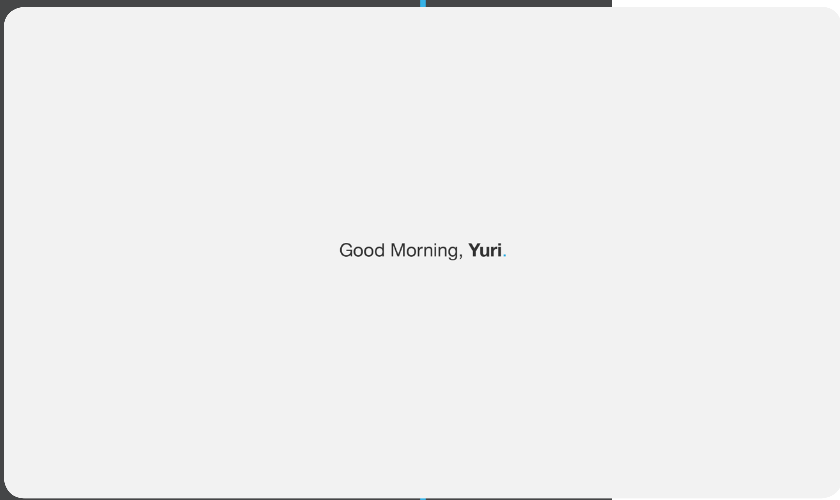


3 **LOGIN** SCREEN II

The profiles have been simplified to communicate a clean and modern look and feel, as it was found that the use of images was too distracting.

USER INTERACTION

| Press the login-button.

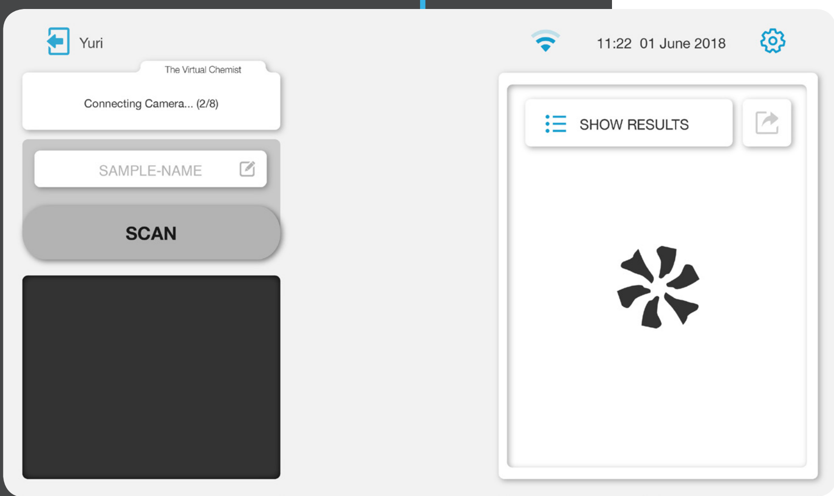


4 **WELCOME** SCREEN

A short message is displayed to provoke the assistant-like user experience.

USER INTERACTION

None

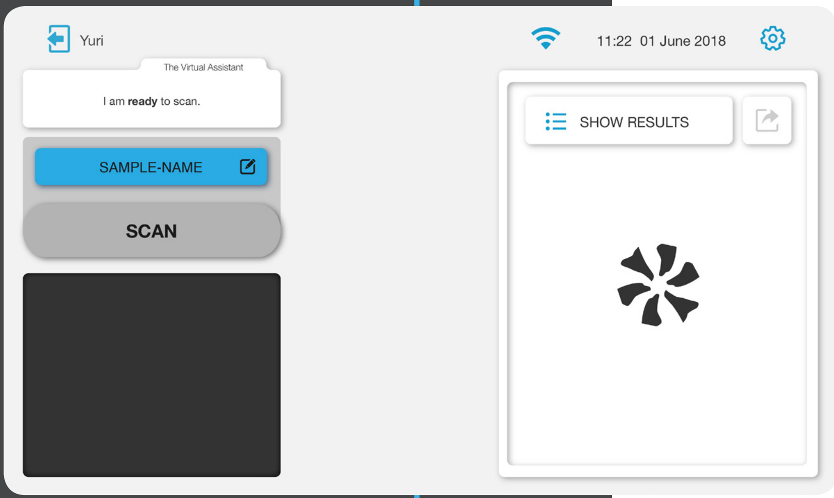


5 **PREPARATION** SCREEN

The Virtual Assistant communicates the tasks that are being completed. During this time the user cannot setup a scan.

USER INTERACTION

| None

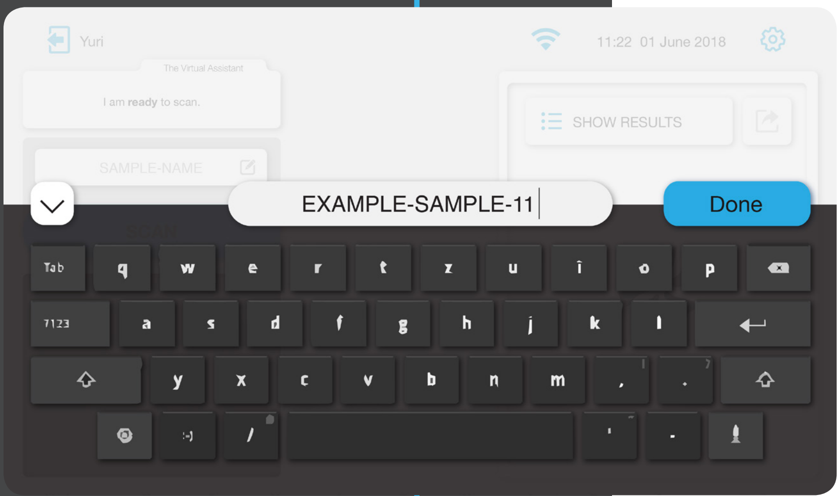


6 **READY** SCREEN I

The Virtual Assistant notifies the user that all tasks have been completed and highlights the SAMPLE-NAME, with the profile colour selected by the user.

USER INTERACTION

| Press SAMPLE-NAME

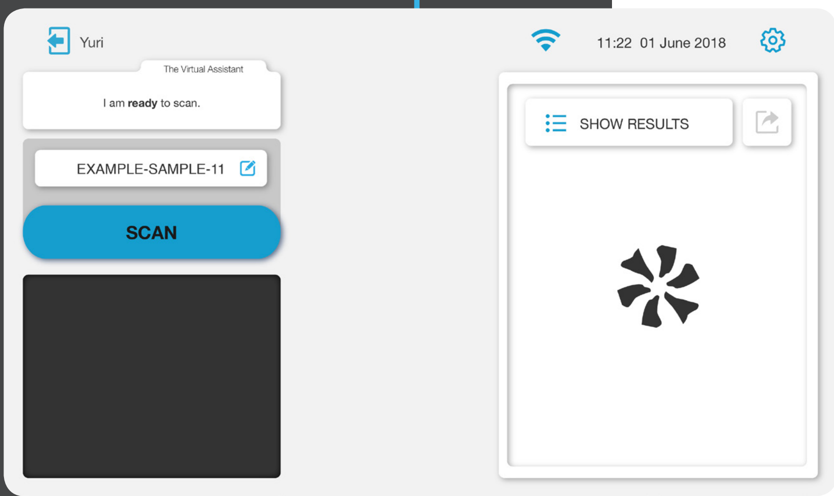


7 **INPUT** SCREEN

The DONE-button is highlighted after the user enters the first character, to clearly communicate the function and presence of the button. (Alternatively the user can also press ENTER when using a keyboard)

USER INTERACTION

| Type a SAMPLE-NAME
| Press ENTER

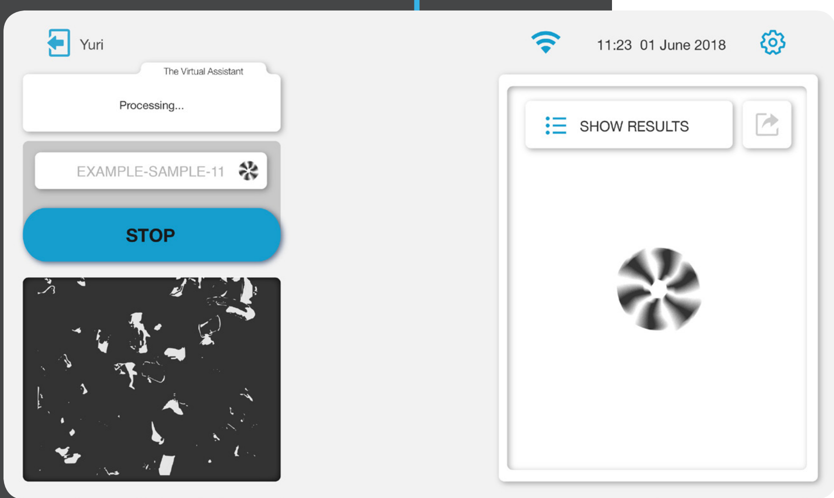


8 **READY** SCREEN II

The Virtual Assistant validates the provided sample name and communicates that the system is ready to scan.

USER INTERACTION

| Press SCAN

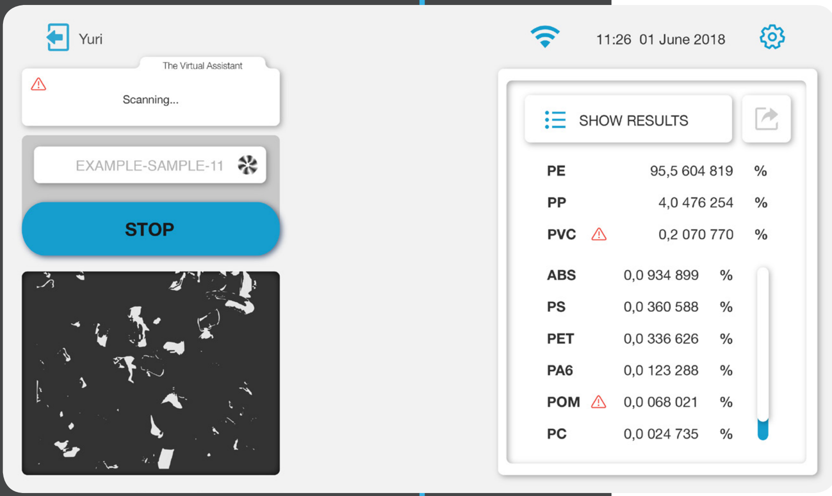


9 **SCANNING** SCREEN I

The waterfall is shown; the icon on the right starts to rotate to indicate that the data is being processed, if the data is processed it is shown and the icon disappears; the rotating icon on the left indicates that a scan is in progress.

USER INTERACTION

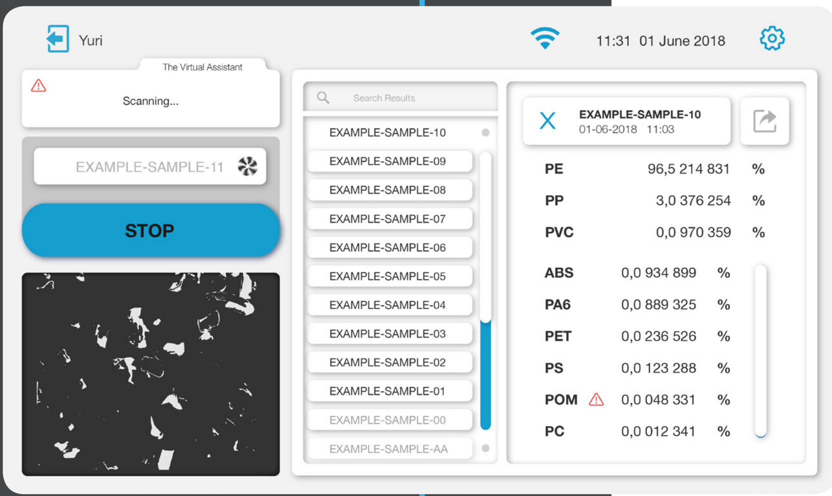
None



10 SCANNING SCREEN II

The current composition data is visualised in results window.

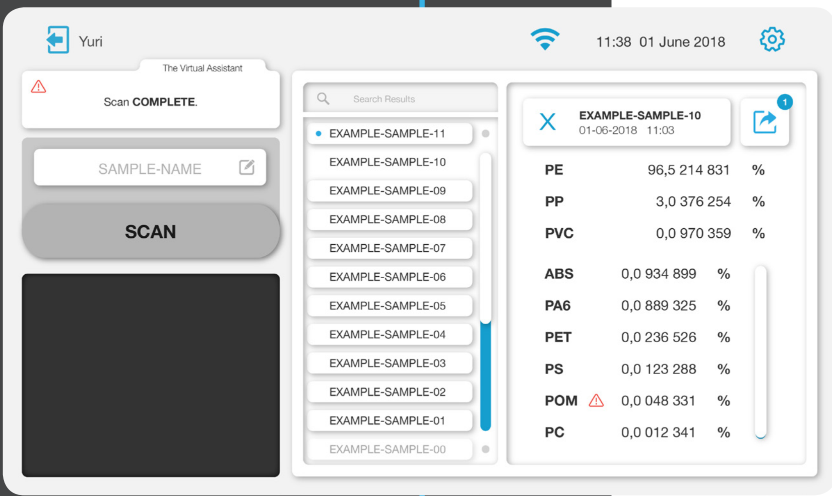
USER INTERACTION
| SCROLL through the data
| Press SHOW RESULTS



11 SCANNING/RESULTS SCREEN

The results history is presented, including the search function. The name of the selected dataset is shown in the window above the results.

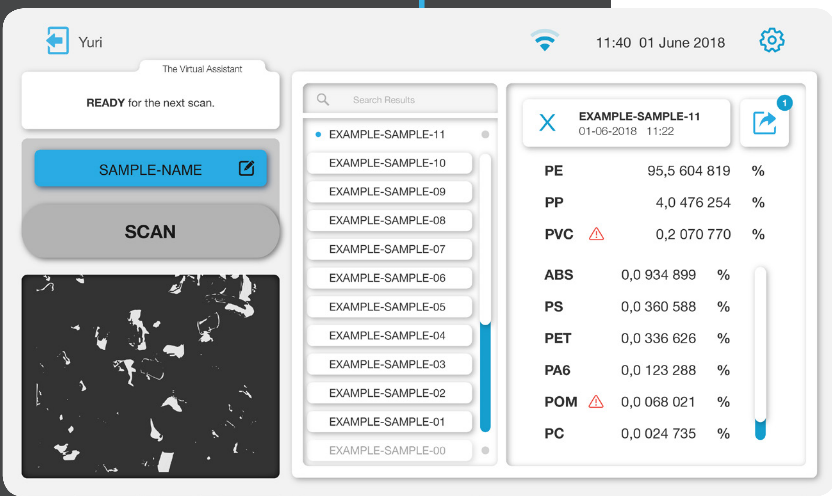
USER INTERACTION
| SCROLL through the results
| Select a DATASET
| Press STOP



12 SCAN COMPLETE SCREEN

After pressing STOP, the sample-name is moved to the results window by an animation so that it can be visually tracked. Additionally, the export button communicates that a new scan is available for export.

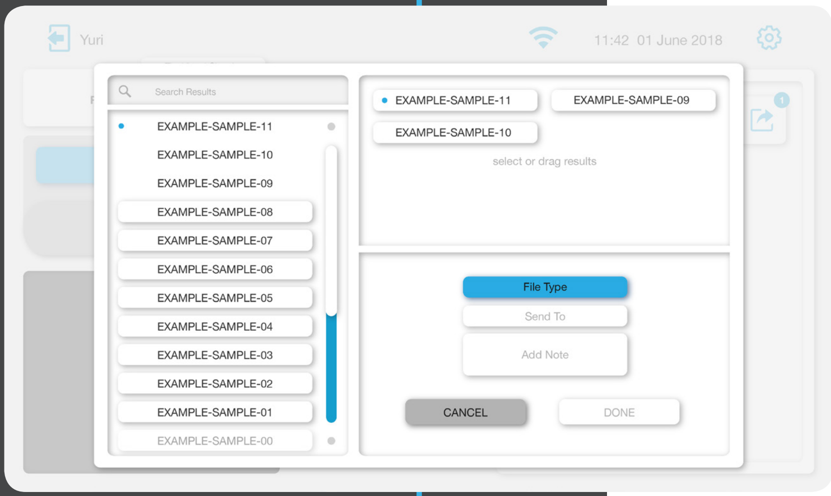
USER INTERACTION
| Select the new DATASET



13 NEXT SCAN SCREEN

The next user interaction will reset the SAMPLE-NAME button. A user is able to interact with the data to their liking, or decide to scan another sample (which will require the container to be emptied, if necessary)

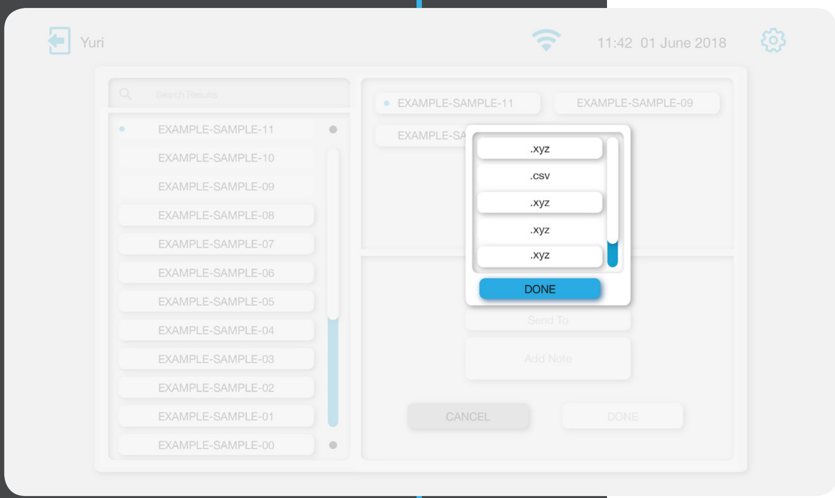
USER INTERACTION
| Press EXPORT



14 **EXPORT** SCREEN I

The EXPORT screen is presented and automatically adds the new dataset to the export window on the right, additional datasets can be selected or dragged into the same window. The FILE TYPE button is only highlighted if a dataset has been selected.

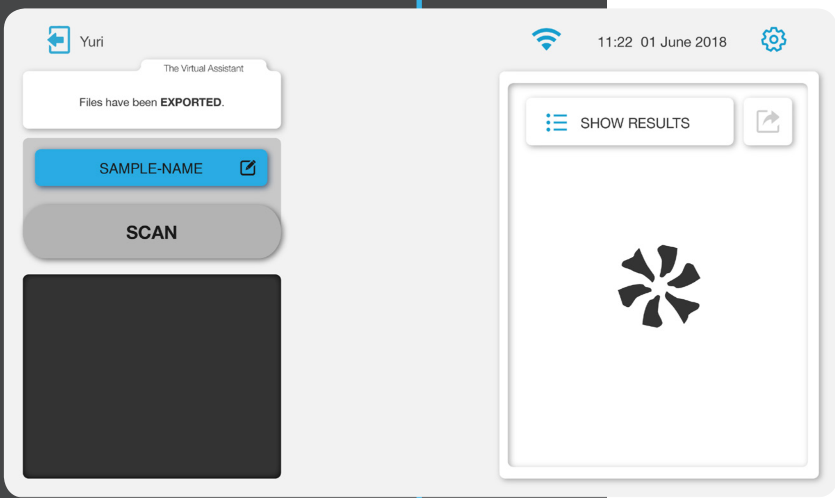
USER INTERACTION
| Press FILE TYPE



15 **EXPORT** SCREEN II

A small window pops-up, providing the user with a variety of file extensions that are facilitated by the software. The user is enabled to select more than one file extension in order to maintain workflow efficiency.

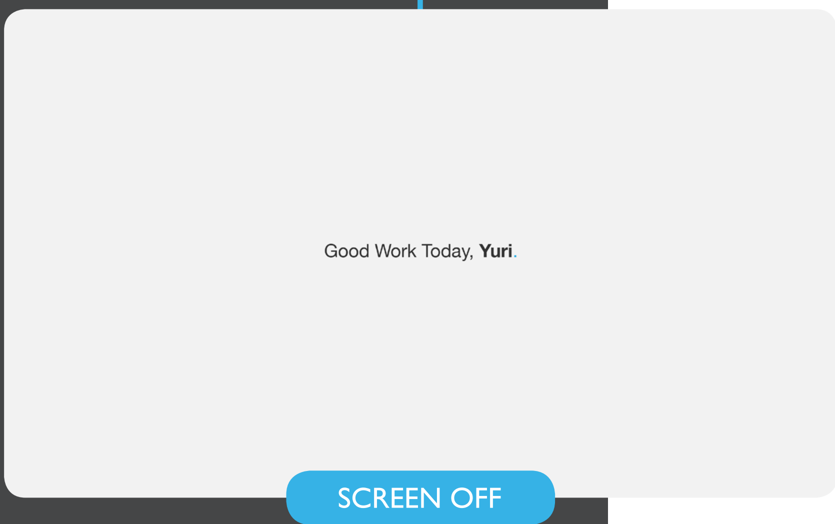
USER INTERACTION
| Press DONE



17 **SCANNING** SCREEN III

The Virtual Assistant communicates that the dataset was exported successfully. The user can now decide to setup a new scan, interact with the results, or logout.

USER INTERACTION
| Press the LOGOUT ICON



18 **GOODBYE** SCREEN

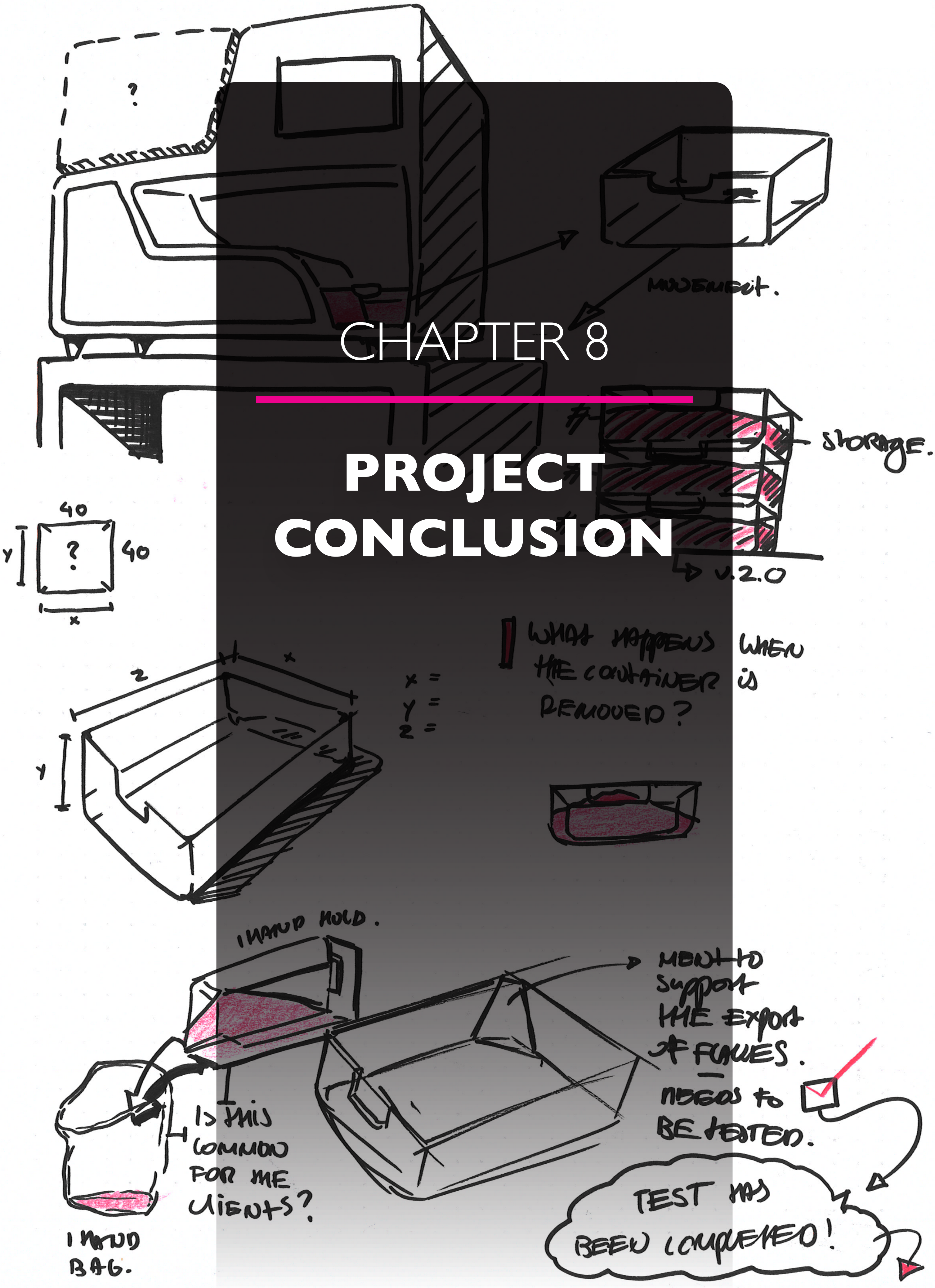
The Virtual Assistant greets the user, provoking the assistant-like user experience.

USER INTERACTION
None

The final step towards concluding this thesis report was to reflect upon the design to determine if the design brief had been met during the internship. This reflection and recommendations are presented in the next chapter.

CHAPTER 8

PROJECT CONCLUSION



TO DESIGN AN **EFFICIENT** AND **INTUITIVE INTERACTION**[1] THAT ENABLES **ANYONE**[2] TO **CORRECTLY OPERATE**[3] THE VIRTUAL CHEMIST, AND PROVOKE AN **ASSISTANT-LIKE USER EXPERIENCE**[4].

8.1 EFFICIENT AND INTUITIVE INTERACTION

The newly designed workflow and the introduction of the Virtual Assistant have enabled the completion of the workflow to be highly efficient and intuitive. Further improvement could be achieved, but as this was not included for this project's scope and it can be concluded that the Virtual Chemist has been designed to be efficient and intuitive.

8.2 ANYONE

During the user test it was already observed that, even without prior knowledge, it is possible to complete the workflow through the assistance of the Virtual Assistant. However, further testing on a higher level of fidelity is required to determine if anyone can operate the Virtual Chemist.

8.3 CORRECTLY OPERATE

The user interface was designed in such a way, that the workflow is completed correctly each time. Which was also validated through the user test.

8.4 ASSISTANT-LIKE USER EXPERIENCE

The experience of the Virtual Assistant was not validated during this project, as it requires a higher fidelity prototype.

CHAPTER 8.1 | LIST OF RECOMMENDATIONS

The following recommendations are based on the reflection results that have been presented throughout the report.

- **The Virtual chemist's weight (>100kg) needs to be addressed**, as it currently requires at-least three individuals to transport.

- **The Volumetric Feeder should be able to be closed** after usage to ensure that the internal sub-systems are not contaminated.

- **The current container interaction will lead to a stress injury and must be addressed,** by redesigning the interaction with this sub-system.

- **The scanned samples should be stored,** enabling clients to keep track of a data base/ scan evidence.

- **The product aesthetics should be revised** in order to communicate a further developed look and feel that matches the expectation for an expensive composition analysis tool.

- **Emptying the container after each scan should be addressed further,** which will increase workflow efficiency and prevent the development of a RSI.

CHAPTER 9

REFERENCES

(Thompson et al, 2009) Thompson et al.. 2009. Our Plastic Age. Philosophical Transactions of the Royal Society B: Biological Sciences. [Online]. 364(1526), 1973-1976. [15 August 2018]. Available from: http://rstb.royalsocietypublishing.org/content/364/1526/1973

(Geyer, Jambeck & Law, 2017) Geyer, R, Jambeck, J.R & Law, K.L. 2017. Production, use, and fate of all plastics ever made. Science Advances. [Online]. 3(7). [15 August 2018]. Available from: http://advances.sciencemag.org/content/3/7/e1700782.full

(EllenMacArthurFoundation, 2016) World Economic Forum, Ellen Macarthur Foundation & Mckinsey & Company (2016). The New Plastic Economy, Rethinking The Future of Plastics. [Online]. [15 August 2018]. Available from: https://www.ellenmacarthurfoundation.org/assets/downloads/EllenMacArthurFoundation_TheNewPlasticsEconomy_Pages.pdf

(Wilcox, Sebille & Hardesty, 2015)
nWilcox, S, Sebille, E & Hardesty, B.D. 2015 . Threat of plastic pollution to seabirds is global, pervasive, and increasing. PNAS. [Online].112(38), 11899-11904. [12 September 2018]. Available from: http://www.pnas.org/content/pnas/112/38/11899.full.pdf

(Henn, 2017)
Henn, C. 2017. These 5 Marine Animals Are Dying Because of Our Plastic Trash Here's How We Can Help. 5 February 2017. One Green Planet. [Online]. [12 September 2018]. Available from: http://www.onegreenplanet.org/animalsandnature/marine-animals-are-dying-because-of-our-plastic-trash/

(Verma et al, 2016)
Verma et al.. 2016. Toxic Pollutants from Plastic Waste. Procedia Environmental Sciences. [Online]. 35(2016), 701-708. [08 September 2018]. Available from: https://ac.els-cdn.com/S187802961630158X/1-s2.0-S187802961630158X-main.pdf?_tid=1783e2c0-3008-4bd9-887f-28d24b4ee277&acdnat=1537448162_cabead869b2e6e5cd0aec69bd2bc6eeb

(Blastic, 2018)
Blastic. 2018. Toxicity of plastics. [Online]. [08 September 2018]. Available from: https://www.blastic.eu/knowledge-bank/impacts/toxicity-plastics/

(1bagatatime, 2018)
1bagatatime. 2018. Plastic Bag Clean Up Costs. no-date. 1 Bag at a Time. [Online]. [08 September 2018]. Available from: https://1bagatatime.com/learn/plastic-bag-clean-costs/

(Knapton, 2017)
Knapton, S. 2017. The Telegraph. [Online]. [07 September 2018]. Available from: https://www.telegraph.co.uk/science/2017/03/20/paradise-lost-hotels-bury-waste-sand-keep-tourists-happy/

(Rinkesh, 2015) Rinkesh. 2015. Causes, Effects and Solutions of Plastic Pollution. 1 November. Conserve Energy Future. [Online]. [05 September 2018]. Available from: https://www.conserve-energy-future.com/causes-effects-solutions-of-plastic-pollution.php

(Bellware, 2016) Bellware, K. 2016. Global Water Shortage Risk Is Worse Than Scientists Thought. 15 February. HuffPost. [Online]. [08 September 2018]. Available from: https://www.huffingtonpost.com/entry/water-scarcity-study_us_56c1ebc5e4b0b40245c72f5e

(ASTM International, 2014) ASTM international. 2014. Standard Practice for Coding Plastic Manufactured Articles for Resin Identification. [Online]. [15 August 2018]. Available from: https://compass.astm.org/download/D7611D7611M.10061.pdf

(Modorplastics, 2017) Modorplastics. 2017. Thermoset vs Thermoplastics. [Online]. [22 June 2018]. Available from: https://www.modorplastics.com/plastics-learning-center/thermoset-vs-thermoplastics/

(Luijsterburg, 2015) Luijsterburg, B. J. (2015). Mechanical recycling of plastic packaging waste Eindhoven: Technische Universiteit Eindhoven DOI: 10.6100/IR783771

(Lohse, 2000) Lohse, D.J. 2000. POLYOLEFINS. Applied Polymer Science: 21st Century. [Online]. NA(2000), 73-91. [18 July 2018]. Available from: https://doi.org/10.1016/B978-008043417-9/50008-8

(Plastics Europe, 2018) Plastics Europe. 2018. An analysis of European plastics production, demand and waste data. [Online]. [22 July 2018]. Available from: https://www.plasticseurope.org/application/files/5715/1717/4180/Plastics_the_facts_2017_FINAL_for_website_one_page.pdf

(Hopewell, Dvorak & Kosior, 2009) Hopewell, J, Dvorak, R & Kosior, E. 2009. Plastics recycling: challenges and opportunities. Philos Trans R Soc Lond B Biol Sci. [Online].364(1526), 2115–2126. [08 June 2018]. Available from: http://rstb.royalsocietypublishing.org/content/364/1526/2115

(GRID-Arendal, 2017) GRID-Arendal. 2017. The trade in plastic waste. [Online]. [11 June 2018]. Available from: https://grid-arendal.maps.arcgis.com/apps/Cascade/index.html?appid=002738ffb18548818a61cc88161ac464

(European Commission, 2018) European Commission. 2018. A European strategy for plastics in a circular economy. [Online]. [08 June 2018]. Available from: http://ec.europa.eu/environment/circular-economy/pdf/plastics-strategy-brochure.pdf

(European Commission, 2011) European commission. 2011. Plastic waste in the environment. [Online]. [19 May 2018]. Available from: http://ec.europa.eu/environment/waste/studies/pdf/plastics.pdf

(CEWEP, 2017) Confederation of European Waste-to-Energy Plants (CEWEP). 2017. Landfill taxes and bans. [Online]. [22 June 2018]. Available from: http://www.cewep.eu/wp-content/uploads/2017/12/Landfill-taxes-and-bans-overview.pdf

(One World, 2014) One World. 2014. Wat gebeurt er met plastic afval?. 25 September. Journalistiek voor een eerlijke en duurzame wereld. [Online]. [19 April 2018]. Available from: https://www.oneworld.nl/achtergrond/wat-gebeurt-met-plastic-afval/

(Babich, 2018) Babich, N. 2018. 3 Common Ways To Use Illustrations in UI Design. 28 June 2018. UX Planet. [Online]. [26 July 2018]. Available from: https://uxplanet.org/3-common-ways-to-use-illustrations-in-ui-design-864d4dfadd5

(Nielsen, 1993) Nielsen, J. 1993. Response Time Limits. 1st January. Nielsen Norman Group. [Online]. [19 July 2018]. Available from: https://www.nngroup.com/articles/response-times-3-important-limits/

(Neil & Andrady, 2009) Neil, M.A. & Andrady, A.L. 2009. Applications and societal benefits of plastics. Philosophical Transactions B. [Online]. 364(1526), 1977-1984. [13 May 2018]. Available from: http://dx.doi.org/10.1098/rstb.2008.0304

(DINED, 2018) DINED. 2018. dined.io.tudelft.nl. [Online]. [24 Augustus 2018]. Available from: https://dined.io.tudelft.nl/en/reach-envelopes/tool

(CCOHS, 2018) CCOHS. 2018. www.ccohs.ca. [Online]. [26 August 2018]. Available from: https://www.ccohs.ca/oshanswers/ergonomics/standing/standing_basic.html

FIGURES

(B+B, 2018) B+B. PET-hot-washer [Current product aesthetics, a hot wash device used for PET.]. Retrieved May 13, 2018, from http://www.bub-anlagenbau.de/products/washing/pet-hot-washer/#&gid=1&pid=1

(Recycling magazine, 2018) Recycling magazine. 2018. Recycling-magazinecom. [Online]. [17 September 2018]. Available from: https://www.recycling-magazine.com/wp-content/uploads/2016/06/Abb-1-Anlagenbild-kl.jpg

(All county recycling, 2018) All county recycling. 2018. Allcountyrecyclingcom. [Online]. [03 May 2018]. Available from: http://www.allcountyrecycling.com/images/slider/banner1.jpg

(DS Smith, 2018) DS Smith. 2018. Dssmithcom. [Online].
[23 Oktober 2018]. Available from: https://www.dssmith.com/contentassets/781bef495220471fbfd5d56a0ea493c3/037_dssmith-46.jpg

(Clean Malaysia) Clean Malaysia. 2018. Cleanmalaysiacom. [Online]. [2 Oktober 2018]. Available from: https://cleanmalaysia.com/2017/01/09/littering-waste-threats-health-environment/

(Ocean, 2018) Ocean. 2018. Oceansiedu. [Online]. [6 June 2018]. Available from: http://ocean.si.edu/ocean-life/seabirds/laysan-albatrosses-plastic-problem

(National Geographic, 2018) National geographic. 2018. Nationalgeographiccom. [Online]. [6 June 2018]. Available from: https://www.nationalgeographic.com/magazine/2018/06/plastic-planet-waste-pollution-trash-crisis/

(UX Planet, 2017) UX planet. 2017. UX Planet. [Online]. [6 June 2018]. Available from: https://uxplanet.org/f-shaped-pattern-for-reading-content-80af79cd3394

(DINED, 2018) TU delft. 2018. Tudelftnl. [Online]. [6 June 2018]. Available from: https://dined.io.tudelft.nl/en/database/tool