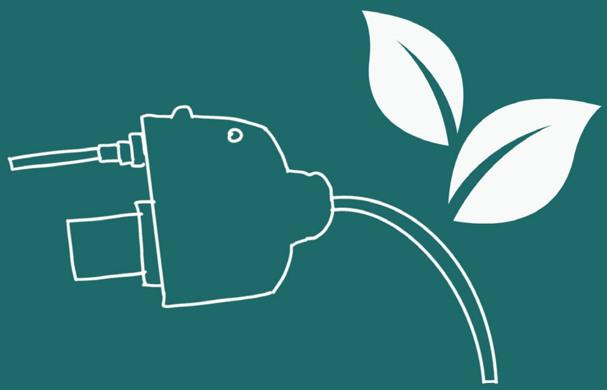
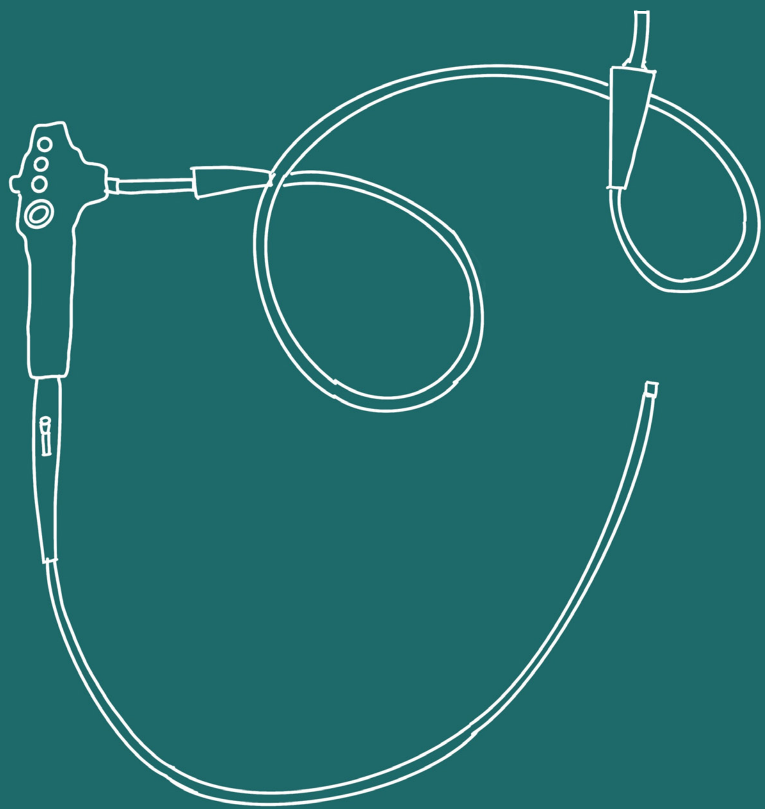


Towards Greener Colonoscopy

Identifying and Addressing Environmental Impact Hotspots



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MSc Thesis Integrated Product Design
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Industrial Design Engineering

Towards Greener Colonoscopy:
Identifying and Addressing Environmental Impact Hotspots

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Acknowledgments

Dear reader,

I would like to express my gratitude to all who have supported and contributed to the completion of this thesis.

First and foremost, I would like to thank my supervisors at the TU Delft. Thank you JC and Tamara for thinking along with me during the meetings. I felt a great support by you, which motivated me to bring out my best.

Thank you JC, for helping me think ahead about the project. Your future-oriented and enthusiastic mindset was a great influence. Thank you Tamara, for always being available when I needed feedback. Your feedback on the report was invaluable on the establishment of this thesis.

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And last but not least, I want to thank my parents and brother for always believing in me. Your unwavering support and encouragement have always made me believe that I can accomplish anything I set my mind to. To my lovely friends, thank you for motivating me in my studies while also enjoying life with me!

This graduation project marks the end off my student life in Delft. But as one chapter closes, another begins. Up to many more hopeful, peaceful, grateful chapters in life.

Ps. I hope this thesis, inspires and reminds you to be careful about your own environmental impact.

All to improve sustainability,

Ceyda Izci

Table of Contents

Section 1

Section 2

Section 3

Section 4

Abbreviations

EMC: Erasmus Medical Center
Ch. : Chapter
LCA: Life Cycle Analysis
HCP: Healthcare Professional
PJM: Product Journey Map

Glossary

Medical terms

(colonoscopy) Accesoires - tools used during a colonosopy procedure to assist with various tasks.

Biopsies - a sample of issue taken from the body to examine it more closely.

Biopsy Forceps - these are used to obtain tissue samples.

Colonoscope - a long flexible medical device with a camera on one end, used during a colonoscopy procedure.

Colonoscopy procedure - a procedure that is performed in the endoscopy department to examine the inside of the rectum and colon.

Endoscopist - medical doctor specialized in performing endoscopic (colonoscopy) procedures to examine and treat the inside of the body.

Endoscopy department - a hospital department where procedures are performed to look inside the body. There are different types of endoscopy procedures to examine various internal parts of the body.

HiX system - a digital platform used in the healthcare system to store information

Polyps - small clumps of cells inside the colon that can develop into colon cancer.

Sustainability terms

Co-creation - a collaborative process where multiple stakeholders work together to create value and develop new ideas.

Environmental impact hotspot - an area in the procedure or product that has a significant impact on the environment.

Reprocessing - cleaning products so that they can be used again.

Reuse - using a product again for the same purpose, rather than disposing of it.

Single-use - products that are designed to be used once and then discarded.

Sustainability - meeting current environmental, social end economic needs without compromising the ability of future generations to meet their needs.

Sustainable intervention - an action or strategy designed to reduce the

Executive Summary

The healthcare sector in the Netherlands is responsible for about 7% of the CO_2 emissions. The EMC has committed to enhancing its environmental sustainability efforts by signing the Green Deal 3.0. This agreement sets ambitious targets for the EMC, including a 55% reduction in CO_2 emissions by 2030 compared to the 2018 *Green Deal Samen Werken Aan Duurzame Zorg (Green Deal 3.0) | Greendeals*, n.d.). These targets are ambitious and call for immediate action.

The endoscopy department is found as the third highest largest contributor to hospital waste (Siau et al., 2021). This highlights the importance of improving the sustainability of the endoscopy department to meet the set targets.

This project set three main goals:

- Creating an overview of all the consumables within the workflow of HCPs used in colonoscopy procedures.
- Identifying and addressing the environmental impact hotspots of colonoscopy procedures.
- Enhancing the sustainability of the reusable colonoscope with a redesign.

To achieve the first goal, the Product Journey Map method is used. Data on waste streams and the human interactions during the use of the colonoscope are gathered through observations and interviews conducted at the endoscopy department at the EMC.

After visualizing the Product Journey of the colonoscope in the EMC, it was easier to identify the environmental impact hotspots. The Value Hill model with the R-strategies was used to design sustainable interventions, to reduce the environmental impact of the hotspots. The identification of the environmental impact hotspots and the design of sustainable interventions are also carried out in a co-creation session with HCPs. Mapping out the colonoscopy procedure in a visual, including waste streams and human interactions, accelerated the ideation process with HCPs.

Furthermore, the focus of this project was on redesigning the colonoscope to enhance its sustainability. To achieve this, the literature was first explored to compare single-use with reusable colonoscopes. It became clear that implementing single-use colonoscopes would result in a 40% increase in net waste mass compared to reusable colonoscopes (Baddeley et al., 2022). However, one of the advantages of single-use colonoscopes was that they were easy to use. This was as an inspiration for the redesign of the reusable colonoscope which detects maintenance on time and prevents the damage that can occur during the use of it.

Finally, all the designed sustainable interventions and the redesign of the colonoscope are compiled into a revised Product Journey map. This revised PJM compares the new ideas with the practices, illustrating how the environmental impact of colonoscopy procedures can be reduced.

Figure retrieved from Freepik (Premium Vector | Team Of Physicians Performs Colonoscopy, Diagnostics Of The Intestine. Bowel Health. Tiny Medical Doctors Examining Gastrointestinal Tract And Digestive System. Gut Microorganisms And Friendly Flora, 2021)

01
Project Introduction

This chapter provides an introduction to the graduation project. It starts with an explanation of the project's background in section 1.1. After, section 1.2 outlines the problem that initiated this graduation project. Section 1.3 presents the project approach, providing an overview of its various phases. Finally, section 1.4 elaborates on the circular design strategies implemented throughout the project.

1.1 Background

Green deal 3.0

The healthcare sector helps prevent diseases and improves our quality of life. In the Netherlands, the healthcare sector is also responsible for about 7% of CO2 emissions. Additionally, 4% of the waste and 13% of the resource consumption in the Netherlands are generated by the healthcare sector. Therefore, the healthcare sector is working on 'sustainable care' in the Green Deal. This Green Deal aims to reduce CO2 emissions and environmental impact, with a focus on the reuse of resources and materials (Green Deal Samen Werken Aan Duurzame Zorg (Green Deal 3.0) | Greendeals, n.d.).

EMC sustainability goals

The EMC has committed to enhancing its environmental sustainability efforts by signing the Green Deal 3.0 ("Joke Boonstra Tekent Green Deal 3.0 Namens Universitaire Medische Centra," 2023). This agreement sets ambitious targets for the EMC: including a 55% reduction in CO2 emissions by 2030 compared to 2018. This means that in 2026, the EMC already needs to reduce 30% of its CO2 emissions. The long-term goal for 2050 is to be a climate-neutral hospital.
In addition to targeting CO2 emissions, the EMC aims to reduce raw materials usage by 50% by 2030. This includes ensuring that at least 20% of all medical devices and accessories are reusable by 2026.
Beyond the quantitative targets, Green Deal 3.0 also focuses on raising awareness among EMC employees and patients about sustainability. This educational component is essential for creating a culture of environmentally responsible healthcare professionals throughout the hospital.

Green teams

Several Green Teams have been set up in the EMC. Each green team consist of approximately four to eight colleagues who are self-directed and use concrete, accessible initiatives to kick-start sustainability locally within their department, group, or sector (Erasmus MC, n.d.).
The endoscopy department at the EMC also has a Green Team, composed of healthcare professionals who volunteer their time to improve the department's sustainability.

Convergence ZEE

This graduation project was part of the ZEE project.
The ZEE Consortium is a collaboration with three institutes: Erasmus MC, TU Delft and EUR, through the Zero Emissions Endoscopy (ZEE) project they aim to analyse the flow of materials from the endoscopy department and develop interventions that enhance sustainability ("Erasmus MC Invests in Sustainable Healthcare," 2023)

Figure 1.1: Logo of the ZEE consortium

1.2 Problem

In the previous Section 1.1, the Green Deal that EMC has agreed to was discussed, along with the additional targets they have set to improve the hospital's sustainability. These targets are ambitious and call for immediate action.

Therefore, this graduation project focuses on improving the sustainability of the endoscopy department, which is often identified as the third largest contributor to hospital waste (Siau et al., 2021). This also implies that implementing sustainable interventions in the endoscopy department can significantly reduce EMC's environmental impact.

In this project, one of the research goals was to identify and address environmental impact hotspots at the endoscopy department at the EMC. While Life Cycle Assessments (LCA) are often used to identify these hotspots, they should not be the sole method employed.

To effectively improve sustainability in the healthcare sector, it is crucial to adopt a human-centred approach. Especially, when healthcare professionals are involved in sustainability efforts, it is important that they can easily understand the issues and reflect on their own practices. This will encourage them to take action to reduce the environmental impact of their own department.

Additionally, it is important to not only focus on the sustainability of the department but also on the products used within it, such as the colonoscope. The interest in single-use colonoscopes are rising (Siau et al., 2021), but they have a huge environmental impact compared to reusable colonoscopes. Therefore, it is only more important to highlight and improve the reusable the colonoscope.

1.3 Project Approach

A previous graduate student from the IDE Faculty at TU Delft conducted a waste audit on the colonoscopy procedures at EMC (Clercx Lao, 2024). Since colonoscopy is one of the most frequently performed endoscopy procedures at EMC and to build upon the work of the previous graduate student, this project also focuses on colonoscopy procedures in the endoscopy department.

This project has several main goals:

- Creating an overview of all the consumables within the workflow of HCPs used in colonoscopy procedures.
- Identifying and addressing the environmental impact hotspots of colonoscopy procedures.
- Enhancing the sustainability of the reusable colonoscope with a redesign.

This thesis is structured according to the Double Diamond Process, as shown in Figure 1.2. It involves diverging to explore broad areas and then converging to focus on more specific areas. This cycle is repeated twice, to form a double diamond (Design Council, z.d.).

- In the **discover phase** (section 1) the focus was on the introduction of the project, to gain a better understanding of the colonoscopy procedures and their associated sustainability issues.
- In the **define phase** (section 2) the focus was on identifying environmental impact hotspots through the PJM and designing sustainable interventions to enhance the sustainability of the endoscopy department.
- In the **develop phase** (section 3) the focus was on exploring the literature on single-use and reusable colonoscopes and redesigning the reusable colonoscope to improve its sustainability.
- In the **deliver phase (**section 4) the focus was on combining the designed sustainable interventions in section 2 with the redesign of the colonoscope from section 3 in a revised PJM, and concluding the report.

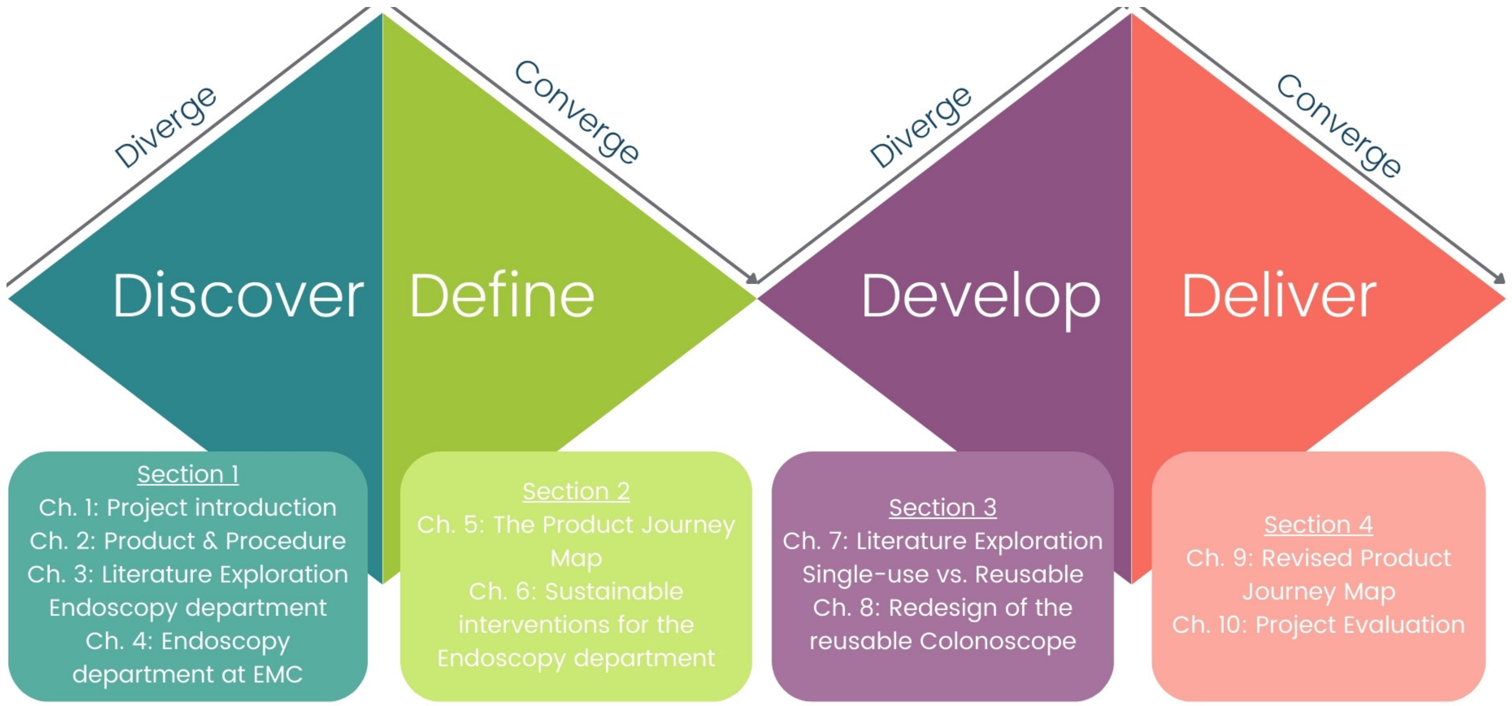

Figure 1.2: Implementation of the Double Diamond in the project

1.4 Circular Design Strategies for Healthcare

Two sustainability methods are used throughout this graduation project to design circular solutions within the healthcare context. Section 1.4.1 explains the Product Journey Map method, which is used to map out the colonoscopy procedures at the EMC, including the waste streams and human interaction. Section 1.4.2 describes The Value Hill model, which is used to categorize the environmental impact hotspots and design suitable interventions to improve the department's sustainability.

1.4.1 The Product Journey Map

The Product Journey Map is a method for visualizing the life cycle of a product to identify environmental impact hotspots and enhance the product's sustainability. Since the PJM is a relatively new method, it has not been validated extensively. This allows for easier adaptation of the method to specific use cases. There are various ways to visualize the PJM. For example, see Figure 1.3 for the visualization of the PJM in the Delft Design Guide (Van Boeijen et al., 2014). Recently, a former master's student from the TU Delft created a new version of the PJM based on the existing method, see Figure 1.4 (Kooijman, 2021).

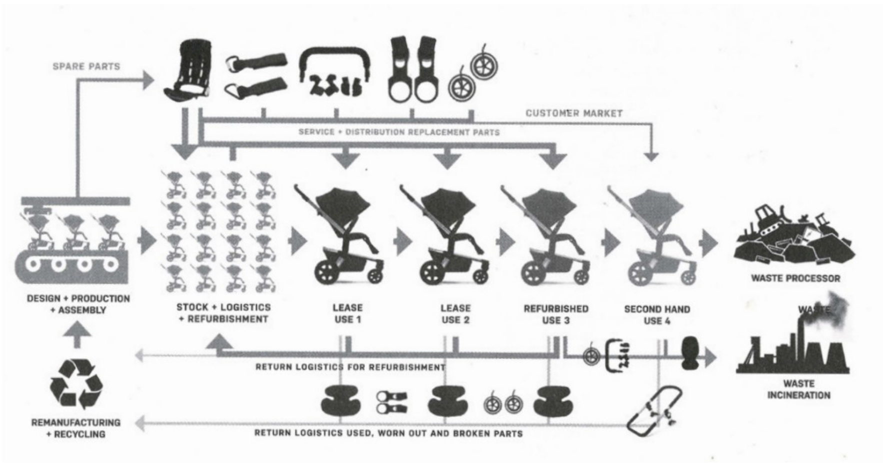

Figure 1.3: The PJM from the Delft Desing Guide (Van Boeijen et al.,

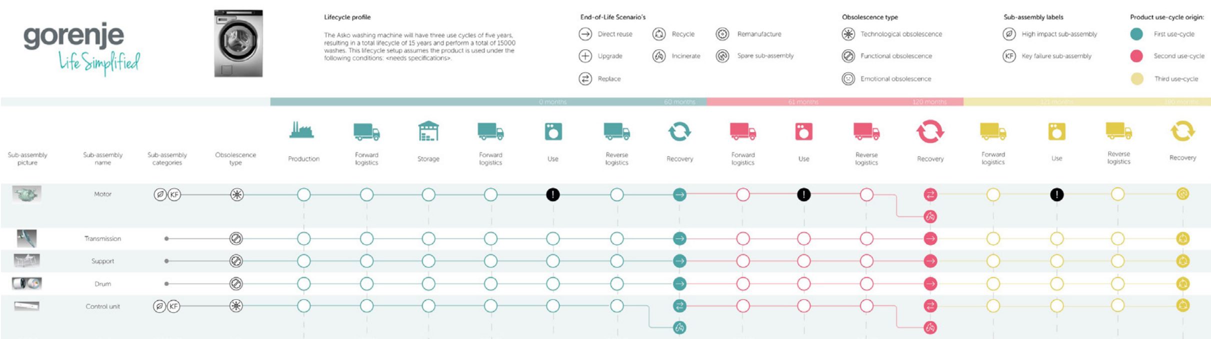

Figure 1.4: The PJM from F. Kooijman's Master thesis (Kooijman, 2021)

As shown in both PJMs in Figure 1.3 and Figure 1.4, the focus was on the entire lifecycle of the product. However, this thesis primarily focuses on the product's use within the EMC, see Figure 1.5, as the aim is to identify and address environmental impact hotspots in the endoscopy department at the EMC.

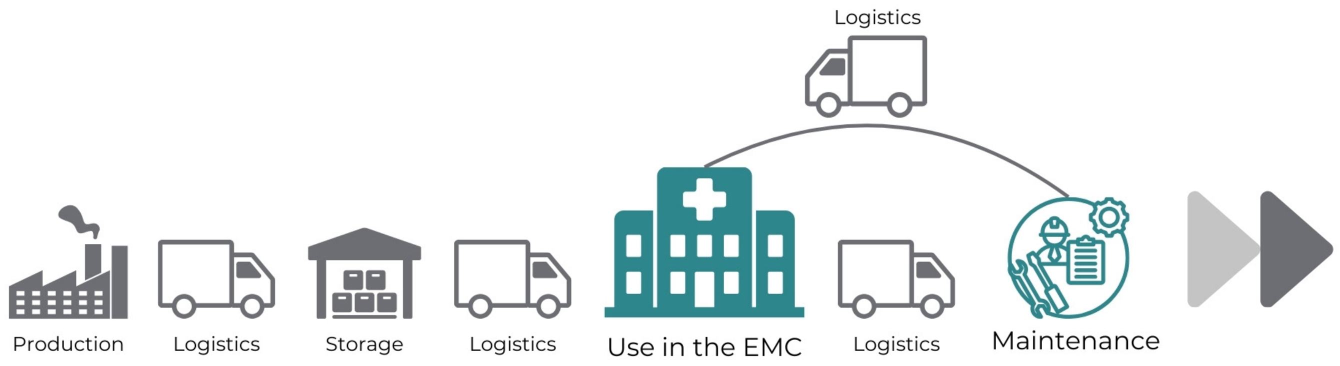

Figure 1.5: Blue icons indicate the focused stages of the product's lifecycle in this project

Zooming in to the use case of the product in the department, made it easier to include more details of the procedures. Therefore, different waste streams were mapped out, including the human interactions with each step of the product in the EMC. More about the PJM can be found in Chapter 5.

1.4.2 The Value Hill Model

The Value Hill model illustrates how R-strategies can be used to increase the circularity of a product system, as shown in Figure 1.6.

This method is used to design suitable interventions to reduce the environmental impact of the endoscopy department at the EMC. The designed solutions are explained in Chapter 6.1.

The higher loop strategies are used to eliminate waste early in the design process.

- **Refuse:** Make the product redundant by abandoning its function or by offering the same function with a radically different product.
- **Rethink:** Make the product be used more intensively.
- **Reduce:** Increase efficiency in product manufacture or use by consuming fewer natural sources and materials.

The medium loop strategies are applied to extend the lifespan of the product's lifecycle.

- **Reuse:** Reuse by another consumer of discarded product which is still in good condition and fulfils its original function. In healthcare, products could be reused by sterilization or disinfection.
- **Repair:** Repair and maintenance of defective product so it can be used again.
- **Refurbish:** Restore an old product and bring it up to date.
- **Remanufacture:** Use parts of discarded products in a new product with the same function.
- **Repurpose:** Use discarded product or its parts in a new product with a different function.

The lowest loop strategies focus on the recovery of the materials to be recycled.

- **Recycle:** Process materials to obtain the same (high grade) or lower (low grade) quality.
- **Recovery:** Incineration of material with energy recovery.

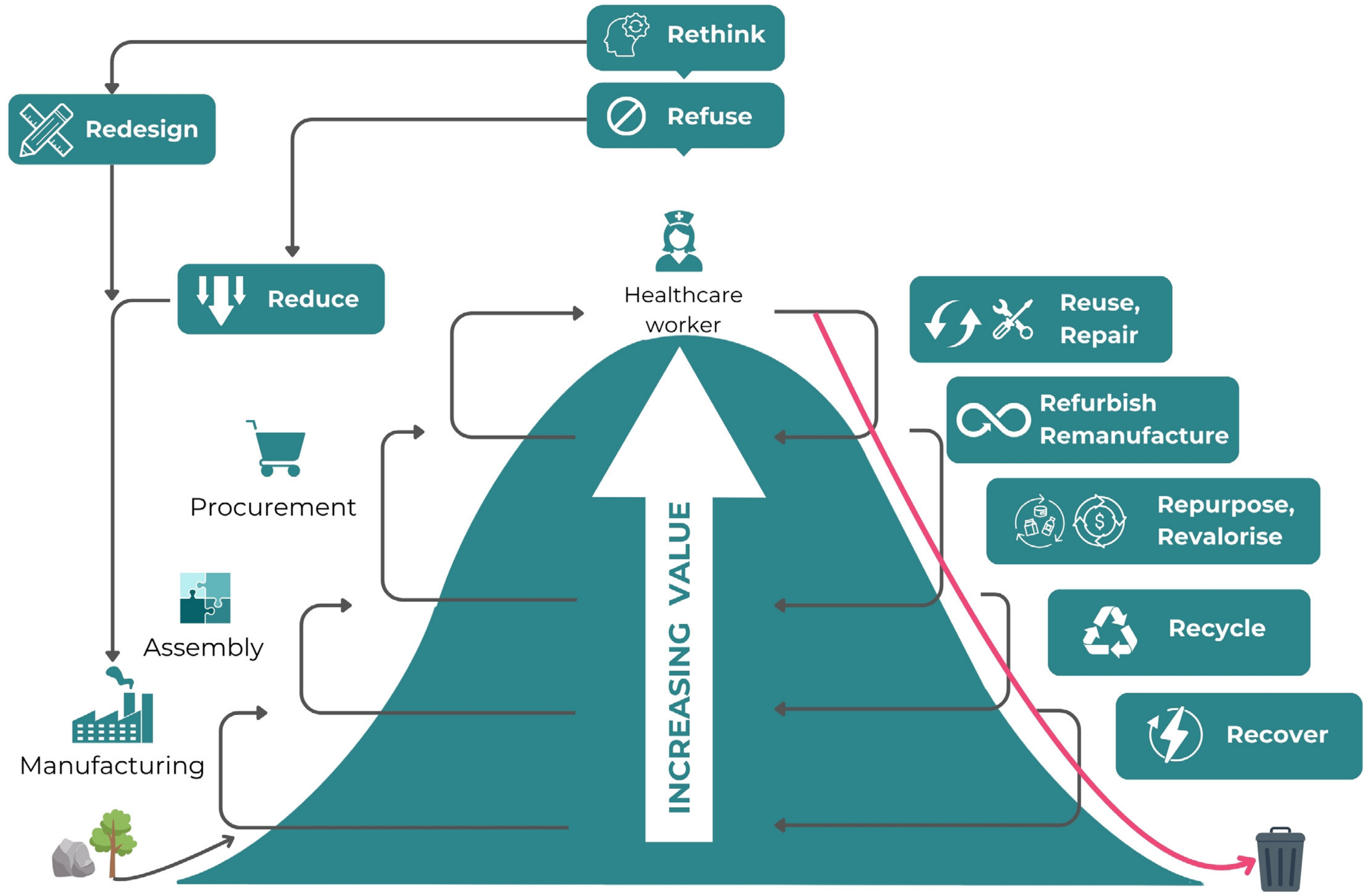

Figure 1.6: The Value Hill model (Metabolic, 2021)

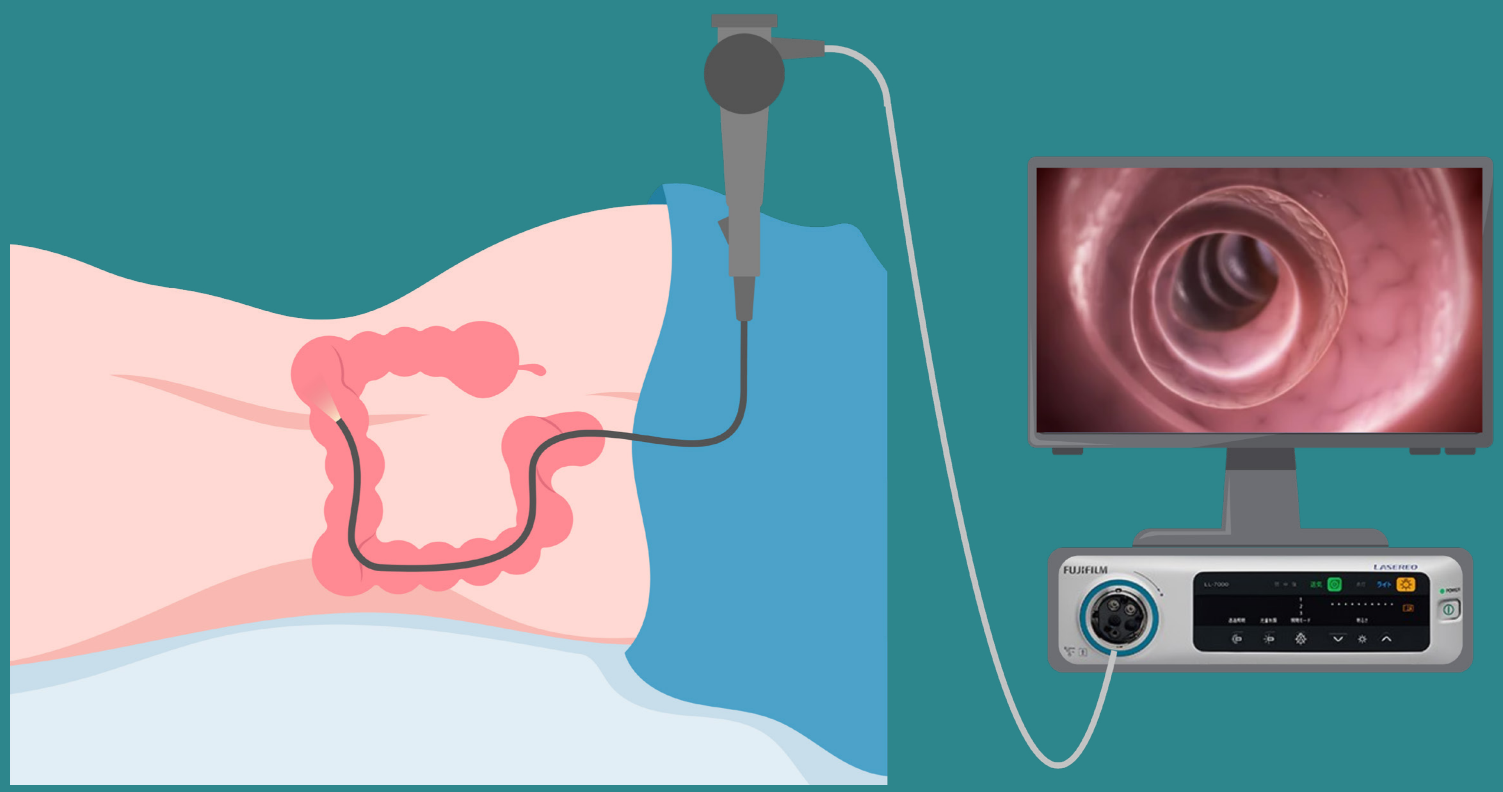

Figure 2.1: Simplified picture of a colonoscopy procedure

02
Product & Procedure

The colonoscope is a medical device that is used to look inside the body by inserting it through the anus, as shown in Figure 2.1. Colonoscopy allows doctors to observe the interior surfaces of the colon without having to make large incisions (Achord & Muthusamy, 2019). Colonoscopes are used for diagnostic purposes but can also be used for therapeutic purposes such as removing polyps and taking biopsies.
Section 2.1 provides an in-depth explanation of the reasons and the method for colonoscopy procedures. Subsequently, Section 2.2, provides a detailed description of the colonoscope's product characteristics.

2.1 Procedure

Healthcare pathway

The EMC performed 4500 gastroscopies and 2500 colonoscopies in 2023. These patients have different healthcare pathways, that lead them to the EMC.

In 2014 the national colorectal cancer screening program was introduced for people between the ages of 55 and 75 in the Netherlands. This screening program increases the chance of an early phase detection of colorectal cancer and therefore prevents 2250 annual deaths (Facts And Figures, z.d.).

People in the age range are invited every 2 years to take a stool test and when the outcome of this test is positive, they are invited to undergo a colonoscopy procedure. As can be seen in Figure 2.2, this meant that around 62,000 people in the Netherlands went for a colonoscopy procedure in 2021. With the ageing population, this means that there will be a rise in the colonoscopy procedures as well as the environmental impact related to colonoscopy.

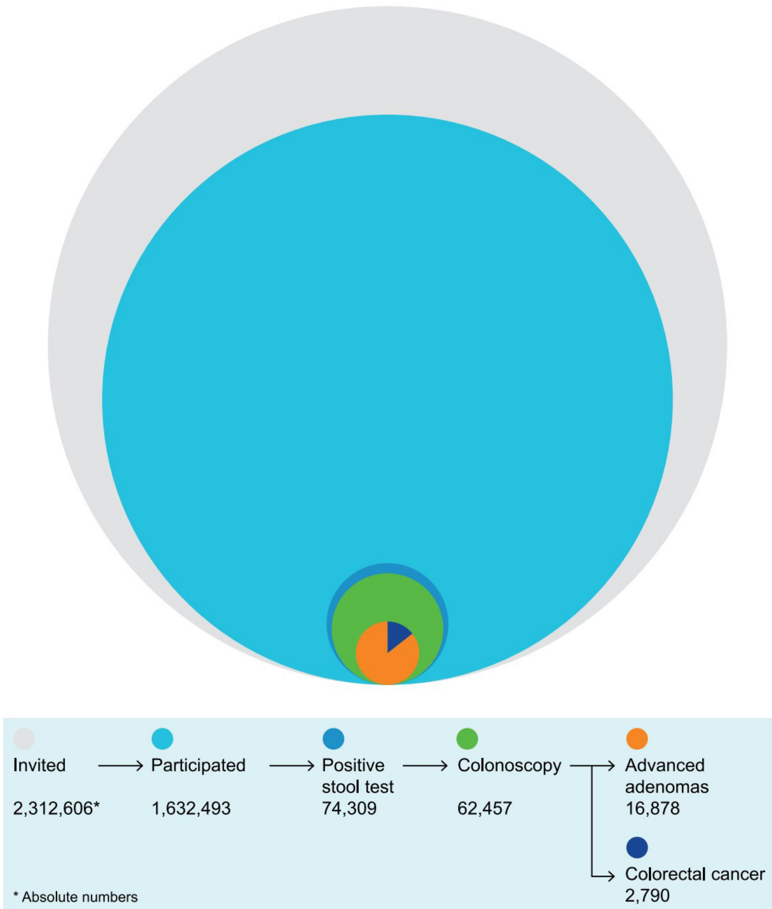

Figure 2.2: The scope of the colorectal cancer screening program in 2021. The number of participants in the various phases of the screening program is shown. (Ministerie van Volksgezondheid, Welzijn en Sport, 2023)

Next to the colorectal cancer screening program, there are also other reasons for performing colonoscopy procedures. These procedures may be recommended by a healthcare professional when a patient has one of the following symptoms, or in the case of an emergency (Department of Health & Human Services, z.d.) :

- Bleeding from the rectum;
- Blood in the stools;
- Pus or mucus in the stools;
- Unexplained abdominal pain;
- Changes in bowel habits such as unexplained and long-lasting diarrhea.

Figure 2.3: Different ways of patients visiting the EMC for a colonoscopy procedure

Colonoscopy Procedures

Understanding how colonoscopy procedures are performed is essential before addressing the sustainability issues. To illustrate the steps involved in these procedures, a storyboard has been created, as shown in Figure 2.4.

1. Before undergoing the actual colonoscopy procedure at the EMC, the patient must complete some preparatory steps. This includes drinking a solution that stimulates digestion. Additionally, the patients need to avoid eating for 24 hours before the procedure, ensuring that the large intestine is empty and the endoscopist has a clear view during the

2. When arriving at the EMC, the patient must wear a special underwear with a hole at the back so that the endoscopist can find their way easily to the anus.

3. The patient then lies on a bed in the recovery room and waits until the healthcare professionals are ready. When everything is prepared, a nurse will escort the patient from the waiting room to the procedure room.

4. The HCP will ask for the patient's information details. After, they will sedate the patient and insert the colonoscope through the anus.

5. Then the procedure begins. There will be at least three healthcare professionals in the room: the endoscopist, a nurse assisting the endoscopist, and a nurse comforting the patient. The endoscopist will examine the inside of the colon.

6. When a polyp is identified, the endoscopist will take a sample, called a biopsy, using a biopsy forceps. The sample is placed in a container and sent to the microbiologist for further identification and analysis of any disease.

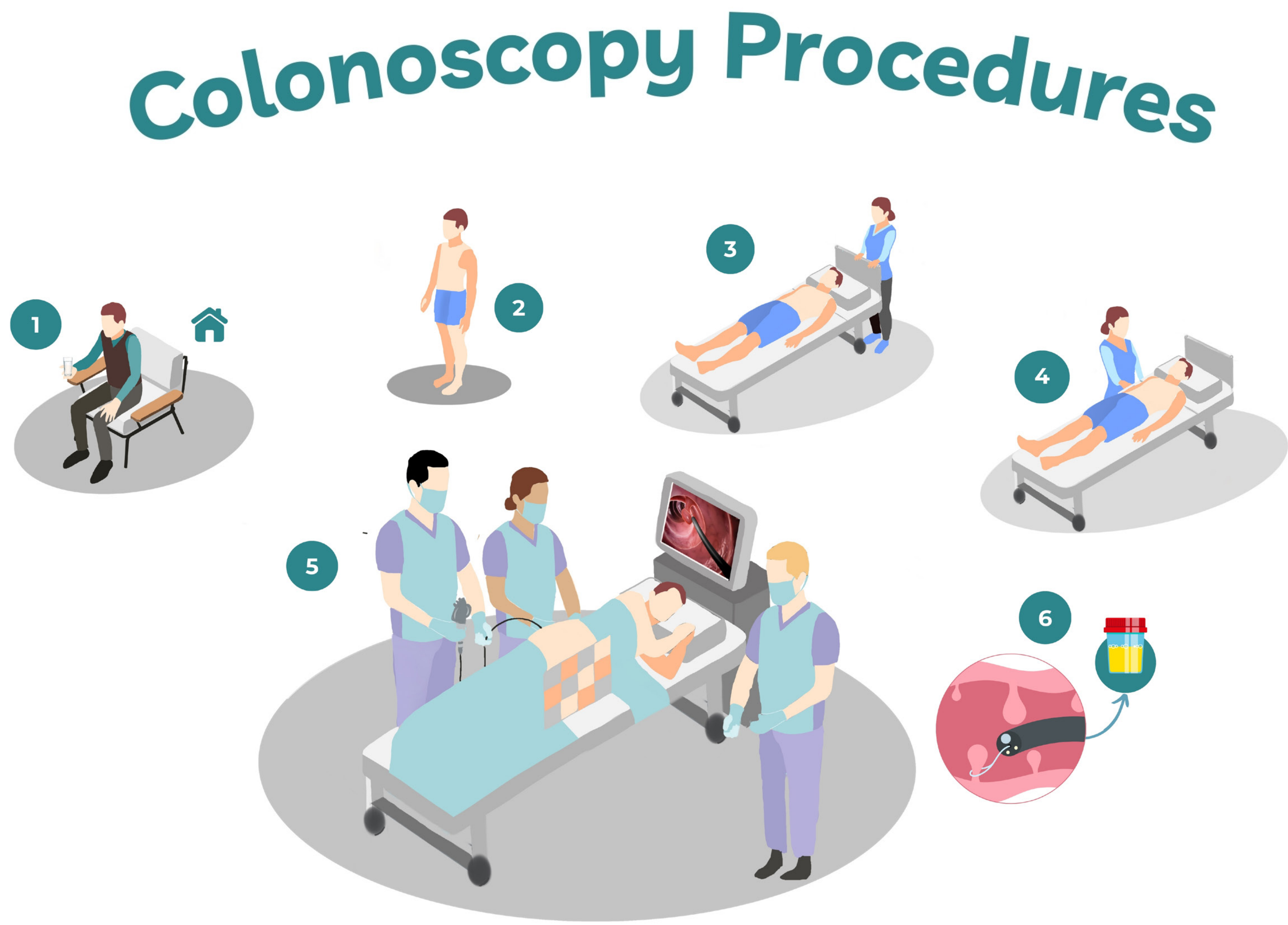

Figure 2.4: A storyboard of the colonoscopy procedure at the EMC

2.2 Product Characteristics & Functionalities

The colonoscope

The colonoscope can be divided into 3 main parts, see Figure 2.5:

- The control section: this part of the colonoscope is operated by the endoscopists.
- The insertion tube: this is the long and flexible part of the colonoscope which is inserted through the anus of the patient.
- The connector: this part serves as the interface between the colonoscope and external devices. It connects the colonoscope to the light source and the video processor.

The control section

The endoscopists can control different things at the control section of the colonoscope, see Figure 2.6:

- They can rotate the distal end up/down or left/right with the angulation control lever.
- They can insert forceps or other accessories in the working channel to collect biopsies, remove polyps or perform other therapeutic procedures.
- There are several buttons on the colonoscope to capture pictures or recordings and to change the settings of the camera in the endoscope.

The insertion tube

The insertion tube is the long and flexible tube part of the colonoscope that is inserted through the anus of a patient. The tube houses critical elements of the colonoscope such as the light guide, electrical wires, working channels to insert forceps or other accessories and, water- and CO_2 channels. All these elements have a very small diameter as the insertion tube has an outside diameter of 15 mm. The elements are protected with a wire band that is coated with rubber, see Figure 2.7. This has a smooth texture to minimize the patient's discomfort when inserting it into the body and it makes it easier to clean, as the chances will be lower that dirt sticks to it compared to a rough surface.

The connector

The connector part links the colonoscope with external devices that are placed in the procedure room like the light source and the video processor. The connector also includes ports for various cables that transmit power, data or fluids like CO_2 and water which are necessary for the procedure, see Figure 2.8.

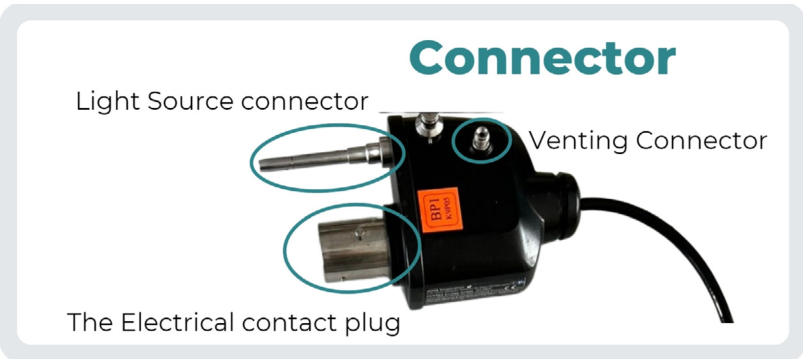

Figure 2.8: The connector of the colonoscope

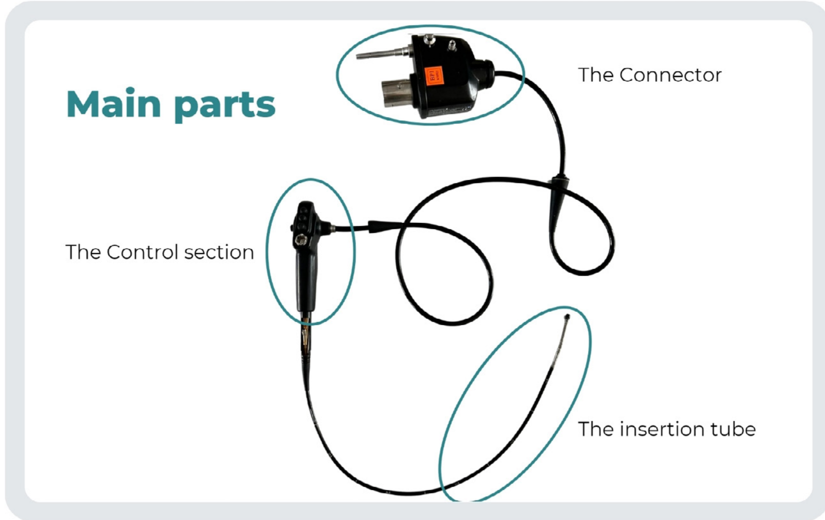

Figure 2.5: The main parts of the colonoscope

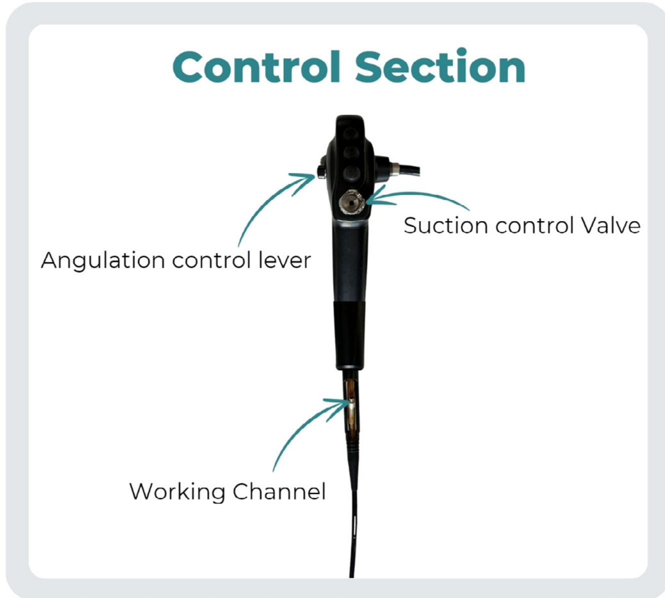

Figure 2.6: The control section of the colonscope

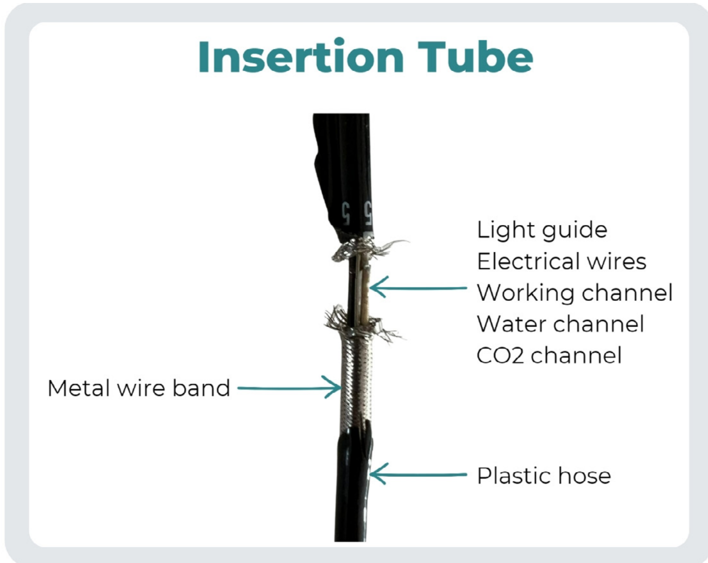

Figure 2.7: The inside view of the insertion tube

Equipment needed for colonoscopy

For the colonoscope to function effectively, several other equipment are essential in the procedure room, as shown in Figure 2.8:

- **The video processor** enhances and displays the images captured by the colonoscope's camera, allowing for clearer visualization.
- **The light source** provides the necessary illumination for the camera to capture clear images inside the body.
- **The monitor** displays the live recordings from the colonoscope's camera, enabling endoscopists to view the internal organs in real time.
- **The flushing pump** ensures there is sufficient water to clean the colonoscope's lens and to water jet the inside the organs, clarifying the viewing surface.
- **The CO_2 insufflator** delivers CO_2 into the patient's body to create more space for the colonoscope, this provides better visibility and more room to move the endoscope and other surgical instruments in the body. It is preferred to use CO_2 instead of air, as it is absorbed more quickly by the body. Therefore, it reduces the risk of gas-related complications after the procedure and minimizes patient discomfort.

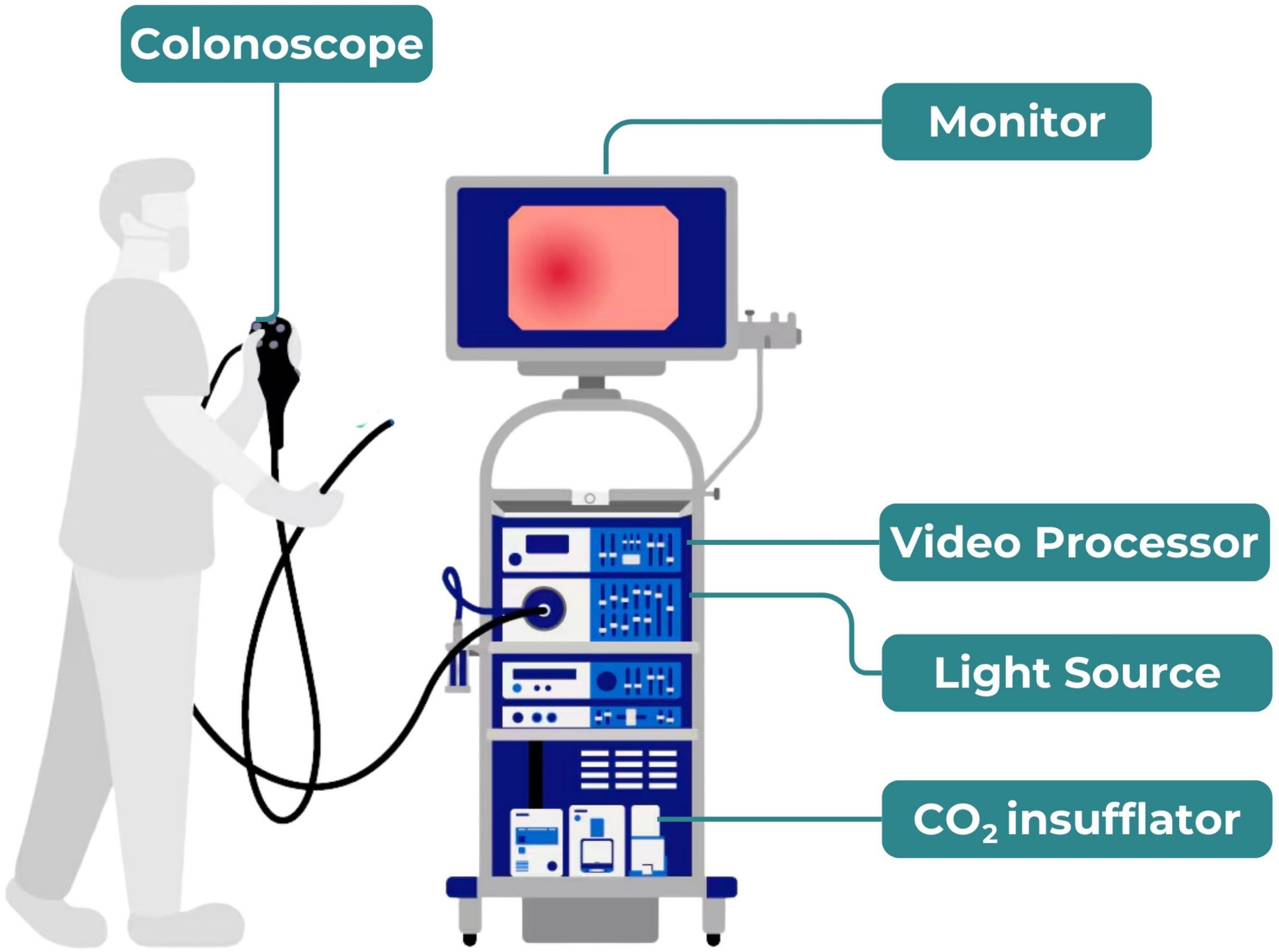

Figure 2.8: The set-up of an endoscope system (Picture of the colonoscope system retrieved: Let's Learn About Endoscopes : Olympus Kids Class : Social : Sustainability : OLYMPUS, n.d.)

03

Literature Exploration

Endoscopy Department

This chapter describes previous research efforts to identify factors contributing to **CO_2** emissions in the endoscopy department. It highlights the importance of using a multi-criteria method, as various variables influence the department's sustainability.

The third largest contibutor to hospital waste
Endoscopy happens to be a resource-intensive speciality as there are high throughput caseloads, repeated travel for patients and relatives, the usage of non-renewable waste streams like cleaning detergents and CO_2 for patient pain relief, single-use consumables, and resource-heavy decontamination process (Baddeley et al., 2022). It was estimated that endoscopy incurs the third highest burden of hospital waste, generating approximately 3.1 kg per bed day (Siau et al., 2021).

Multi-criteria method
As mentioned earlier, there are many different reasons why the endoscopy department is the third largest contributor to hospital waste. Therefore, it is important to use a multi-criteria method when analysing the waste streams in the endoscopy department. An ambulatory Gastrointestinal endoscopy (GIE) centre in France used this approach in a study of their department's waste streams. This study accounts for direct and indirect greenhouse gas emissions from energy consumption (gas and electricity), medical gases, medical and non-medical equipment, consumables, freight, travel, and waste (Lacroute et al., 2023). The results of this study are shown in Figure 3.1.

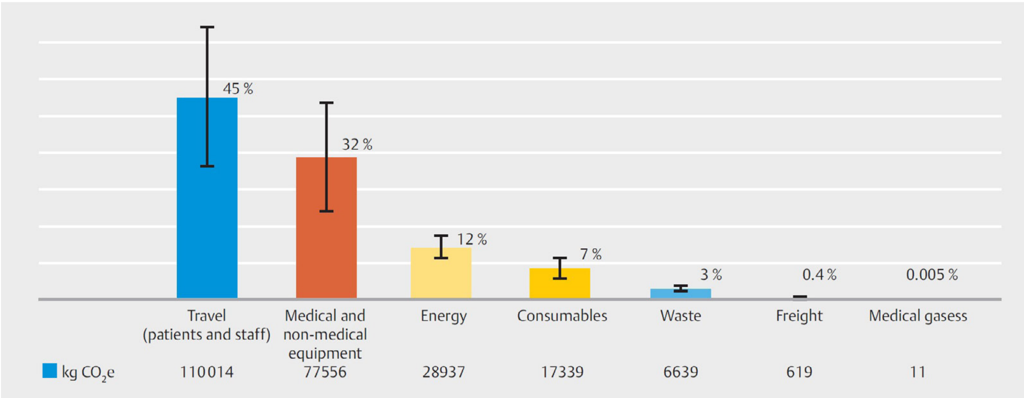

Figure 3.1: Contribution of different greenhouse gas emission classes to emissions at the centre in 2021 in kg of carbon dioxide equivalent (kg CO2e). (Lacroute et al., 2023)

Factors of sustainability in colonoscopy
Understanding the variables that influence the department's sustainability is crucial for designing interventions that minimize the environmental impact.

Travelling
Colonoscopy involves a large number of procedures each year, as explained in Section 2.1. This causes staff and patients to travel from home to the hospital, indirectly contributing to the hospital's CO2 emission.
The best way to avoid this travel overload is to reduce the number of procedures performed. This can be achieved through more specialized triage, the use of greener alternative surveillance approaches.(Donnelly, 2022).

Medical and non-medical equipment
From the study shown in Figure 3.1, the second highest contributor to the overall waste in the endoscopy department is medical and non-medical equipment (Lacroute et al., 2023). This includes all apparatus used in the department, as shown in Figure 3.2. Another study examined the energy use per day at their endoscopy department in the US, revealing a consumption of 277,1 kWh per day (Desai et al., 2023).

The high electricity consumption in hospitals is due to the constant operation of equipment and the significant energy required for reprocessing colonoscopes. Switching to double-basin washing machines can help reduce energy consumption, as both basins operating simultaneously use 25% less energy (Neves et al., 2023). Additionally, installing sensors to automatically turn off the lights in unused rooms can further reduce energy consumption.

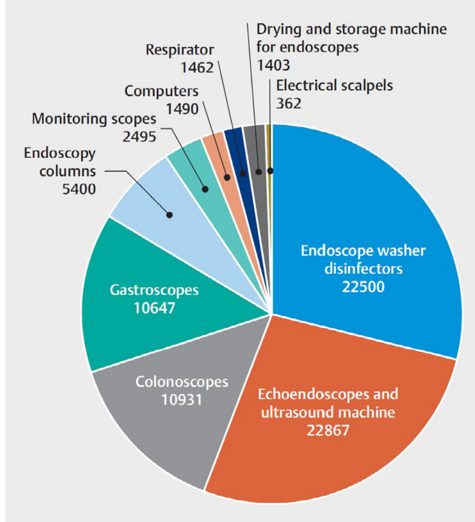

Figure 3.2: Greenhouse gas emissions by medical and non-medical equipment at the center in 2021 in kg of carbon dioxide equivalent (kg CO2e). (Lacroute et al., 2023)

Single–use accessories
In the last two decades, there has been a steep increase in the use of single-use colonoscopic accessories. In the past, reusable accessories were commonly used. This transition from reusable to single-use lacks scientific justification. However, indirect data suggest that this shift has significant economic and environmental implications (Neves et al., 2023c).

Single-use accessories are often needed for procedures. They consist mainly of plastics and are individually packaged.

These are some examples of single-use accessories needed for a procedure (Siau et al., 2021) :
- Oxygen tubing;
- Privacy gowns;
- Bags and pots;
- Intravenous cannulas and dressings;
- Suction tubing;
- Colonoscope buttons;
- Plastic caps;
- Biopsy forceps.

04 Endoscopy Department at the EMC

This chapter describes the architectural layout of the endoscopy department and the workflow of the healthcare professionals in the department at the EMC during a colonoscopy procedure.

Every endoscopy department can differ considering their architectural layout which influences the workflow of the stakeholders (Mergener & Tanner, 2019). Understanding who the stakeholders are and how they operate in the endoscopy department is important to know before performing in-depth field research.

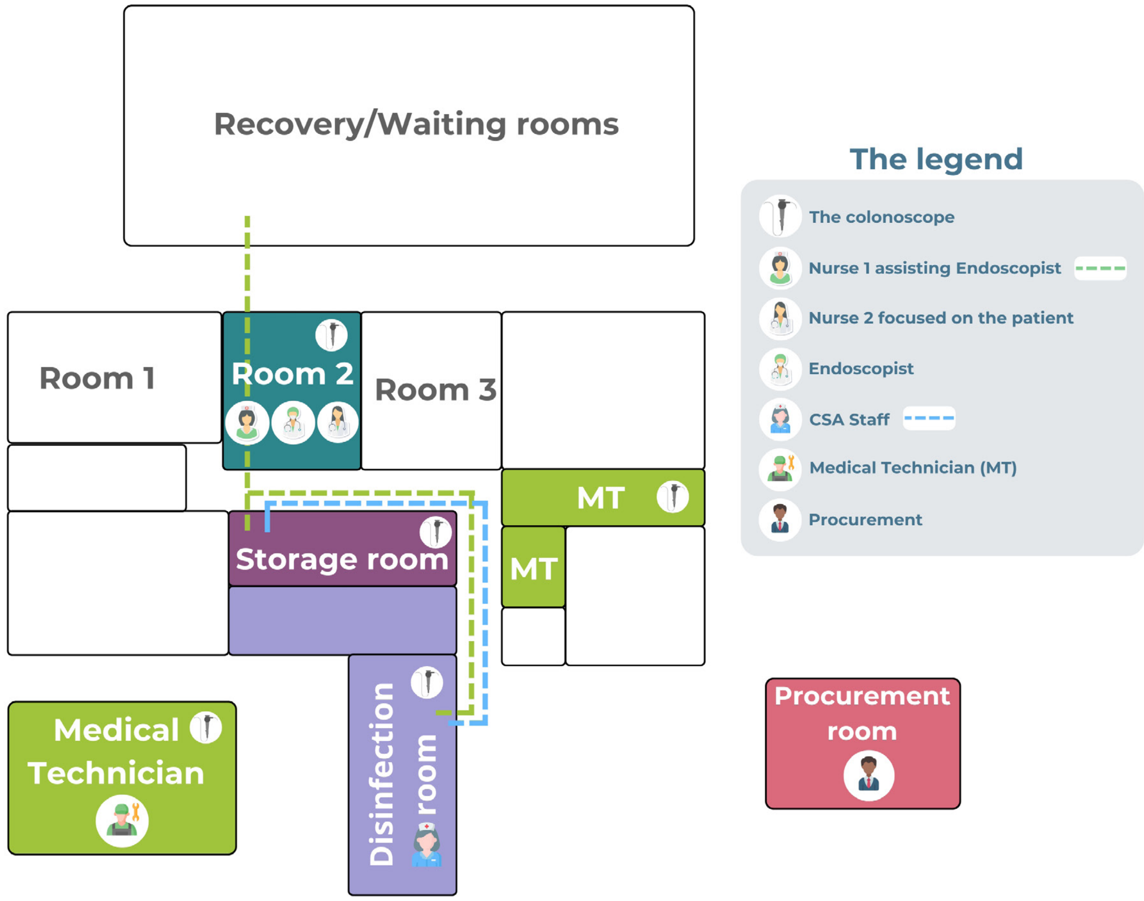

Figure 4.1: The layout of the Endoscopy Department of the EMC.

Procedure room (Room 2)

The procedure room is the physical place where colonoscopy procedures are performed at the EMC.
During a colonoscopy procedure, the team consists of at least 3 healthcare professionals:

- The **endoscopist** typically remains in the procedure room to review the patient's digital records before the procedure begins.
- The **nurse that assists the endoscopist** often stays located in the procedure room and prepares all the accessories required to perform the procedure.
- The **nurse that comforts the patient** moves before and after the procedure throughout the department, to transport the colonoscope.

Once the preparations of the nurses and endoscopists are completed, the patient is picked up from the waiting room and brought to the procedure room.

Figure 4.2: The Procedure room

Disinfection and storage room

In the disinfection room, the disinfection staff (CSA) staff operates. This is where nurses bring contaminated colonoscopes for reprocessing. The CSA staff is responsible for disinfecting the colonoscopes, as well as inspecting them for any defects. After cleaning, they also remove the colonoscopes from the washing machine and place them in the drying cabinets, which are located in the storage room.

Medical Technician rooms

When technical issues occur in the endoscopy department, the medical technician investigates and searches for the right solution. If a defect in a colonoscope is detected, the technician examines the issue and coordinates with the procurement staff members to initiate contact with the colonoscope's supplier.

Procurement rooms

Procurement is responsible for managing relationships and maintaining contact with the colonoscopy-specific supplier. They are the ones who reach out to the supplier when general maintenance for the colonoscope is needed. When significant costs are involved for repairs, procurement decides whether to proceed with the repairs or to replace the equipment. This decision-making process is informed by their oversight of costs, cash inflows, and outflows.

Key Takeaways - Section 1

- Due to the **national CRC screening program,** a large number of colonoscopy procedures are performed among the elderly. This number is **expected to rise** as the population ages, which will have an **increasing impact** on the environment.
- From Section 2.2, it can be concluded that the colonoscope is **well-enclosed,** which makes it **difficult to disassemble** the product for repair.
- Endoscopy is a **resource-intensive department** including **different factors** that contribute to CO_2 emissions. To analyse these factors effectively, it is crucial to use a **multi-criteria method** during observations.
- A **lot of external equipment** are necessary in the procedure room for the colonoscope **to function** and these devices all require **energy.**
- It's important to not only consider the **procedure room** but also the **disinfection and storage room,** as **reprocessing** significantly contributes to the CO_2 emissions associated with reusable endoscopes.
- When **designing sustainable interventions,** it **must fit** into the existing **workflows of healthcare professionals** at the EMC to ensure that the sustainable interventions do **not add additional steps** to the already **demanding workflow** of HCPs.

Section 2

05
The Product Journey Map

This chapter marks the beginning of section 2, which focuses on improving the sustainability of the colonoscopy department.

In this chapter, the product journey map method is used to map out the waste streams of the physical places where the colonoscope is mainly used:

- Procedure room
- Disinfection and storage room
- Maintenance

To create the Product Journey map, information was gathered through observing and interviewing healthcare professionals in the colonoscopy department.

5.1 The Set-up

The PJM includes different factors which are grouped in layers. The beginning and the end of a layer are visualized by dotted lines, see figure 5.1:

- The **first layer** explains the general steps of use including time spent on a task.
- The **second layer** shows the human interaction at each step.
- The **third layer** shows the different waste streams of each step.

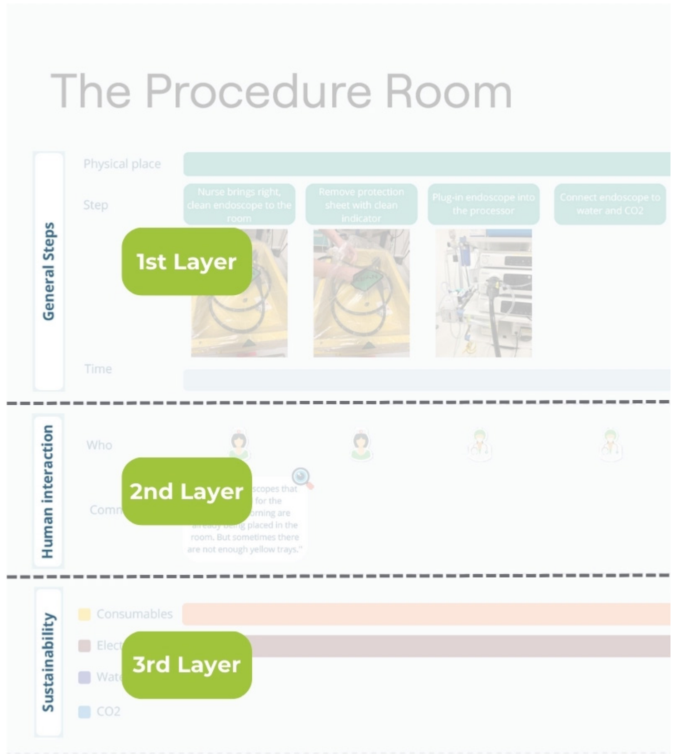

Figure 5.1: Explanation of the layers

General Steps

In the first layer, see Figure 5.1, every small step performed in the procedure or disinfection and storage room is explained. Pictures are included to make the steps visible. Time is an important factor to include in improving sustainability as shortening the duration of a step will mean that the equipment will also be used for a shorter period, leading to reduced energy consumption.

Human interactions

The second layer of the PJM, see Figure 5.1, outlines the human interactions at each step. People are integral to the three pillars of sustainability, making their inclusion in this map essential. By identifying who is responsible for each step, it becomes easier to determine whom to approach or include at the department when designing interventions that enhance the sustainability of the department. Interesting sustainability-related findings observed during the field research are also included.

Sustainability

The third layer, see Figure 5.1, is the sustainability layer which shows everything that is consumed at every step, including:

- The physical consumables that are disposed after each procedure;
- The electricity that is required for the equipment that operates the endoscope;
- The water that is used during the colonoscopy procedure and for reprocessing the colonoscopes;
- The amount of CO_2 that is sufflated in the patient's body during a colonoscopy procedure. CO_2 is sufflated in the patient's body to reduce the procedural discomfort (Siau et al., 2021).

5.2 Data Collection

5.2.1 Procedure Room

This paragraph explains the methods used to analyse the various factors of the PJM from the Procedure room. An overview of the study methodology for each factor is provided in Table 5.1.

Table 5.1: Study methodology of data collection in the Procedure room

Factors	Method
General Steps	1 day of **Observation.**
Human Interactions	1 day of **Observation.** **Interviews** with the CSA staff during the one day observation.
Physical consumables	**1 day of Observation**
Electricity	**Interview** with Medical Technician **Observations** in disinfection and storage room. **Desk Research**
Water	**Interview** with Medical Technician **Desk Research**
Detergents	**Interview with Medical Technician**

General Steps

Almost every step in the PJM is supported with a picture that is taken during observations. Except during the procedure, pictures are not taken out of consideration for the patient. Timing each step accurately within the procedure room is challenging due to the overlap of activities, this led to the decision to combine steps into phases and allocate time to that. These time allocations are based on rough estimates from observations and have been refined through discussions with an endoscopist.

Human interactions

Observations conducted over 2.5 days were used to determine which HCP is responsible for specific steps. During the observations, conversations were held with the nurses and endoscopists performing colonoscopy procedures. From these discussions, findings related to sustainability were documented.

Sustainability

The physical consumables that are used in the procedure room for colonoscopy procedures at the EMC were identified by a former master's student from the TU Delft. In this waste audit, she collected and categorized the products that were discarded after procedures over several days (Clercx Lao, 2024). From this data, she was able to calculate the average amount of physical consumables—such as forceps, gloves, and kidney cups—used and disposed of after each procedure. The results of this waste audit can be found in Appendix A.

During a one-day observation, an overview has been created detailing the equipment that is used for the colonoscopy procedures in the EMC. The medical technician identified each apparatus with a brand name and product number.

With this information, the electrical properties of each device could be found in technical data sheets searched online. The calculations of the energy consumption can be found in Appendix B.

Water is utilized in two distinct ways in the procedure room. It is used during a procedure when the colonoscope is in the patient's body and after use when it is flushed. The amount of water that is placed in the kidney cup for flushing is measured with a measuring cup. For the water that is used during colonoscopy procedures on a day, an estimation has been made with the nurses and endoscopists.

There is not a specific amount of CO_2 that is sufflated in every procedure. Therefore the average amount of CO_2 that is used, is searched in the literature.

5.2.2 Disinfection and Storage room

This paragraph explains the methods used to analyse the various factors of the PJM from the Procedure room. An overview of the study methodology for each factor is provided in Table 5.2.

Table 5.2: Study methodology of data collection in the Disinfection and Storage room

Factors	Method
General Steps	1 day of **Observation.**
Human Interactions	1 day of **Observation.** **Interviews** with the CSA staff during the one day observation.
Physical consumables	**1 day of Observation**
Electricity	**Interview** with Medical Technician **Observations** in disinfection and storage room. **Desk Research**
Water	**Interview** with Medical Technician **Desk Research**
Detergents	**Interview with Medical Technician**

General Steps
The steps performed by the CSA staff are often sequential. Therefore each step could be timed during observations, a template was used for this, see Appendix C. Subsequently, these time allocations were discussed with the CSA staff.

Human Interactions
The interactions of the CSA staff with the colonoscope at each step were observed, and sustainability-related findings from the interviews were documented in the Product Journey Map.

Sustainability
During the observations, the discarded physical consumables were noted. It was observed that two types of consumables are used: some are discarded at the end of the day, while others are disposed after each procedure.

The equipment required to reprocess the colonoscopes were identified by the medical technician. The technical data sheets were found online, to calculate energy consumption. The results of these calculations are detailed in Appendix B.

A water tank is used for the manual pre-cleaning of the colonoscope. The dimensions of this tank were measured to calculate the water usage. Additionally, a washing machine is used for thorough cleaning of the colonoscope. The water consumption per washing cycle is specified in the washing machine's technical data sheet.

The type and quantity of detergents used during the cleaning process of the colonoscope were provided by the medical technician.

5.2.3 Maintenance

Two Product Journey Maps have been created for the maintenance procedures: one describes the procedure when a defect on the colonoscope is identified, while the other explains the process for regular maintenance of the colonoscope.

General Steps and Human Interactions
In the EMC, the medical technician is responsible for maintaining the colonoscope. Additionally, the CSA staff performs leak tests to check if the colonoscope is defect. Therefore, interviews were conducted with both the medical technician and CSA staff. After these interviews, the general maintenance steps and sustainability-related findings were documented.

5.3 Results

Based on the information gathered through the methodologies explained in the previous paragraphs, four Product Journey Maps have been created:

- For the Procedure room, see Figure 5.2;
- For the Disinfection and Storage room, see Figure 5.3;
- The regular maintenance, see Figure 5.4;
- The maintenance when there is a defect, see Figure 5.5

The environmental impact hotspots were identified in the Product Journey Map by considering the 9R strategies from the Value Hill Model. Further explanation on this can be found in Chapter 6.1.

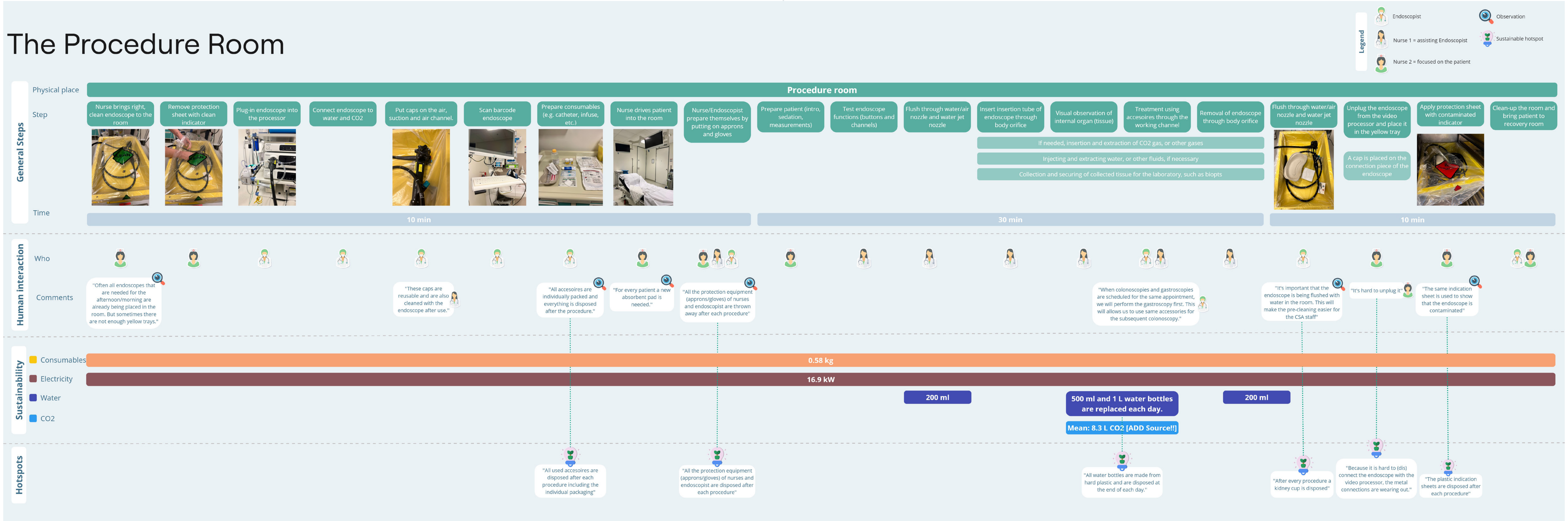

Figure 5.2: The Product Journey Map of the Procedure Room

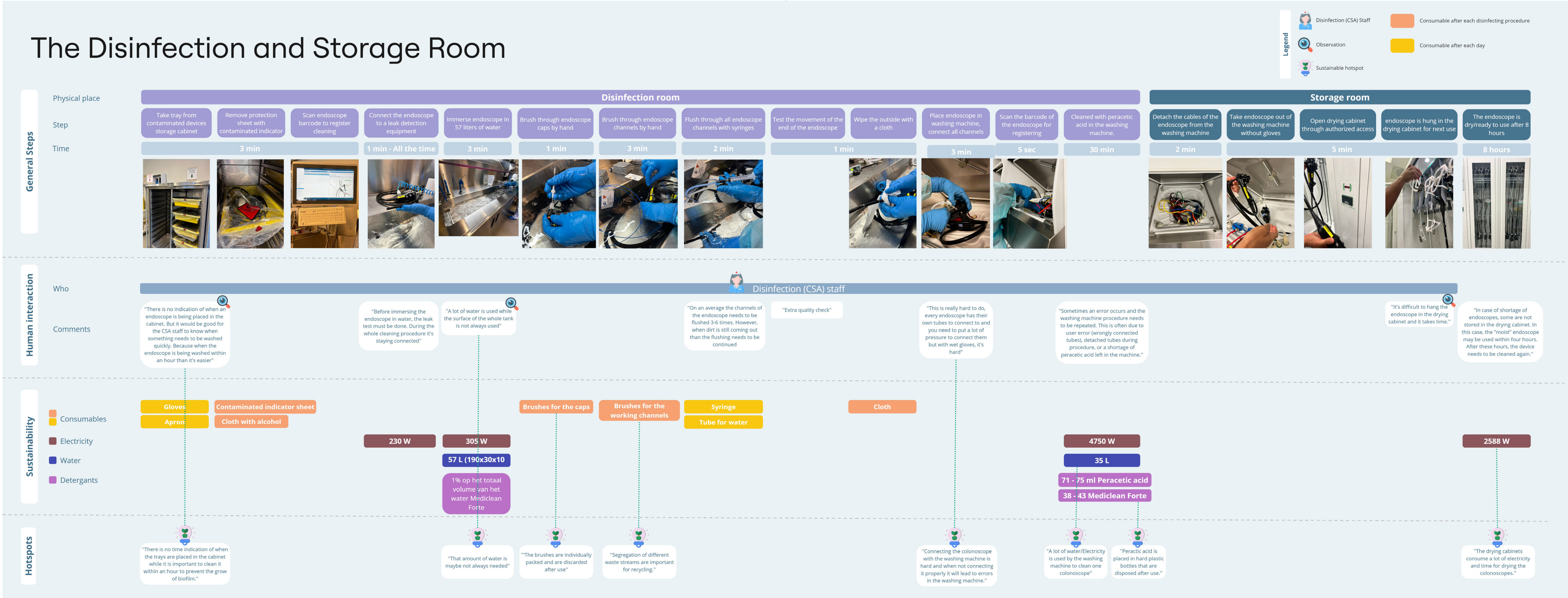

Figure 5.3: The Product Journey Map of the Disinfection and Storage room

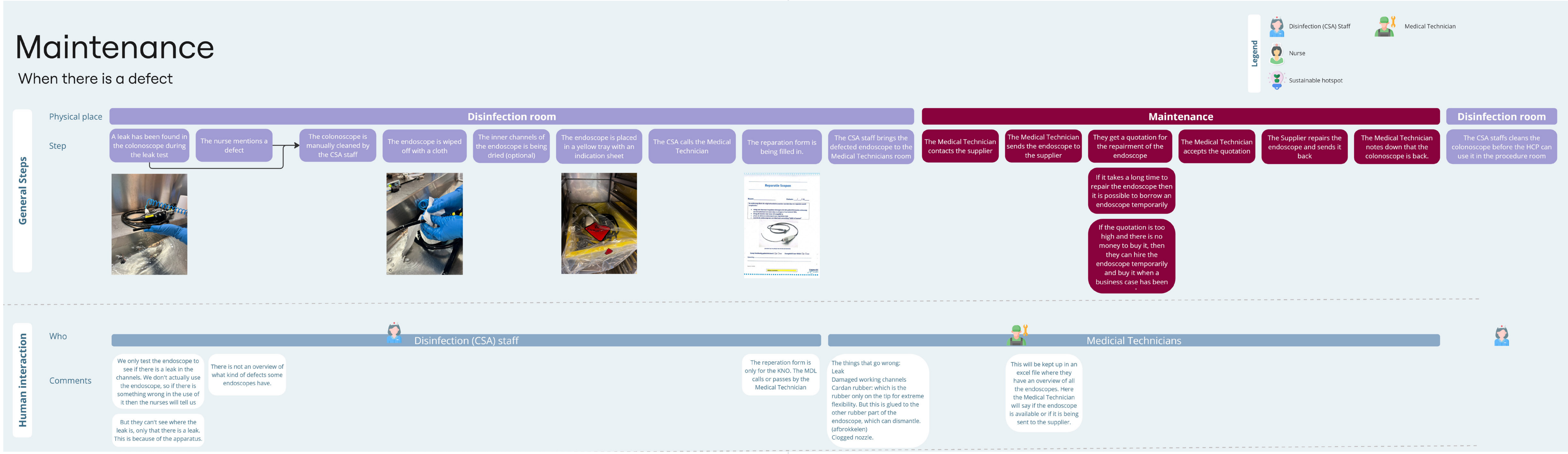

Figure 5.4: The Product Journey Map of the Maintenance when there is a defect

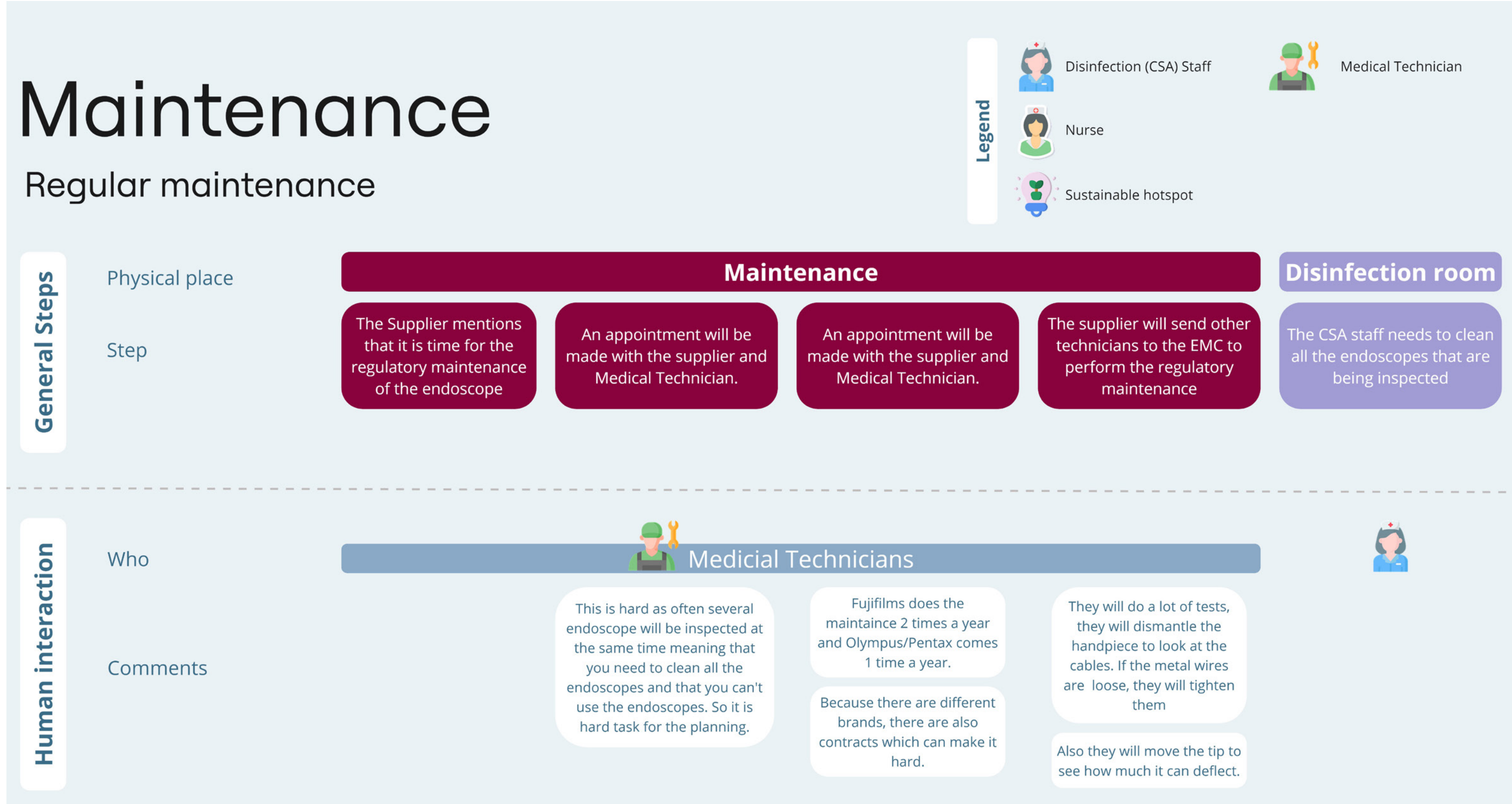

Figure 5.5: The Product Journey Map of Regular Maintenance

06 Sustainable Interventions

at the Endoscopy Department

This chapter describes the environmental impact hotspots that were identified in the endoscopy department at the EMC.

Section 6.1 describes the environmental impact hotspots that were identified through the PJM, see Chapter 5. This section also explains the sustainable interventions that were designed to reduce the environmental impact of the hotspots. The Value Hill model with the 9R strategies is used in this process.

The involvement of healthcare professionals is essential to promote sustainability within the department. Therefore, a co-creation session was held with Healthcare professionals to collectively brainstorm ideas to improve department's s sustainability, see Section 6.2.

6.1 Environmental Impact Hotspots Identification

The environmental impact hotspots were identified through qualitative and quantitative research conducted for setting up the Product Journey Maps. The results of these Product Journey maps are explained in Chapter 5.

In total, 15 environmental impact hotspots were discovered. For each hotspot, a sustainable intervention has been designed, to reduce the environmental impact, as shown in Tables 6.1 and 6.2. The value hill model with the R-strategies was used in this process to design suitable interventions. More information on the Value Hill model and the R-strategies can be found in Section 1.4.2.

Table 6.1: The Environmental Impact hotspots with the sustainable interventions - Procedure Room

Hotspot description	R-strategy	Sustainable intervention
All used accessories including their packaging are disposed after each procedure.	Reduce	To reduce packaging waste, it would be important to identify if it is necessary to individually pack each single-use accessory.
All the protection equipment (aprons/gloves) of nurses and endoscopists are disposed after each procedure.	Recycle	It is important to divide the plastic waste with other waste, so it could be more easily recycled.
All water bottles are made from hard plastic and are disposed of at the end of each day	Rethink	Place a sterilized water tap in the procedure room, so the hard plastic bottles don't have to be disposed after use, but can be reused by filling up the bottles with sterilized water.
After every procedure, a kidney cup is disposed	Reuse	Replace the single-use kidney cups with reusable ones.
Because it is hard to (dis) connect the endoscope with the video processor, the metal connections are wearing out.	Rethink	To make it easier for the HCPs to connect the colonoscope with the video processor, make the design of the connector smaller and design a smoother hand grip.
The plastic indication sheets are disposed after each procedure	Refuse	Replace the plastic single-use indication sheets with a reusable hard plastic one.

In Table 6.2, the environmental impact hotspots of the disinfection and storage room are written with the R-strategy that is used to design an intervention to reduce the environmental impact of the hotspot.

Table 6.2:. The Environmental Impact hotspots with the sustainable interventions - Disinfection and Storage room

Description	R-strategy	Explanation
There is no time indication of when the trays are placed in the cabinet while it is important to clean them within an hour to prevent the growth of biofilm (*Kwaliteitshandboek Reiniging en Desinfectie Flexibele Endoscopen*, 2022).	Rethink	To make cleaning easier with reduced material usage, colonoscopes need to be cleaned within an hour. However, the current duration for which colonoscopes remain in the cabinet is unknown. To organize the cleaning priority, a timer will be placed next to each colonoscope.
That amount of water may not always be needed.	Reduce	To reduce the amount of water needed, the length of the colonoscope should be shortened. Therefore, splitting the colonoscope into two pieces would be beneficial, as the connector would not require thorough washing.
The brushes are individually packed and discarded after use.	Rethink	The entire brush is disposed of after each procedure, but the handle could be made reusable while only the brush itself is discarded after use. This approach will prevent the unnecessary disposal of the whole unit.
Segregation of different waste streams is important for recycling.	Recycle	Currently, there is only one waste bin in the disinfection and storage room. To recycle plastic easily, it is important to separate plastic waste from other types of waste.
Connecting the colonoscope with the washing machine is hard and when not connecting it properly it will lead to errors in the washing machine.	Rethink	It is important to design a tool that simplifies connecting the colonoscope to the washing machine, to reduce the risk of failure of the washing machine's cleaning procedure.

A lot of water/electricity is used by the washing machine to clean one colonoscope.	Reduce	Currently, one washing machine is used for each colonoscope. However, there are washing machines available that can clean two colonoscopes simultaneously. Using these machines would reduce the electricity and water required for cleaning (Neves et al., 2023).
Peracetic acid is placed in hard plastic bottles that are disposed of after use.	Rethink	To reduce the waste of hard plastic bottles used for peracetic acid, a peracetic acid tap machine can be used in the disinfection room to refill the bottles (Peracetic Acid | Watter B.V).
The drying cabinets consume a lot of electricity and time for drying the colonoscopes.	Refuse	Instead of using the drying cabinets, use the plasma typhoon (*Accessories & Randapparatuur | PENTAX Medical (Benelux)*, which requires less electricity and time to dry the colonoscope.

6.2 Co-Creation session with the green team

Improving sustainability in the healthcare sector requires collaboration, it can't be achieved alone. Involving healthcare professionals is crucial as they can offer valuable insights that can be integrated in their workflow. To brainstorm together, a co-creation sessions was organized with nurses from the green team of the colonoscopy department.

Figure 6.1: The invitation poster

6.2.1 Method

Participants

The co-creation was open to all Healthcare professionals from the endoscopy department who were interested in enhancing the sustainability of their department. An invitation poster was sent, to encourage participation, as shown in Figure 6.1

Three nurses with an interest in sustainability participated in the co-creation session. The diverse age range led to engaging conversations, with the older nurse talking about how colonoscopy procedures were performed in the past compared to current practices.

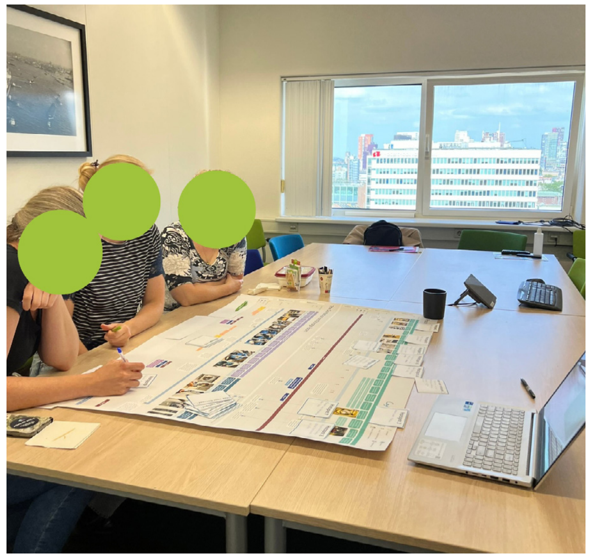

Figure 6.2: The participants during the co-creation

Equipment

A presentation was created and displayed on a laptop during the co-creation session, as shown in Figure 6.3. The full presentation can be found in Appendix C. The Product Journey map was printed as an A0 poster to ensure everyone could read each step. Additionally, small cards were provided for nurses to write down hotspots and ideas.

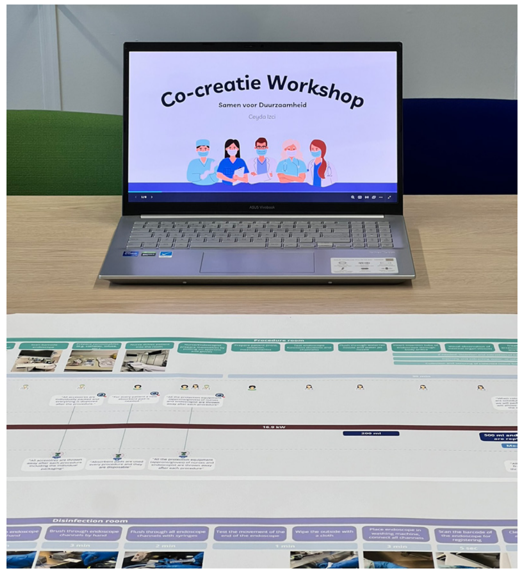

Figure 6.3: The set-up for the co-creation session

Procedure

Before identifying the hotspots, a small presentation was given, which included introductory activities to help participants get acquainted and discuss the topic of sustainability. The presentation can be found in Appendix D.

Afterwards, the nurses explored the Product Journey Map and discussed several steps together, to brainstorm on how they could reduce the environmental impact. Their ideas were written down on the cards and placed on the A0 poster of the PJM at the relevant step in the procedure, as shown in Figure 6.4.

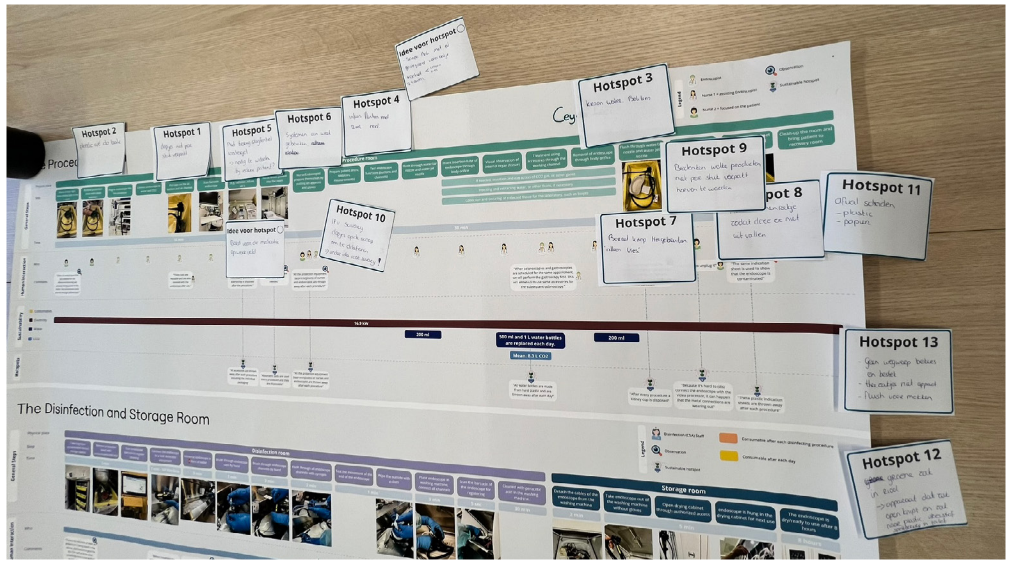

Figure 6.4 The ideas of the nurses were written down and placed on the poster

6.2.2 Results

The identification of the hotspots written down by the nurses can be found in Table 6.3. In this table, extra explanation is added with a suitable R-strategy to enhance sustainability.

Table 6.3:. The Environmental Impact hotspots with Sustainable interventions - Co-Creation session

Hotspot identification	R-strategy	Explanation
Do not package the caps individually.	Reduce	The single-use caps are currently individually packaged and disposed after each procedure. However, they could be stored in a box in the procedure room to eliminate the need for individual packaging. However, it is important that nurses can pick one cap at a time to ensure that the remaining caps stay sterile.
Don't use plastic as an indication sheet.	Refuse	The nurse mentioned, that in the past, they did not use disposable plastic indication sheets but instead a hard plastic lid that was used which was reusable.
Use tap water to flush the colonoscope with.	Rethink	The nurses mentioned that they once used tap water to flush the colonoscope. If sterilized water is not required, they could reuse the water bottles.
Need to change the non-return valve for the water jet for each procedure.	Reuse	The nurses expressed doubt whether the non-return valve for the water jet needs to be replaced for every procedure.
Use the water system for one week.	Rethink	Currently, they are required to change every bottle of sterilized water at the end of each day. However, since the water is already sterilized, they believe the bottles could be used for a longer period.
A better system for the gloves, so that they don't fall out of the package.	Rethink	The nurses explained that after every procedure, they need to dispose their current gloves and pick new ones. However, multiple gloves often fall out of the package at once. To prevent this a former master student from the TU delft designed a rack where gloves boxes can be placed (Van Den Berg, 2024).
It will be good to really think through about which consumables really need to be individually packaged.	Refuse	Currently, almost every accessory is single-use and individually packaged. This means that after each procedure, both the accessories and their packaging need to be discarded.
Separate plastic waste with cardboard.	Recycle	Plastic and paper waste are currently discarded in the same bin, but separating them is important for recycling.
Green bag with bodily fluids segregated and disposed.	Rethink	To make it easier for nurses to dispose of the bodily fluids that come out during the procedure, they brainstormed ideas for a system where the fluid bag could be discarded in the procedure room. This system would automatically separate the fluids from the plastic and transport them to the waste room.
No disposable cups and cutleries in the department. Also the tea bags don't have to be individually packaged.	Refuse	The nurses mentioned that it is important that everyone uses reusable cups and cutleries to enhance sustainability in the department.
Tray with integrated kidney cup.	Rethink	Currently, they dispose the kidney cup after each procedure. However, the nurses suggested integrating the kidney cup to be reused and since it is necessary for every procedure, it makes sense to incorporate it into the tray.

Key Takeaways - Section 2

- Creating the PJM requires various approaches to gather diverse data. Therefore it is important to use a combination of **qualitative** and **quantitative** data.
- Only focusing on the **use of the colonoscope** made it **easier** to include more details, such as different **waste streams** and **human interactions** at each step.
- There is **no standardization** when looking at the colonoscopes, this results in the need for different kinds of single-use consumables to reprocess the colonoscopes.
- Designing sustainable interventions requires diverse approaches, as each hotspot has a unique context. **The R-strategies** were particularly helpful in this process.
- Visualizing the steps of the colonoscopy procedure in a Product Journey Map facilitates discussions about sustainability with healthcare professionals. It **bridges the gap between HCPs and non-HCPs** by being able to point out the areas targeted for improvement.
- **Visualizing the data** on sustainability is important as it **accelerates** idea generation during the co-creation session. This is particularly crucial in the **Healthcare context** where HCPs often have **limited time.**

07

Literature Exploration

Single-use vs. Reusable Colonoscope

This chapter describes the environmental impact hotspots that were identified in the endoscopy department at the EMC.

Section 6.1 describes the environmental impact hotspots that were identified through the PJM, see Chapter 5. This section also explains the sustainable interventions that were designed to reduce the environmental impact of the hotspots. The Value Hill model with the 9R strategies is used in this process.

The involvement of healthcare professionals is essential to promote sustainability within the department. Therefore, a co-creation session was held with Healthcare professionals to collectively brainstorm ideas to improve the sustainability of the endoscopy department, see chapter 6.2.

7.1 Single-use Colonoscopes

Single-use colonoscopes are always ready for use and guaranteed to be sterile, as a new colonoscope is unpacked for each patient and disposed of after each use. This convenience makes them easy to use, as illustrated in Figure 7.1, compared to reusable colonoscopes, shown in Figure 7.2.. Additionally, single-use colonoscopes only need to be connected to the video processor. The light source is integrated in the connector which eliminates the need for an external light source. The connector of single-use colonoscopes in Step 2 of Figure 7.1 is also smaller compared to the connector of the reusable colonoscopes in Step 2 of Figure 7.2.

The interest in single-use colonoscopes are also rising, due to endoscopy-associated infections with reusable colonoscopes (Siau et al., 2021).

Despite the advantages of single-use colonoscopes, their environmental impact is significantly greater compared to reusable colonoscopes. Implementing single-use colonoscopes would result in a 40% increase in total net waste mass (Baddeley et al., 2022). This is primarily due to manufacturing processes that contribute to over 90% of the CO_2 emissions (Shaji et al., 2022).

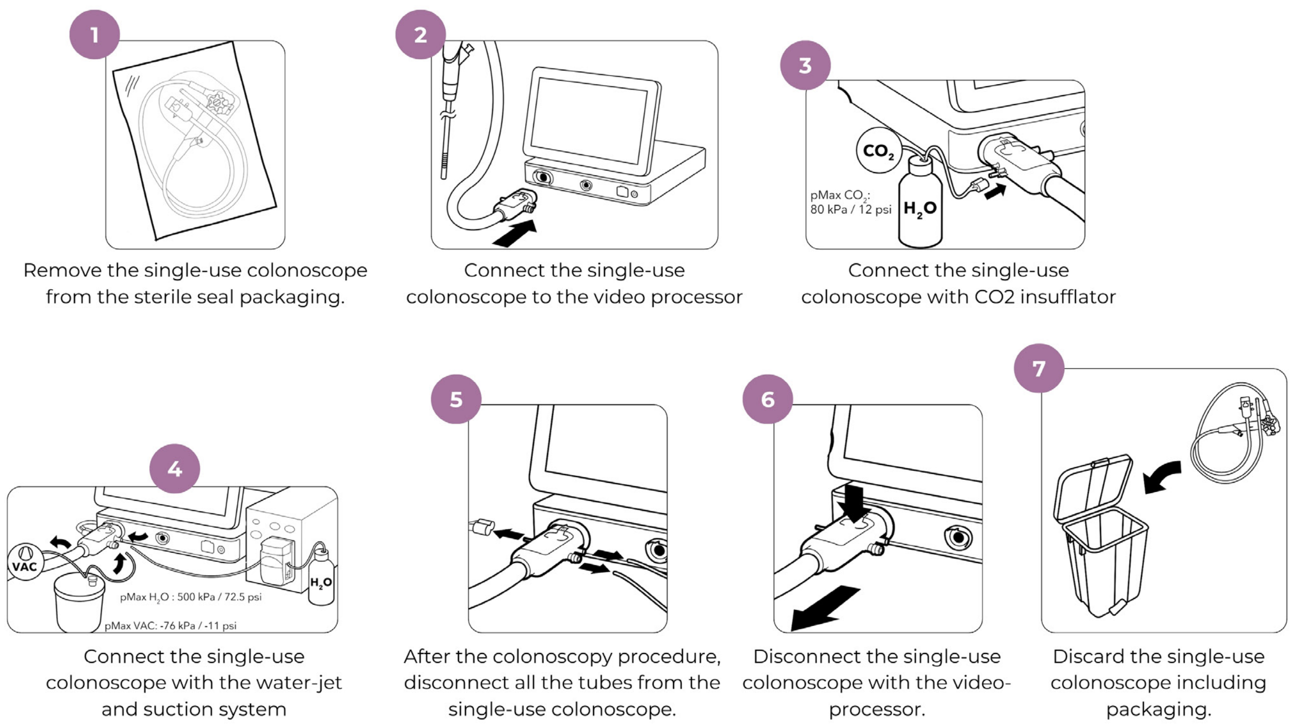

Figure 7.1: Summary of the use of single-use colonoscopes (“Instructions For Use Ambu AScope Gastro”, 2021)

7.2 Reusable Colonoscopes

More steps are required when reusable colonoscopes are used, as they need to be reprocessed after each procedure before they can be used on another patient, as shown in Figure 7.2.

Reusable colonoscopes are designed for multiple uses, therefore the hardware in the colonoscope is of better quality compared to a single-use colonoscopes. The major components of reusable colonoscopes are metal (approximately 70% of the total mass) and plastic (approximately 25-30% of the total mass). In contrast, single-use colonoscopes consists primarily of plastic and a lesser proportion of metal (De Santiago et al., 2022). Additionally, another study concluded that the average camera quality of single-use colonoscopes is significantly lower than that of reusable colonoscopes (Luo et al., 2022).

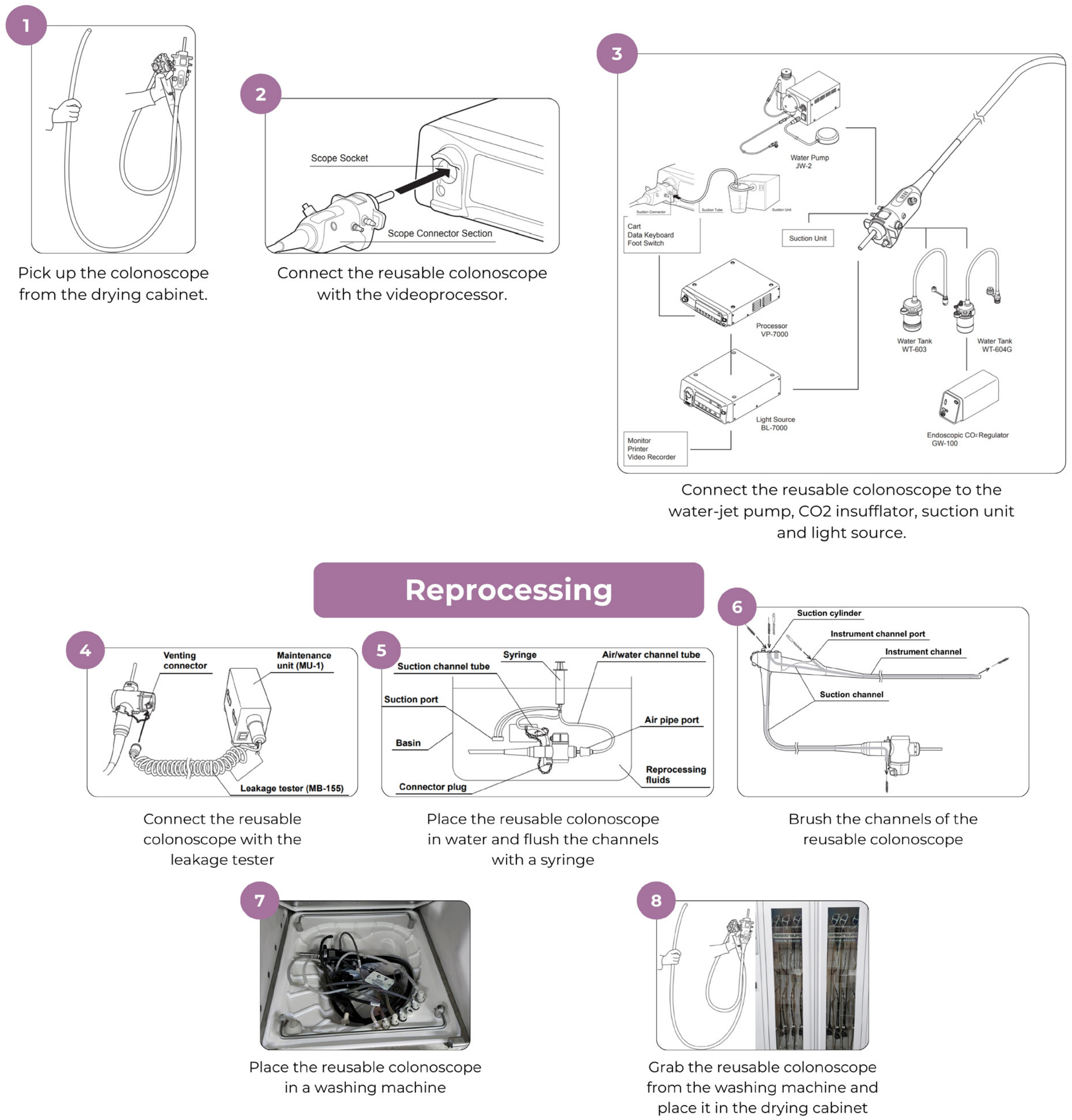

Figure 7.2: Summary of the use of reusable colonoscopes (“Operation Manual Evis Exera II Duodenovideoscope”, 2022)

7.3 Comparison of single-use with reusable colonoscopes

No specific literature on the costs of colonoscopes could be found. However, when examining other reusable endoscopic product, such as cystoscopes, it can be concluded that reusable cystoscopes become more cost-effective with increased patient use (Kim et al., 2022), as shown in Figure 7.3. This is because the investment costs for reprocessing the cystoscope are distributed over a larger number of patients.

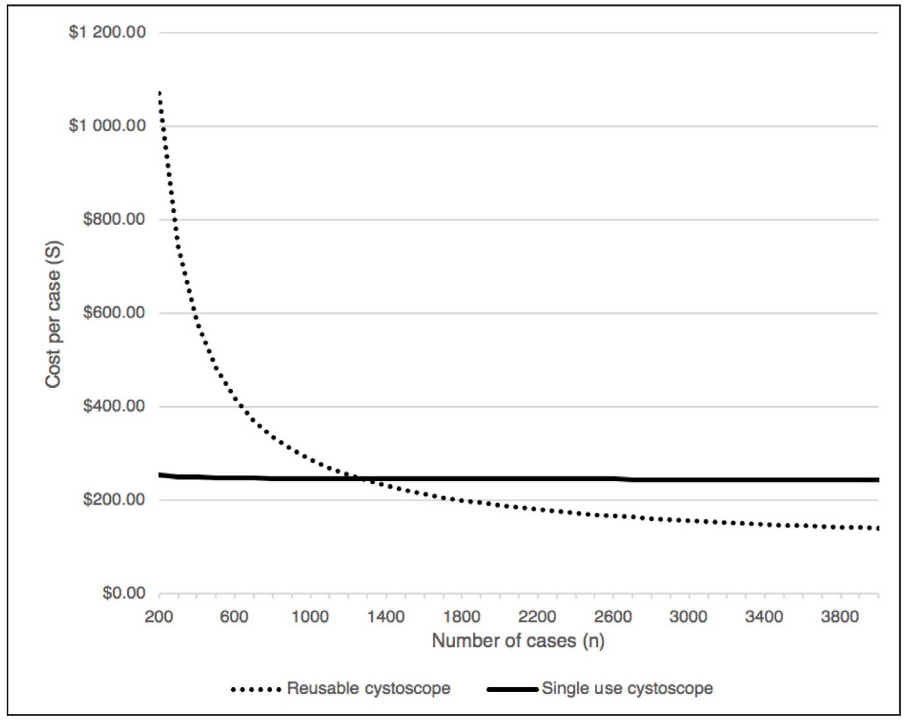

Figure 7.3: Comparing the costs per case for reusable (dotted lines) and single-use cystoscope (solid lines) dependent on case volume. The lines intersect at 1265 cases. (Kim et al., 2022)

All the specifics of single-use colonoscopes and reusable colonoscopes mentioned in the previous section are summarized in Table 7.1.

Table 7.1: Comparison between single-use and reusable colonoscopes

Single – use colonoscopes	Reusable colonoscopes
High impact on the environment	Less impact on the environment
No risk of infection (*Ambu aScope Gastro | Single-use Gastroscopy | Ambu*, z.d.)	Risk of infection.
Easy to set up and in use	More external equipment is needed (light source)
Predictable cost	Capital investment is needed
Less camera quality	Better camera quality
Consists primarily of plastic	Major components are from metal

Figure 7.4: Single-use colonoscope (Ambu aScope Gastro | Single-use Gastroscopy | Ambu, z.d.)

Figure 7.5: Reusable colonoscope (FUJIFILM Healthcare Americas Corporation, 2023)

Section 3

08 Redesign of the Reusable Colonoscope

The previous chapter reveals that it is essential to continue with the reusable colonoscope as it has a lower environmental impact compared to the single-use colonoscope. Nonetheless, there is still potential to enhance the sustainability of the reusable colonoscope. This chapter describes the redesign process with a final redesign of the reusable colonoscope.

Section 8.1 identifies the environmental impact hotspots for the reusable colonoscope. Section 8.2 present the redesign ideas aimed at addressing these hotspots. These redesign ideas were evaluated by 2 endoscopists, a medical technician and a microbiologist, the results of this evaluation is explained in 8.3.

Section 8.4 discusses the improved redesign ideas based on feedback gathered through the evaluation. The final redesign is explained in Section 8.5.

8.1 Hotspots Identification

This chapter focuses on the identification of the environmental impact hotspots of the reusable colonoscope at the product level. Interviews were conducted with a medical technician and a postdoctoral researcher with a specialisation in the lifespan of endoscopes at EMC. Based on these interviews and the literature exploration in chapter 7, the environmental impact hotspots were identified.

These environmental impact hotspots focuses on the use of colonoscopes at EMC and highlights which parts are often damaged. These hotspots are linked to specific parts of the colonoscope that can be improved, as shown in Figure 8.1. The identification of these hotspots was essential to make redesign recommendations aimed at enhancing the sustainability of the colonoscope.

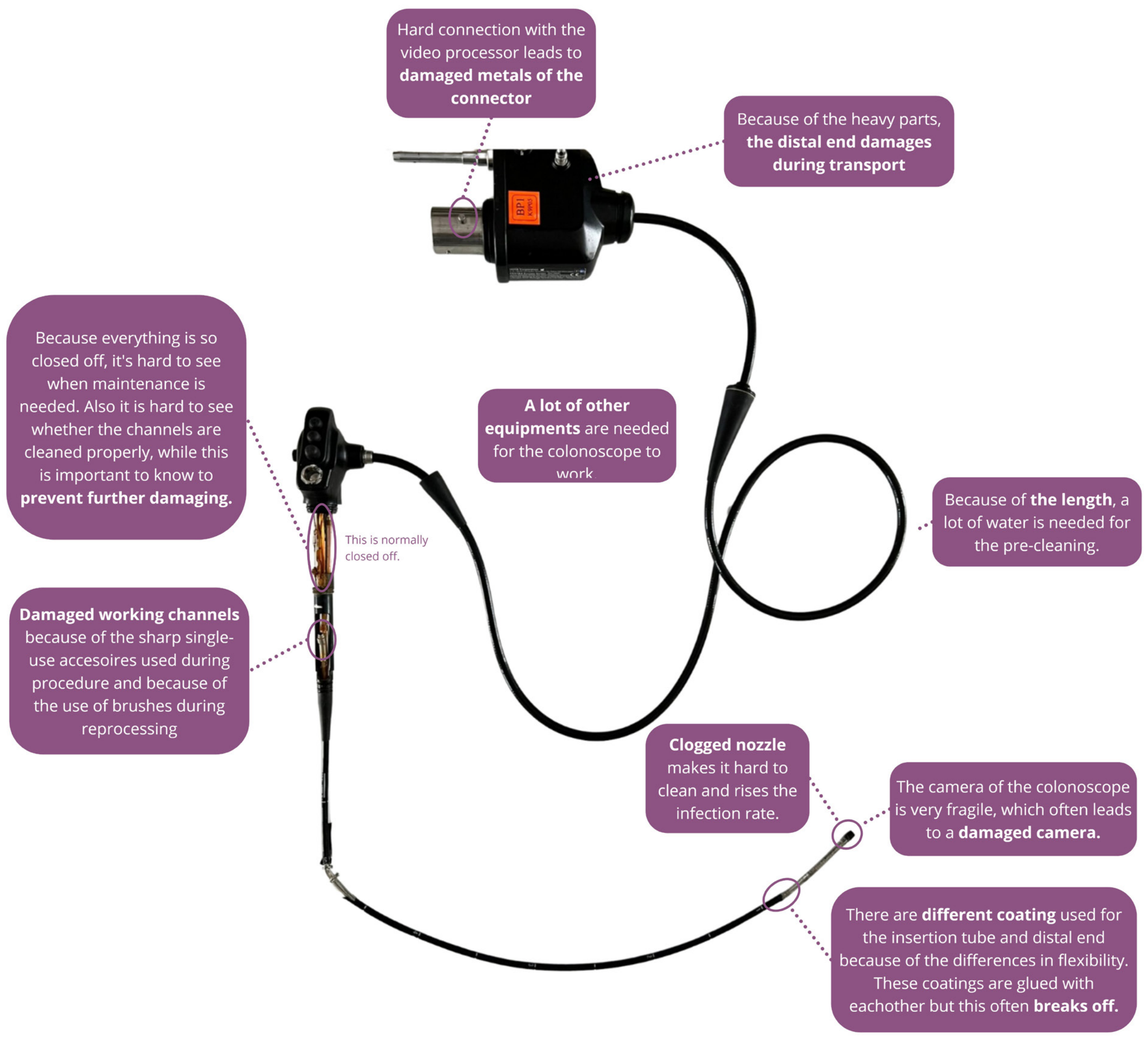

Figure 8.1: The environmental impact hotspots of the reusable colonoscope

8.2 Redesign Ideas

The redesign ideas were focused on addressing the environmental impact hotspots identified in Figure 8.1. There are various factors that influence the lifespan of the product. Therefore, it is important to have a broad perspective when designing a circular medical device.

In Figure 8.2, the current design is shown to provide a clearer understanding of the redesign ideas.

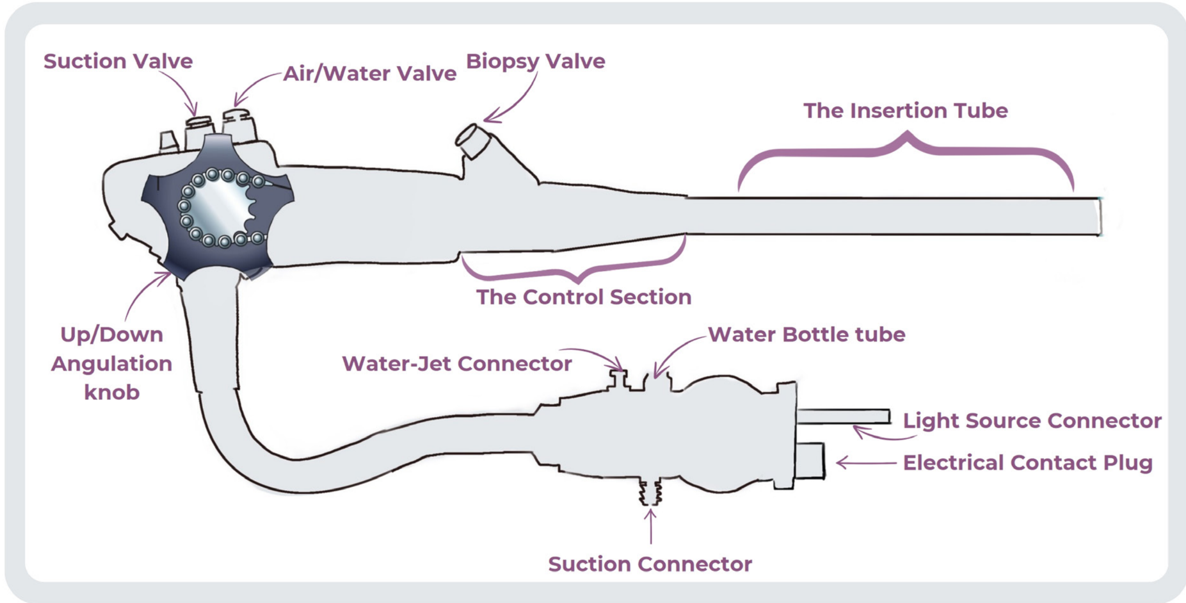

Figure 8.2: Current design of the colonoscope

Idea 1 - 360 Degrees camera colonoscope

In the design shown in Figure 8.5, the standard flat camera of the colonoscope is replaced with a 360-degree camera. This eliminates the need for the angulation knob, as the 360-degree camera provides wide angles and removes the necessity to rotate the distal end. Additionally, this design requires less maintenance since there are no strings from the angulation knob that needs to be tightened.

In the current design of the colonoscope, there are two different coatings for the insertion tube and the distal end, due to the variation of their flexibility. According to the medical technician, these coatings are bonded with glue that often deteriorates over time. However, with a 360-degree camera, there is no need for angulation of the distal end since the camera already provides a broad view. This allows to use a single coating for both the insertion tube and the distal end.

Idea 2 – Plug & Play Colonoscope

Due to the colonoscope's length, the water tank used for pre-cleaning measures 1.9 metres (Dörr Kampen, 2023), which results in a significant use of water. If the colonoscope can be disassembled, see Figure 8.6, only the upper part needs to be immersed in the water tank. This will result in a smaller water tank, thereby reducing water usage for pre-cleaning the colonoscope.

Figure 8.3: The water tank used for pre-cleaning the colonoscopes (Dörr Kampen, 2023)

Additionally, the lower part of the colonoscope can remain in the procedure room. This eliminates the risk of the connector damaging the camera during transport from the procedure room to the disinfection and storage room.

Idea 3 - Portable colonoscope

Currently, a lot of external equipment is needed in the procedure room for the colonoscope to function, see Figure 8.4.

To reduce the amount of external equipment, this idea proposes to integrate the light source into the connector of the colonoscope, similar to single-use colonoscopes. This integration eliminates the need for an external light source, which will make it easier to transport the colonoscope system between rooms.

Figure 8.4: The current colonoscope system in the procedure room

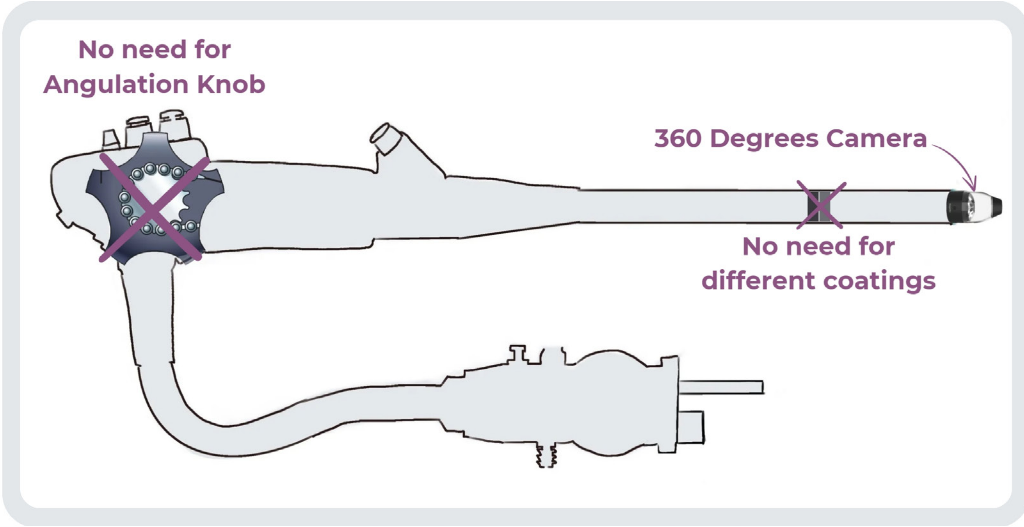

Figure 8.5: Idea 1 - 360 degrees camera colonoscope

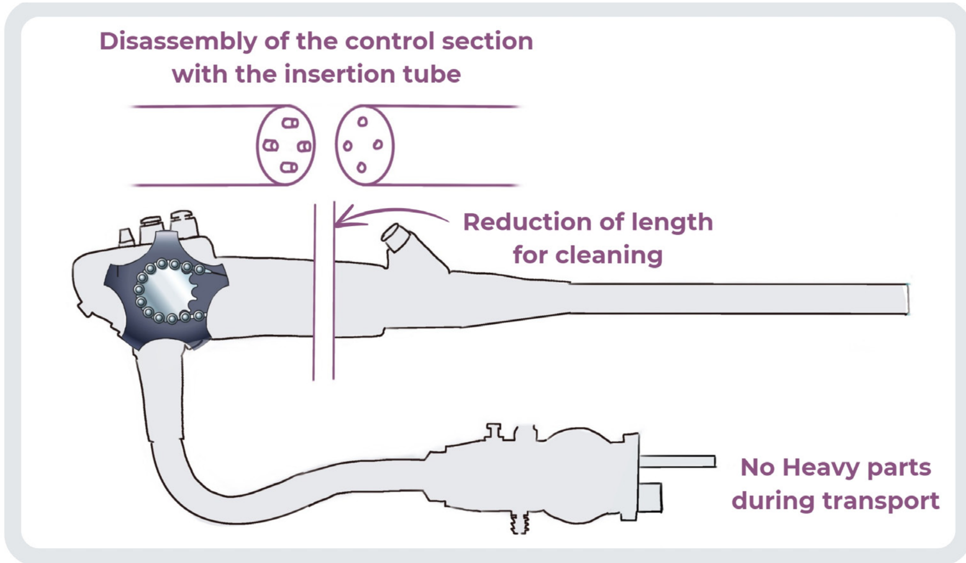

Figure 8.6: Idea 2 – Plug and Play colonoscope

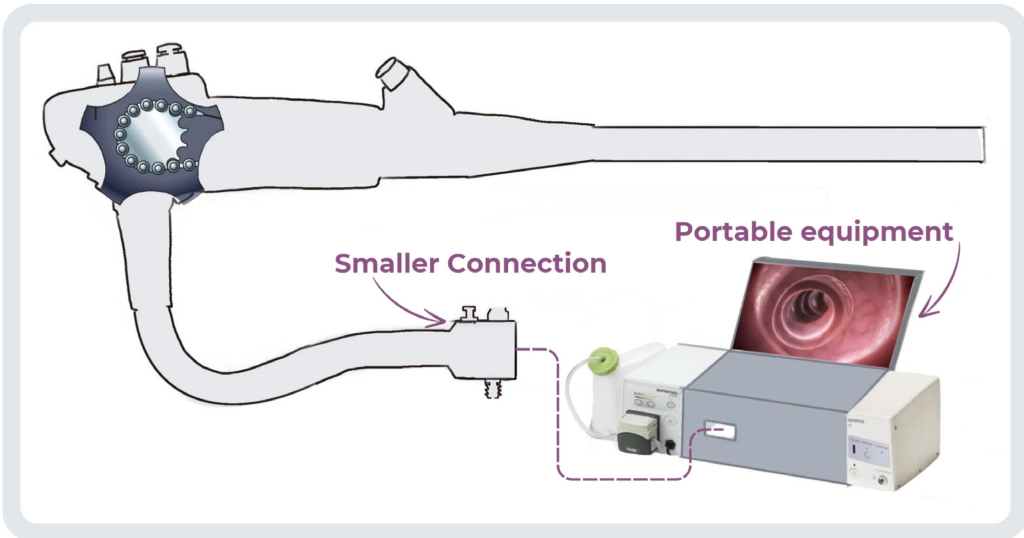

Figure 8.7: Idea 3 – Portable colonoscope

Idea 4 – Integrated reusable Biopsy Forceps colonoscope

In the past decade, the primary use of colonoscopes has shifted from being diagnostic devices to more therapeutic tools (Pasricha, 2004). However, the design has not evolved, which led to an overuse of single-use biopsy forceps. To prevent this waste, reusable biopsy forceps will be integrated into the colonoscope, as shown in Figure 8.9. The biopsy samples will be transported through the working channel via suction.

Idea 5 - Strainer to avoid clogged nozzle

The medical technician mentioned that a significant amount of dirt often collects at the distal end of the colonoscope, which makes it difficult to clean. To address this issue, the proposed design includes the integration of a removable strainer at the end of the insertion tube, as shown in Figure 8.10. This to ensure that the nozzle can be thoroughly cleaned.

Idea 6 - Smoother hand grip connector

The postdoctoral researcher mentioned that it is challenging to connect the colonoscope with the video processor, which causes the metal in the connector to wear out. To make it easier for the HCPs to connect the colonoscope with the video processor, a smoother grip will be added to the end of the colonoscope, see Figure 8.11.

Idea 7 – Maintenance detector colonoscope

It is important to know on time when maintenance is needed, to prevent further damage to the colonoscope. However, since the colonoscope is a medical device that is inserted into the patient's body, it is well enclosed, which makes it hard to determine if maintenance is needed.

This redesign aims to make it easier to detect when maintenance is needed. Therefore, the outer plastic part of the control section will be made transparent, as this part is always disassembled when regular maintenance is performed.

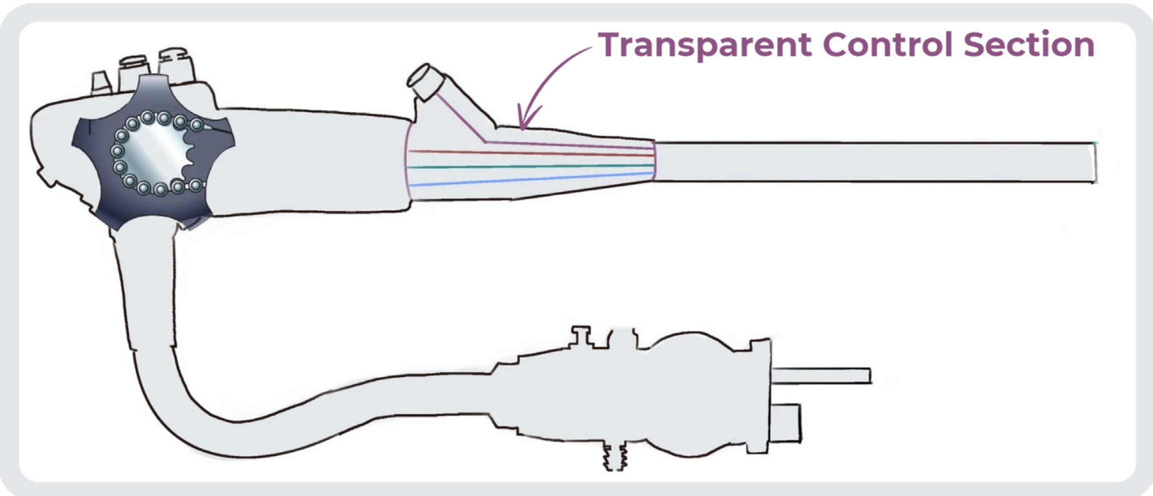

Figure 8.8: Idea 7 - Maintenance detector colonoscope

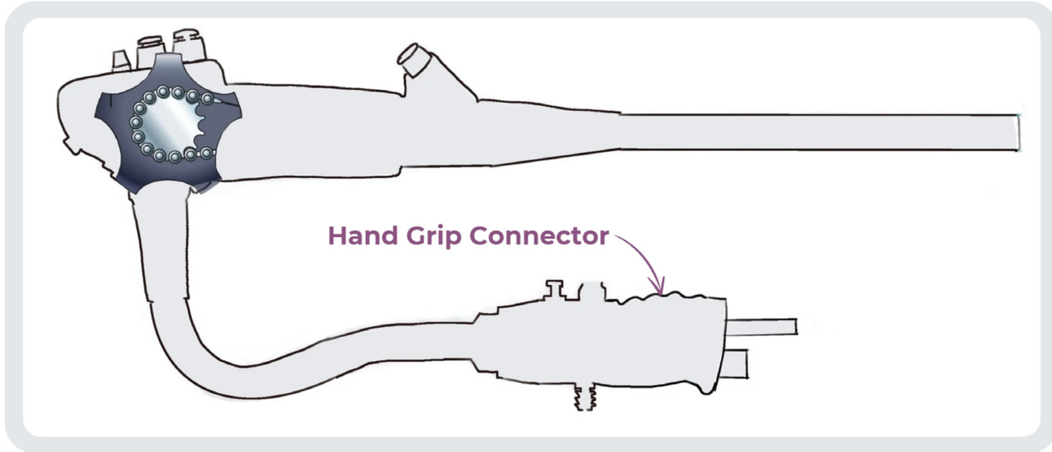

Figure 8.9: Idea 4 – Integrated reusable biopsy forceps

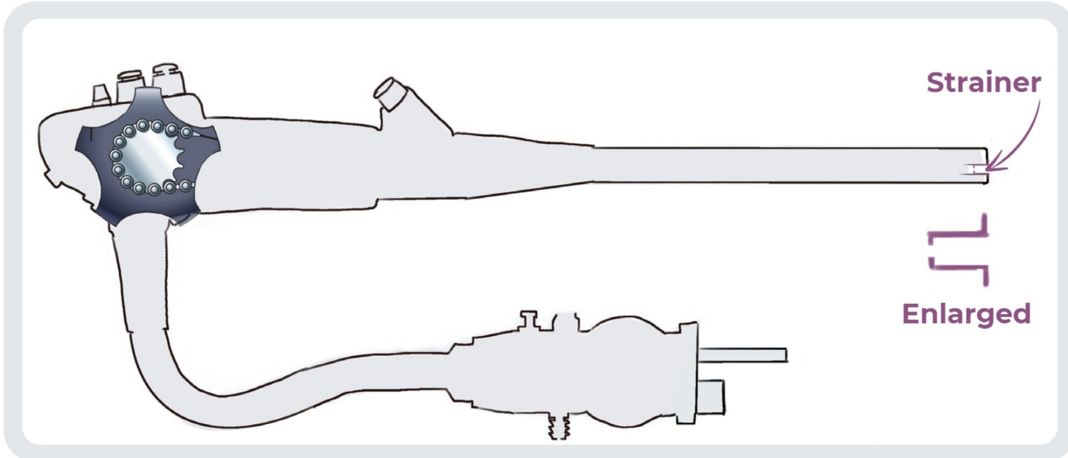

Figure 8.10: Idea 5 - Strainer to avoid clogged nozzle

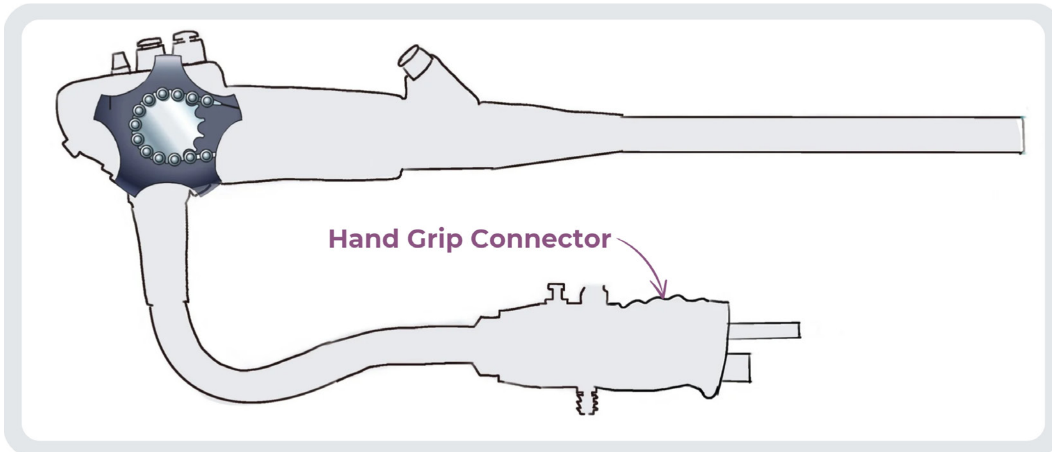

Figure 8.11: Idea 6- Smoother hand grip connector

8.3 Evaluation Ideas

Healthcare professionals from the EMC were interviewed to gather their perspectives on the ideas, as they frequently work with colonoscopes and can provide valuable insights.

8.3.1 Method

To gather feedback from different perspectives, participants with various backgrounds were interviewed, including:

- Two Endoscopists
- Medical Technician
- Microbiologist

Each participant was individually interviewed for approximately half an hour. During the interview, seven ideas were presented and discussed one by one. For the full presentation, see Appendix E. At the end of the interview, participants were asked to rank their top three ideas.

The summary of feedback gathered from each participant can be found in Appendix F. These opinions were considered in the improvement of the ideas in section 8.4.

Participants were asked to rank their top three ideas. Figure 8.12 shows how many times each idea was mentioned in the participants' top three selections.

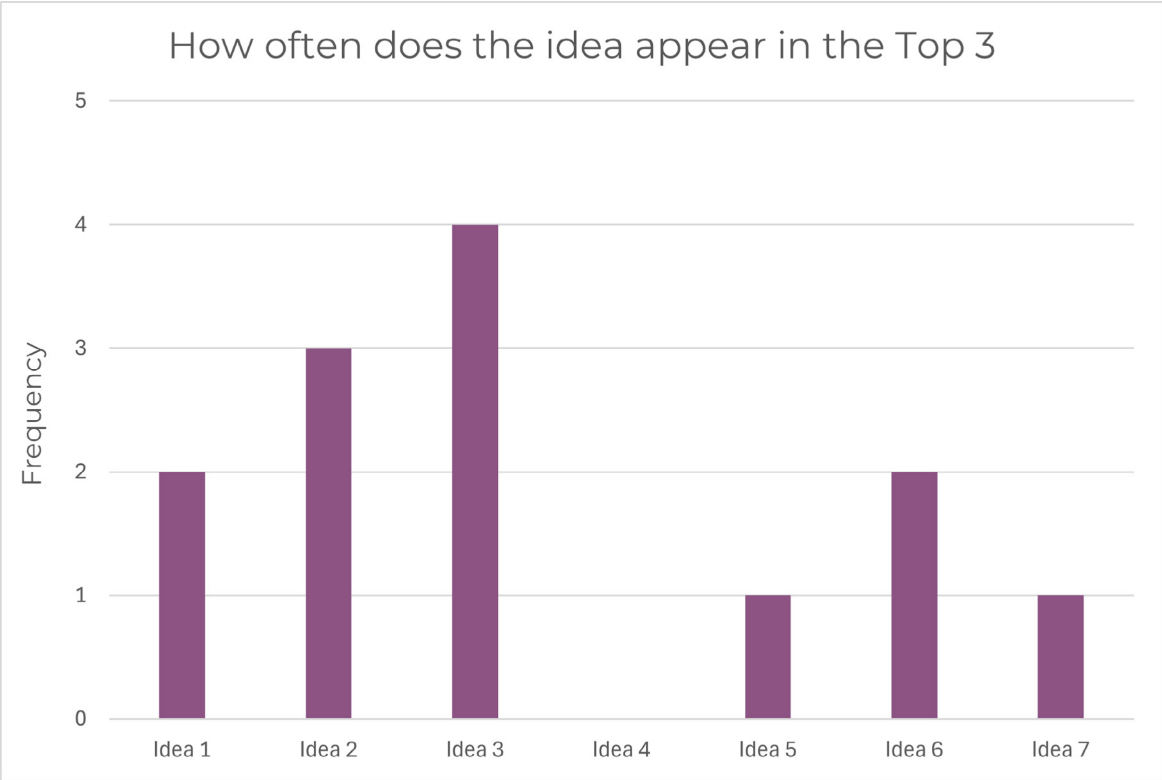

Figure 8.12: The amount that ideas are mentioned in participants' top 3

8.4 Improved Redesign Ideas

After ideas have been evaluated with Healthcare Professionals from the EMC, the ideas have been improved. The explanation of these improvements can be found in this section.

Idea 1 – 360 Degrees camera colonoscope

Most of the Healthcare Professionals found this idea interesting as it represents a different way of working with a colonoscope. However, they noted that endoscopists would need training to interpret the 360-degree images since the view will be different.

Additionally, it will be important to ensure sufficient lightning with a curved camera to avoid shadowing. Therefore, the redesign includes extra light sources near the camera, as shown in Figure 8.13. However, one endoscopist expressed concer about the feasibility of removing the angulation knob, as certain parts of the intestine require the colonoscope to be very flexible to navigate.

Idea 2 – Plug and Play colonoscope

All Healthcare Professionals mentioned that it would be better to split the colonoscope below the control, as shown in Figure 8.14. This approach would still allow to clean and flush the valves in the procedure room. Additionally, it would be easier for HCPs to connect the parts since there are no movement cables in the lower section.

Idea 3 – Portable colonoscope

This idea was ranked in everyone's top three during the evaluation. An endoscopists noted that the disposable colonoscopes do not require an external light source because it is integrated into the connector. This feature has been incorporated into the improved design as well. However, it is important that the light source can be easily replaced. The medical technician mentioned that, with some brands, the aluminium cooling box must be discarded before he light source can be changed. This leads to additional waste, which needs to be prevented. Therefore, in this design, the aluminium cooling box will be behind the light source.

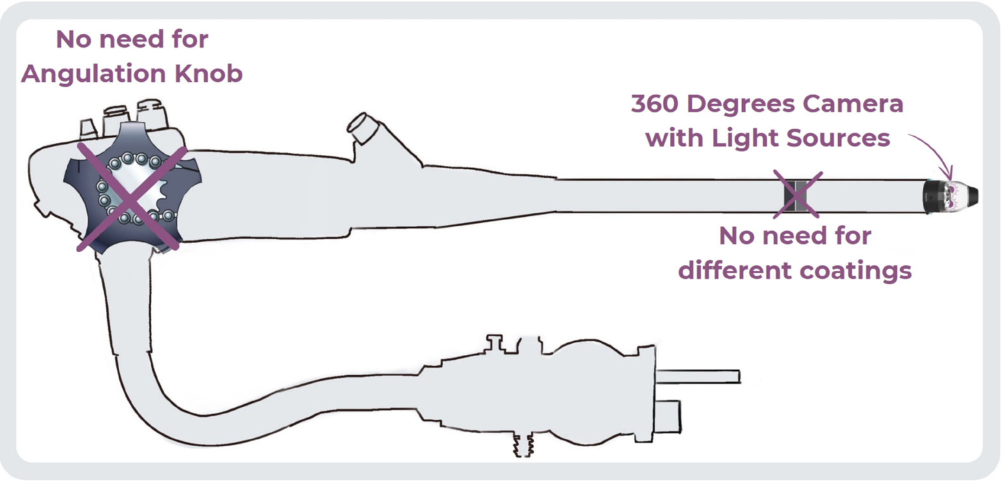

Figure 8.13: Improved Idea 1 - 360 Degrees camera colonoscope

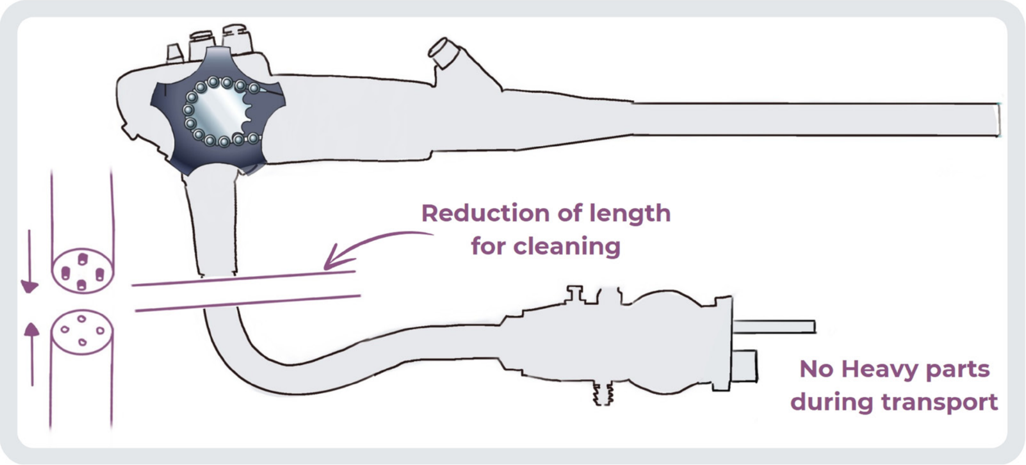

Figure 8.14: Improved Idea 2 - Plug and Play colonoscope

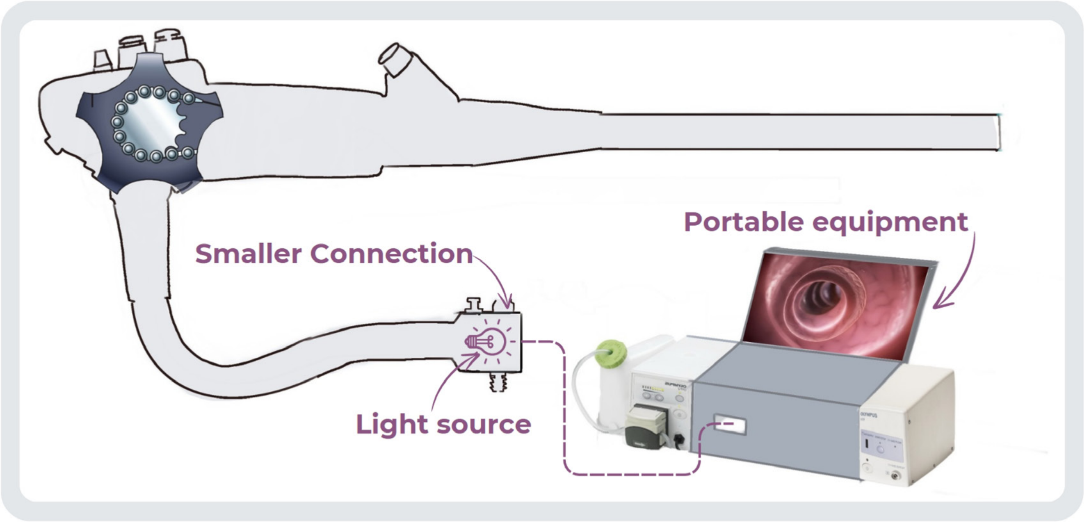

Figure 8.15: Improved Idea 3 - Portable colonoscope

Idea 4 – Integrated reusable Biopsy Forceps colonoscope

Everyone mentioned that cleaning the colonoscope would be a challenge with this idea, as they believe it will take more time to ensure thorough cleaning around the biopsy forceps. Additionally, it is important for one side of the colonoscope to be closed off to create suction. This step is illustrated in Figure 8.17.

Idea 5 – Strainer to avoid clogged nozzle

Many Healthcare professionals questioned this idea, as it was not clear to them how it works. The concern was that the biopsy forceps need to pass through the strainer while others do not. To clarify this, a septum membrane has been added, as illustrated in Figure 8.18. This membrane ensure that only the biopsy forceps can pass through.

The medical technician recommended placing the strainer idea closer to the valves, see Figure 8.19. This is because the O-rings of the valves often become loose and accidentally end up in the water-jet channel which prevents the colonoscope's camera to be cleaned.

Idea 6 – Smoother hand grip connector

All Healthcare professionals liked this idea, and some mentioned that the smoother hand grip would be especially important for those with smaller hands.

Idea 7 – Maintenance detection colonoscope

The endoscopist liked the aim behind this idea, where it would be possible to detect when maintenance is needed. The medical technician mentioned that it is still important to check for maintenance by disassembling the colonoscope to inspect the loose cables. However, this could be addressed by adding strain gauges on the cables, which can provide a signal when they become loose, see Figure 8.16

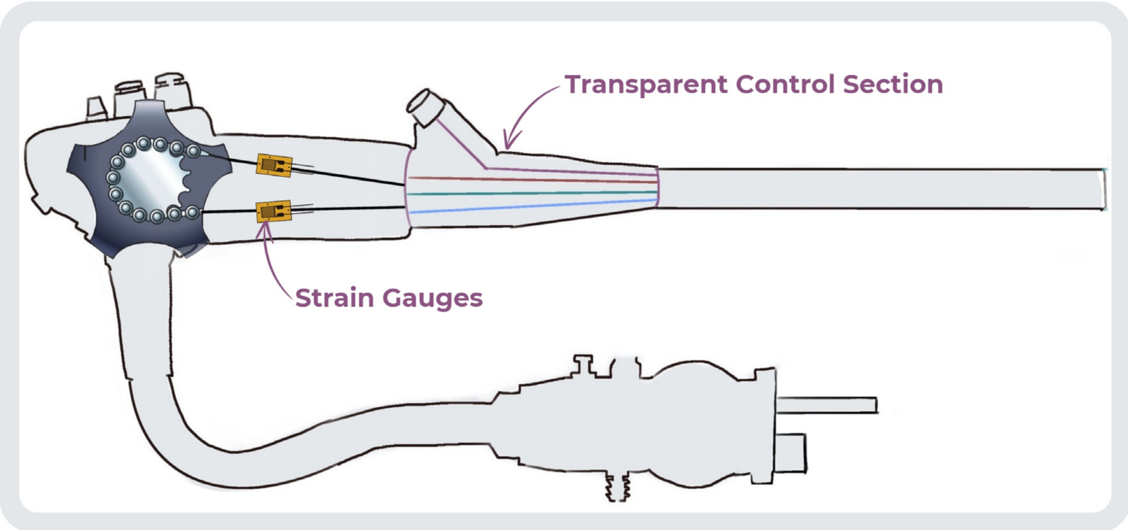

Figure 8.16: Improved Idea 7 - Maintenance detection colonoscope

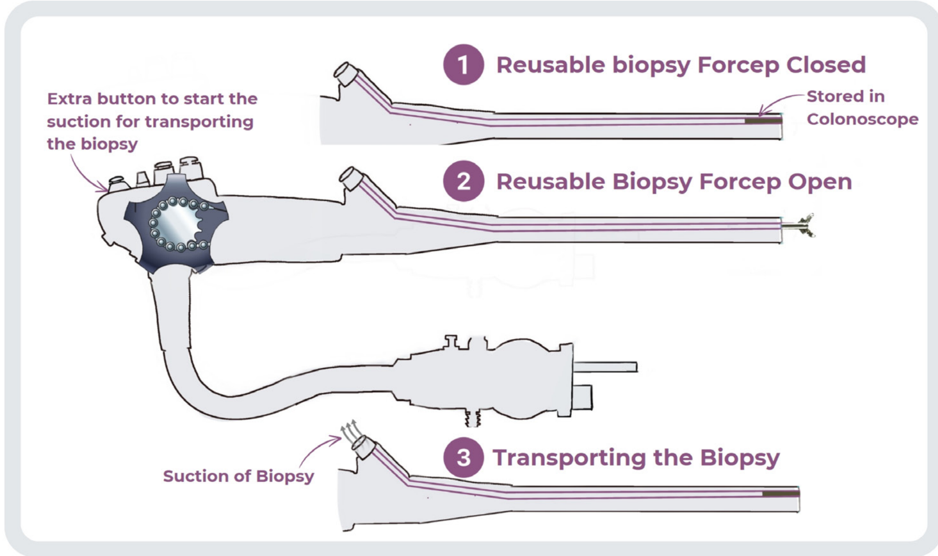

Figure 8.17: Improved Idea 4 - Integrated reusable Biopsy Forceops colonoscope

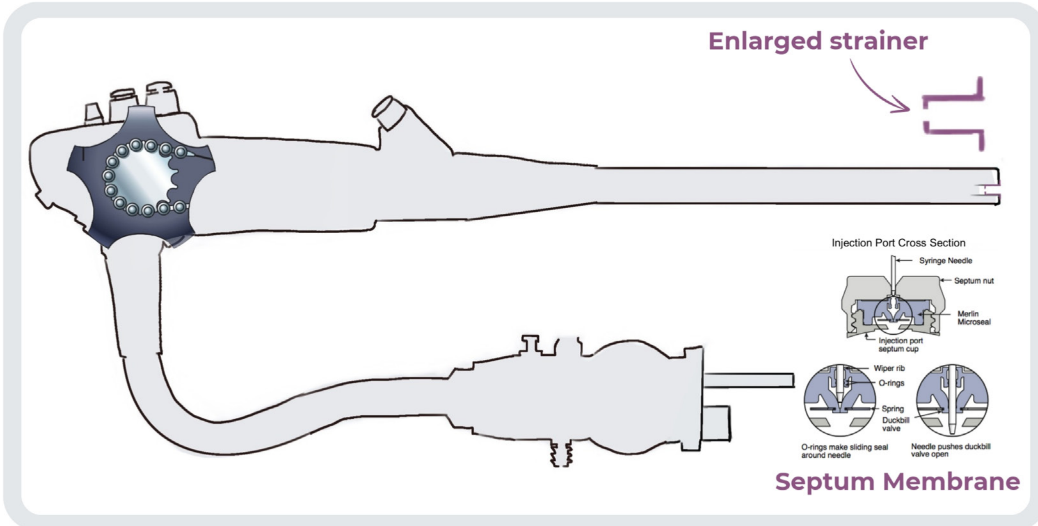

Figure 8.18: Improved Idea 5 - Strainer to avoid clogged nozzle

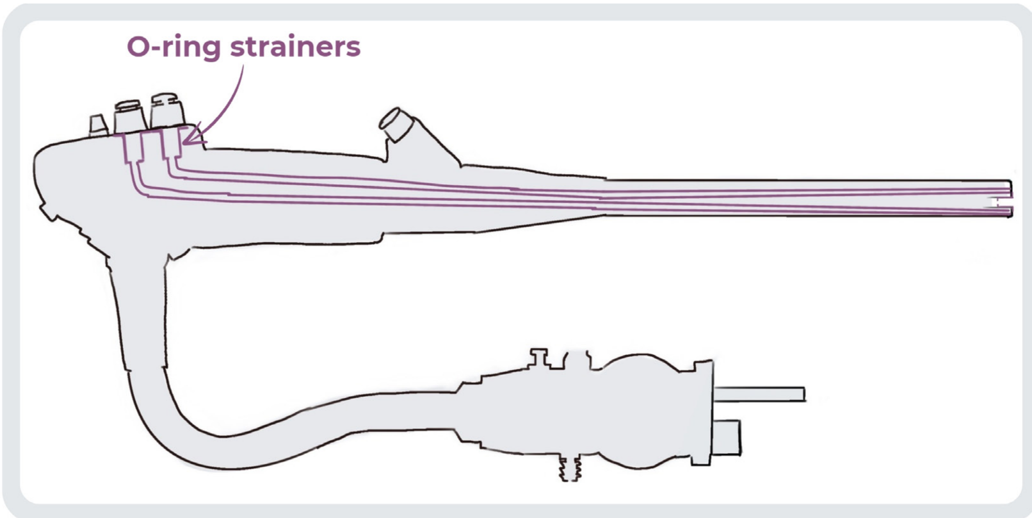

Figure 8.19: Improved Idea 5 - Strainer to avoid clogged nozzle (O-rings)

8.5 Final Redesign

The final redesign of the sustainable colonoscope is explained in this section. Section 8.5.1, provides an explanation of the final redesign idea and section 8.5.2 describes how the final redesign would function in the colonoscopy procedures.

8.5.1 The Product

The final redesign of the colonoscope, as shown in Figure 8.20, combines several of the improved ideas discussed in section 8.4.

The main aim of this final redesign is to enhance the sustainability of the reusable colonoscope by prolonging its lifespan.

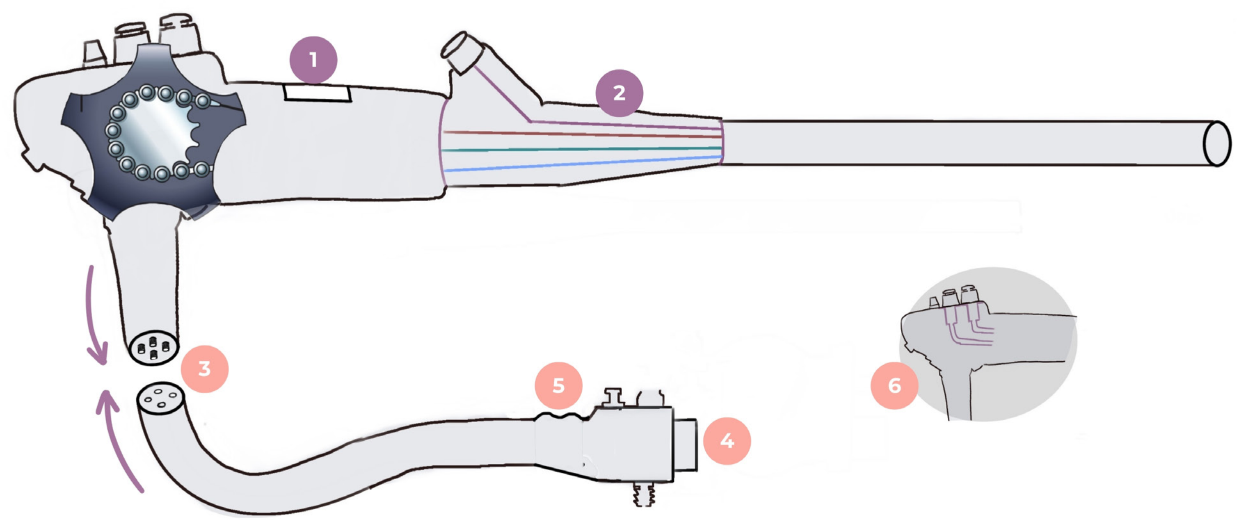

Figure 8.20: The Final idea of the sustainable colonoscope

The main aim of this final redesign is supported by two objectives which consists of different product characteristics, as shown in Figure 8.20.

1. **Detect maintenance on time.**

   The colonoscope is well enclosed as it is a medical device inserted into the patient's body, which makes it difficult to determine whether maintenance is needed. Therefore, regular maintenance is scheduled once a year. However, it is crucial to detect the need for maintenance promptly to prevent further damage from a failure.

   During regular maintenance of the colonoscope, the control section is disassembled to identify the areas that need attention. To enhance the visibility of maintenance without disassembly, the control section will be made transparent (point 1). This will allow the CSA staff to regularly inspect cable connections. Additionally, strain gauges will be installed on the cables which can provide a signal when they become loose (point 2).

2. **Prevent damage to the colonoscope.**
   The reasons why the colonoscope often requires repair are noted in Section 8.1. To prevent these failures, various design choices were implemented, as shown in Figure 8.20.

   The colonoscope is divided into two sections (point 3), which allows the lower part with the connector to remain in the procedure room. This prevents the connector from potentially damaging the camera which can occur during transport from the procedure room to the disinfection and storage room.

   The connector is also made smaller (point 4) with a smoother hand grip (point 5), to simplify the connection between the colonoscope's connector and the video processor. This prevents metals in the connector wear out, which was a concern with the current difficult connection of the reusable colonoscopes. Additionally, the light source will be integrated into the connector of the colonoscope, similar to what is found in single-use colonoscopes. As a result, an external light source will no longer be needed.

   Furthermore, a strainer will be added (point 6) to prevent the O-rings of the valves will entering the water-jet channel). This ensures that water can still flow through the channel to clean the colonoscope's camera.

8.5.2 The Procedure

Figure 8.21, illustrates the final redesign of the colonoscope and its intended use in the endoscopy department. Steps 4, 5 and 6 are based on the easy connection of single-use colonoscopes with the external equipment.

Another benefit of this design is that once the lower part of the colonoscope is connected to the external equipment, it can remain connected until the end of the day. Only the upper part of the colonoscope needs to be changed and connected after every procedure.

After the colonoscopy procedure is performed, the lower part will be wiped off in the procedure room and the colonoscope's upper part will be pre-cleaned in the water tank in the disinfection room. Currently, the entire colonoscope is immersed in the water tank. Therefore, it has a larger content of water, compared to when only the upper part needs to be immersed in the water tank.

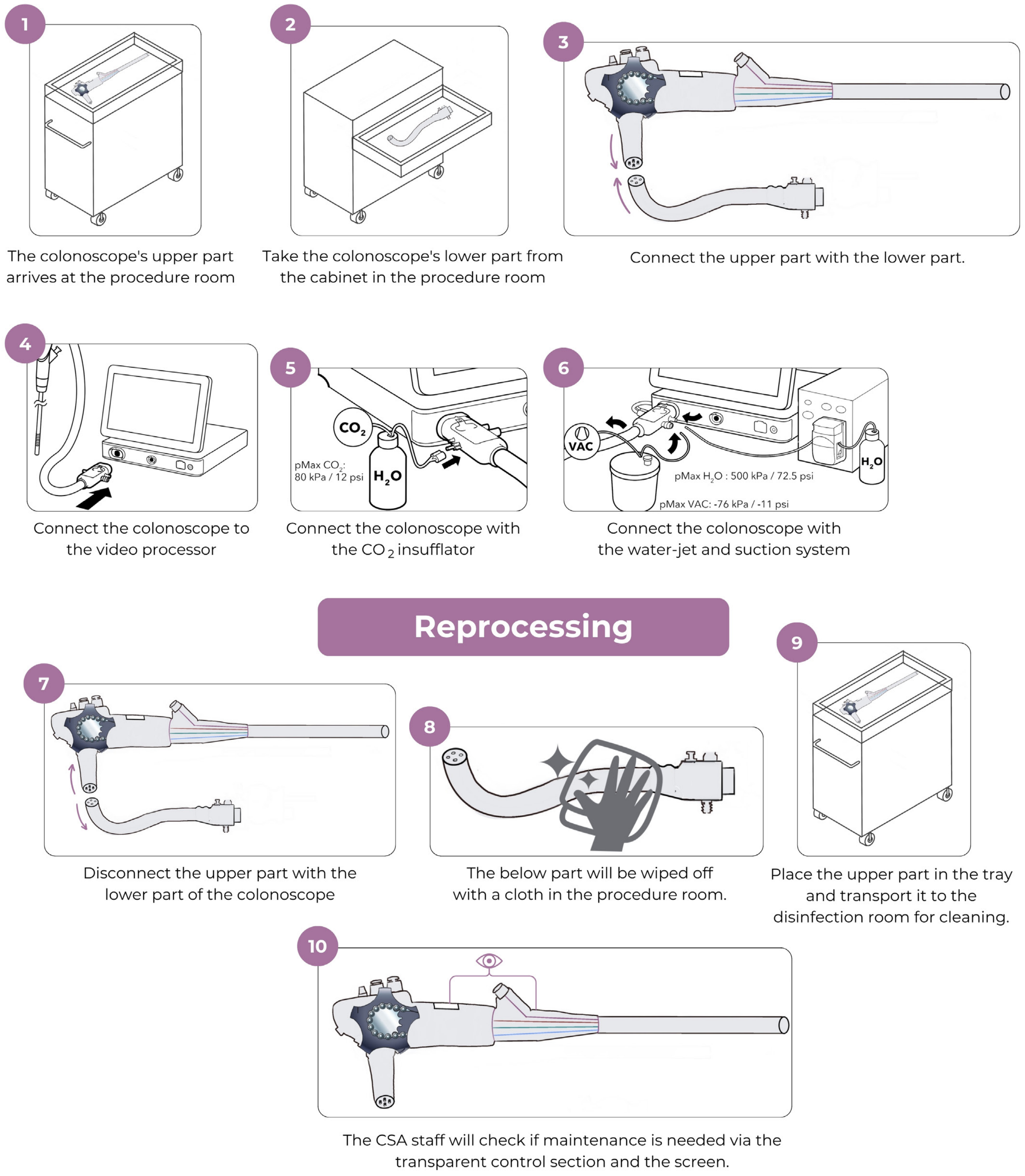

Figure 8.21: Manual on how to use the final redesign
(Step 4, 5 and 6 are retrieved from: "Instructions For Use Ambu AScope Gastro", 2021)

Key Takeaways - Section 3

- Even after considering the waste that is being produced from cleaning reusable endoscopes, implementing single-use endoscopes will result in a 40% increase in total net waste mass. Therefore it is important to continue **using reusable colonoscopes.**
- When designing sustainable **reusable colonoscopes, single-use colonoscopes** can work as an inspiration as they are **easy to use.**
- When **designing for sustainability** it is important to have a **broad perspective** as there can be different factors that influence the sustainability of a product.
- Discussions with the medical technician revealed that the **reasons** for sending colonoscopes for **repair** are **not documented**. However, this information is crucial for providing **recommendations to the supplier** to prevent repairs and extend the lifespan of the colonoscope.
- To **prolong the lifespan** of the colonoscope it is important to detect the **need for maintenance on time** and **prevent any damage** on the colonoscope.

Section 4

09
Revised Product Journey Map

This chapter marks the beginning of Chapter 9 which shows the revised PJM and evaluates the project.

In this chapter, the designed sustainable interventions for the procedure, disinfection and storage room (from Chapter 6) with the final redesign idea of the colonoscope (from Chapter 8) are combined in a revised Product Journey Map.

These revised product journey maps compare the current way of practise to the proposed steps in the endoscopy department to show how the environmental impact can be reduced.

The new Product Journey Map consists of three layers, as shown in Figure 9.1.

- The **first layer** explains the intended steps to a greener procedure room/ disinfection room.
- The **second layer** explains the R-strategy that is used to design the sustainable interventions, as explained in Chapter 6.
- The **third layer** discusses how the current step is performed in the procedure room at the EMC.

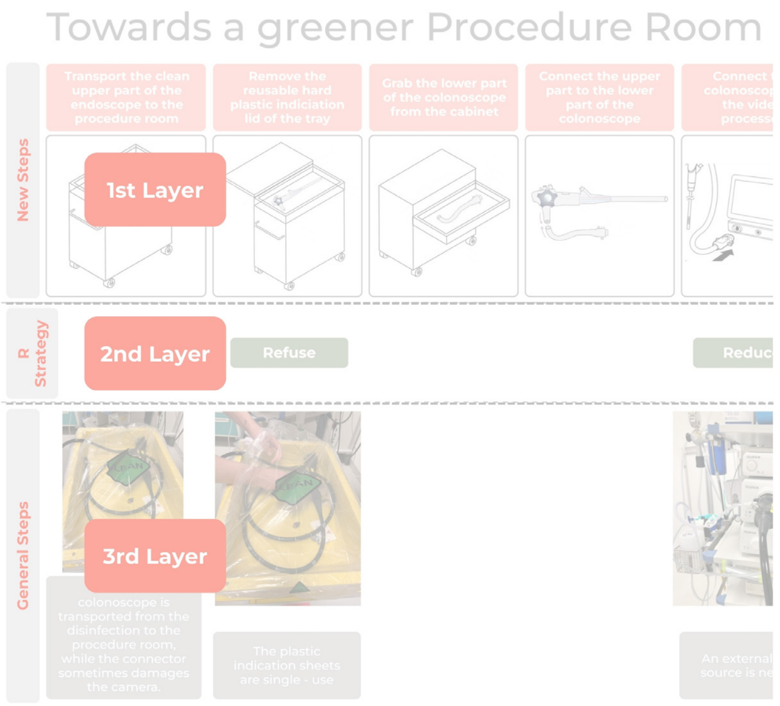

Figure 9.1: Explanation of the layers

The revised Product Journey Map for the procedure room is shown in Figure 9.2 and the revised PJM of the disinfection room is shown in Figure 9.3.

Towards a greener Procedure Room

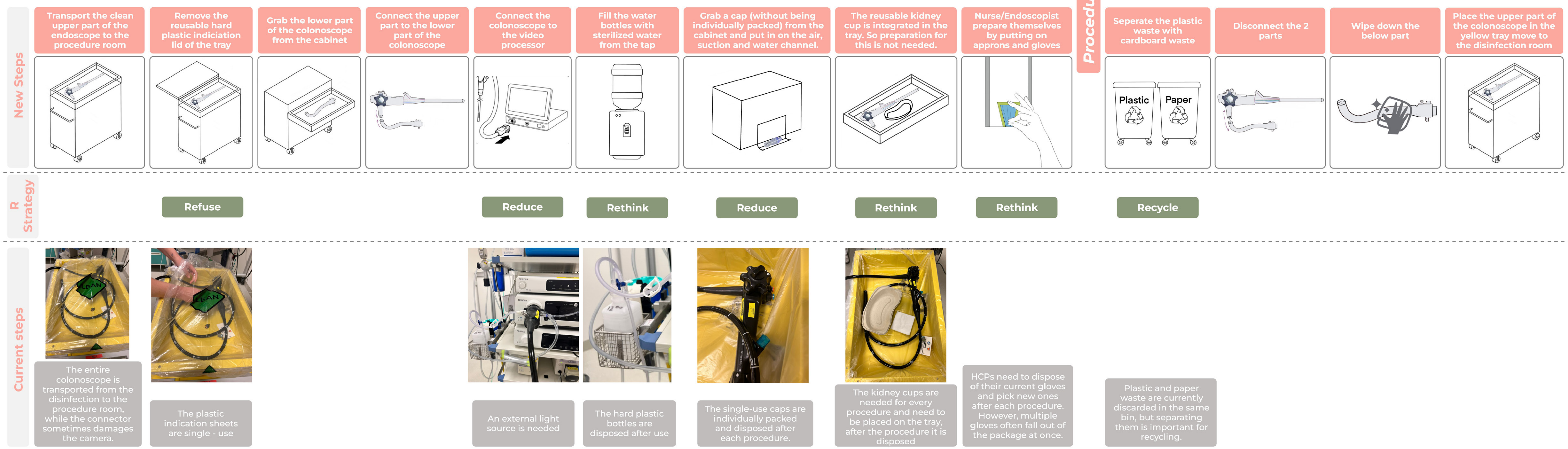

Figure 9.2: The revised PJM of the Procedure Room

Towards a greener Disinfection Room

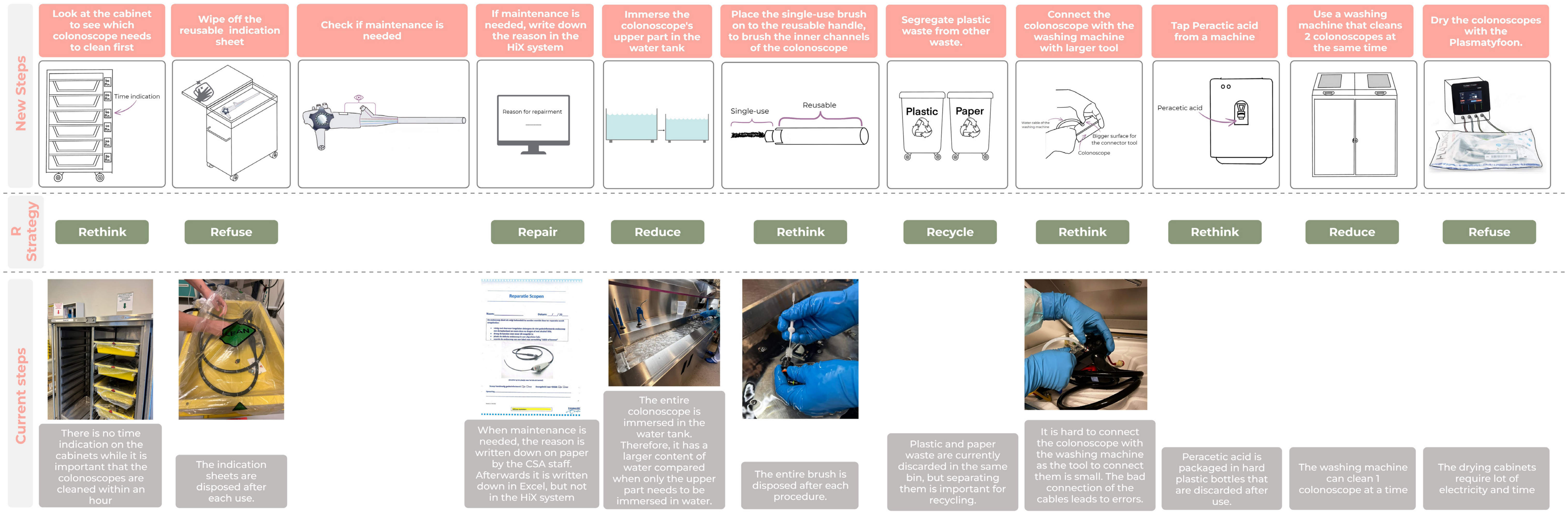

Figure 9.3: The revised PJM of the Disinfection Room

Section 4

10
Project Evaluation

This chapter evaluates the graduation project. Section 10.1 describes the conclusion. Section 10.2 gives recommendations on how to further reduce the environmental impact of colonoscopy. Furthermore, Section 10.3 discusses the limitations of the graduation project. Additionaly, Section 10.4 provides a personal reflection.

10.1 Conclusion

The overall conclusion of this graduation project is that designing sustainable interventions in the healthcare sector requires a systemic approach. It is crucial to focus on enhancing the sustainability of the colonoscopy procedures in the endoscopy department, as well as improving the sustainability of the products used in the department, such as the colonoscope.

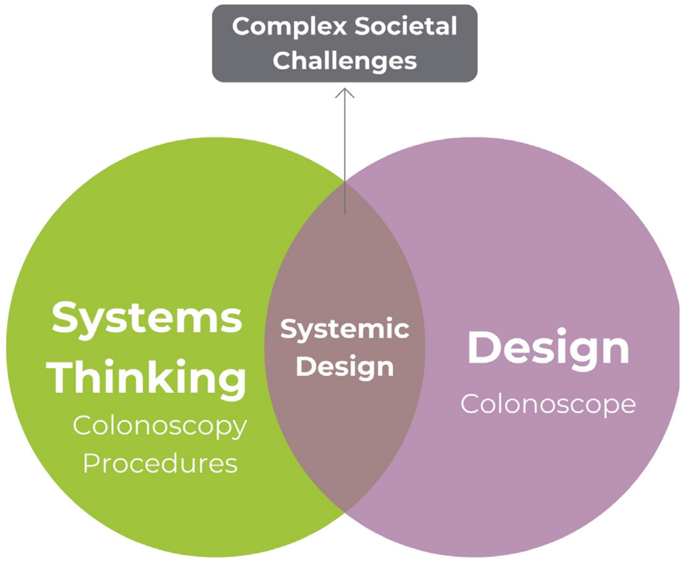

Figure 10.1: The Systemic approach applied in this graduation Project

During the creation of the PJM, the focus was placed on the use of the colonoscope within the department. This focus made it easier to include more variables in the PJM, such as waste streams and human interactions. This comprehensive overview of the colonoscopy procedures made it possible to identify the environmental impact hotspots.

Creating the PJM as a visual, made it also easier to brainstorm ideas with Healthcare professionals during the co-creation session. This visual bridged the gap between a non-medical person discussing medical topics, as the HCPs could easily point out what they were talking about. This accelerated the process of designing ideas to improve the department's sustainability. In a 45-minute session, 14 ideas were generated. This highlighted the importance of using circular methods that are easy to understand by HCPs.

The focus on designing with a circular mindset led to a redesign that includes timely maintenance detection and damage prevention. This approach aims to prolong the lifespan of the colonoscope, thereby minimizing waste from disposing of the device. Additionally, it became clear that the reusable colonoscope needs to improve its usability to remain competitive with the more user-friendly single-use colonoscopes.

10.2 Recommendations

There are several recommendations for achieving a greener colonoscopy. Section 10.2.1 explains the recommendations given to the endoscopy department. Section 10.2.2 describes the recommendations to the colonoscope supplier for improving the colonoscope.

10.2.1 Endoscopy department

During the identification of environmental impact hotspots, it was observed that many single-use consumables are used. Therefore, it is recommended to find reusable alternatives for these items. In chapter 9, some ideas for these alternatives are provided. Also, segregate the plastic waste from other waste to encourage recycling within the department.

Furthermore, it is recommended to discuss with suppliers whether it is necessary for all consumables to be individually packaged. For instance, some single-use consumables, like the non-return valves used on the water-jet channel of the colonoscope, do not come in contact with the patient, but are still individually packed, leading to additional waste.

Also, it is important to document the reasons for sending colonoscopes for repair in the HiX system. This information is essential to determine whether the defect is due to the way of usage or the design of the colonoscope. Understanding these causes can help to prolong the lifespan of the colonoscope and inherently reduce the environmental impact.

The PJM revealed that a significant amount of equipment is needed in the endoscopy department, which leads to high energy consumption. Therefore, it is recommended to find alternative equipment that uses less electricity. For example, consider using plasmatyfoons for drying colonoscopes instead of traditional drying cabinets or double basin washing machines.

During this project, a 45-minute brainstorming session with the PJM led to the identification of around 15 hotspots. Therefore, it is advisable to conduct more of these brainstorming sessions with the green team and develop a plan of action to implement these ideas. Additionally, include the CSA staff in these discussions, as many sustainable improvements can also be made in the disinfection room.

10.2.2 Colonoscope designers

To the designers of the colonoscope, consider developing a modular design. For instance, the lower part of the colonoscope can remain standard, as this section does not need to enter the patient's body. Then focus on changing only the upper part of the colonoscope for differentiation. This modular design will reduce the materials that are needed for reprocessing the colonoscopes and also it will improve the usability of the reusable colonoscopes, as shown in Section 8.5. Furthermore, strive to simplify the design and look for inspiration from single-use colonoscopes.

10.3 Limitations

This graduation project was primarily focused on improving the sustainability of the colonoscope within the endoscopy department. However, to fully identify potential improvements for the colonoscope, it is important to also consider the production phase.

The overview of the waste streams in the PJM was based on several assumptions , see Appendix G, that need to be validated more methodologically.

Due to the extensive research required to identify environmental impact hotspots, less time was available for the redesign of the colonoscope. For further projects, it will be important to also include the manufacturer of the colonoscope in the process.

10.4 Personal Reflection

This graduation project helped me evolve as a designer but also contributed to my personal growth.

Working with Healthcare Professionals
It was exciting to work closely with healthcare professionals and observe the differences between our disciplines. As designers we are used to think outside the box, I experienced that this mindset is not as common among healthcare professionals. My experience as a member of the Medisign student board has already confirmed my interest in designing for the healthcare sector. This graduation project has only strengthened my conviction to continue working in this field. Designing in the healthcare sector requires a human-centred approach, which brings me great satisfaction in my work.

Sustainability in the Healthcare sector
Furthermore, I widened my knowledge on the topic of sustainability during the graduation project. In the past, I was always very focused on detailing my work at a technical level. However, during this graduation project, I learned to also look beyond the product and to think about the future. Talking to HCPs made me realize that in the field of sustainability, it is also important that you include and convince others in the process.

Project management
Alongside my growth as a designer, I also experienced personal development. As a non-medical person, I was a bit hesitant in the beginning to contact others in the healthcare sector. However, during this graduation project, I mostly had positive experiences, which led to more excitement in meeting others in this sector. Additionally, I presented several times for HCPs, which was a great way to practice my presentation skills. Finally, when I reflect on my writing skills at the beginning of this thesis, I must say that I made significant improvements.

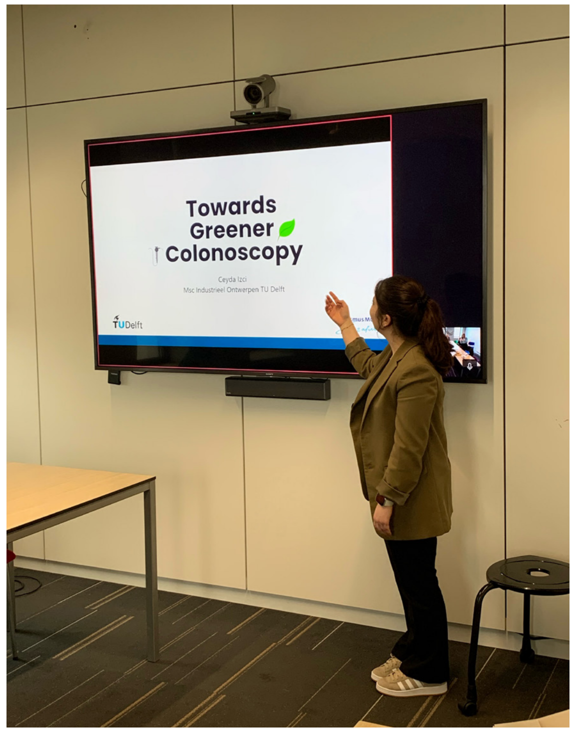

Figure 10.2: Me presenting during the kick-off of the ZEE consortium

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Appendices

Appendix A: Waste Audit

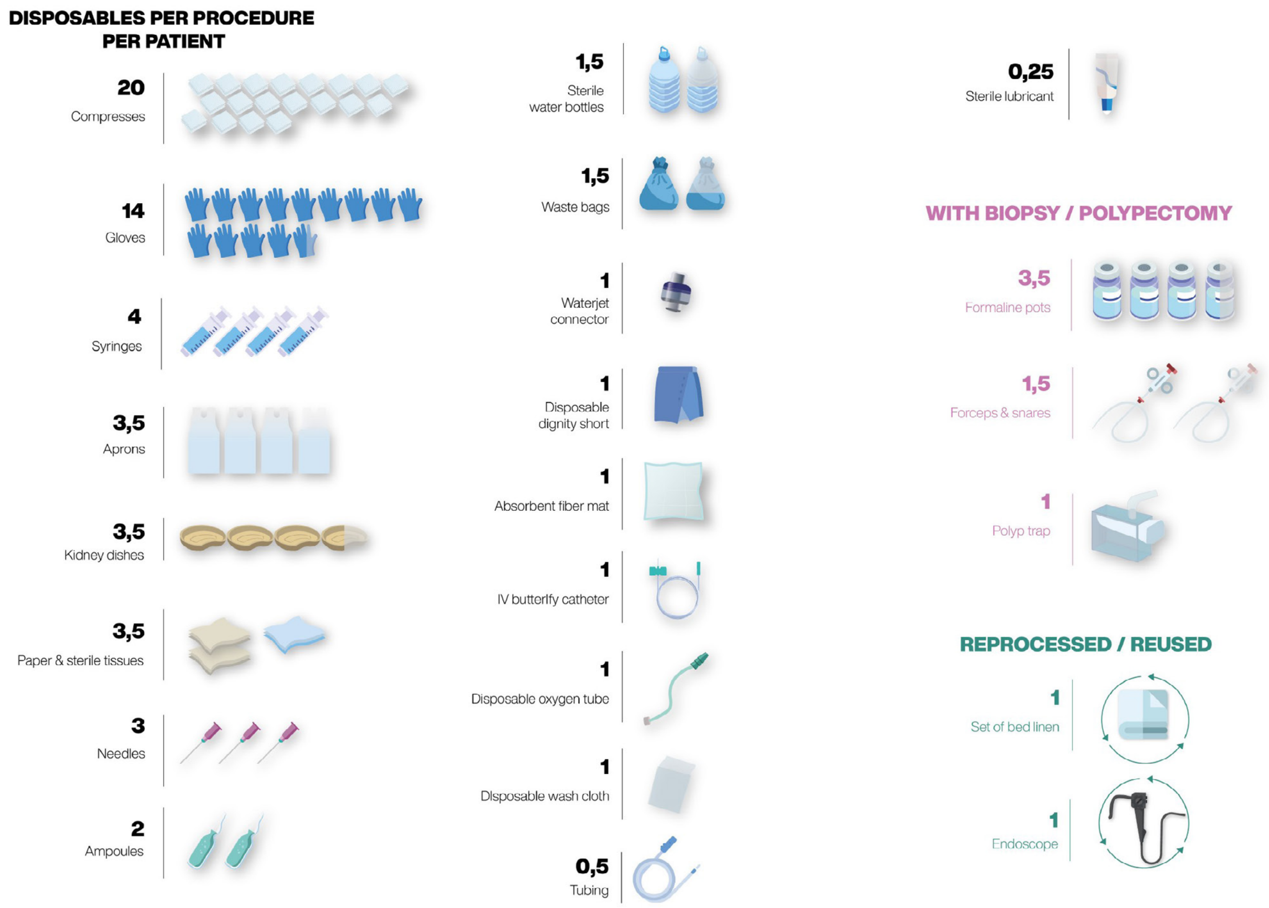


Figure A.1: Average use of products per patient, derived from waste audit and observations. (Clercx Lao, 2024)

Appendix B: Energy consumption calculation

The energy consumption has been calculated using different methods, as the same type of technical data was not always available for each piece of equipment. Generally, power was calculated by multiplying the voltage by the current. However, when a power factor was provided, it was also included in the calculations. In some cases, the kilowatt-hour (kWh) value was given in the technical data sheet of the apparatus, and this only needed to be multiplied by the procedure time. For all other equipment, the voltage was multiplied by the current and time to determine the energy consumed per procedure.

Table B.1: The energy consumption calculation of the equipment in the procedure room per colonoscopy procedure

Product	Brand	Product number	Amount	Voltage [V]	Power Factor	Apparent Power [VA]	Current [A]	Power [Wh]	Per procedure [W]
Light source	Fujifilm	BL-7000	1	230			1.2	276	229.08
Video Processor	Fujifilm	VP-7000	1	230					
Flushing Pump	Olympus	OFP-2	1	230	0.6	100	60	13800	11454
Insufflator	Olympus	UCR	1	230	0.6	40	24	5520	4581.6
Monitor	Onyx	Zeus-248ST-C8-1010	2					60	99.6
Monitor	NDS	Radiance Ultra 27	2					70	116.2
Patient Monitor	Drager	M540	1	230			1.5	345	286.35
Total								20,2 kWh	16.9 kW

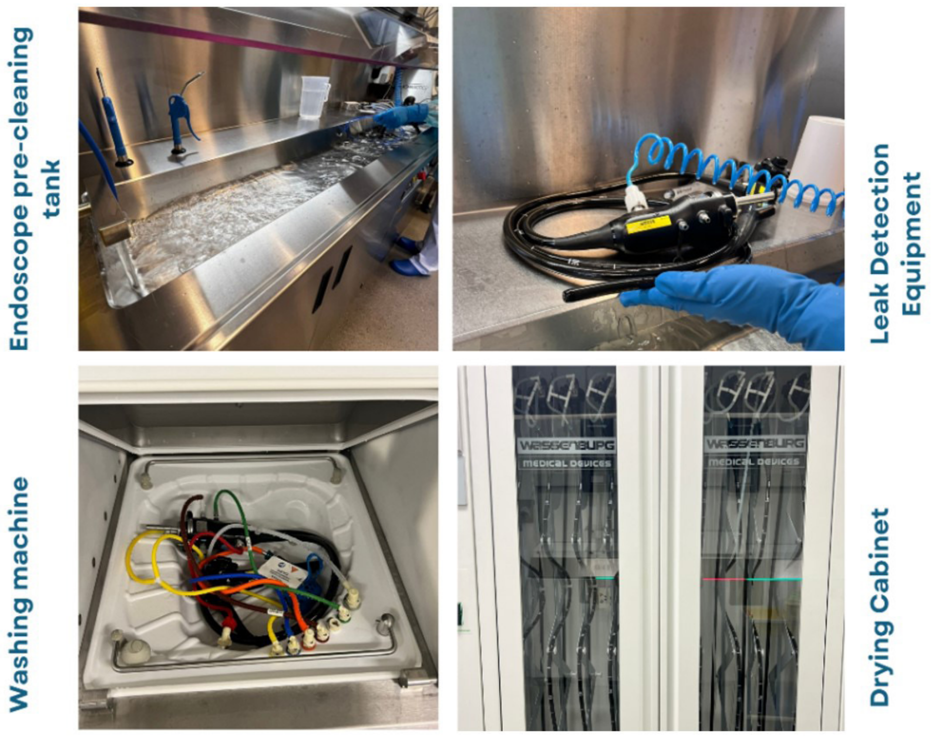
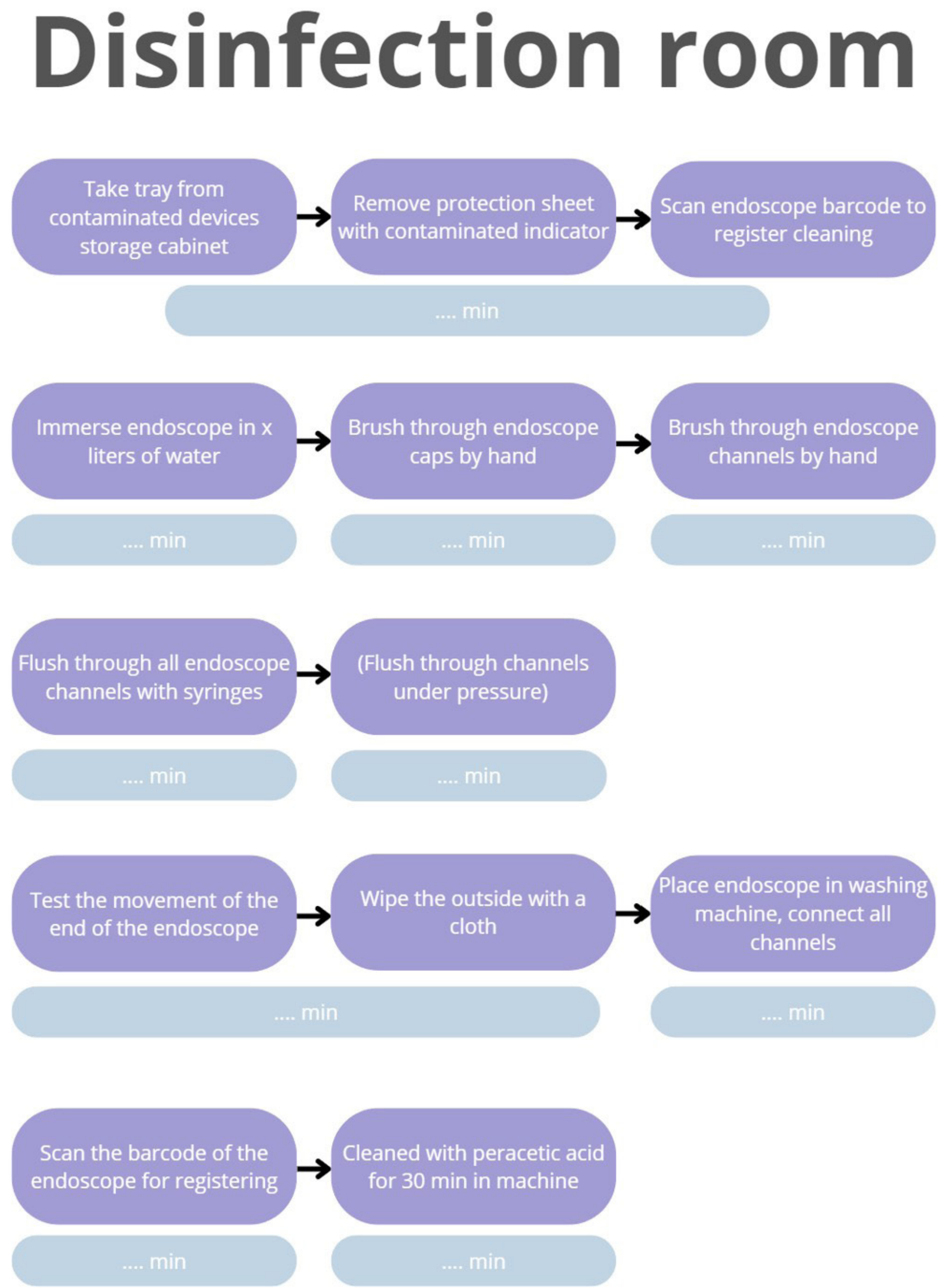


Figure B1: The equipment in the disinfection and storage room

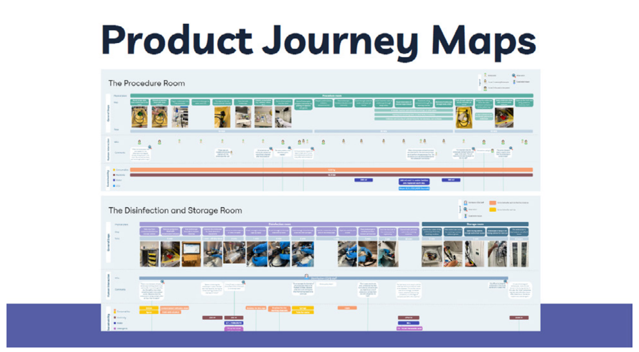
Table B.2: The energy consumption calculation of the equipment in the procedure room per colonoscopy procedure

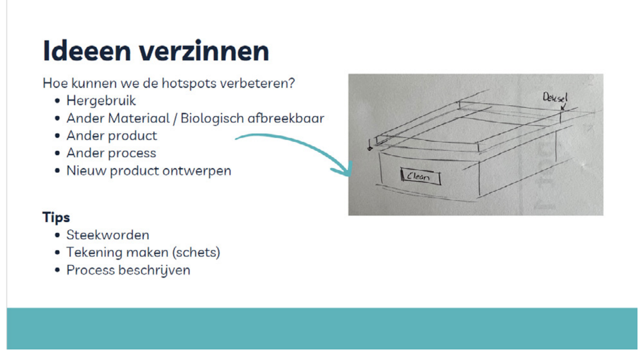
Product	Brand	Product number	Amount	Voltage [V]	Current [A]	Power [Wh]	Time [minutes]	Per procedure [W]
Drying Cabinet	Wassenburg	Dry300	1	230	7,5	1725	90	2588
Washing machine	Wassenburg	WD 440 PT	1			9500	30	4750
Endoscope pre-cleaning tank	Dorr Kampen	Scopenvoor reiniger	1	230	16	3680	15	305
Leak Detection equipment	MediTop	SLT V2	1	230	4	920	15	230
Total						15,8 kWhS		7,9 kW

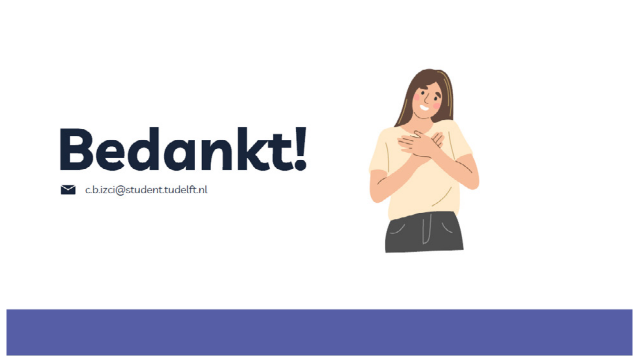
Appendix A: Template timing in Disinfection room



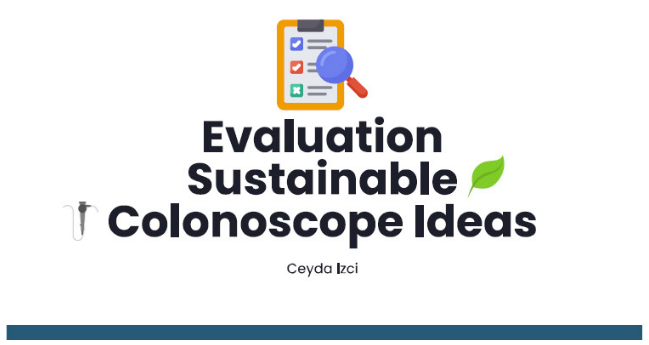
Appendix D: Co-Creation Presentation

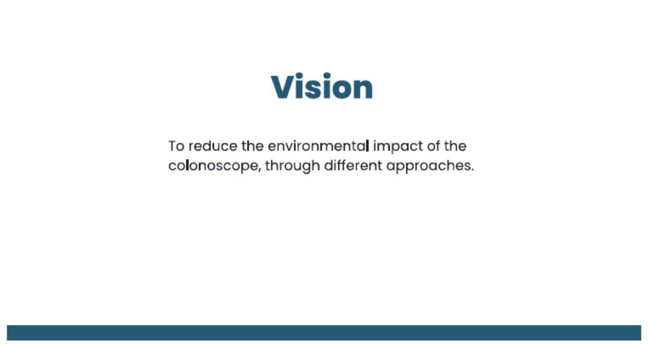


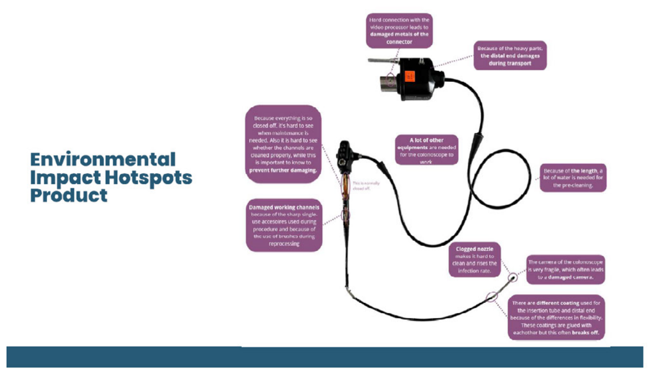


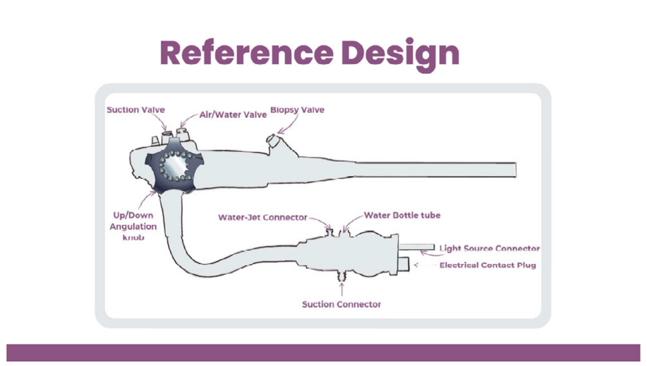


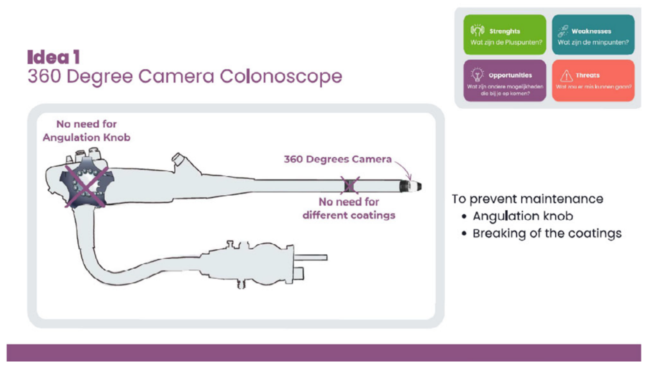
Appendix E: Presentation Evaluation Ideas

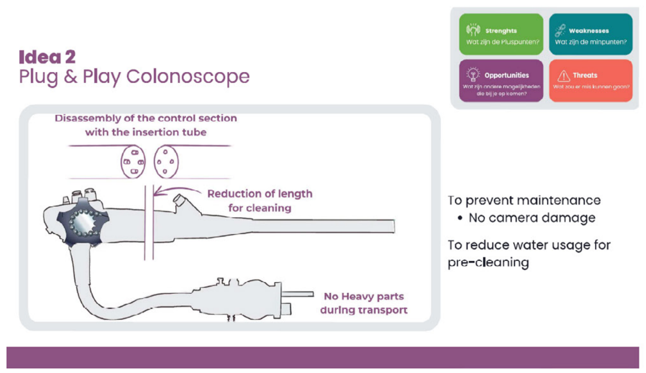


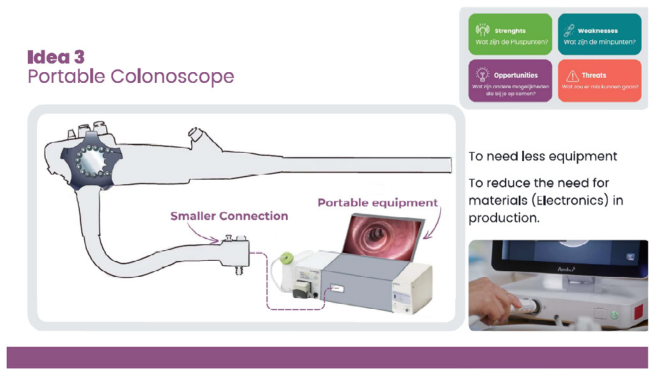




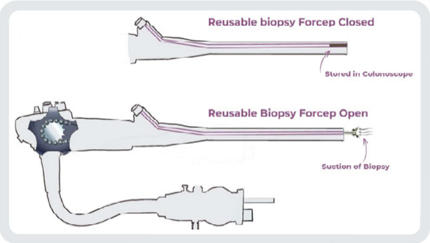






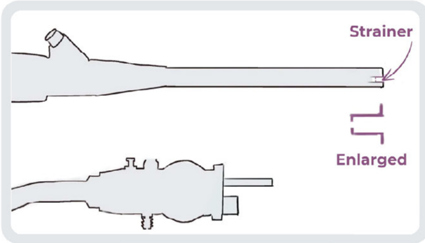


Idea 4
Reusable Biospy Forcep



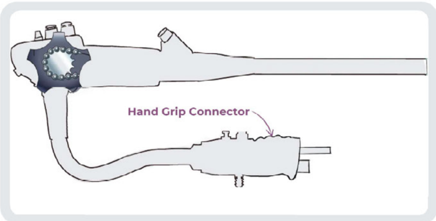
To need less consumables

Idea 5
Strainer to avoid clogged nozzle



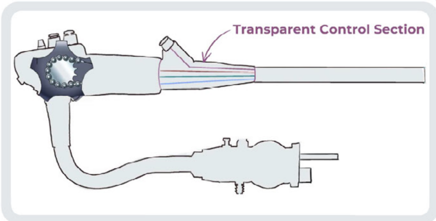
To need less chemicals -> be sure that it is clean

Idea 6
Smoother Hand Grip



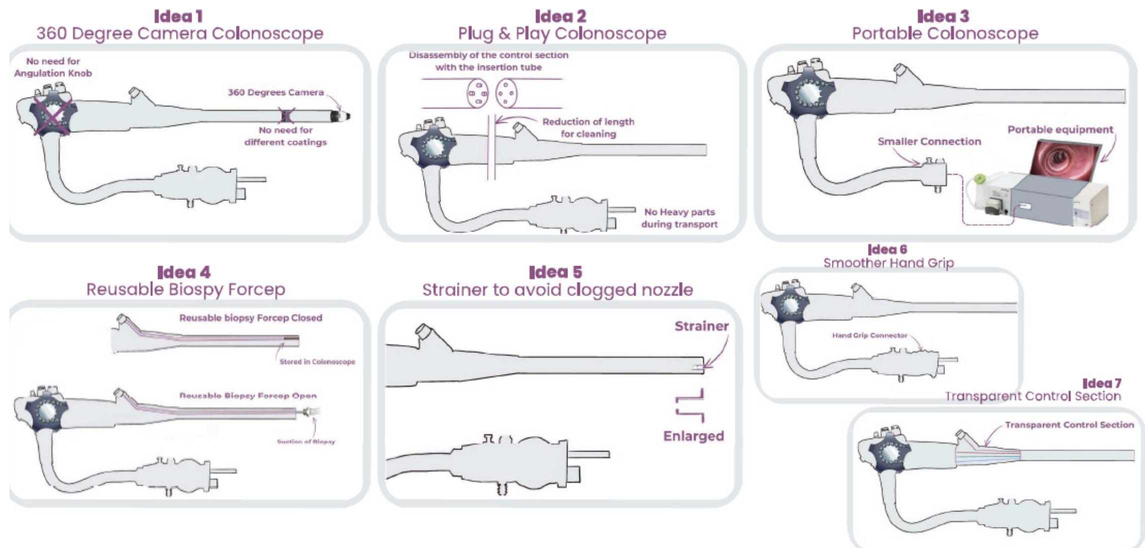
To Prevent Maintenance of the metals.

Idea 7
Transparent Control Section



To Prevent Maintenance by easily looking if it is needed.

Alle ideeen



Appendix F: Summary of feedback on ideas from HCP

Endoscopist 1

Idea 1	Idea 2	Idea 3	Idea 4	Idea 5	Idea 6	Idea 7
• For the view 360 degree camera is good. • But Angulation knob is still needed to pass the intestine	• It will become hard to have one universal colonoscope because of the different dimensions needed. • I think it will be better to make the split below so that you still can flush	• It will be nice to make it smaller. • Still provide the opportunity that the endoscopist can connect the video processor to the bigger screen • The light sources is in the connector for the disposable colonoscope, that's why an external light source equipment is not needed	• I think there needs to be thought about the cleaning process of the forcep. • Also what if you need another accesoire, like the retrieval net?	• Good, I don't know much about this topic	• Good, that will be handy	• I think the aim of the idea that you can know in time if maintenance is required is interesting

Medical Technician

Idea 1	Idea 2	Idea 3	Idea 4	Idea 5	Idea 6	Idea 7
• Educating the endoscopist on how to view the 360 degree view will be important. • Also an software will be needed to flatten the view	• I think it will be better to split the colonoscope below the control section, so it will be still easier to continue the movements, because connecting the water and eletricity channels is relatively easy to do bbut movements not	• Pentax has a combination of the lightsource and videoprocessor in one apparatus • The light source can be changed by the medical technician but by some brands like the Pentax you first need to throw away an Aluminum box.	• Cleaning the colonoscope will be harder • Also you need to be guarenteed that nothing like a tissue will be left over. • The challenge will be that the diameter of the colonoscope stays small	• It is important that this does not come loose. • I think it will be hard to transport the tissue through the channel. • I think it will be nice to have a strainer at the control section, because the O-rings of the valves become loose and will be stuck at the end of the nozzle that adds water that cleans the camera	• This will be nice for the HCP that have smaller hands because the connector is indeed big.	• I think it will be a nice gimmick to have but not really usefull because you will need to feel if the angulation knob is getting loose.

Endoscopist 2

Idea 1	Idea 2	Idea 3	Idea 4	Idea 5	Idea 6	Idea 7
• It will be hard to work with a 360 degree camera as you will need 3 monitors to look at.	• I would put the split below the control section. So you can still flush the colonoscope	• It is interesting to know why they still didn't change that to make the connection smaller	• Cleaning the colonoscope will be harder	• Maybe you can add something like a membran. So you can go through that.	• There is a new design of Pentax with a smoother hand grip.	• Nice

Microbiologist

Idea 1	Idea 2	Idea 3	Idea 4	Idea 5	Idea 6	Idea 7
• Interesting, but I think you should then have more light sources, because your camera would be not flat.	• Interesting idea to make the colonoscope modular. I think you should set up a new cleaning protocol to clean the hand grip	• Maybe there are also colonoscope with a hybride function. That you only throw away one part instead throwing away the whole colonoscope.	• It can be hard to transport a biopte after each time, because to create suction you need to close one side of. Maybe you can have a bucket in the design where you can collect the bioptes	• I don't understand this idea	• The good thing about this design I think is that you also thougth about the person that needs to use it.	• Nice

Appendix G: Limitations of the PJM

General Steps

From observations and discussion with an endoscopist, it has been decided to choose 50 minutes for the overall time spent during a colonoscopy procedure. However, for more scientific measurement of the average duration of a colonoscopy procedure, the time could be tracked in the HiX system from when an endoscope is scanned upon entering the procedure room to when it is scanned upon exiting.

Sustainability

The electrical properties of the equipment are retrieved from the products' technical data sheets to calculate the energy consumption. For a more accurate results of the energy consumption during a treatment, it is recommended to measure the electricity consumption of each device using a power meter. The appliance would then be plugged into the power meter and the power meter into the wall outlet.

The energy consumption calculations are based on the equipment that is necessary for the endoscope to work. Yet there are also other optional equipment that can be used during a colonoscopy procedure for support. These apparatus are the Fujifilm video assistant, Electrosurgery equipment and the AI Data analyser. It must be identified how many times these equipment are used.

The exact amount of water that is needed for a single colonoscopy procedure couldn't be precisely determined. An estimation has been made with the endoscopist and nurses. To know the specific amount of water that is used during a colonoscopy procedure, it is advised to attach a full bottle of water to the colonoscope and to measure how much water there has been left from the bottle after the procedure.