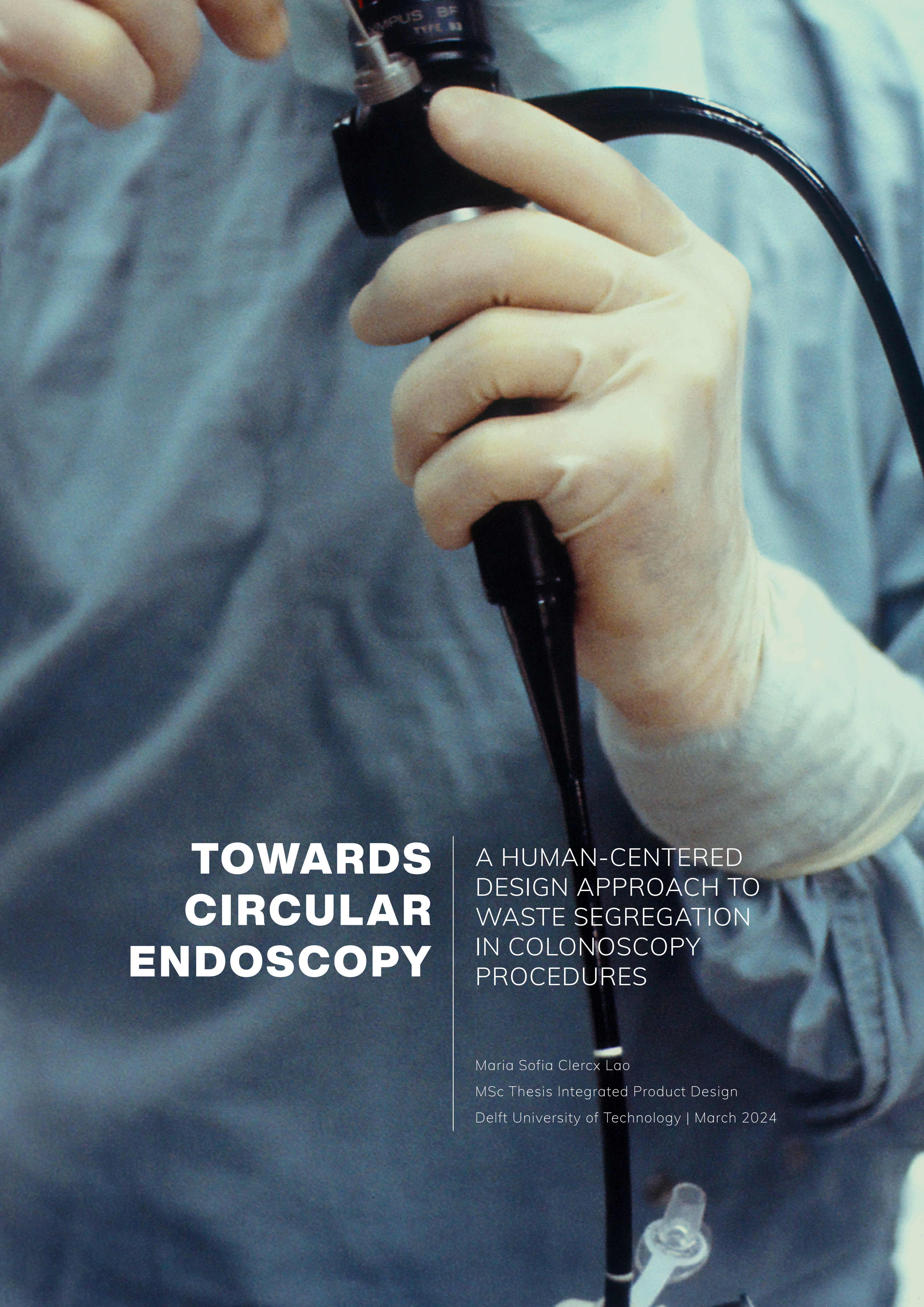


TOWARDS CIRCULAR ENDOSCOPY

A HUMAN-CENTERED DESIGN APPROACH TO WASTE SEGREGATION IN COLONOSCOPY PROCEDURES

Maria Sofia Clercx Lao

MSc Thesis Integrated Product Design

Delft University of Technology | March 2024

MSc Thesis Integrated Product Design
Delft Universtity of Technology
Industrial Design Engineering

Towards circular endoscopy

María Sofía Clercx Lao
4670450

Defended on 14 of March 2024

TU Delft supervisory team
Department of Sustainable Design Engineering
Prof.Dr.Ir. J.C. Diehl (chair)
Ir. C.P.J.M. Kroon (mentor)

Erasmus MC supervisor
Head of Gastroenterology Department
Dr. P.J.F. De Jonge (client mentor)

Acknowledgements

To JC, thank you for your constant commitment throughout this project and for always taking the time to hear my ideas and to aid me in new direcions. I never felt alone in tackling complex decisions leading up to the milestones of my graduation. This is due to your ability to connect students and professionals in design and healthcare and for involving us in many interesting activities. I am really grateful to have had a supervisor that can spark joy in the complex thing that is sustainability.

Thank you Caroline, for helping me find my way as a designer in this project through your expertise and directness. Your fresh insights and to-the point mentoring helped me gain clarity in certain moments when I felt stuck (and it was always nice having a coffee with you).

To Pieter-Jan, I am really grateful to have been able to work on-site and that you and JC could enable an immersive experience during this project. The depth of the project would not have been the same if I was not able to experience the atmosphere of the endoscopy unit. Thank you, I have learned so much by being able to observe and ask questions and to work alongside the endoscopy staff and other healthcare professionals.

A special thank you to Michelle, Leonie and Rolien for reacting so positively on the collaboration sessions during the creative phase of my project. Your practical point of view was a crucial input to the outcomes of this research.

Lastly, thank you friends, family and fellow graduation buddies in EMC and TU Delft, for keeping my head up, exchange ideas, for sharing a coffee or a drink. I will look back at my student years with a feeling of richness and fulfillment.

Abbreviations

CE – Circular Economy

CRC – Colorectal cancer

EMC – Erasmus Medical Centre

EOL – End of life

ERCP – Endoscopic retrograde cholangiopancreatography

GMW – General medical waste

GT – Green team

HMW - Hazardous medical waste

LCA – Life cycle analysis

OEM – Original Equipment Manufacturer

PPE – Personal protective equipment

SD – Sterilisation department

SUD – single-use device

Glossary

Biopsy: A biopsy is a medical procedure that involves taking a small sample of body tissue so it can be examined under a microscope (NHS, 2024).

Care pathway: A mutually agreed framework for the decision-making and organization of healthcare processes.

Co-creation: A form of collaboration in which all participating stakeholders can influence the process and its result, and is characterized by dialogue, common ground, enthusiasm, action and result-orientation (TU Delft, n.d.).

Endoscopist: The physician who performs the endoscopic procedure.

Hazardous medical waste: Also known as regulated medical waste. It refers to waste that includes infectious tissue, blood or sharps and potentially threatens the health of people in the environment.

Polyp: A projecting growth of tissue from a surface in the body, usually a mucous membrane (Cancer Council, n.d.).

Polypectomy: The removal of a polyp.

Shared-decision making: A process where healthcare professionals and patients decide which treatment or care pathway is best for the patient. It involves discussing benefits and drawbacks, as well as the patient's preferences and circumstances.

Sustainability: Meeting the needs of the present without compromising the ability of future generations to meet their own needs (United Nations, 1987).

Waste segregation: the process of properly separating material groups in order to optimize retrieval and recycling.

Executive summary

Healthcare is a major contributor to the negative effects on the environment, leading to adverse effects on the physical and mental health of people globally (IPCC, AR6). The Dutch healthcare sector alone is responsible for 7-8% of the national carbon footprint, 4,2% of total waste and 13% of raw material extraction (Steenmeijer et al. 2022).

This project was set up in three main parts to identifying opportunities for sustainable interventions in colonoscopy procedures for the EMC gastroenterology department. Throughout the project, a human-centered design approach was maintained

Literature review on sustainability in healthcare and environmental impact of endoscopy.

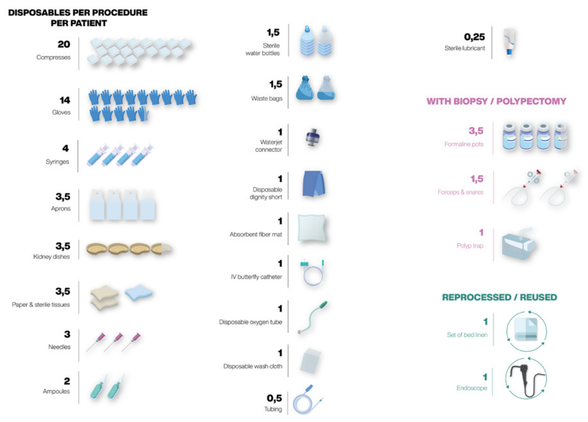
Context research

Material flow analysis (MFA) in the form of a waste audit.

Based on circular strategies Reduce and Recycle, the research outcomes were synthesized into an intervention that aligns to the EMC's policy statements for sustainability:

- reduce waste with 10%
- increase recycling with 20%

Waste audit data was used as an input for co-creating with endoscopy nurses, where the focus was put on retrieving plastics from GMW because of their significant contribution to total emissions when incinerated (López-Muñoz et al., 2023).



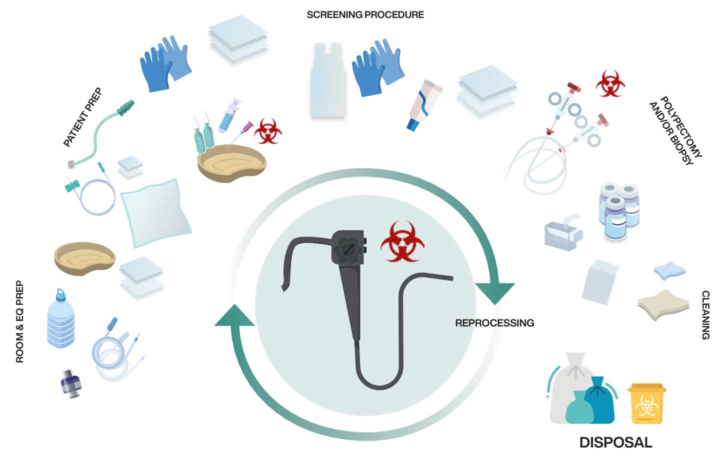
Ideation was done in co-creation sessions to solve the problem of integrating waste segregation inside the complex environment of a colonoscopy treatment room for current system boundaries.

Outcomes

While it is ideal to implement higher R-strategies for designing out waste early on in the process, waste cannot be ruled out completely. Therefore, implementing a waste segregation system in the endoscopy treatment room presents an opportunity to enhance waste management in EMC and align with sustainability goals.

The proposal is a demonstration rather than a product concept, to show small incremental changes within the current system boundaries can help achieve the EMC goals. The intervention was estimated to reduce the weight of incinerated GMW with at least 40% with segregation of plastic products, and additional 16% by disposing of absorbent products in TONTO. Additional research is needed to determine the true recyclability potential of the plastics.

With the foresight of the implementation of new products in the system and a circular model where materials of these products have to be kept in the loop, the endoscopy nurses will be equipped and trained to accomodate these changes, and maintain sustainable practices.



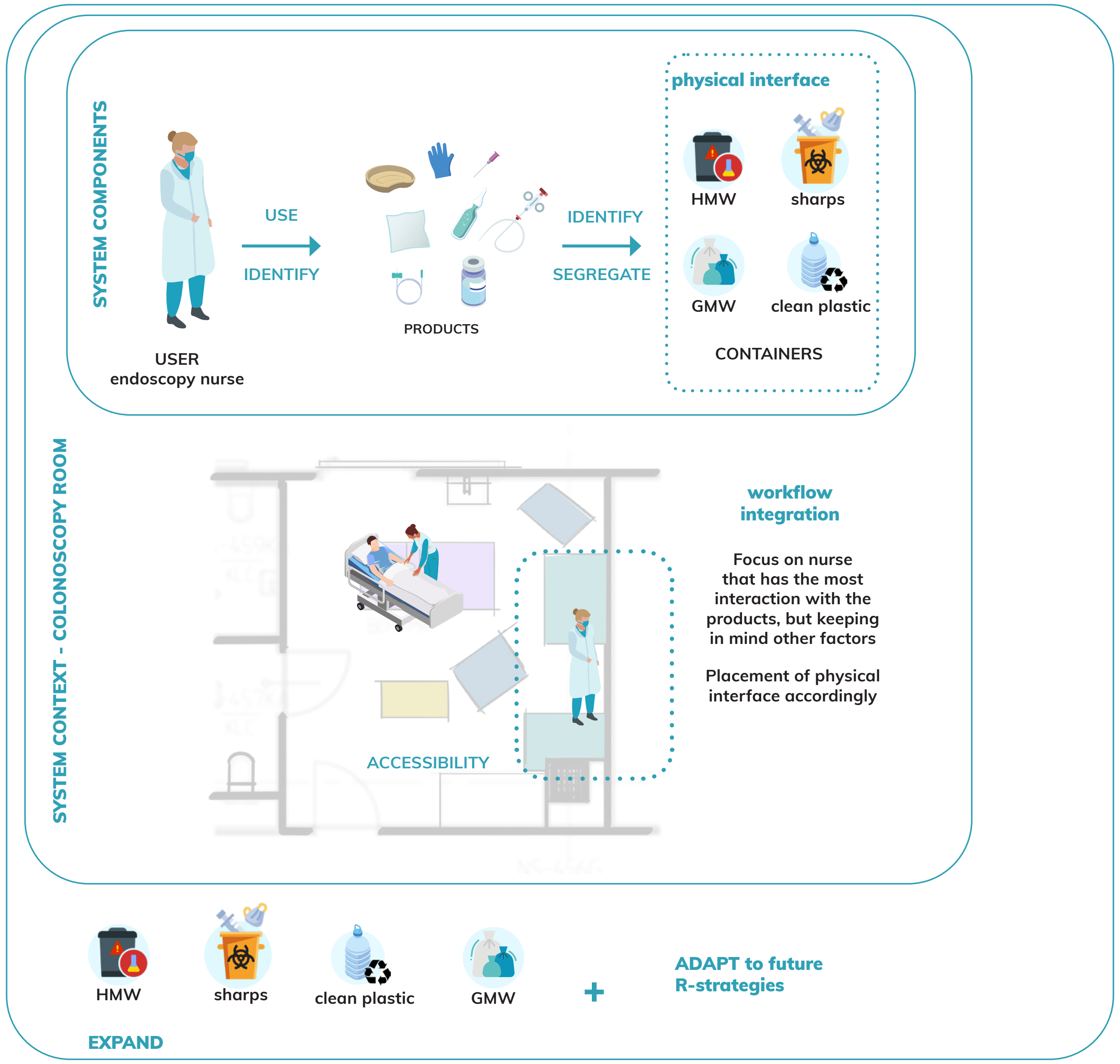


Table of Contents

01

SECTION

PROJECT INTRODUCTION

This section introduces the context of climate change and healthcare. It also highlights the urgent need to transition towards sustainable healthcare practices. It elaborates further on the project background, research & design method and can be seen as the reading guide for the document.

01

1.1

The need for sustainable healthcare

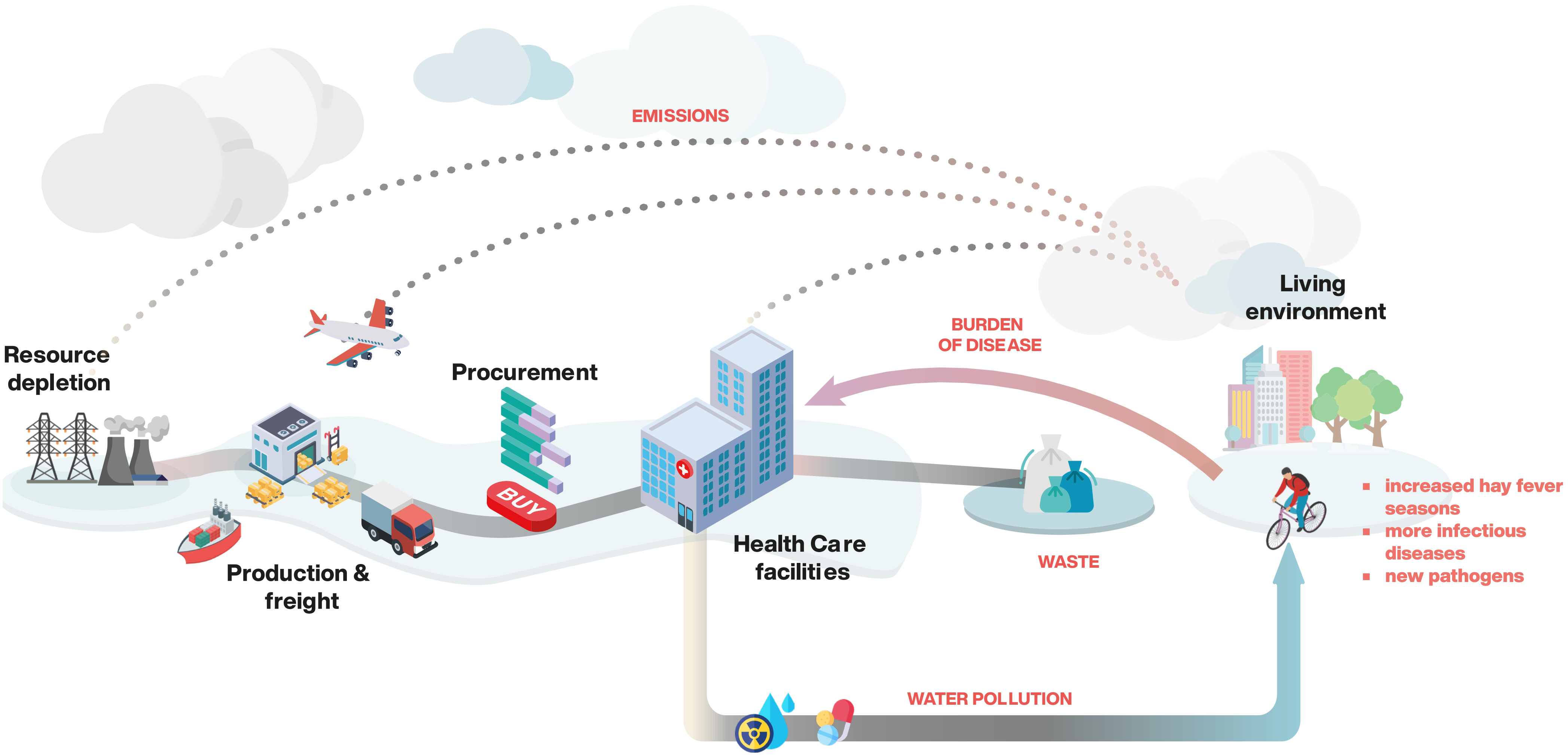


Figure 1.1: Diagram of the environmental footprint of a chain, with the self-reinforcing effects on public health and the living environment. Adapted from RIVM (2022).

The healthcare paradox is pushing the urgency of healthcare facilities to transition towards a climate neutral system (Green Deals, n.d.).

The healthcare paradox

The United Nations (UN) third Sustainable Development Goal is to ensure healthy lives and promote well-being for all (United Nations, n.d.). However, climate change and healthcare are intertwined in a paradoxical relationship (Figure 1.1). While the healthcare sector's main focus is to provide accessible and qualitative healthcare for all, it is also a major contributor to the negative effects on the environment, leading to adverse effects on the physical and mental health of people globally (IPCC, AR6).

Hence the paradox: rapidly changing climate conditions exert significant strains on healthcare, increasing the demand for health services while simultaneously impairing the system's ability to respond (World Bank Group, 2024).

The climate crisis is the largest threat to public health, leading to increasing healthcare challenges and costs (Medicine, 2023). The Dutch healthcare sector alone is responsible for 7-8% of the national carbon footprint, 4,2% of total waste and 13% of raw material extraction (Steenmeijer et al. 2022).

Therefore, healthcare's transition towards a climate neutral and sustainable economic model is necessary to build resilience to significant and growing health impacts (Health Care Without Harm & Arup, 2019).

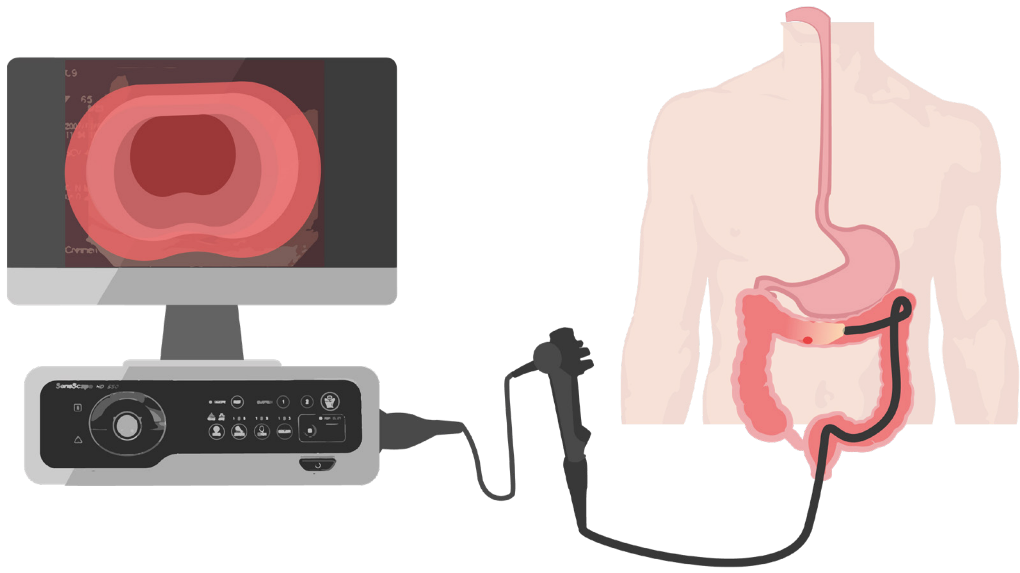


Figure 1.2: Schematic and simplified overview of an endoscopic procedure examining the colon (a colonoscopy).

Need for circular endoscopy

Gastroenterology or gastrointestinal endoscopy is a medical specialty that examines the gut with imaging equipment (Figure 2). Together with the operating theatre (OT) and intensive care unit (ICU), it also ranks in the top three most resource-intensive medical specialties that contribute significantly to a hospital's carbon footprint (De Santiago et al., 2022). This is due to endoscopy's high caseload, intensive decontamination processes, the amount of patient travel and visits, and the focus on single-use medical equipment and consumables (Siau et al., 2021).

The number of endoscopic procedures in the Netherlands was estimated around 625.000 in 2021. In that year, 10.500 endoscopic procedures were performed in Erasmus MC (EMC) alone. The high-throughput of endoscopy procedures in the Netherlands is related to the focus on colorectal cancer (CRC) prevention (or 'bevolkingsonderzoek', BVO). This screening plan prevents 2.250 annual deaths (Maag Lever Darm Stichting, 2023), but also causes an average of 50.000 additional procedures per year across the Netherlands (CBS, 2018). With an ever aging population, **the health demand in gastroenterology is expected to rise and so are the environmental effects related to endoscopy, pushing the need for more sustainable practices.**

1.2

Project background

"Create an irreversible transformation to healthcare with minimal impact on climate, environment and living environment in 2050."

Inevitable change: the Green Deal

EMC is one of the many healthcare institutions that has signed the Green Deal 3.0. The green deal was made to reach legally bound climate targets to reduce emissions by at least 55% in 2030 (Delivering the European Green Deal, 2021). The purpose of the Green Deal for sustainable healthcare is to create an irreversible transformation across the entire healthcare system (Green Deals, n.d.).

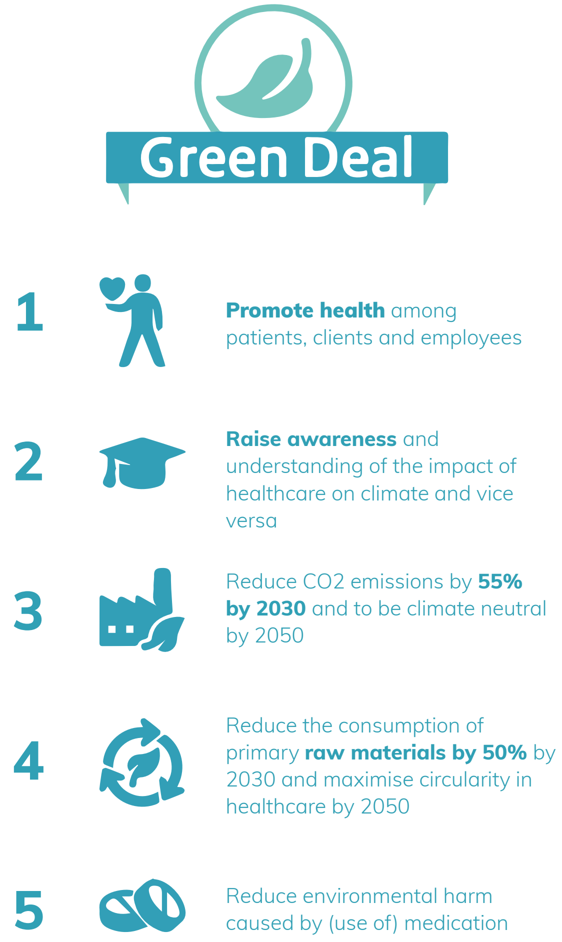


Figure 1.3: Pillars of the Green Deal 3.0 for Sustainable Healthcare, adapted from Green Deals (n.d.).

Sustainability goals of EMC

To meet the targets of the Green Deal 3.0, EMC has defined multiple horizons for reducing carbon emissions and to improve waste management.

The EMC's ambition for 2025 is to have **40% of their waste recycled** (Erasmus MC, 2022). This is a steep change considering the percentage of recycled waste is currently at 20% (PreZero, 2023). Additionally, to **reduce their carbon footprint with 55%**, EMC has described profound implementation of waste source separation and waste reduction by 10% as crucial shifting points for their 2030 sustainable strategy. Lastly, the long-term goal is to become a **climate neutral hospital in 2050**.

Green Teams

Multiple 'Green Teams' and sustainability-oriented projects have already been set up in the OT and ICU to estimate their environmental impact. Green teams play a pivotal role in driving sustainable initiatives within the organisation and are comprised of individuals who are enthusiastic for sustainable practices. Their initiatives are conducted alongside their day-to-day clinical practices, and it must be recognized that the reliance on these teams may lead to increased pressure and responsibilities. This project offers the Green Team endoscopy an explorative overview as an initial step towards the prioritization of sustainable interventions.

Exploring the opportunities for systemic and behavioural change

Currently, there is an urgent need for precise data and healthcare-specific metrics to properly document greenhouse gas (GHG) emissions from healthcare facilities and to implement decarbonization (Singh et al., 2022). The first priority is to review existing practice to identify areas for sustainable interventions (Siau et al., 2021), such as waste reduction.

Additionally, the lack of sources on behavioural factors around waste disposal by medical staff indicates that more research is needed to understand the context of waste disposal in healthcare. Clinical activities are the major drivers of resource utilisation and waste generation in healthcare (Sherman et al., 2020). Therefore, the engagement of healthcare professionals should never be excluded in the transition towards sustainable clinical practices.

It is assumed that the aforementioned challenges to reach the EMC's sustainability horizons can only be tackled from within the organization, meaning that extensive research has to be done on the EMC endoscopy's specific waste streams, as well as improving behavioural awareness and adaptation in the endoscopy unit with the aim to create optimal conditions for sustainable systemic change.

Relevance to project stakeholders

Identifying the waste streams is just an initial but important step as a basis for further research in endoscopy. This project enables new relations between Green Teams, medical professionals, designers, waste management actors and more. EMC finds itself in a unique strategic position as an academic hospital to have a leading role in the implementation of sustainable endoscopy.

Existing literature focuses on the healthcare community prioritizing the collection of carbon emission data and reduction of waste. Nonetheless, this puts additional administrative load on the already understaffed healthcare workforce (Ministerie van Volksgezondheid, Welzijn en Sport, 2023).

Moreover, with the forecast of an ageing population, the number of gut disease patients is expected to grow with 10% in 2030 (Maag Lever Darm Stichting, 2023a), meaning the demand for endoscopy practice (and costs) will continue to rise. In addition, healthcare costs for gut diseases in the Netherlands were 14% higher in 2019 than they were in 2015 and therefore account for 3,8% of the total healthcare costs (VZinfo, n.d.; Maag Lever Darm Stichting, 2023a).

With this forecast there is a need to transition towards a sustainable business model that fits the structure and ambition for circular change in the EMC.

Healthcare is a complex system

Healthcare is a complex system, therefore it is not always possible to predict changes or the effects of interventions on these systems (Ratnapalan & Lang, 2019), because the system is dynamic and its behaviour changes over time (McGill et al., 2021).

Therefore, even the most seemingly simple intervention can result in complex interactions and emergent outcomes across that system (Shiell et al., 2008), and should take into account all the different actors across system levels.

In the following sections the project approach is explained regarding complexity.

1.3

Circular strategies for healthcare

The Value Hill model depicts different strategies for a circular economy (CE) (Figure 4 & Appendix C). In a CE products and materials are able to go through repeated cycles of obsolescence and recovery strategies (R-strategies) while maintaining the highest level of integrity possible (Kane et al., 2018). Throughout this project different R-strategies are addressed.

Even though lower loops are the least circular, Recycling and Recovery are the most actionable R-strategies for healthcare according to literature. However, this project questions the “simplicity” that is expressed for the implementation of lower loop strategies and is further explored in the following sections.

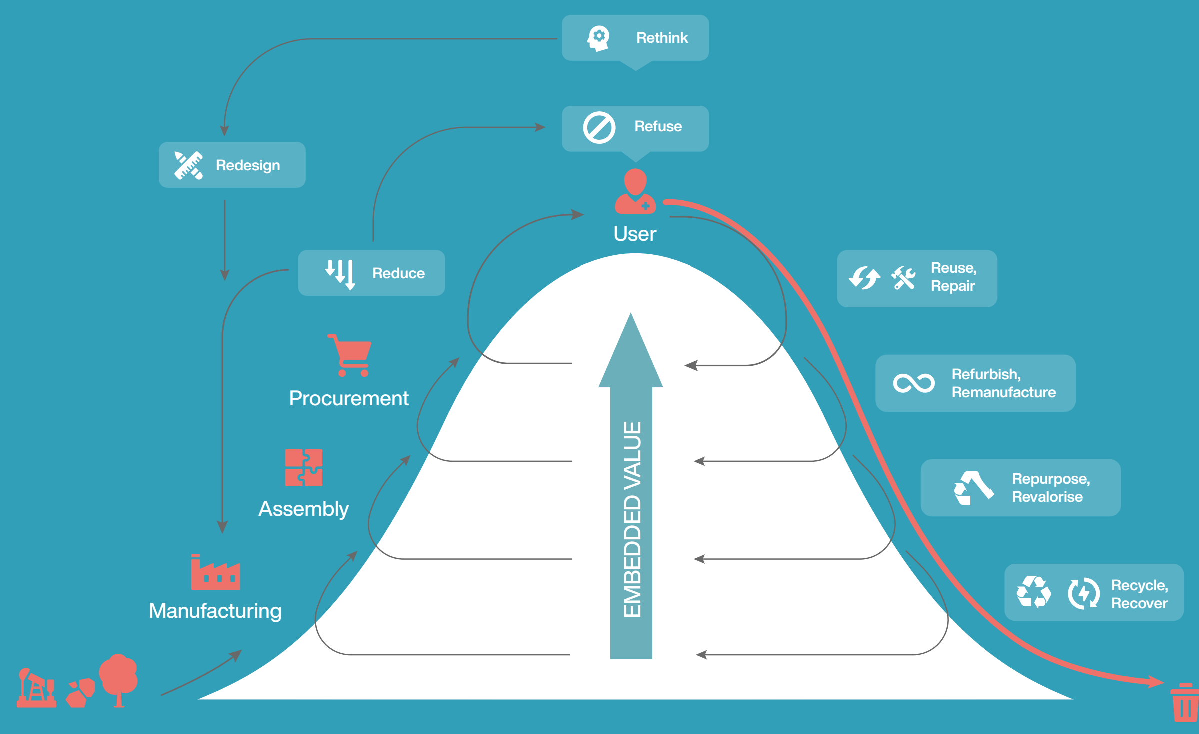


Figure 1.4: Value hIll model, adapted from Metabolic (2022).

Higher loop strategies eliminate waste early on in the design process (Circularise, n.d.).

- **Refuse**: bans the use of harmful materials, production process, or abandons redundant function of products
- **Rethink**: making a product more use-intensive
- **Reduce**: aims to increase the efficiency of product manufacturing or use

Medium loop strategies focus on prolonging the product’s life cycle through different levels of retention (Circularise, n.d.).

- **Reuse**: use a product again for the same purpose in its original form. In healthcare this is done through 'reprocessing' or sterilization.
- **Repair**: Repair and maintenance of a defective product so it can perform once more.
- **Refurbish**: Restoring a product to as-new condition.
- **Remanufacture**: integrating product components that are still perfectly intact into new products with the same function
- **Repurpose**: incorporates discarded components into a completely different product for an alternative purpose

Lastly, the **lowest loop strategies** focus only on the recovery of materials to be upcycled, downcycled or to recover some of the energy used for production (Circularlise, n.d).

- **Recycle**: collecting waste and transporting it to a facility for sorting into different categories before it is processed into new materials.
- **Recovery**: energy or heat recovery from waste incineration.

1.4

Project scope & method

Initial project brief:

Mapping the waste streams and identifying hotspots as an opportunity to design sustainable interventions in the endoscopy department

Scope

Prior to the kick-off of this project, observations and shadowing of three types of endoscopic procedures were conducted: upper GI endoscopy (oesophagus and stomach), colonoscopy (colon) and ERCP (liver and pancreas). Additionally, observations of the reprocessing of endoscopes were conducted at the sterilisation department (SD) for endoscopy.

Because of the complexity inherent to the context, the focus of this project is only on colonoscopy procedures. A colonoscopy is an endoscopic procedure that screens the large intestine (colon), including surgical procedures such as polypectomies and biopsies. This project relies on three main goals:

1. **Mapping and quantifying of non-hazardous waste for colonoscopy procedures.**
2. **Identifying hotspots as an opportunity to design sustainable interventions.**
3. **Raising awareness in staff through visualisation of the acquired data.**

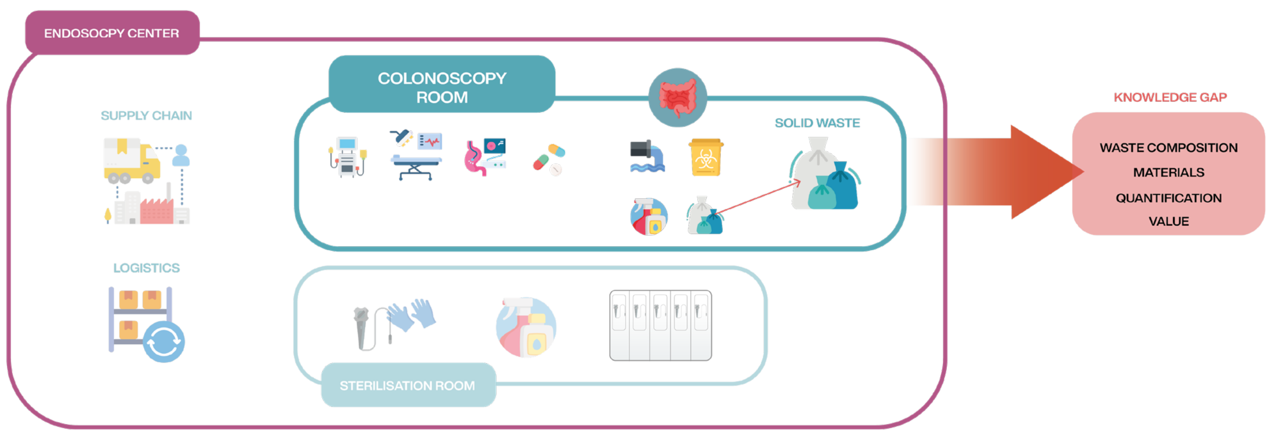


Figure 1.5: Project scope.

Method

A methodological approach was applied to tackle the complexity of this project in order to ensure comprehensiveness and informed decision-making throughout. The research phase consisted of three main parts:

Literature review on sustainability in healthcare and environmental impact of endoscopy.

Context research in the clinical setting through internal analysis of EMC, observations, informal interviews and expert meetings.

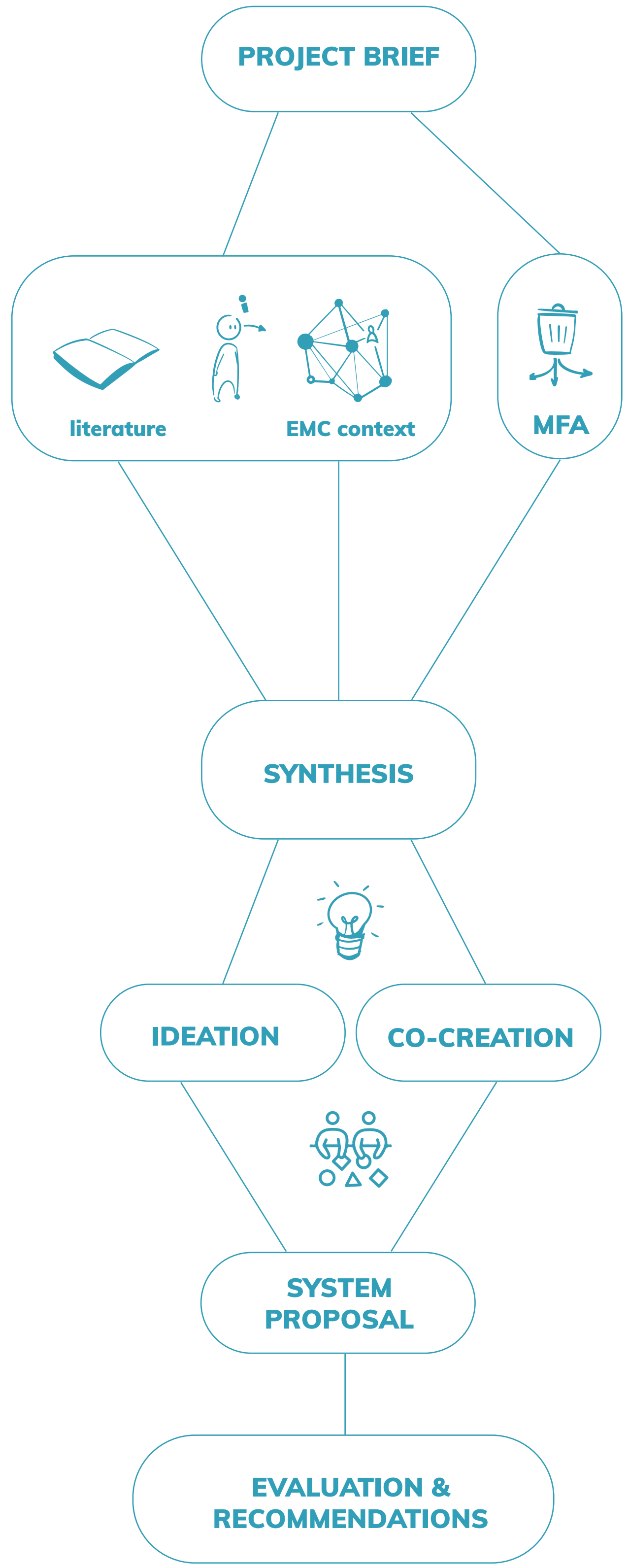
Material flow analysis (MFA) in the form of a waste audit. Mapping the solid waste produced in colonoscopy procedures, its material composition, and quantifying the amount of products wasted.

Hereafter, these three research directions were synthesized and reframed into a new problem definition, a design goal and a proposal for interventions.

The proposed solution combines the insights and design drivers derived from all three research aims and present a holistic solution based on human-centred design (HCD) and established through co-creation sessions with the staff.

Human-centered design

The project is approached from a system design perspective and focusing on human-centered design (HCD). Human-centered design is a practice where designers focus on four key aspects: people and their context (1), understanding and solving root problems (2), understanding that everything is a complex system with interconnected parts (3) and finally, the implementation of small interventions (4) (Interaction Design Foundation, 2021). In short: truly meeting the user needs throughout the process.



02

SECTION

AN OVERVIEW OF ENDOSCOPY PRACTICE

& SUSTAINABLE HEALTHCARE CHALLENGES

Endoscopy contributes in many ways to a hospital's environmental impact. This section discusses endoscopy in more detail and provides a summary of research directions for sustainable endoscopy derived from literature. It depicts the context factors of the Dutch healthcare system and how this influences the transition to sustainable endoscopy practice in EMC.

02

2.1

Endoscopy practice in the Netherlands

In 2023 EMC performed 4500 gastroscopies and 2500 colonoscopies.

Endoscopy in the Netherlands

Gastrointestinal (GI) endoscopy is a surgical procedure where a patient's digestive system is inspected with a flexible endoscope. Multiple types of endoscopic procedures are performed annually in the EMC. In 2023 EMC performed 4500 upper GI endoscopies and 2500 colonoscopies. Upper GI endoscopy (240.00 per year) and colonoscopy (290.000 per year) are the most common practices of endoscopy in the Netherlands.

The high-throughput of endoscopy procedures in the Netherlands is related to the focus on colon cancer prevention (Figure 2.1). Since 2014, patients between 50 and 75 years of age are requested to undergo screening for CRC and colonoscopy procedures to prevent late diagnosis of colorectal cancer. This screening plan prevents 2.250 annual deaths (Maag Lever Darm Stichting, 2023).

With an ageing population the health demand in GI endoscopy is expected to rise and so are the environmental effects related to endoscopy.

EMC's role in the care pathway

"A care pathway is a complex intervention for shared decision-making and organisation of care processes for a well-defined group of patients during a well-defined period of time" (Vanhaecht, 2007). The Dutch CRC care pathway includes: referral, diagnosis, treatment, aftercare, and (in some cases) palliative care (Van Deursen et al., 2023), see Figure 2.2.

EMC plays a crucial role in the diagnostics phase of the CRC care pathway as an academic hospital, since **complex patients are often referred to EMC after having (multiple) unsuccessful treatments in peripheral hospitals.**

Figure 2.1: CRC screening program "Informatie bevolkingsonderzoek darmkanker." (RIVM, 2022).

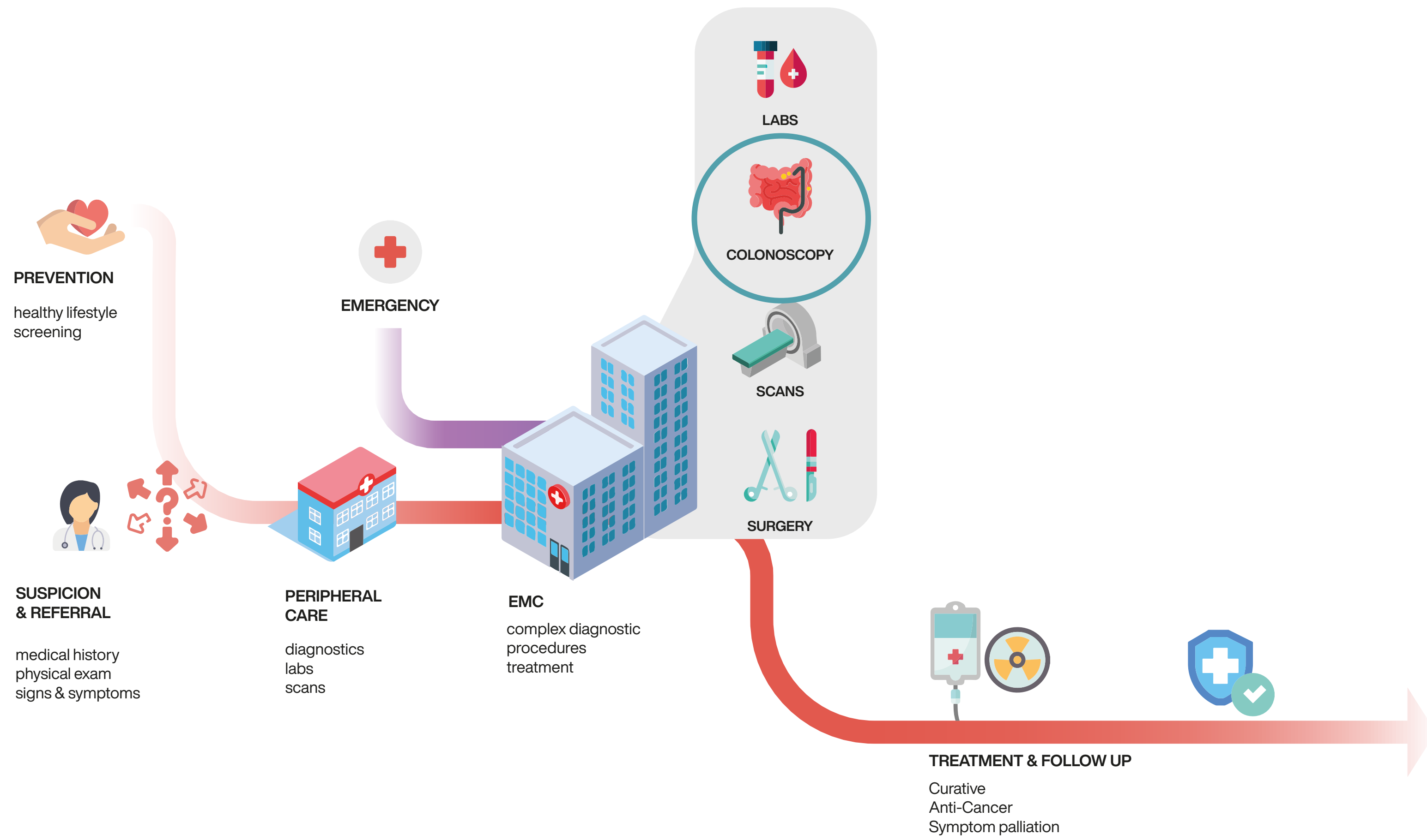


Figure 2.2: A schematic overview of the CRC pathway showing the different phases and drivers for a patient's care. Based on Bevolkingsonderzoek Nederland (2022) & Adrz (2023). The role of colonoscopy in EMC is just a small fragment of the total care pathway.

2.2

Endoscopy's environmental impact

A full literature review on the environmental impact of endoscopy can be found in the Appendix. Most of the literature was based in the US, meaning that the estimated impact (e.g. emissions from transport) might diverge from the reality in the Dutch healthcare system due to the countries' significant differences in scale. This subsection aims to provide a holistic overview of the different domains of endoscopy's environmental impact derived from the literature.

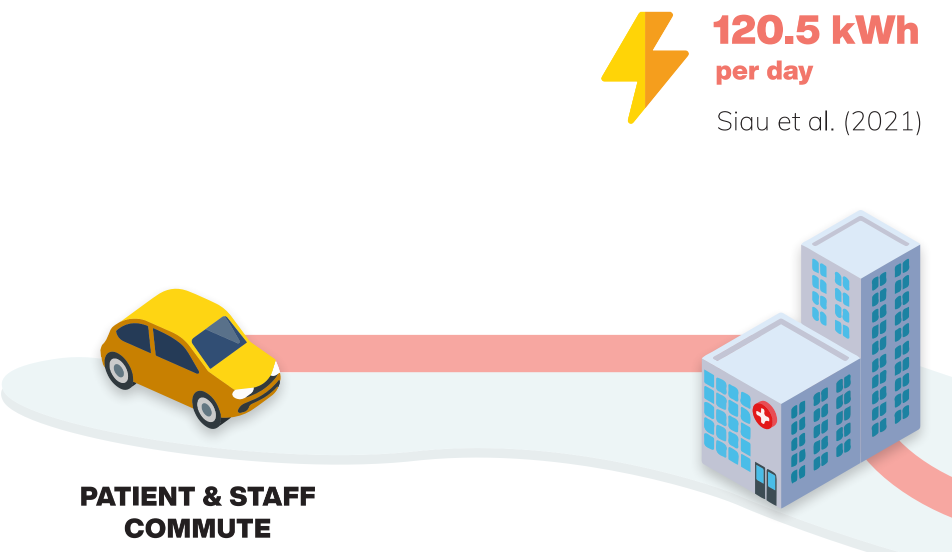
Complexity and consumption

The level of complexity in endoscope design (Appendix B) has enabled endoscopists to perform diagnostics and treatment simultaneously during an outpatient procedure, reducing the duration of hospitalisation time for one patient as opposed to general surgery. This enables larger capacity for the number of patients. However, with endoscope complexity comes an ever increasing number of single use devices (SUDs) used for these procedures.

The need for standardization

Partly due to the amount of disposables, it is estimated that the waste generated by endoscopy is **0.50 to 2.1 kg** per procedure, the majority of which is incinerated (De Jong, 2023). Waste incineration from medical facilities often emits toxic pollutants during the process (de Melo et al., 2021), due to the high ratio of plastic and metal components in the waste (Namburar et al., 2021).

Presently there are no standardized frameworks for capturing impact from clinical practices and therefore, the revised literature is fragmented into different domains lacking homogenity (Appendix C & Figure 2.1). These discrepancies between methods and metrics create difficulties in forming comprehensive and complete assessments on the actual impact of endoscopy practice.



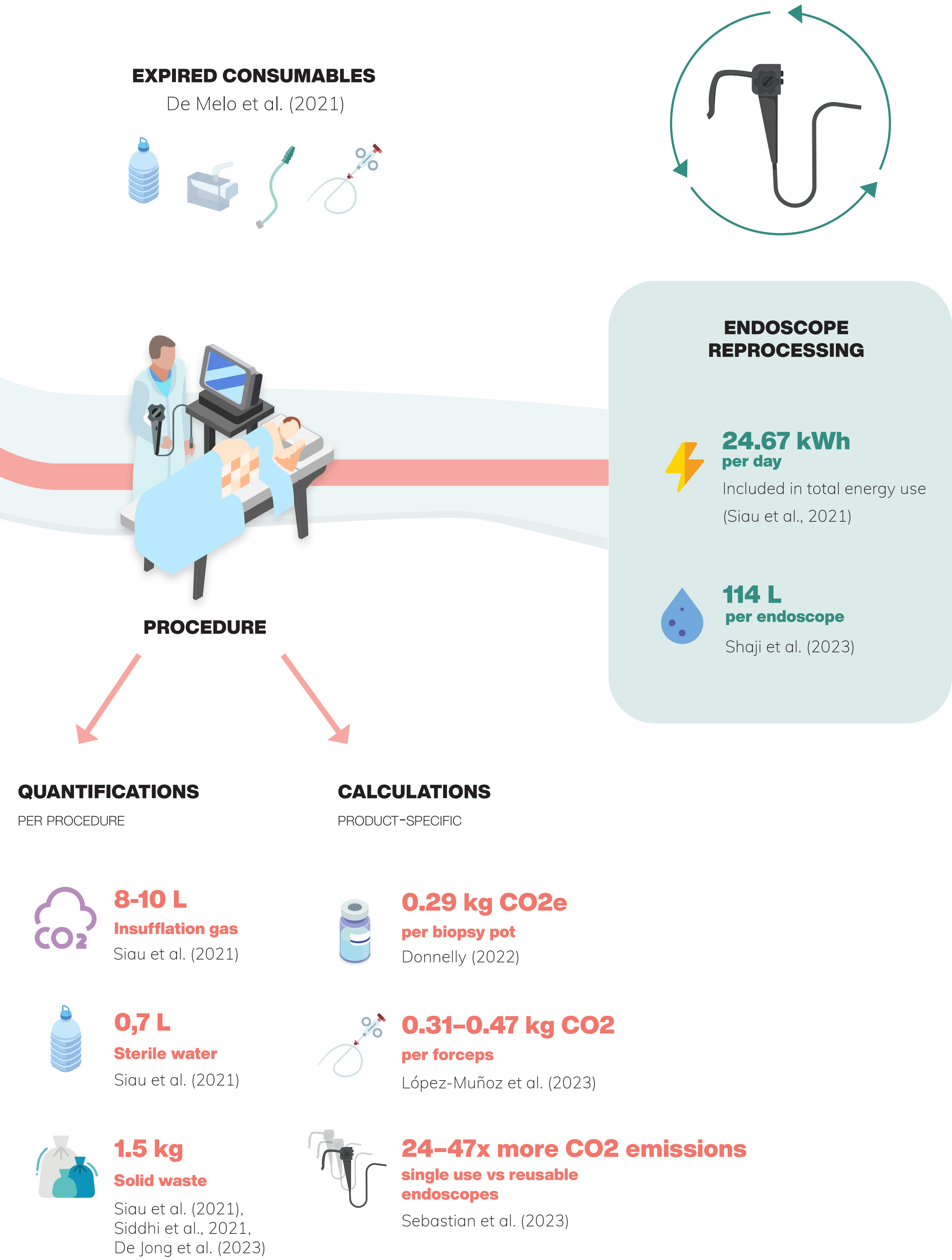


Figure 2.1: Overview of ENDOSCOPY's environmental impact in numbers in different domains of current literature.

Key prioritization points

MAPPING CURRENT PRACTICE

There is a consensus among healthcare facilities that mapping and quantifying must be the first step in decarbonization and is reflected in the literature (Singh et al., 2022). But it goes further than just mapping the sum of estimations and LCAs of routinely used products. **Detailed analyses of the sustainability of each step in endoscopy** activities would allow the identification of small but cumulative beneficial changes that could decrease environmental impact (Maurice et al., 2020).

IMPROVE EFFICIENCY OF SERVICES & PRODUCTS

Secondly, this mapping would lead to identification of opportunities where the number of SUDs can be reduced. For example, this can be achieved by reusing endoscopic accessories between procedures, when combining upper endoscopy followed by colonoscopy within the same patient (Cunha Neves et al., 2023).

Reduce | Rethink

ALTERNATIVE PRODUCTS

On the path of SUDs, healthcare facilities should seek alternatives to SUD which are more environmentally friendly. Knowledge of carbon footprint is crucial to select the most sustainable alternatives because there are large variations between brands (López-Muñoz et al., 2023).

Refuse

DESIGN FOR RECYCLING OR REUSE

20-25% Of waste generated from clinical practices is potentially recyclable (Lee et al., 2002). The carbon footprint of recycled hospital waste is **50 times** less than incinerated waste (Shaji et al., 2023). Not all the parts of a product can be recycled because of the risk of infection, thus products should be designed in such a way that recyclable products and parts can be easily segregated during waste disposal and that have a proper indication for healthcare staff. This goes for packaging material as well. With these interventions, healthcare staff can be trained for proper waste disposal. Therefore, workflows need to be redesigned for proper waste segregation.

Redesign | Recycle, Recover | Reuse, Repair

Earlier in the value chain, legislation should be implemented where original equipment manufacturers (OEMs) are required to design for reuse. Servitization, a strategy where manufacturing firms extend their business into services as a way to develop new revenue streams and improve customer value (Choo et al., 2021), could potentially be used as an effective green strategy in healthcare in the form of OEM reprocessing (Benedettini, 2022).

Rethink

SUSTAINABLE PROCUREMENT

Current procurement policies do not include sustainability as an integral element of the procurement procedure (Personal communication with Maarten Timmermann, 2023). A push from regulators is needed in order to implement sustainability as a criterion in the procurement of healthcare products and services.

Reduce | Refuse

CHANGING (WASTE) BEHAVIOUR

Changing the behaviour in healthcare staff will be one of the most challenging factors in the transition to sustainable healthcare and goes beyond creating awareness which is often the first step. While there are groups such as Green Teams composed of individuals with a high intrinsic motivation for sustainable change, the hardest is convincing the entire team into changing mental models and workflow routines which have been habituated during years of clinical practice.

SHARING IS CARING

Some strategies can be labelled as simple, such as reducing the amount of products and reycling waste. However, using the term "simple" in a context which is inherently complex should be avoided as it might be perceived as less urgent. Additionally, it does not encompass the following: simple strategies are implementable provided that there is a fitting innfrastructure and a framework or demonstration on how to (re) create these interventions within a specific environment. It is important that strategies are **shared** as a basis of **insipiration** for other healthcare professionals.

Most departments of EMC are high-complexity medical specialties and therefore have their own protocols and materials inherent to their clinical practice. For instance, these include waste management protocols, resulting in discrepancies in waste management even within the organization. What works in one department may not work in another, but **increasing communication between Green Teams in other departments could be valuable.**

MULTIPLE STRATEGY APPROACH

Setoguchi et al. (2022) critically emphasises how the **majority of the commonly implemented strategies will not be enough** to limit the global warming to the target of 1.5 °C, and that health care professionals must also take important steps to reduce overuse of health care services, including medical products, diagnostic procedures, and therapeutic interventions. The most sustainable care is the care that is not needed. **Therefore, extending the sustainability strategies to early in the care pathway to focus on prevention is necessary.**

Designers play a major role in linking different stakeholders to reach sustainability goals in endoscopy by understanding context, products and services and synthesizing them together.

2.3

Challenges in the sustainability transition in healthcare

The literature on endoscopy practice has provided a clear distinction of research priorities. However, other systemic factors described in this subsection might impede change or exacerbate current unsustainable endoscopy practice and are important to take into account. Most of these factors are related to EU regulations and the Dutch healthcare system, and are more elaborately described in Appendix C.

Clusters

VARYING AWARENESS

In the evaluation of the Green Deal 2.0 (Ministerie van Volksgezondheid, Welzijn en Sport, 2022) the largest discrepancy was the difference in awareness and felt urgency throughout different organizational levels: in 73% of participants in governance levels and only 36% of participants in the workplace. **A lack in perceived urgency** among the workforce might negatively influence incorrect waste disposal and the adoption of sustainable interventions in the workplace, and enhances the seriousness of improving awareness amongst staff.

LACK OF FINANCIAL STRUCTURES AND SUPPORT

There is a need from healthcare facilities for financial support in different modes of entry which are not limited to subsidiary support, but also include changing current financial structures and mechanisms (Ministerie van Volksgezondheid, Welzijn en Sport, 2022), e.g. adapting the procurement strategies as mentioned in the previous subsection.

This concludes that there is a need for national governmental action in terms of budget and a cultural change along the whole care chain (read: including all stakeholders) in order to support health facilities in the Netherlands in implementing sustainable interventions.

PRODUCT SAFETY & PROTOCOLS

The healthcare sector is strictly regulated through extensive safety regulations, including EU medical device regulation (MDR), In Vitro Diagnostic Medical Devices regulation (IVDR) and the framework of Product Liability Directive (PLD). The ongoing revision of the current PLD framework might result in an even more constrictive regulatory environment maximising the liability for manufacturers (MedTech Europe, 2022), which might impede sustainable strategies such as reusing or reprocessing from being implemented in the healthcare sector.

The preference for SUDs comes from the consensus that **human error is the most common cause behind inadequate reprocessing** (Voiosu et al., 2023). This results in full liability on the processor. However, adequate reprocessing can be addressed by training programs and standardized education (Beilenhoff et al., 2017)

PATIENT INVOLVEMENT

The Dutch healthcare system is based around shared decision-making (Cooperatie VGZ, n.d.), in which the patient retains full autonomy in their own care journey often resulting in greater efficacy of treatment. However, this can alter the environmental impact of the care pathway as the journey progresses. Therefore, not only healthcare staff but also the patient must be considered as an important stakeholder in the sustainability transition of the care pathway.

The adoption of reprocessing is held back partly because of the absence of (a system for) patient consent on reusable SUDs, due to a **lack of data** on device malfunction, infection risk and the ethical dilemma about reprocessing SUDs (Kwakye et al., 2010). This is why healthcare system has increasingly adopted the standard choice for single-use medical devices, given that they reduce liability and complexity for hospitals (Benedettini, 2022).

This further emphasizes the need for sustainable interventions along the whole care pathway and to not limit the interventions to the healthcare force, but also engage the patient in the sustainable transition.

COST OF TRANSITION

It is estimated that the sustainability transition in the Dutch healthcare sector will cost around 1,6-3,4 billion euro as one time investment plan, as well as additional annual costs of 350-750 million euro (Vereniging Gehandicaptenzorg Nederland, 2023). This costs may include adaptation of infrastructure and real estate, as well as the transition to the use of renewable energy, and moreover training the workforce to function within the new system parameters.

CHANGING BEHAVIOUR AND MENTAL MODELS

Apart from context factors such as financial resources and education, understanding the mental models and behaviour in sustainable change is often overlooked, while it can provide crucial information for understanding, anticipating, and overcoming implementation challenges (Holtrop et al., 2021). Healthcare professionals are expected to adapt to a culture of sustainability but there is no blueprint for developing this corporate culture (Ramirez et al., 2013). The framework of the Triple-C model has identified that the facilitation of interventions rely on the engagement of staff and their support (Khalil & Kynoch, 2021).

This ties back into the previous subsections, in which is described how interventions and protocols are mostly pushed from a top-down approach in the system. Therefore, the development and design in interventions should be done in a **co-creative** manner in alle the stages.

SUMMARY & KEY TAKEAWAYS

SUMMARY

Awareness continues to be one of the main challenges in the sustainability transition.

While this is widely felt among higher system organization levels, it is unclear how it applies to department levels, while organizations rely on these levels for implementing change.

There is a lack of standardization in metrics and methods for impact assessment in current and future practice.

This alongside the complexity of measuring all system elements along the care pathway, currently the overview of endoscopy's environmental impact is fragmented.

Focusing on a single strategy will not be enough to reach sustainability targets of the Green Deal 3.0.

Healthcare facilities should not only share scientific research but also their experiences in the clinical practices to apply small but cumulative changes that can reduce environmental impact.

Switching to recyclable or reusable products or materials is key.

Their use should be encouraged by changing legislation for OEMs and ingraining sustainability in procurement policies.

KEY (DESIGN) DRIVERS

Interventions should encourage and improve awareness to bridge the discrepancy between departmental level awaress and ogranizational awareness.

Endoscopy in the Netherlands is highly related to CRC screening program and therefore the cumulative interventions should extend along the whole care pathway.

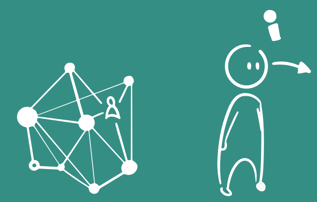
Literature seems to undermine the actual **complexity** of the healthcare context when suggesting "simple" short-term interventions.

Detailed mapping of current practice is essential for identifying opportunities in the specific clinical context of EMC.

A large part of the materials could already be fit for recycling and therefore this needs to be identified.

03

SECTION



THE EMC ENDOSCOPY UNIT

ANALYZING COLONOSCOPY PROCEDURES

Colonoscopy is taken as a scope in this empirical research for analyzing system elements, mapping unrecycled waste, and gaining a deeper understanding of contextual factors surrounding certain products and their disposal. Colonoscopy's cumulative environmental footprint and its scale across the Netherlands validates the choice for analyzing the impact of this activity rather than any other type of endoscopic procedure.

03

3.1

Endoscopy unit & its actors

This subsection provides overview of the space in which endoscopy practice is performed. The architecture and room composition can affect how products, materials and people move through the space.

Floorplan of the unit

The EMC endoscopy unit is equipped with different rooms (Figure 3.1). As seen in green in the Figure, Rooms 2 and 3 are used for colonoscopy procedures, and occasionally Room 1. These rooms are located farthest from the waste room. Additionally, there are several storage rooms with sterile supplies (e.g.biopsy forceps, endoscopes, oxygen tubes) and non-sterile or general supplies (e.g. compresses, face masks, gloves). There is an embedded sterilization department (SD) which is responsible for daily cleaning and disinfecting endoscopes. There is one waste room in which all different wastes are collected. This floorplan will help to visualise how the materials and people flow through the unit.

Figure 3.1: Floorplan of the endsocopy unit including colonoscopy and upper GI endoscopy rooms 1, 2 & 3.

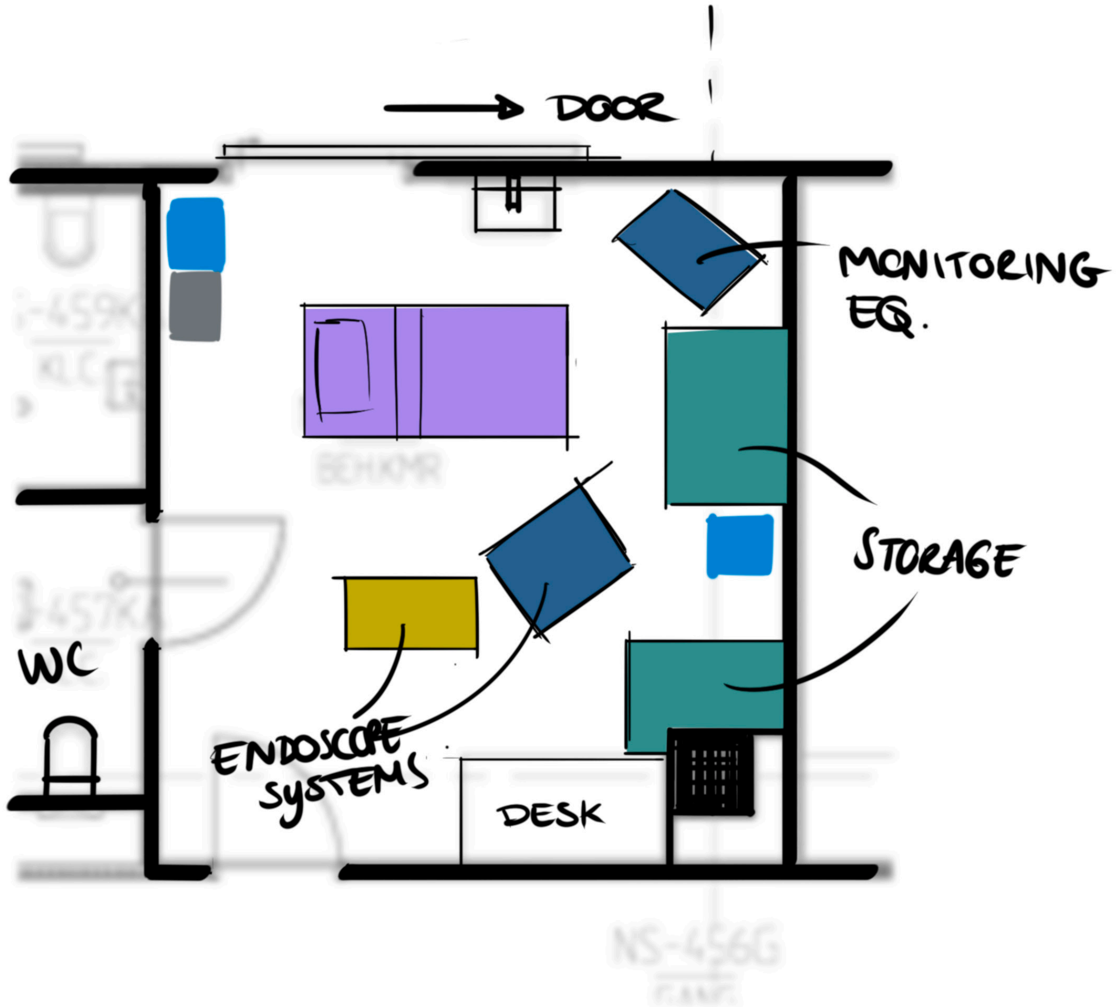


Figure 3.2: Floor plan of Room 2.

Room layout and equipment

Curretly 16 gastrointestinal physicians and 25 endoscopy nurses are working in Erasmus MC. During a colonoscopy procedure, two nurses and one physician are present. Annually the EMC performs around 10.500 endoscopies; 4500 gastroscopies and 2500 colonoscopies were performed in 2023.

The endoscopy rooms are each equipped for the designated procedure, thus the layout each of the rooms is different. In Figure 3.2 and Figure 3.3 all the room elements, equipment and products are annotated.

The elements can move independently across the room and therefore the rooms are modular. The modularity of the room is facilitated by 'floating' monitoring equipment and endoscopy equipment. Additionally, all the patient beds, storage carts and endoscope carts have wheels. The floating monitoring equipment, as well as the patient beds can be adjusted to the adequate height for the endoscopist to maintain the best ergonomic posture as possible.

Waste in treatment room

There are multiple waste streams in the colonoscopy treatment rooms:

Liquids:

- Suction liquid (suction bags)

Hazardous:

- Sharps (yellow sharps container)
- Chemical waste (grey container)

Solid waste:

- General medical waste (GMW, blue bags)

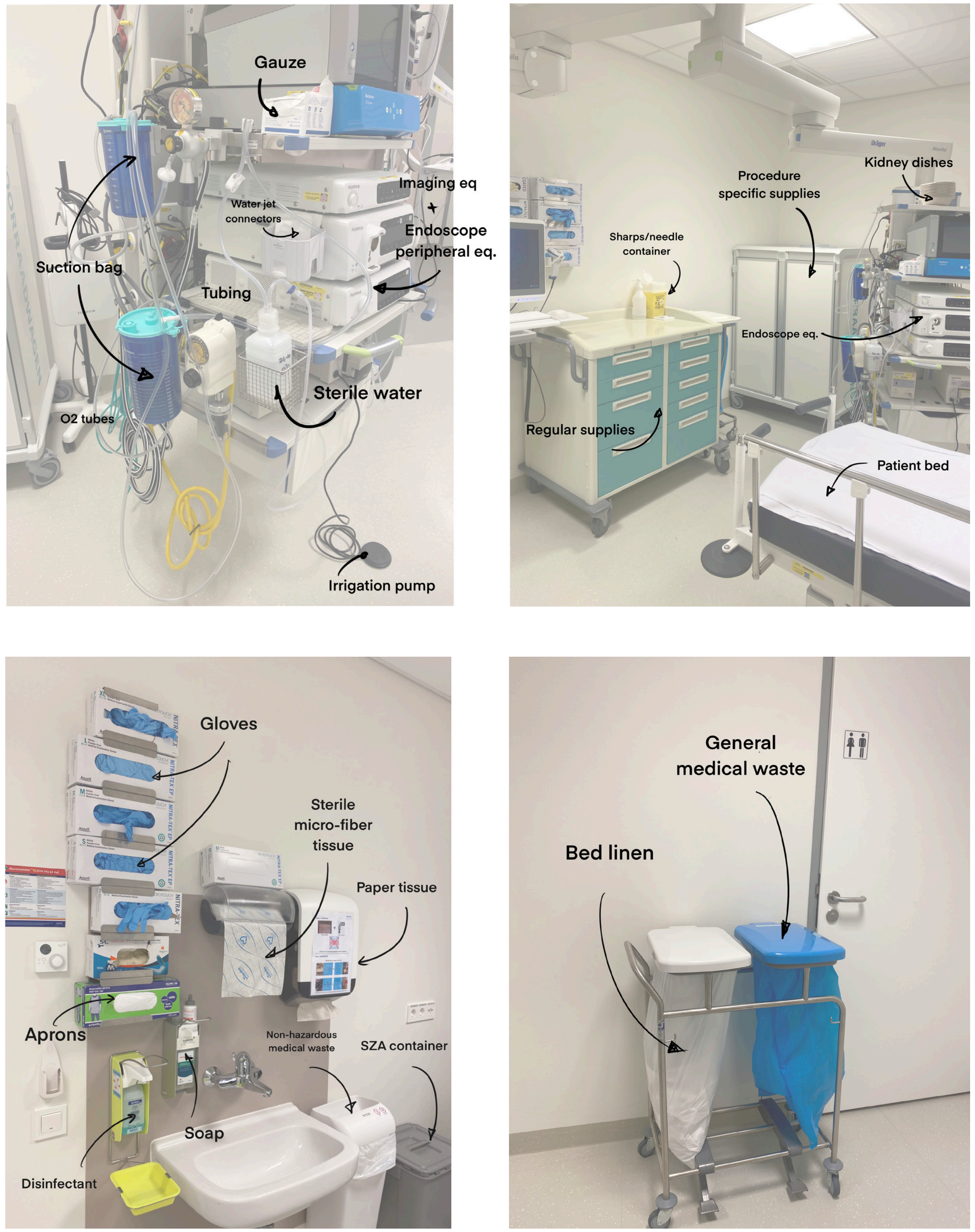


Figure 3.3: Equipment, products and room elements in Room 2.

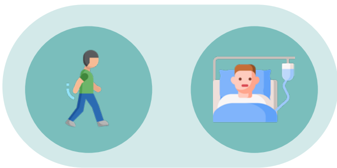
The Endoscopy Unit

Actors and their main concerns/functions

Endoscopy physicians

- Last say in procedures and presents different care pathways to the patient for co-decision making (CDM)
- Performs endoscopies
- Decides on follow-up plan
- Patient administration (digital)

Patient



- Adequate preparation for procedure (starting from home or clinical), i.e. being sober (no food or drinks) and laxation
- Commute to hospital or transfer from other department in EMC.
- Co-decision and autonomy in care pathway

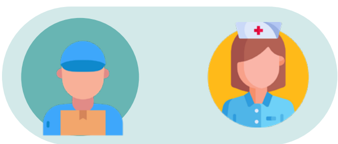
Endoscopy nurses

- Move patients from patient room to treatment room
- Prepare the treatment rooms for endoscopies
- Assisting in procedures (e.g. polyp removal, biopsies, handling of endoscope)
- Calming patients and administering medication
- Cleaning room
- Monitoring medical and endoscopy specific supplies that need to be restocked in room
- Pre-cleaning scopes directly after procedure

Disinfection (CSA) staff

- Leak testing scopes
- Thoroughly cleaning endoscope exterior and interior channels
- Disinfecting scopes with automated scope drying machines
- Responsible for sufficient sterile supply flow (60 scopes/day)

Restock



- A separate team (independent of departments) is responsible for restocking sterile and non-sterile storage 2x per week
- Nurses are responsible for restocking the rooms at the end of each day

Procurement

- These are separate actors for endoscopy department and CSA
- Managing the automated and manual procurement of sterile and non-sterile products
- Maintain overview of costs and cash in and outflows
- Maintain relations and contracts with endoscopy specific suppliers

Waste management

- Supplying clean waste containers
- Emptying waste containers at the end of each day in waste management department

3.2

Colonoscopy procedure in detail

Colonoscopy procedures are described in detail and in a chronological manner. The role of the nurses as endoscopist assistants is highlighted.

Figure 3.4: Endoscopist and nurses performing a colonoscopy (schematic).

Procedure breakdown

During a colonoscopy procedure, two nurses an endoscopist examine the colon of a patient (Figure 3.4). This is done to view the intestine and to potentially detect early stages of colon cancer by detecting polyps.

Prior to the procedure, the patient must prepare by staying 'sober' to ensure adequate visibility in a clean intestine. Sometimes this preparation is done clinically (e.g. patient is already in EMC), but this stage occurs mostly at home before the patient commutes to the hospital.

Most patients are admitted sedation if necessary. This is pre-determined in the referral by the GP or other medical specialist. Standard sedation consists of does of IV medication which can be doubled in extreme

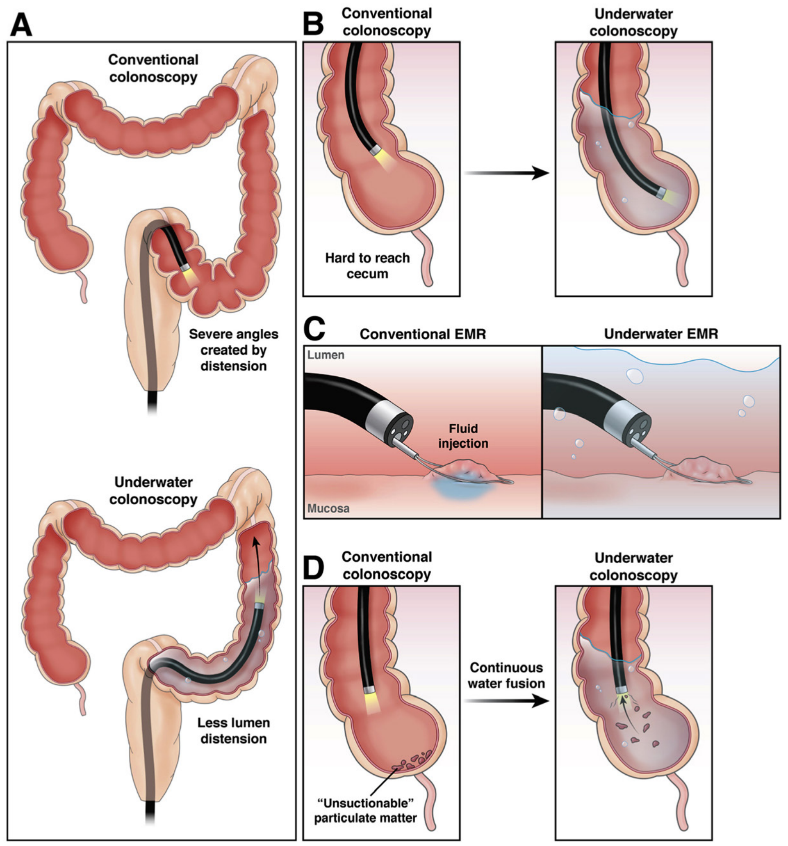


Figure 3.5: Schematic comparison between water-assisted colonoscopy and conventional colonoscopy. Adapted from Anderson (2020).

cases of discomfort, but some patients can endure the procedure without any sedation.

The endoscopist inserts the endoscope until the very end of the colon, while examining the intestine walls. During the pull-back of the endoscope, pictures are taken and if applicable the endoscopist and nurses perform small surgical interventions such as biopsies and polypectomies. The colonoscopy procedures at EMC are both conventional and water-assisted colonoscopies, which use sterile water for irrigation (Figure 3.5).

Biopsy or polypectomy

The nurses and endoscopist work closely together as a team. Some pressure may be applied to the patients abdomen by the nurses, in order to relieve discomfort caused by the bending of the endoscope. Some patients experience more discomfort than others, and hence it varies how busy the nurses are during a procedure.

In case of a biopsy or polypectomy removal, one nurse assists the endoscopist with the forceps or snare (Figure 3.6), that is inserted through one of the endoscope channels.

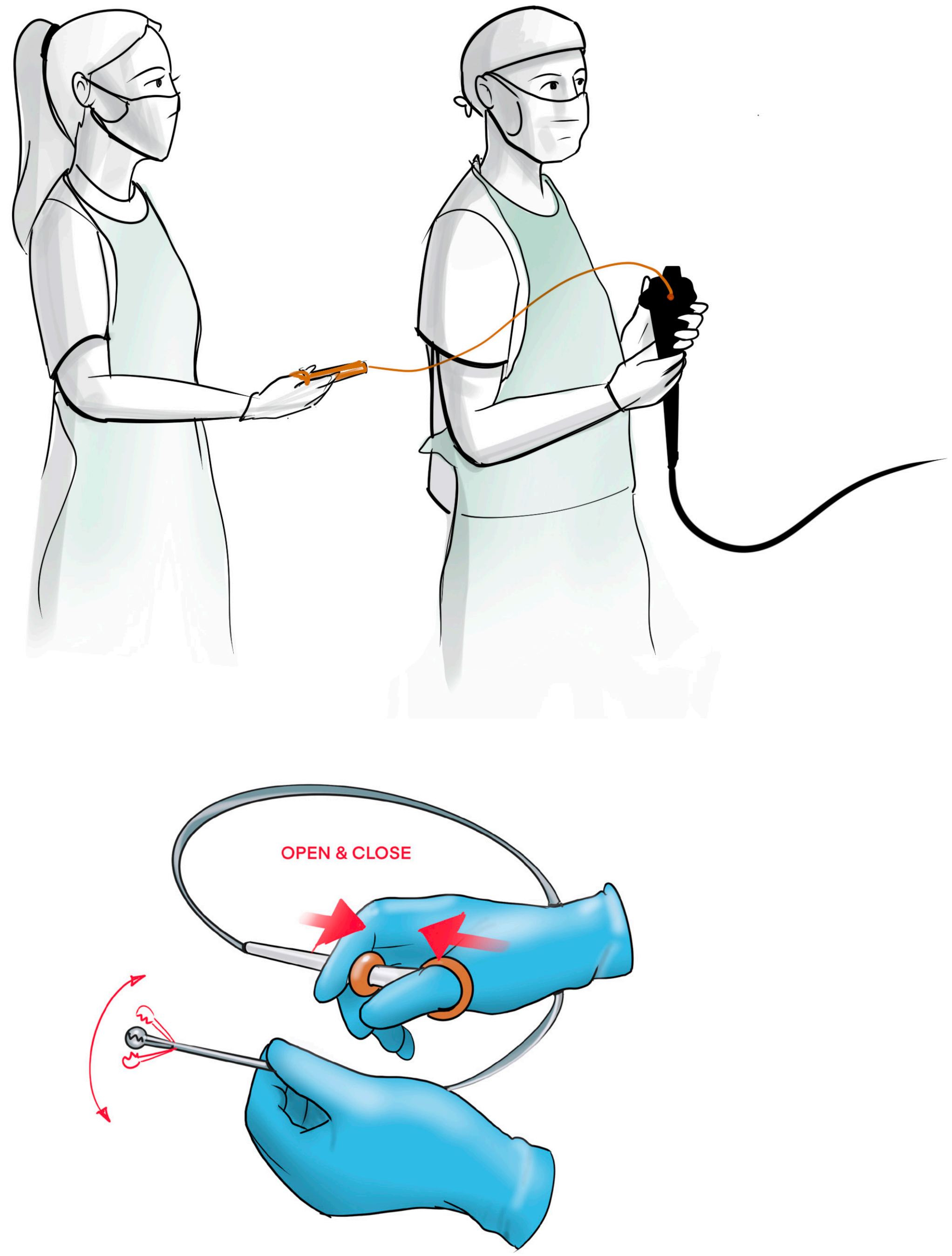


Figure 3.6: Teamwork between endoscopist and a nurse during a polypectomy or biopsy. The forceps or snare can be inserted into one of the endoscope channels. The physician holds the endoscope in place while the nurse manipulates the handle of the forceps.

3.3

Colonoscopy workflow & routinely used products

The workflow was mapped to visualise the moments in the procedure where the most products are used. The workflow map was established through observations throughout the project, and detailed further with insights from co-creation sessions. Understanding the workflow will allow the adaptation of this workflow for implementing interventions.

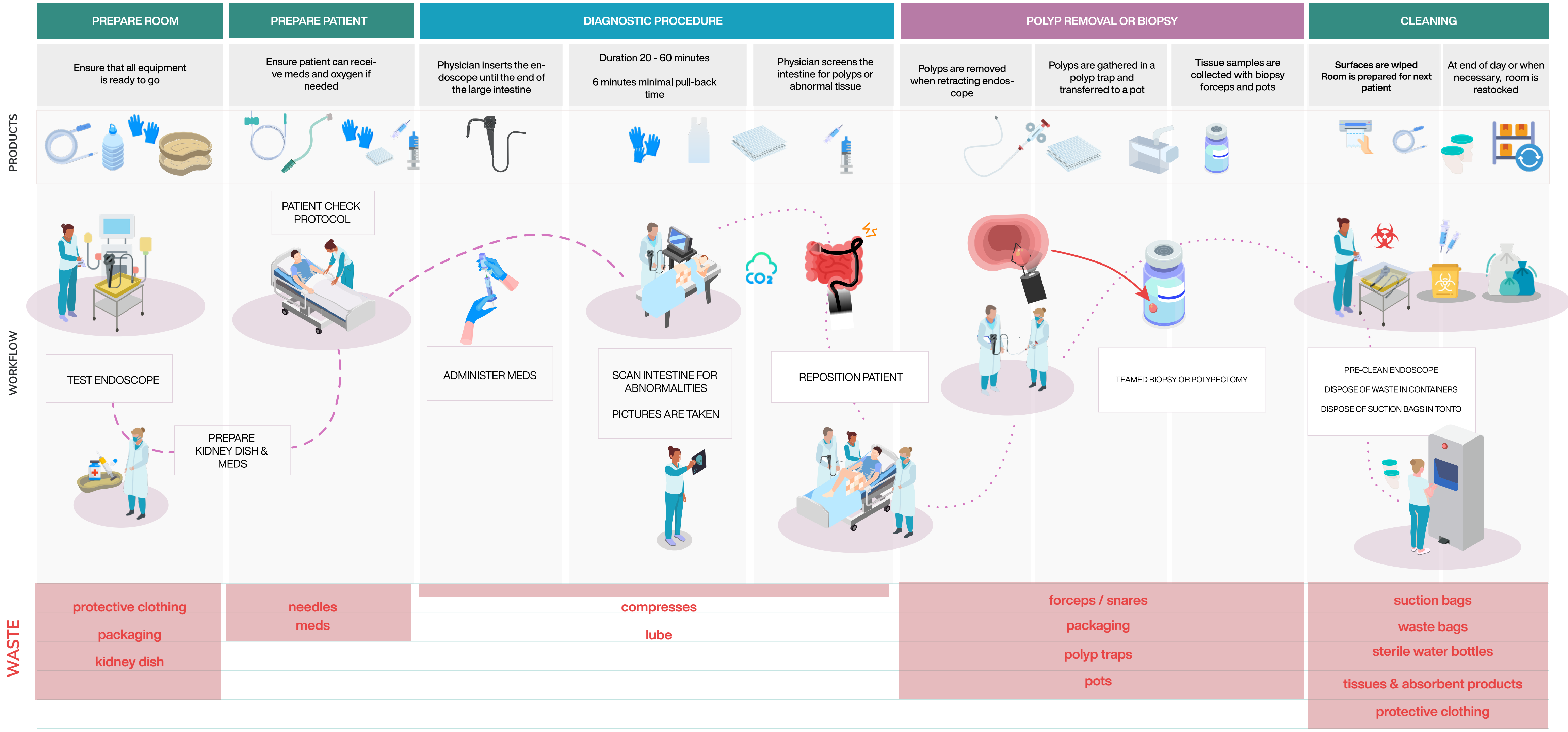


Figure 3.7: Colonoscopy workflow and waste generation per phase.

Workflow map

Based on rigorous observations, the workflow was mapped in Figure 3.7. The workflow is divided into five main phases: room preparation, patient preparation, the general screening procedure, polypectomy or biopsy and cleaning. Colonoscopy workflows are generally really predictable. However, many factors can influence the complexity of the procedure and therefore the number and types of products used. For instance, a patient in extreme discomfort might require a double dose of sedation or a thinner endoscope, increasing the footprint of the procedure.

Colonoscopies are more or less constant. Still, it must be taken into account that multiple variations can occur. These variations affect the amount of products used and the volume of waste created. Almost all colonoscopies occur with sedation. Generally, if the patient has more complications, wastefulness increases. These complications create a strain on the nurse's workflow and is important to keep in mind when designing interventions that potentially affect the nurses' workflow.

Variations within the same type of procedure

Per patient variations include the following:

- With or without polypectomy or biopsy
- The number of tissue samples taken, ranging from 1 to a dozen biopsy pots
- Endoscopic mucosal resection (EMR), a technique that uses electrical current for polypectomy and gelofusion to lift the polyp
- Sedation dose, some patients undergo the colonoscopy without any sedation, some patients need a double dose
- Some patients need additional numbing gel on top of sedation
- In extreme cases of discomfort, sometimes the endoscopist switches to a thinner endoscope
- Combined procedures: To reduce the number of patient visits sometimes upper GI and colonoscopy are performed subsequently on the patient. This increases the amount of products used per patient, but may reduce impact regarding emissions from patient transport.
- Experienced endoscopist vs. apprentice (AIOS). Colonoscopy procedures may take longer with varying experience of the endoscopist. Additionally, if there are any uncertainties during the procedure a second physician can be paged for advice. This not only increases the energy use for insufflation and imaging, but also increases the use of personal pretective equipment (PPE).

Room and patient preparation

Nurses are the main interactors with waste in the treatment rooms. Their main role is to reinforce the endoscopist while performing the colonoscopy. Before anything else, the room is equipped and tubing is connected to the peripheral devices and endoscope.

The physician's role is to maintain the endoscope inside the patient's intestine. Therefore, nurses are the ones handling most of the products. Ideally, each nurse has her/his own task flow within the total workflow.

Patients are always equipped with an IV butterfly catheter, regardless of any sedation. This allows the nurses to handle quickly in the case of sudden discomfort in the patient. After the endoscopist has completed the checklist, one of the nurses can administer any sedation.

Screening & surgical procedures

The endoscopist inserts the endoscope in the patient's intestine and screens for any polyps or abnormal tissue. Nurses might be requested to take photo's of the tissue during the pull-back time of the endoscope. If applicable, a polypectomy or biopsy is performed with one nurse. The other nurse is responsive to the patient and aids in repositioning. **This implies that each of the nurses could in theory have a separate workflow.**

Cleaning & restock

The room is then cleaned for the next patient or the next day. Activities include restocking of the room storage units by an assistant nurse, wiping all surfaces with ethanol or sterile tissues and disposing of waste.

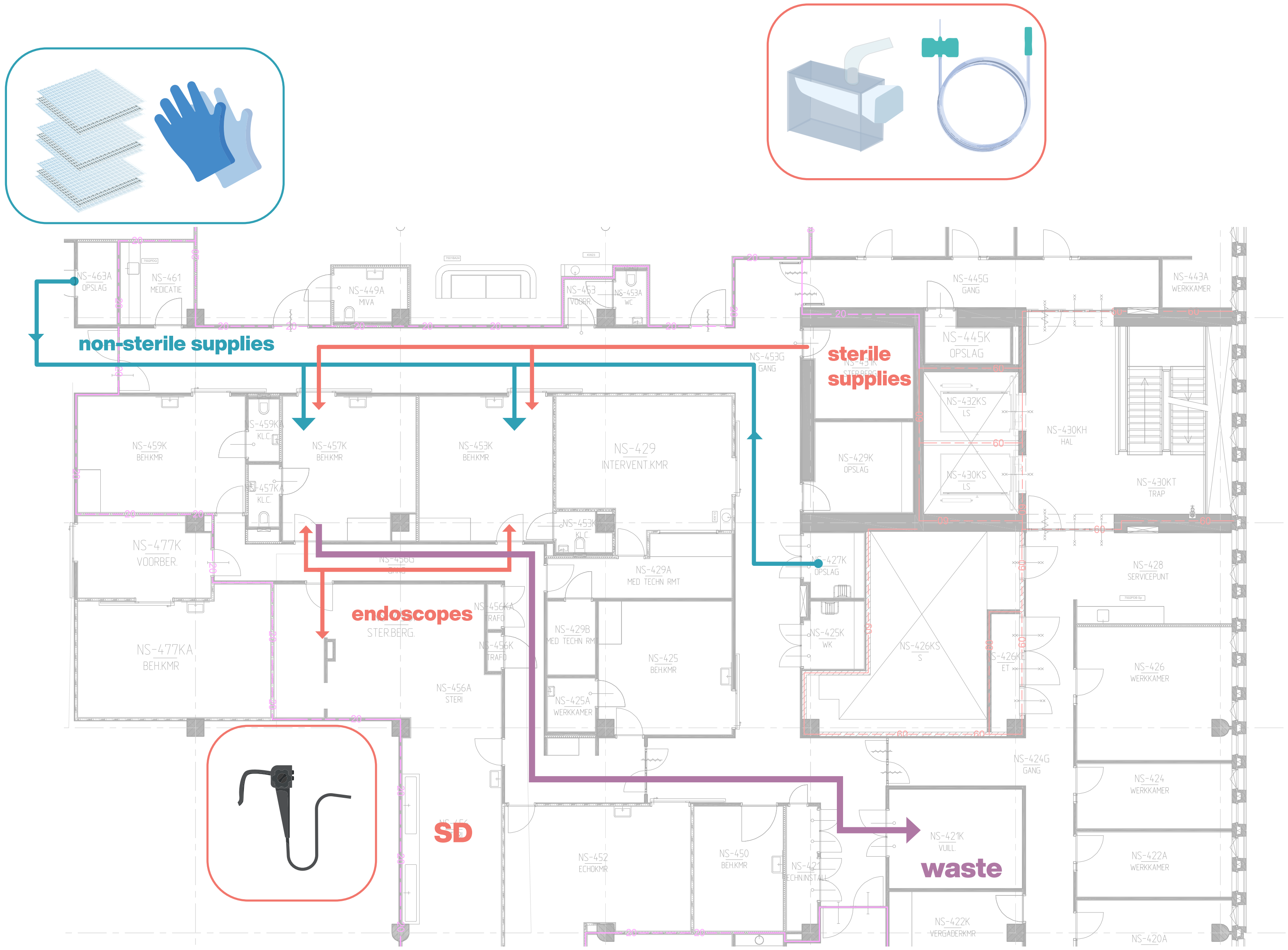


Figure 3.8: Routes of restock and waste disposal by nurses in the endoscopy unit from and to Room 2 and 3.

In Figure 3.8 the restock routes are visualised as well as the waste disposal routes from Room 2 and 3.

Waste disposal

Not all products are discarded in the room. Suction bags containing large amount of fluids are disposed in the TONTO, which is a special container located in the waste room (Appendix D). Additionally, empty sterile water bottles are disposed in a separate plastic bottle container to be recycled, which is also located in the waste room. As seen in Figure 3.8, the waste room is located farthest from Room 2 and 3. According to endoscopy nurses this often results in the segregation of waste being felt as a hassle. This implies that there are no optimal conditions for proper segregation of waste.

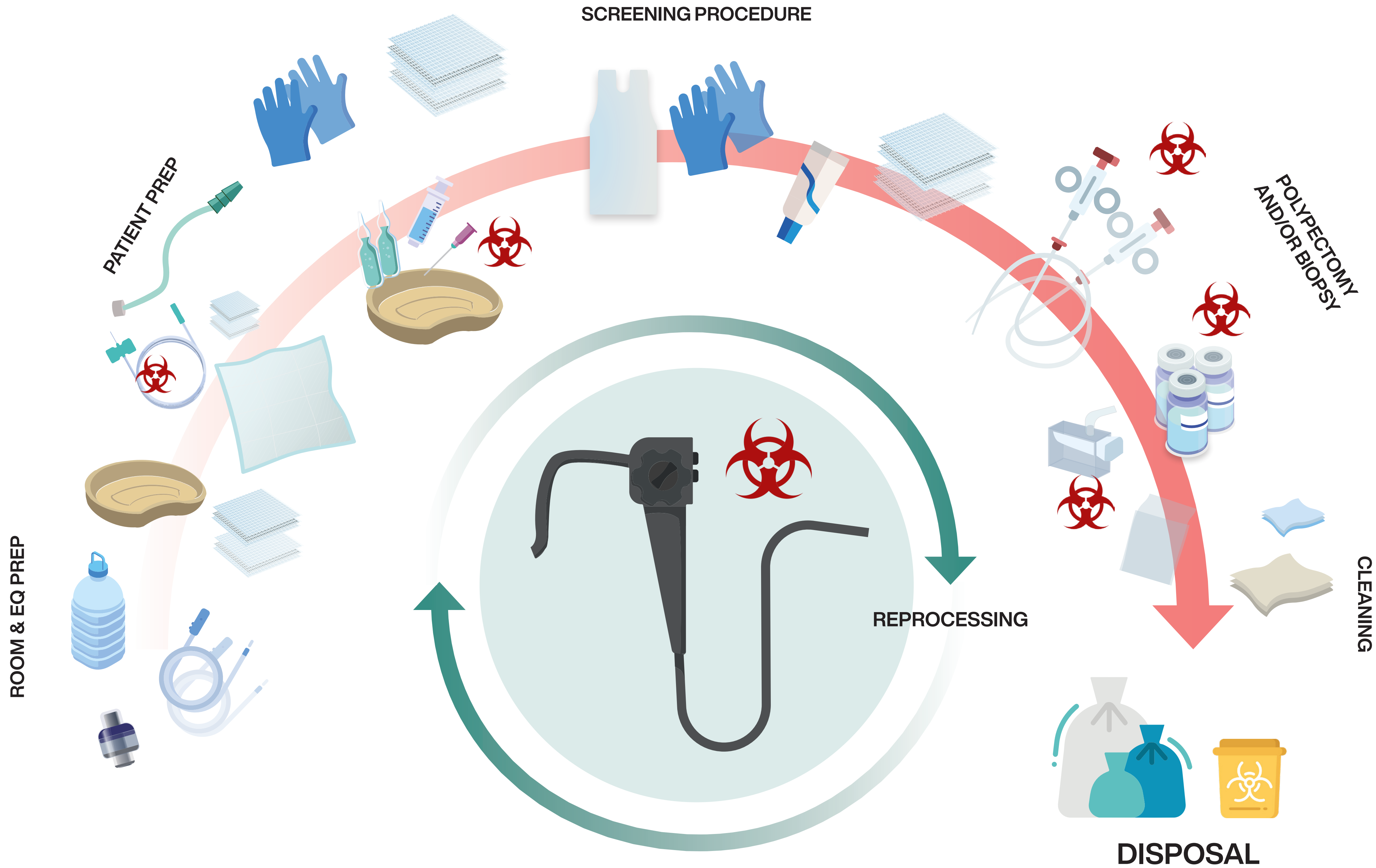


Figure 3.8: Routinely used products for colonoscopy

Routinely used products

In colonoscopies a wide variety of products is used (Figure 3.8). These include medical and non-medical consumables, but also durable products and equipment. Benedettini (2022) describes multiple product groups that have the potential to be durable but that are used as SUDs (Appendix C), however, EMC does not use reusable accessories in their current practice. Therefore, only endoscopes are kept in the loop through reprocessing, while the rest of all the products follows a linear path. Bed linen is also washed, but it is not included here since it is not a medical product.

Usually products from the same supplier are used, however in the case of supply chain strains, the endoscopy unit always has alternative suppliers to overcome shortage. According to the endoscopy staff, some struggle may occur because of certain product preferences, as a result of a change in product experience which disturbs the workflow. This might lead to more use of products, but further research is needed.

Most of the SUDs used in colonoscopies are from Boston Scientific, Cook Medical, Duomed, Olympus and Fujifilm (internal research EMC, 2023). These are trusted manufacturers and have a special relation with academic hospitals, since they are **key contributors to research funding**. The contracts between EMC and these suppliers rely on professional relations, rather than on mere transactions. This complicates strategies such as refusing the use of certain products or switching to other suppliers.

Refuse

Current colonoscopy waste ends up incinerated, including the hazardous waste which is incinerated in even higher temperatures. The types of products used are now identified, **but what is actually disposed of in an EMC colonoscopy procedure?**

SUMMARY & KEY TAKEAWAYS

SUMMARY

While the workflow of the nurses is sctructured, multiple variations can complicate the process resulting in more waste or occasionnally unused products.

Waste disposal is not seen as a part of the workflow.

Due to colonoscopy's predictability and structure, there is little to no share of the products being unused, except for some accidental compresses or gloves.

Therefore, the strategy of reducing the number of products might not be applicable.

Some products are used as a result of clinical protocols, such as an IV butterfly catheter, which is used regardless of the sedation of the patient.

Most waste is created at the preparation phase, biopsy or polypectomy, and cleaning at the end of day.

The EMC's role as academic hospital can complicate certain sustainability strategies. Apprentice doctors and nurses might dispose of waste incorrectly due to their lack of experience in the department, and switching to more sustainable products is challenged by the types of contracts of the suppliers.

Refuse

KEY (DESIGN) DRIVERS

Routinizing the intervention into the current workflow will be the best way to adopt a sustainable practice.

Nurses are the main interactors with products.

Waste management inside the treatment rooms: can the system be improved to create a less complex workflow with waste?

Optimizing the workflow for waste disposal

Varying team compositions with different experience levels > **need for simplicity and clarity of tasks.**

04

SECTION

WASTE OF COLONOSCOPY PROCEDURES

MAPPING AND QUANTIFYING PRODUCTS & MATERIALS

As seen before in Section 2, a colonoscopy procedure generates different waste streams. General medical waste does not differentiate between materials or hazard level. Thus, there might be potential to reduce the amount of incinerated waste volume and create new recyclable waste streams. This section visualises the consumption per procedure and identifies the disposed materials as hotspots for a redesign opportunity as seen from a HCD-approach.

04

4.1

Waste audit on solid waste from one colonoscopy room

The waste of colonoscopy procedures was analyzed using a HCD-approach. The behaviour and workflow of the endoscopy staff is highly influenced by the products they use and vice versa. Therefore, in this subsection the data of the waste audit is presented in a visual way with the aim of sensitizing endoscopy staff and sparking awareness. The visual documentation of the audit was presented during the monthly department meeting with nurses and was used to activate the Green Team to participate in a set of co-creation sessions.

Waste in endoscopy room

The general waste can be discarded in three different general waste bags across an endoscopy room, potentially creating a challenge for efficient disposal. Sharps and harsh chemicals (i.e. formaline cups) are discarded in separate containers which are incinerated at higher temperatures. **The general waste is mixed regardless of the level of hazard of a product or material, resulting in the contamination of potentially recyclable materials.**

Waste audit

A waste audit was performed with the aim of mapping and quantifying the products discarded in a single colonoscopy procedure. The full waste analysis report is found in Appendix D.

Conventional waste audits do not focus on the disposal behaviour, hence a combined method was applied. The method consisted of the observation of 15 colonoscopy procedures conducted during 5 afternoon programs, of which 3 procedures were used as an observation pilot. Each individual observation was followed by waste sorting of the waste bags specific to the observation room the next day, see Figure 4.1.

The method can be seen as a pilot for future waste audits, since it combined workflow and product counting during observations and quantification of products in the solid general waste (as conventional waste auditing). This provides a holistic view of the waste disposal. With this in mind, the audit has important limitations.

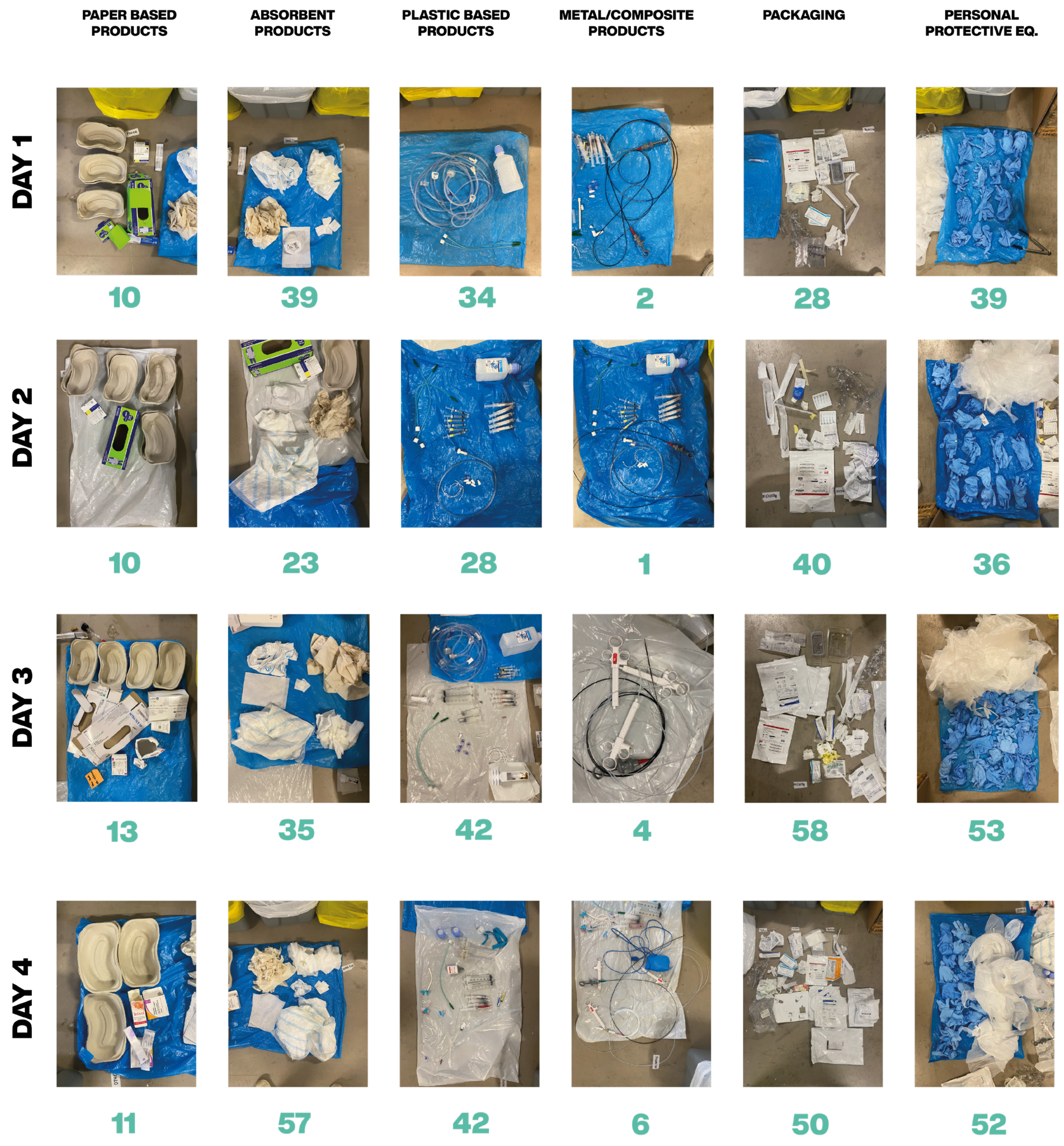


Figure 4.1: Results from the waste audit for colonosocpy procedures in a single room during four consequent afternoons. Note that per day per room the amount of products would roughly double.

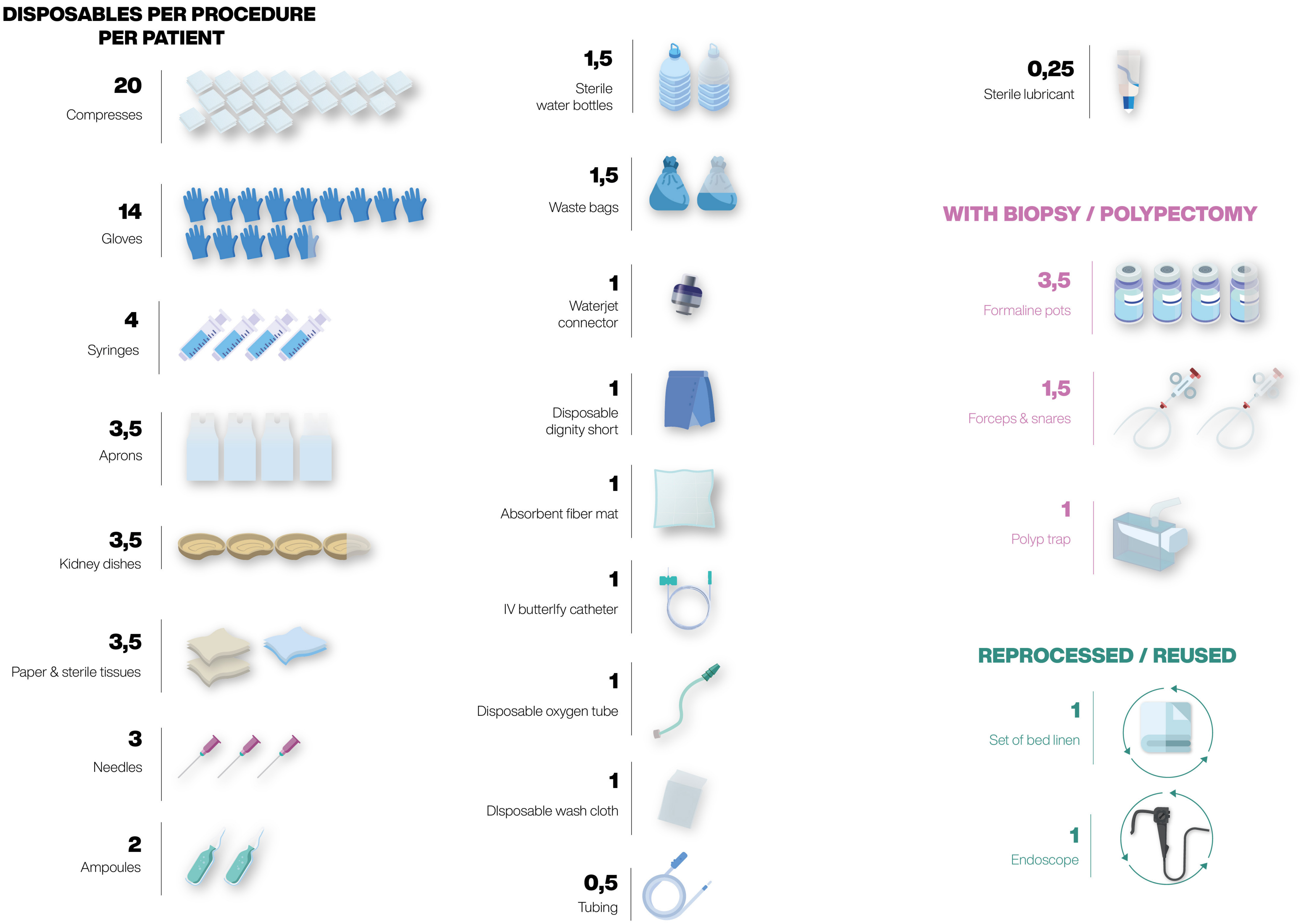


Figure 4.2: Average use of products per patient, derived from waste audit and observations.

Results

The average used products are mapped in Figure 4.2.

The number of products per procedure ranged from **51 to 109 units**. During an average colonoscopy procedure **70,5 products per patient** are used and discarded in a single room and totals to an average of **0,58 kg of solid waste** per patient.

Ratio of used versus unused products

Interestingly, almost all products were used, meaning there is only a very small percentage of occasionally unused products, such as a glove or a compress that fell on the floor. As mentioned before a colonosocpy is fairly predictable and its course is indicated before referral. In contrast to e.g. ERCP procedures, where the visibility is very different and one approach for placing stents or balloons is not always effective, colonoscopy procedures are predictable enough resulting in a quite efficient used/unused ratio of SUDs and consumables per patient.

Number of products

The largest number of products per category was quite consistently in PPE and packaging. This raises the question if these are the largest hotspots. A point for further research is to identify the amount of uncontaminated materials that could theoretically be recycled. Even though the number of medical instruments was really low compared to the amount of gloves and aprons, medical instruments contain critical materials such as stainless steel which are being incinerated. However deeper impact analyses like LCAs are needed to calculate the impact keeping in mind incineration and potential toxicity.

Comparison to literature

López-Muñoz et al. (2023) performed such a LCA on biopsy forceps and polypectomy snares, and found that the results varied widely between product suppliers. Hence, analyses for the specific SUD brands in the EMC are needed.

In the literature review, the use of sterile water was estimated at 0,7 L per patient(Siau et al., 2021) versus 1,5 bottles per patient as observed in the audit. The explanation could be that a sterile water bottle can only be used during 24 hours and therefore is discarded at the end of the day. Thus, any water left in the bottles after all the procedures in a room are completed, is discarded through the drain, increasing the "use" of water per patient.

Sterile water bottles were found in the general waste on three of the four days, even though there is a separate recycling container. This increases the mass of total waste. Further elaborated in section 4.2.

The mass of the solid waste ranged on the lower side of the 0,5-2,1 kg of waste estimated by De Jong (2023). The audit only emcompassed the general waste bags in the treatment room and not in the patient recovery room. In addition the number by De Jong (2023) is not specific to colonoscopy procedures, but also includes procedures such as ERCP where there is also anaesthetic waste. This implies that waste audits are needed that include the mapping of a larger piece of the care pathway.

The complete discussion of the audit is found in Appendix D, but the following are the main recommendations.

Limitations & recommendations

Statistical analysis

The number of unexpected variations in a single colonoscopy procedure requires a new approach where the number of procedures observed can be **statistically analyzed**. This waste audit provided a clear distinction between different colonoscopy procedures but is not fit for conclusions about frequency of procedure variations and frequency of use of the SUDs and consumables, since there were only 15 procedures analyzed over the course of one week. In future audits a longer period of time should be considered for the observations.

Material rather than product categories

The waste was divided into product categories which were then weighed, however this made quantifying of the material composition very difficult. On the other hand, this enabled the comprehension that certain materials are present in all of the different product categories, which are discussed in the following subsection (Section 4.2). For future waste audits it is advised to separate the products into material categories to make as a basis for a more quantitative material analysis.

Wet & dry mix

Dry and wet products are disposed together, which is one of the reasons why the waste becomes contaminated. This also implies that a small percentage of the weight is residual liquids (i.e. in syringes and absorbent products). Because of the mixed waste's infectious nature, the waste bags had to be kept close for personal safety reasons and therefore the liquids were retained. For future audits, (clean) products should be weighed separately to determine the residual liquids percentage.

Behavioural factors

The combination of observing the specific procedures during the waste audit was highly insightful since it helped to specifically identify the varations between colonoscopies. Therefore, the contextual element of this audit remains recommended. Key insights of behavioural factors are depicted in section 4.2.

4.2

Waste disposal & endoscopy staff

In this subsection the most relevant findings for waste disposal from an HCD-perspective are highlighted. During the waste audit, multiple factors were identified that influence the waste disposal behaviour in endoscopy staff.

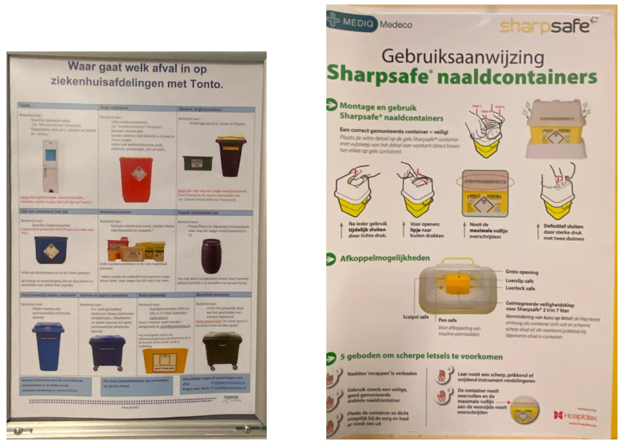


Figure 4.3: Instructions for containers

Waste room

In the waste room there are different types of containers, each of them with a written instruction on how to dispose of specific products, see Figure 4.3. However, even with the presence of these instructions, nurses can be hesitant about where to dispose certain products. Therefore, a 'hesitation container' was introduced to the waste room.

The waste containers are colour coded, However, recent developments within the EMC's waste management have resulted in a different colour of containers. For instance, incineration containers for hazardous waste used to be red, but are now grey because they are made from recycled plastic as an alternative to containers made from virgin plastic. The printed instructions have not been updated since.

Locations of waste in treatment room

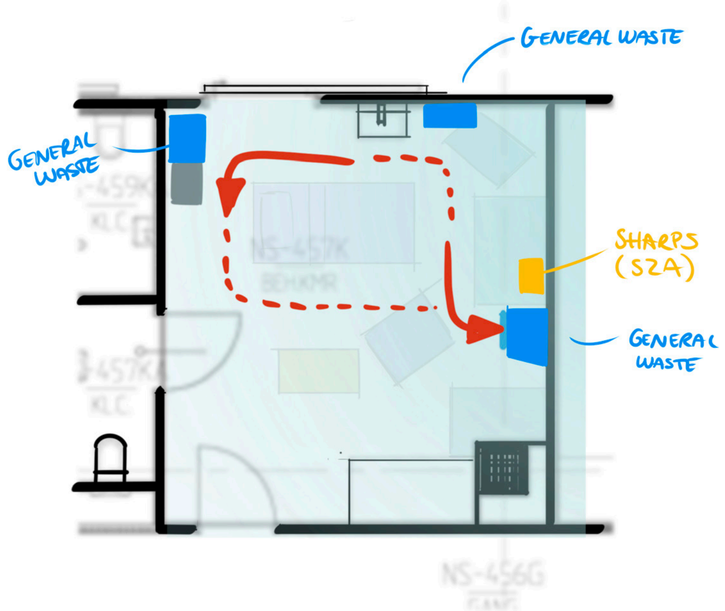


Figure 4.4: Treatment room disposal locations.

In the treatment rooms there are three locations to dispose of general waste (blue bags, Figure 4.4. This leads to inefficient waste distribution. Because the rooms are cleaned after each morning and afternoon shift, the general waste bags next to the sink are often half empty when disposed. Arguably, this waste bag becomes a mostly unused product.

Workflow observations

There seems to be confusion amongst apprentices were to put certain waste types because of unclear or absent instructions. During the worflow, nurses, apprentices, physicians and patients flow in and out of the rooms, and there is little time to provide instructions for waste disposal. For instance, experienced nurses often put the empty sterile water bottles aside to put in the PMD container, while an apprentice nurse is more inclined to dispose of them in the general waste.

In case of more complex procedures such as a polypectomy or biopsy with a large number of samples, multiple forceps are used per patient in order to speed up the process, generating more waste.

If there are complications such as a product shortage or extreme patient discomfort, nurses become highly attentive of the clinical activities, losing attention to waste behaviour completely. This results in e.g. water dripping over the floor, unused compresses and gloves falling onto the floor. Also packaging lingering around the waste bags.

The use of PPE varies per person in the room, especially the use of aprons and facemasks. Aprons and gloves are consistently used by the endoscopist, who has direct contact with the endoscope and therefore with the patient's bodily fluids. Nurses show more irregularities in wearing aprons and gloves; often only one of the nurses equips her- or himself with gloves and an apron, but the motive is "just in case". Aprons and gloves must be discarded if a staff member leaves the room, and a new set of PPE is taken each time a person enters the room. Because of the role as EMC as a teaching hospital, often multiple additional staff members enter the room to assist or advise during a procedure, resulting in a higher number of PPE units than the number of routine staff members.

Intrinsic motivation

While most of the staff is aware of the wastefulness of the procedure, intrinsic motivation to adapt the current system varies among staff members and steers behaviour towards corrections or initiatives. A recent initiative is recycling the sterile water bottles, showing a **proactive approach from a part of the staff within the department.**

4.3

Identification of materials

The waste audit provides a more detailed analysis on specific EMC colonoscopy practice. Now, the results of this audit have to be related to further research directions and design drivers. Since the waste was sorted into product categories, no material quantification method could be applied. However, a qualitative analysis for material identification was done through desk research and literature, as well as the Granta Edupack database to acquire data of the product materials. This serves as a basis for further analysis.

Materials overview

In Figure 4.5 is shown how three main material gorups are present in the different product categories. This figure shows that even in predominantly biobased material products such as a kidney dish, the use of plastics in these products cannot be ruled out. In the case of a kidney dish, plastic can be added as a coating or aggregate to the pulp to make the product waterproof (Debnath et al., 2022), but eliminiating any possibility to recycle or remanufacture the product.

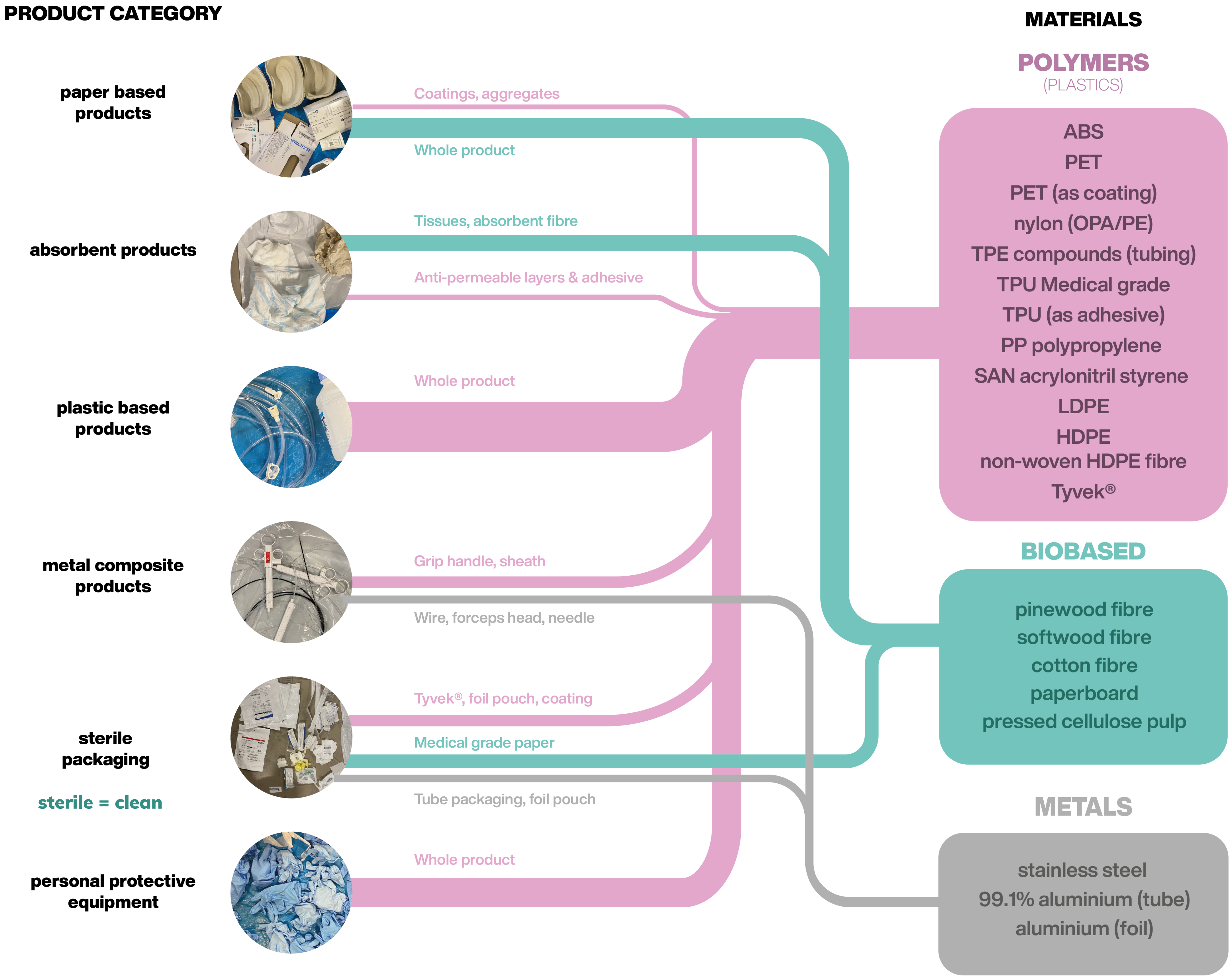


Figure 4.5: Overview of material groups in the different product categories. Please note that the widths are not related to any specific data on weight distribution, since no data was obtained on the masses.

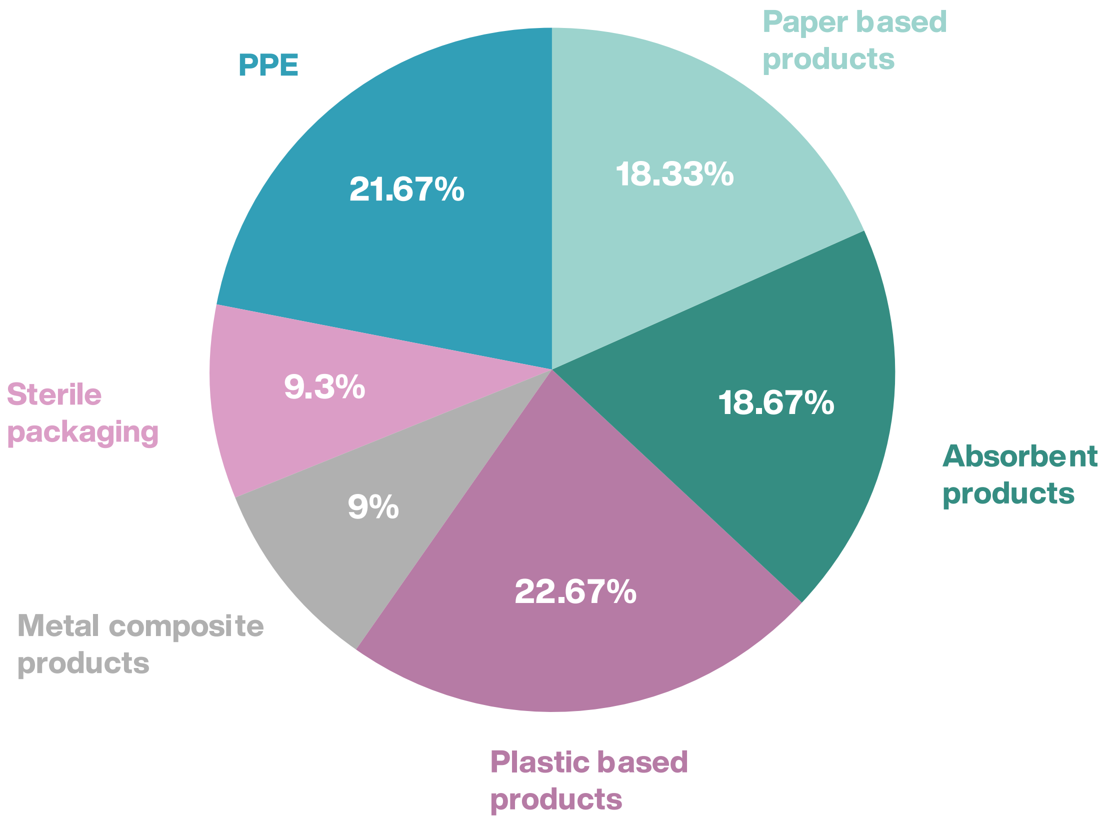


Figure 4.6: Average of the product category percentages based on the waste audit.

Estimate of the plastics percentage

From the waste audit and the material identification, it can be estimated that at least **54% of the waste is composed of plastics** (Appendix D, E). These materials are destined for incineration and the aforementioned could indicate the use of plastics as a hotspot.

Global warming potential

Why do plastics contribute so much to emissions when incinerated? It is related to the global warming potential (GWP) of plastics as opposed to other materials. The GWP is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO2). The larger the GWP, the more that a given gas warms the Earth compared to CO_2 over that time period (US EPA, 2023).

Medical waste incinerators emit a large number of pollutants into the atmosphere (US EPA, 1997). When plastics are incinerated, toxic gases with a higher GWP than CO_2 are emitted. In the study by López-Muñoz et al. (2023), it was concluded that for forceps, snares and haemoclips consisting mostly of plastics, incineration was the main culprit of emissions in their LCA.

Therefore, reducing the mass of incinerated waste can reduce the total amount of emissions. Other product groups consist of similar plastics as forceps and snares. Subsequently, it is likely that they undergo similar production processes. As such, an assumption can be made that the emissions from incinerating these plastics also have a major contribution to the total emissions of the products.

The importance of designing for recycling, as mentioned in section 2.2, is once again highlighted.

Challenges in material identification & segregation

Even if future SUDs and other consumables are designed for recycling or disassembling, there are certain challenges in identifying the specific materials. Especially for medical staff, since they have not been trained in recognizing materials. This is not in their domain or education.

One example is Tyvek®, which is a medical grade "paper", which is actually HDPE (DuPont, 2018). Similarly, PET coatings can be added to biobased medical grade paper to reinforce it (Billerud, 2020). These types of materials are easily identified incorrectly by plain sight.

Some plastics such as TPU which are flexible plastics, are added to products in the form of adhesives (i.e. in fibre mats) or protective layers around movable product parts, such as the sheath on forceps or snares (Lee et al., 2020).

In addition, there is the risk of infection. More research such as López-Muñoz et al. (2023) should be done to identify the product parts that are non-infectious, even if the product has come in contact with the patient. In their research, more than 60% of the material of forceps could be saved for recycling by implementing a simple intervention: adding a mark on the product.

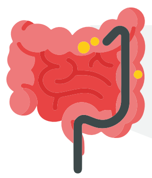
Lastly, the organization of EMC should facilitate waste segregation by making containers available to collect recyclable waste streams. This could alter the interior layout of the treatment rooms, and thus is challenging.

This implies that future products should have identifiable recyclable parts that can be easily segregated in the treatment rooms.

4.4

Translation of the waste audit results into the healthcare context

Now that a set of numbers and materials is provided, it can be used to illustrate the impact of these procedures on a larger scale. To complete, some of the data was used from Section 2.2.



1
procedure / patient

70,5
products

0,58
kg of solid GMW

30-45 min duration

16
procedures per day*

1128
products

9,28
kg of solid GMW

* Morning and afternoon program in Rooms 2 & 3 combined

Erasmus MC

2500
procedures per year in EMC

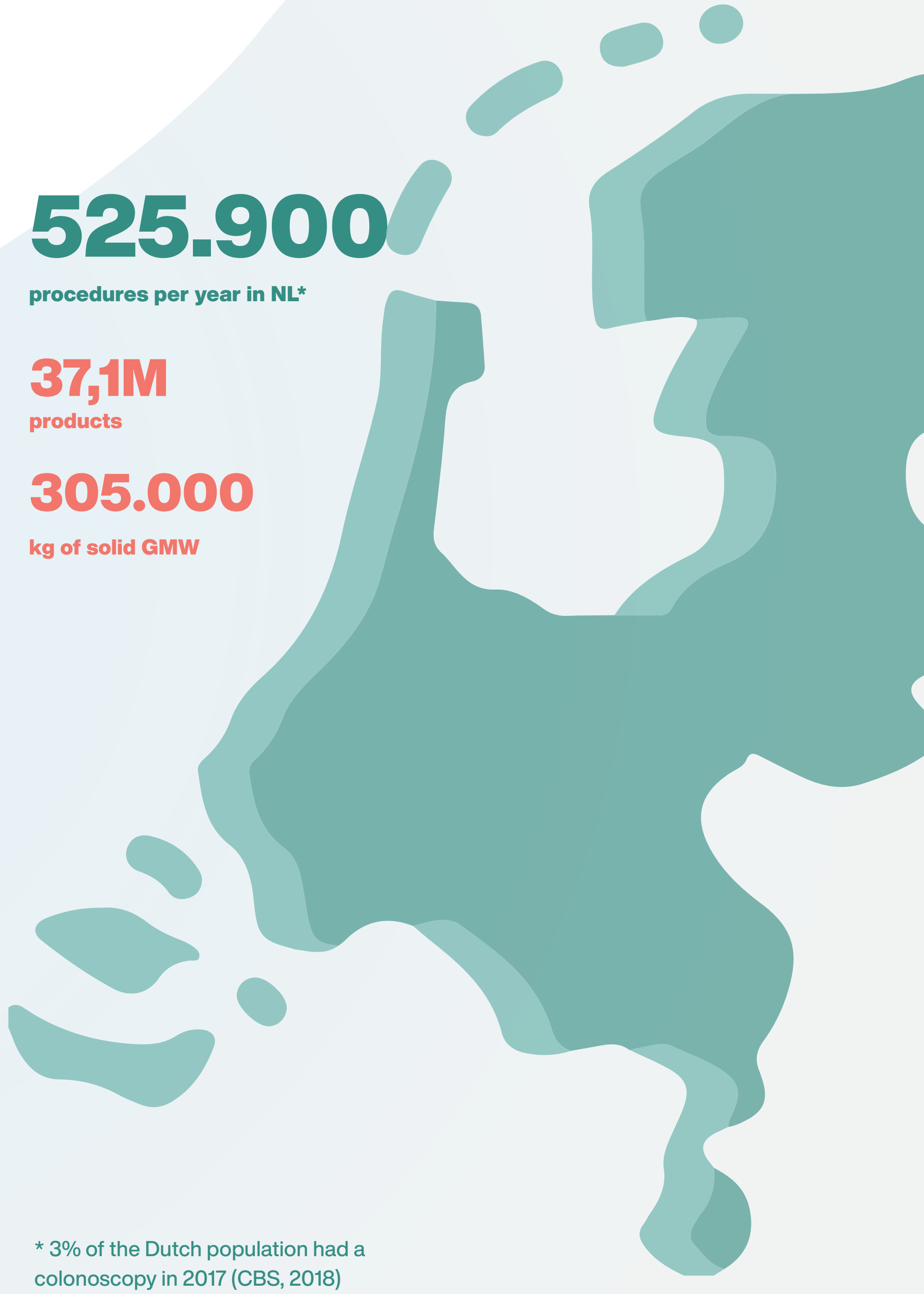
176.250
products

1.450
kg of solid GMW

43,98 MWh
per year
Siau et al. (2021)

17 years
worth of one Dutch household annual energy use
Milieu Centraal (n.d.)

62,72 tons
CO_2-eq per year
Henniger et al. (2023)



525.900
procedures per year in NL*

37,1M
products

305.000
kg of solid GMW

* 3% of the Dutch population had a colonoscopy in 2017 (CBS, 2018)

SUMMARY & KEY TAKEAWAYS

WASTE AUDIT

SUMMARY

An overview and quantification of waste was provided in a visual manner.

For colonoscopies, the number of products is difficult to reduce or refuse, since all the products are actually used.

Reduce | Refuse

The waste audit serves as a pilot for waste analysis to be performed at a larger scale, while taking into account behavioural factors.

The dual method of observation of waste disposal is recommended because it provides a more detailed overview of the used products. E.g. this helped to determine why certain products were wasted one day in comparison to another day, and to determine discrepancy in the use of PPE in relation to the number of people in the treatment room.

Materials were identified but not quantified due to the method of separation into product categories. However, the material flows show the use of polymers in every product category.

Incineration of plastics is a main hotspot in routinely used products such as forceps because of the materials' high GWP.

Identification of product materials for waste segregation is needed but poses challenges for endoscopy staff and recycling.

KEY (DESIGN) DRIVERS

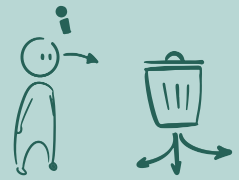
Reduce the amount of incinerated plastic waste

Design for recycling

Product markings for identification

Separate infectious from non-infectious waste

Create new recyclable flows



WASTE DISPOSAL IN STAFF

SUMMARY

There is confusion among staff where to dispose of certain products, but varies greatly among different types of staff members.

There is a lack of visual unity in the desginated containers which indicate which waste goes into which container.

The current workflow influences the waste distribution among the three different containers in the treatment room, resulting in half-empty waste bags.

Rethink

The EMC as a teaching hospital results in more people entering and leaving the room besides the scheduled staff. Multiple additional gloves and aprons are used when there is an extra staff member assisting or advising.

Intrinsic motivation varies in different staff members for adapting the workplace to enable a more sustainable practice. However, there is a **proactive approach** seen in own initiatives such as a plastic recycling container.

KEY (DESIGN) DRIVERS

Take away hesitation in staff

Visualising as much as possible to inform where to put the waste.

Waste segregation is currently seen as a hassle (from section 3.3), because it is not routinized.

Research how staff perceives infectious vs. non-infectious waste

What products are actually infectious?

Increase urgency feeling

05

SECTION

SYNTHESIS

ALIGNMENT OF LITERATURE, CONTEXT & WASTE AUDIT

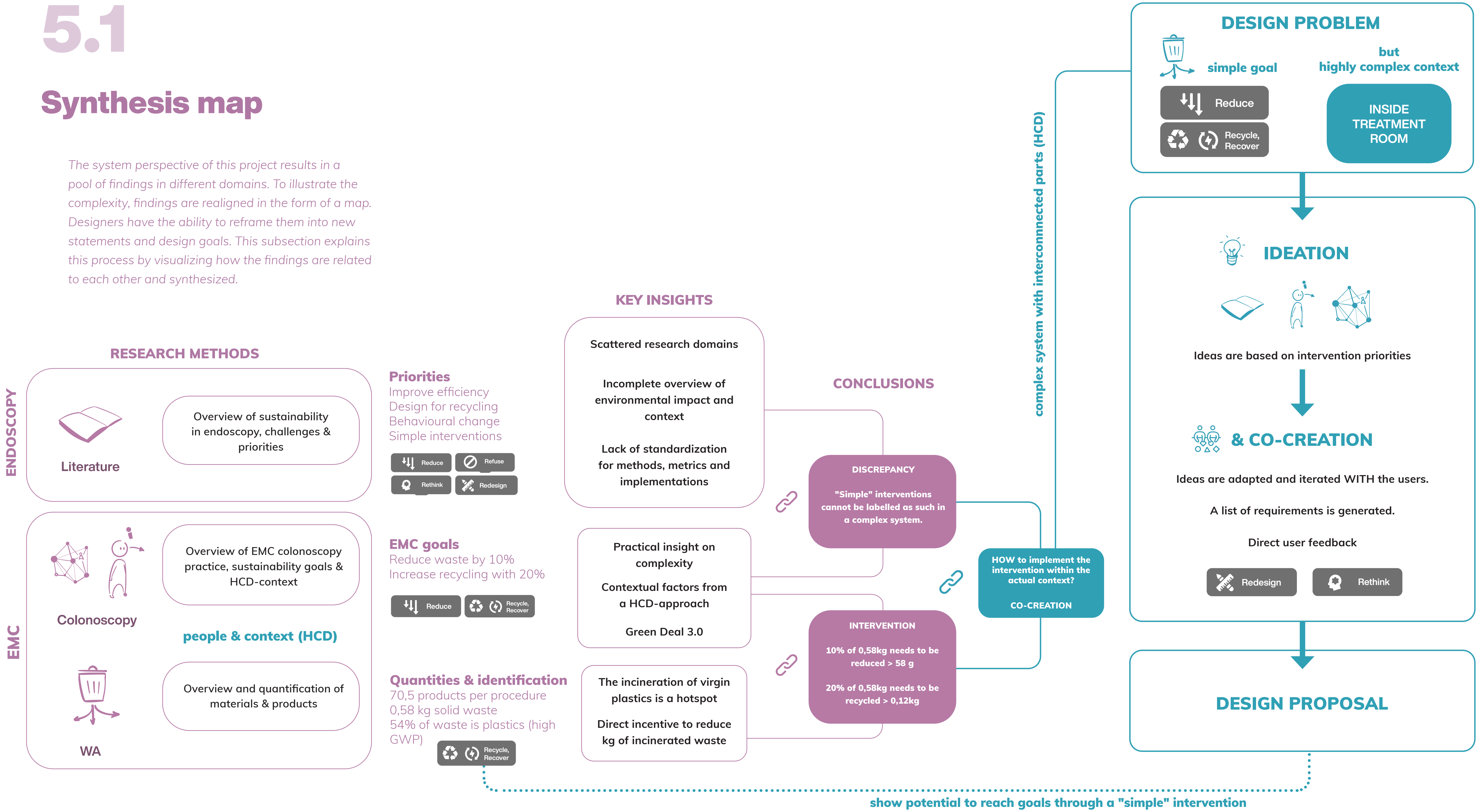
Now that three research directions are completed, the research objectives must be realigned to show their relatedness and to converge the results into a new reframed problem definition. This section provides a summarized overview of the findings, synthesized into a design direction for sustainable interventions.

05

5.1

Synthesis map

The system perspective of this project results in a pool of findings in different domains. To illustrate the complexity, findings are realigned in the form of a map. Designers have the ability to reframe them into new statements and design goals. This subsection explains this process by visualizing how the findings are related to each other and synthesized.



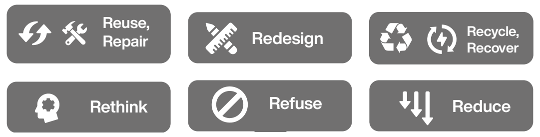
5.2

Synthesis elaboration

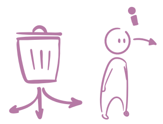
This subsection elaborates on the elements shown in the synthesis map. It is a simplified overview of key findings and conclusions.

Endoscopy & sustainable healthcare context

The Green Deal 3.0 is pushing healthcare facilities to reach environmental targets by 2025, 2030 and 2050. Different strategies for a circular economy (CE) can aid in reaching these goals. For healthcare, the following strategies are prioritized:



By implementing R-strategies, designers can help develop sustainable interventions across multiple system levels. Lower R-strategy 'Recycle' is labelled as a simple to implement strategy.



Waste in EMC context

Endoscopy generates large amounts of waste world wide. For colonoscopies in EMC, the waste generated is 0,58kg of solid GMW per procedure. This number excludes hazardous waste such as sharps and meds and is based on the findings of the waste audit performed inside the treatment rooms. At least 54% of this waste consists of virgin plastics that have a high GWP when incinerated. Its cumulative impact (70,5 products per procedure) is an indicator for a major hotspot. Therefore, Reducing waste and Recycling are prioritized.

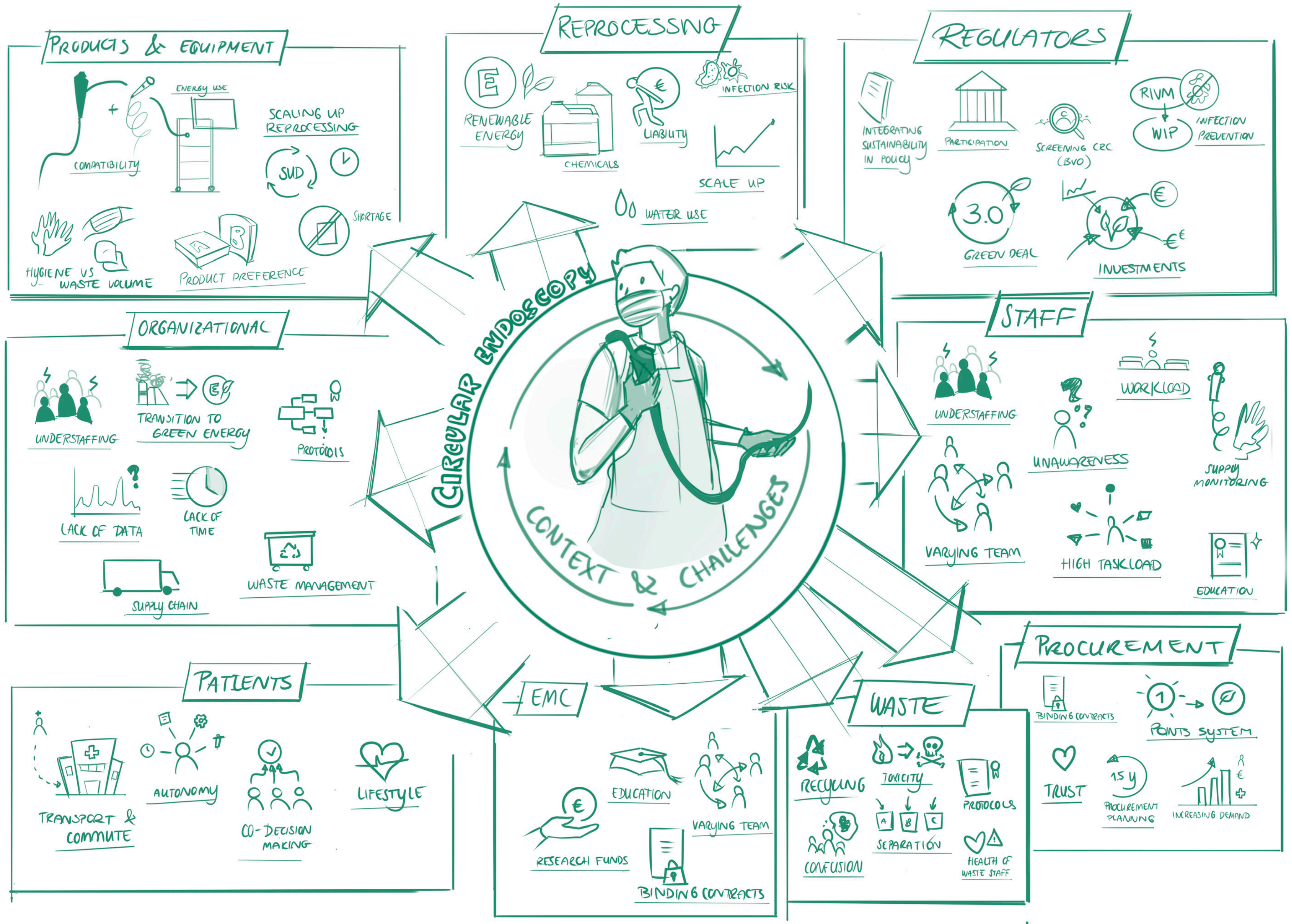


Figure 5.1: Context map of circular endoscopy, summarizing context factors across multiple system levels and stakeholders.

Complexity & actionability

While the goal is simple, the context of endoscopy is highly complex (Figure 5.1). Reducing waste and recycling cannot be "simply" implemented into a complex context such as treatment rooms. Unavoidably, this is the only context where waste segregation for recycling can occur, since it is the only way of identifying infectious and hazardous material from clean and recyclable materials. Consequently, this puts pressure on staff and Green Teams to perform and come up with interventions to meet organizational policy statements of EMC for the sustainability horizons of 2025, 2030 and 2050.

In addition, the optimal conditions for waste recycling are not always facilitated by the organization or are limited by protocols.

The following statements can be made based on drivers and conclusions from all the report sections:

- The lack of awareness in staff is impeding actionable changes that can contribute to reducing the environmental impact of the endoscopy unit in the short-term;
- Additionally, there is a lack of facilitation to implement these short term changes, such as the use of sterile water bottles, the use of alternative materials and the possibility to separate waste correctly;
- Subsequently, a part of the staff perceives the sorting of waste as a hassle while simultaneously feeling pressure from colleagues and higher organisational teams.
- Organisational changes create uncertainty in the staffs waste behaviour, e.g. the changing colour of waste containers, lack of standardization of waste sorting across departments within EMC.
- New recyclable waste streams must be non-infectious or sterilized prior to processing (Personal communication with PreZero, 2024). However, the endoscopy department can make new arrangements with PreZero to specify requirements for the new waste streams.
- Recycling of waste is only a part of the solution, and other R-strategies need to be explored as well.

Reduce

Reduce

To reduce the waste or emissions from waste disposal, the focus is on plastics due to their high GWP and because more than 54% of the waste consists of plastics. To reduce the overall impact, alternative materials with a lower embodiment energy or a lower GWP should be implemented into products.

For medical devices, the Medical Devices Regulation (MDR) as of now does not yet approve the use of recycled, biobased or biodegradable plastics. Additionally, a redesign of a product in alternative materials falls under the category of a new medical device and approval can take up to 18 months, even after an extensive research and design phase (EUROPEAN COMMISSION, 2023). Thus, reducing the use of plastics in the products is unachievable in the short-term and is also not controlled by EMC.

In addition, from section 4 it can be concluded that almost no products end in the waste as unused products.

Therefore, **Reduce** the amount of incinerated material by 10%. This means that 10% of 0,58kg solid GMW should be taken out for recycling or reuse.

Therefore, the most short-term goal is to maximize current potential for recycling of waste.

Maximize recycling potential

By separating infectious from non-infectious materials, new waste flows can be created to increase recycling potential. Since all waste is now discarded as GMW, it is incinerated, and the recycling potential is currently zero. Therefore, infectious and non-infectious waste should be identified.

Recycle

Recycle, Recover

By increasing overall recycling potential and creating new clean waste flows of recyclable plastics, emissions from waste incineration can be reduced, since volume as well as GWP of the waste is reduced. So, if more is recycled, more waste and emissions can be reduced.

Synthesis to waste audit

For the system proposal, the focus is on segregating as much plastic from the GMW as possible.

0,58 kg waste per procedure

of which 54% virgin plastics

10% Reduce | Recycle, Recover 20%

Reduce 58g of incinerated waste

Recycle 0,12 kg of material

Other strategies

While it is ideal to implement R-strategies in uphill activities, such as in the design and manufacturing stage for designing out waste early on in the process, waste cannot be ruled out completely and especially for the short term goals of EMC in 2025 and 2030. Additionally, to implement strategies as reprocessing in the future, waste segregation will still be needed to collect the products separately that are fit for reprocessing. Hence, sensitizing and training staff with **waste segregation for recycling, could already function as a seed for incremental adaptation to the new systems in a CE.**

06

SECTION

OPTIMIZING WASTE SEGREGATION

A SYSTEM PROPOSAL FOR INTEGRATING GMW SEGREGATION IN COLONOSCOPY ROOMS

In the previous section it was argued that reducing the amount of incinerated waste and increasing recycling potential were the priorities for intervention at EMC currently. This section provides a proposal to integrate waste segregation inside colonoscopy rooms. An overview into the design thinking process and outcomes of the co-creation sessions with the Green Team Endoscopy is presented. Relevance for current practice is discussed, as well as for future implementation of R-strategies in a circular healthcare model.

06

6.1

Design approach

DESIGN PROBLEM

simple goal

Reduce

Recycle, Recover

but highly complex context

INSIDE TREATMENT ROOM

Implementation of waste segregation in the colonoscopy treatment Room 2 & Room 3 without jeopardizing the workflow of nurses

DESIGN DRIVERS

behavioural/context

Routinization of intervention

Create an irreversible mindset

Take away hesitation in staff

materials

Separate infectious from non-infectious waste

Create new recyclable flows

Maximize recycling

DESIGN GOAL

Design a system that reduces the amount of incinerated waste, creates new recyclable flows and induces permanent change in the mindset of staff.

REQUIREMENTS

user needs

room layout

regulatory

sustainability

IDEATION

Ideas are based on intervention priorities

& CO-CREATION

Ideas are adapted and iterated WITH the users.

A list of requirements is generated.

Direct user feedback

Redesign

Rethink

DESIGN PROPOSAL

New waste segregation system to maximize recycling potential of current plastic waste

EVALUATION

Viability

Desirability

Feasibility

A brief overview of co-creation

The Triple C model of Khalil & Kynoch (2021) describes barriers and facilitators for the implementation of sustainable complex interventions in healthcare from a behavioural perspective (Appendix C). Staff involvement is paramount to the success and adoption of new interventions (Khalil & Kynoch, 2021). Similarly in design, "involvement of users throughout design and development" is an international standard for human-centered design (HCD).

Therefore, three co-creation sessions were conducted with the Endoscopy Green Team for different goals:

- as a tool for ideation with direct user feedback
- as a means to sensitize staff and spark awareness
- as a means to put forward an accurate list of user needs and requirements

The sessions in short

Session 1 focused on mapping the colonoscopy workflow more accurately, as was depicted in Figure 3.7 in section 3. Through an open discussion it was concluded that colonoscopy workflows allow some space for implementing extra steps for waste segregation. In addition, limitations of the current room layout were identified. Lastly, it became clear that the **nurses relied on the mental model that 'everything in the room is infectious'.**

In Session 2, an ideation on interventions was visualised through ideation sketches (Figure 6.1) and the nurses provided feedback and elaborated on these ideas (Appendix F). At the end of the session, a concluding and more detailed idea for an intervention was established with requirements.

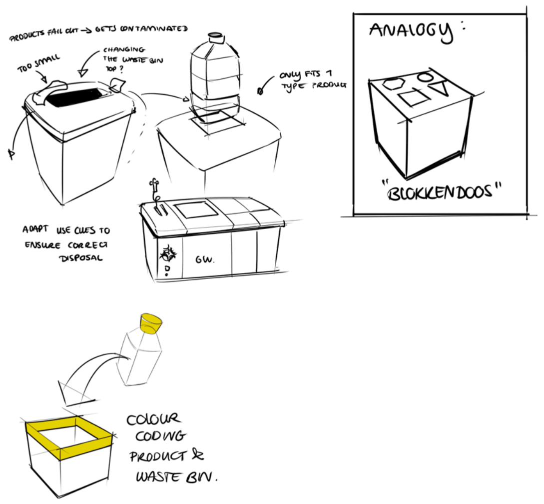


Figure 6.1: Example of ideation sketch presented to the nurses.

In Session 3, lastly the nurses discussed the requirements of how the intervention should be implemented in the room and rearranged the room layout to help illustrate a new workflow, see Figures 6.2 and 6.3. **The focus is specifically for one nurse who assists the colonoscopy.**

Figure 6.2: Endoscopy nurses rearranging equipment and apparatus in treatment room 2.

Figure 6.3: Floor plan used for the co-creation with annotations based on the output.

6.2

Requirements

The requirements of the waste segregation system are divided into different categories, which affect different system levels.

1. User-centered

RQ1.1: Intuitiveness: easy for endoscopy staff to use, ensuring they can quickly and accurately separate different types of medical waste without confusion.

RQ1.2: Accessibility: waste containers should be located according to the workflow of one specific nurse.

RQ1.3: Comfort and safety (ergonomics): minimize physical strain and reduces the risk of injury during waste disposal, i.e. a pedal

RQ1.4: Ease of maintenance and use. This could include features like easily removable and replaceable waste bags or liners, related to RQ

RQ1.5: Clear identification: waste containers are clearly labeled and visually distinct through icons.

RQ1.6: Minimized disruptions: minimize disruptions to medical procedures and patient care activities. e.g. discrete placement

2. Room Layout

RQ2.1: Space Optimization: Design the waste segregation system to fit within the room architecture and fixed equipment.

RQ2.2: Integration in current room layout: Ensure the placement of waste containers without causing congestion of essential areas or doorways.

RQ2.3: Complementary to room aesthetics.

RQ2.4: Emergency preparedness: Incorporate provisions for managing medical waste during emergency situations, i.e. increased waste volume

RQ2.5: Modular system: to facilitate potential changes or upgrades to the waste segregation system in the future.

3. Regulations (safety & hygiene)

RQ3.1: Complies with risk-infection protocols set by the Dutch Infection Prevention Group (WIP).

RQ3.2: Complies with cleaning regulations. The system should be modular to allow deep cleaning and movement accross the room.

4. Sustainability, based on R-strategies of a CE

RQ4.1: Refuse unnecessary additional containers and or material.

RQ4.2: Re-allocate current waste containers in room.

RQ4.3: Recycled Materials: Ensure that materials used in the production of system elements made from recycled content, and are recyclable.

RQ4.5: Minimize the risk of contamination, to ensure clear waste streams

RQ4.6: Reduces volume/weight of the incinerated waste to reduce emissions.

6.3

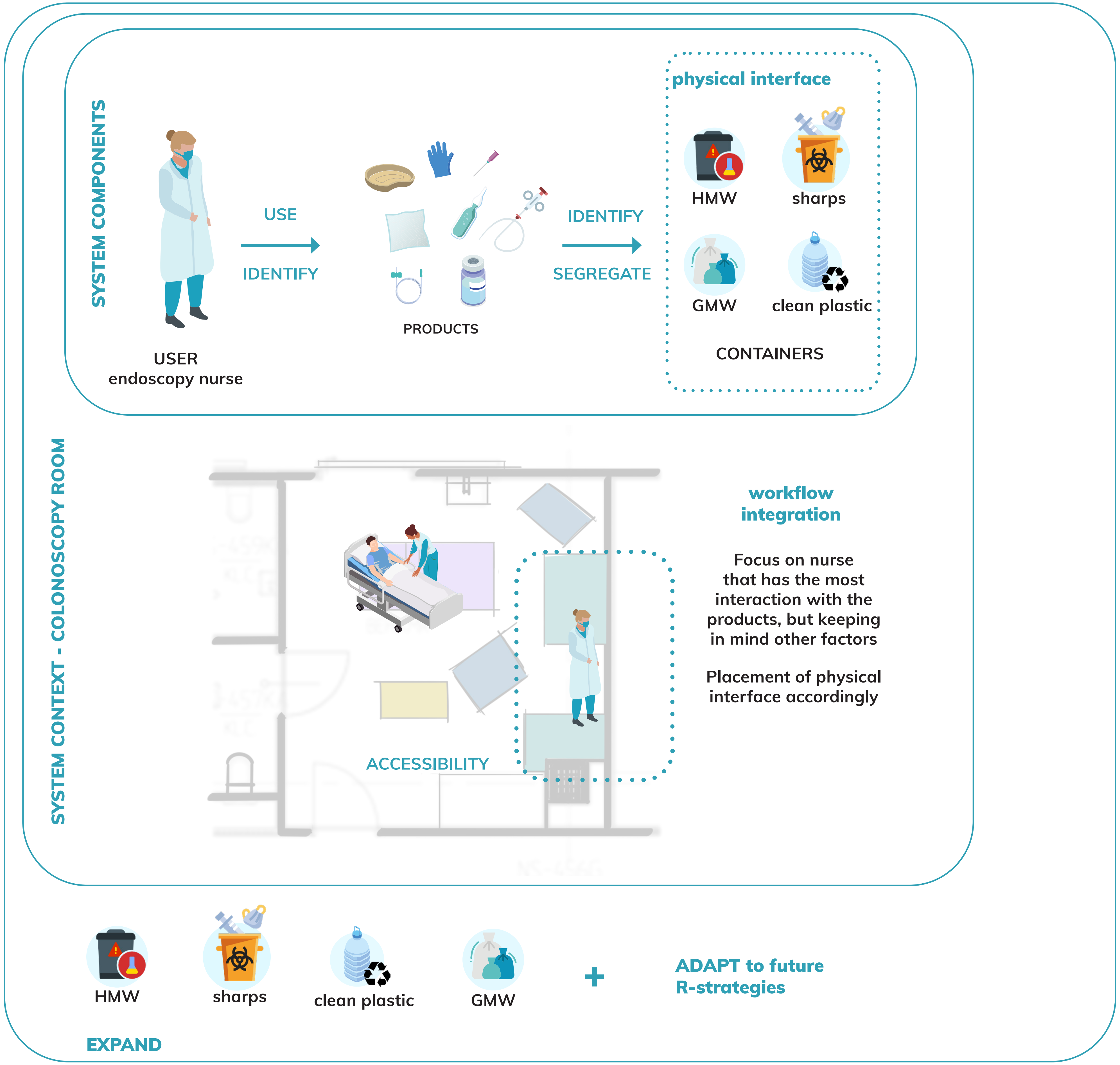
System breakdown & demonstration

The concept system is used as a demonstration for increased waste segregation for GMW in treatment rooms, to create new waste streams for recycling and to reduce the amount of incinerated waste. This subsection shows the elements of the system and each of its carachteristics. This concept is merely a demonstration and it must be noted that it has its limitations.

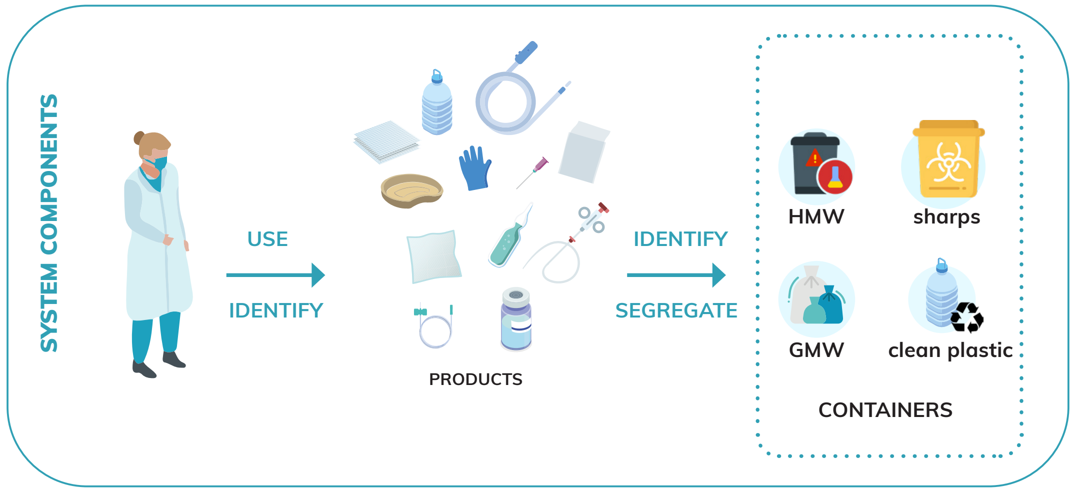
System structure

The system consists of two main parts, the physical interface and the user, and the workflow of the system.

From the co-creation sessions it was decided that the system should focus on the nurse that has the most interaction with products near the two storage cabinets in the room. The largest adjustment is made there because it requires a redesign of the layout.



PHYSICAL INTERFACE



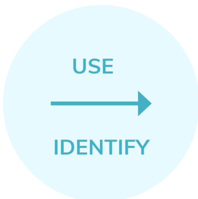
Detailing of identification & segregation

The physical interface consist of user, products and containers. Prior to determining the configuration, two interactions must be highlighted: identification and segregation.

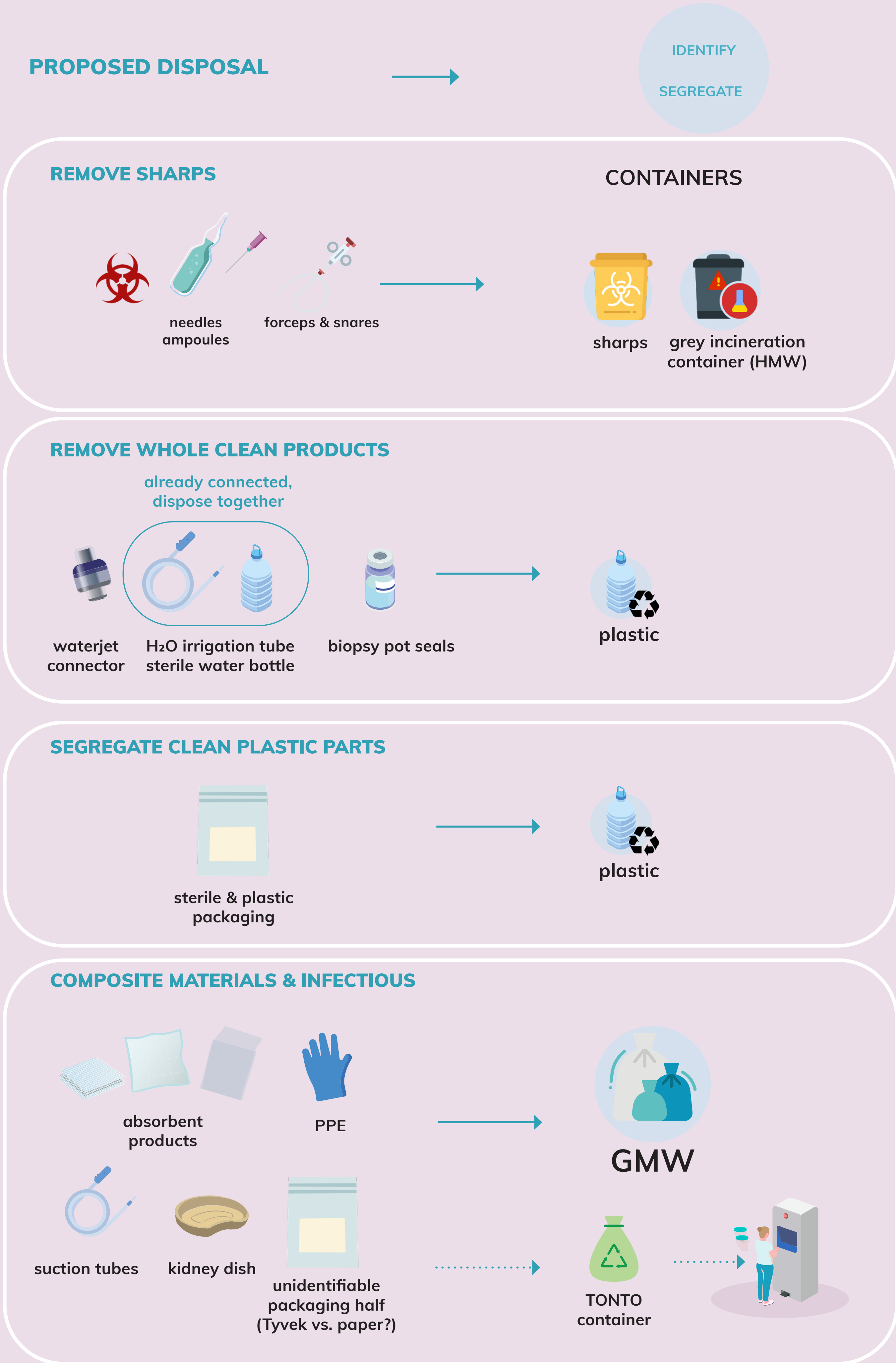
Through co-creation the products which are GMW were divided into infectious and non-infectious.In the grey area are products that are difficult to identify.

Then, a proposed waste segregation with their distinct containers is proposed. Note that the TONTO has been added, as an option. In Appendix H the TONTO instructions are shown, based on that, infectious non-recyclable materials can be disposed of there to reduce the volume of waste transported and incinerated.

PROPOSED PRODUCT IDENTIFICATION



infectious	? grey area	clean
Kidney dish	O_2 tube	Sterile packaing
Needles	Bite block	Cardboard packaging and paper
Syringes	Apron (untouched by patient)	Sterile water bottles
Ampoules		H_2O irrigation tubing
Suction tubing		Waterjet connector
Snares and forceps		Biopsy pot seal
plastics		



CONTAINER DESIGN PROPOSAL

Reduce	Refuse redundant products or unnecessary containers
Refuse	Reuse and reallocate the containers present in the room
Rethink	Reuse and reallocate the containers present in the room

The nurses indicated that they are satisfied with the current design of waste containers in the room. A summarizing visual is presented with user requirements and existing design aspects of the current containers (Appendix I). From a sustainability perspective, there is no need for a new type of container, however for proper waste segregation, a clear indication on the lid must be provided to avoid confusion in disposal in the form of icons (Figure 6..

Nurses also indicated a preference for clear, written and visual instructions but no color coding, since this was perceived as confusing since there are already many different colors. This should be further explored.

Sink container

As seen in section 3 and 4, the container by the sink is hardly used and as a result, the waste bag remains mostly empty. Therefore this container is re-allocated as recycling plastics container.

Added TONTO container

To minimize waste volume, for example PPE or absorbent products can be discarded separate from forceps (metal) and discarded in the container. In the Reinier de Graaf Gasthuis (RDGG), biodegradable bags are used for collecting TONTO-destined waste; this further reduces impact and emissions.

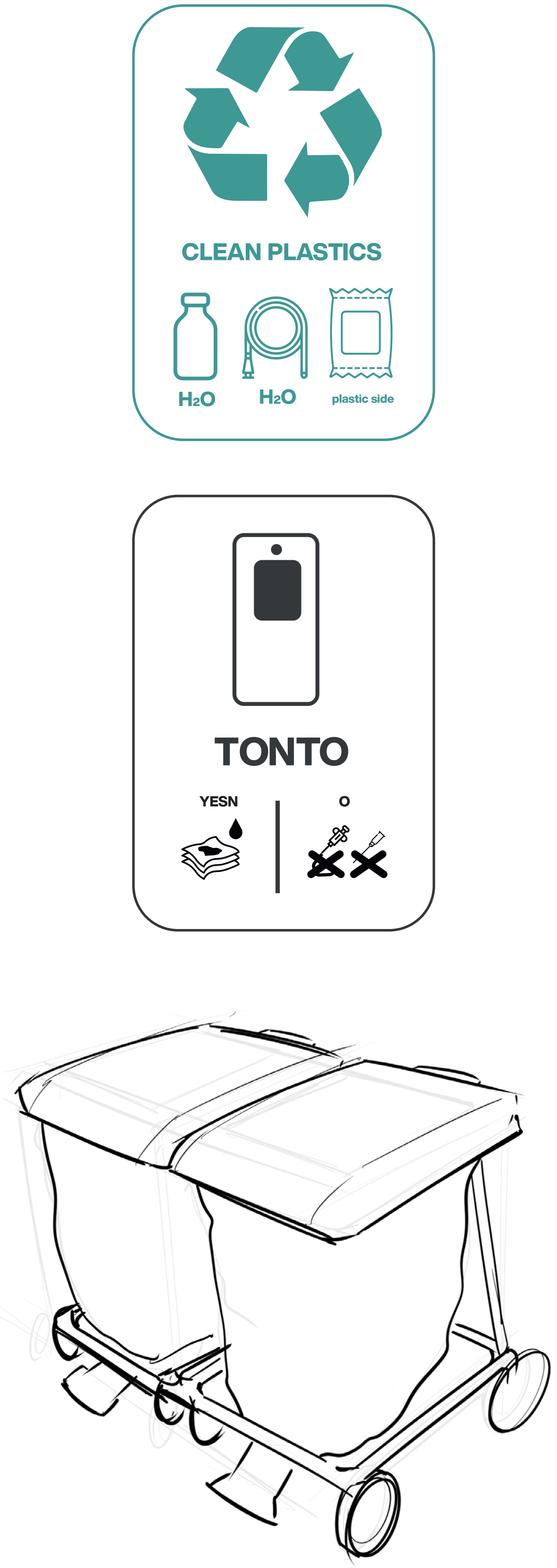
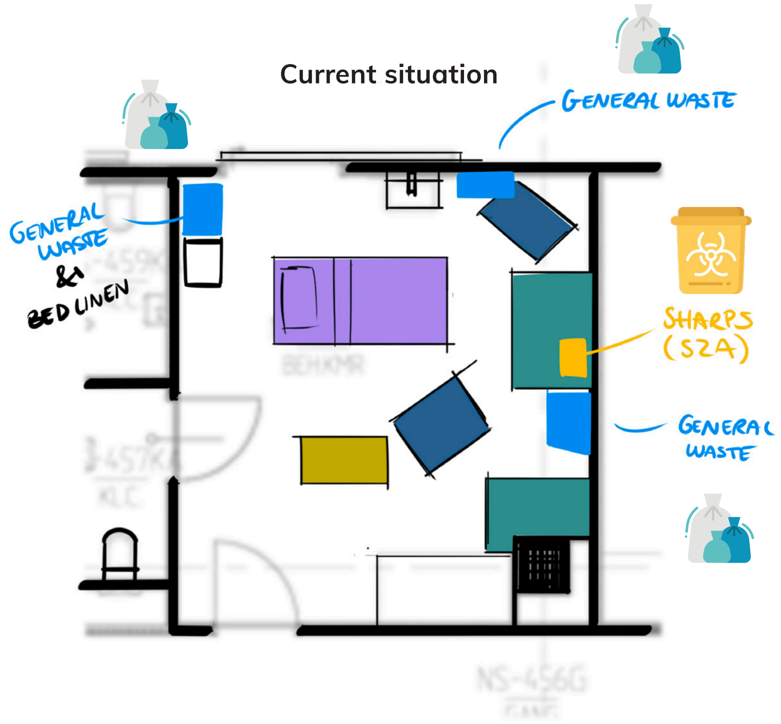


Figure 6.4: Labelling waste containers for clarity

INTEGRATION



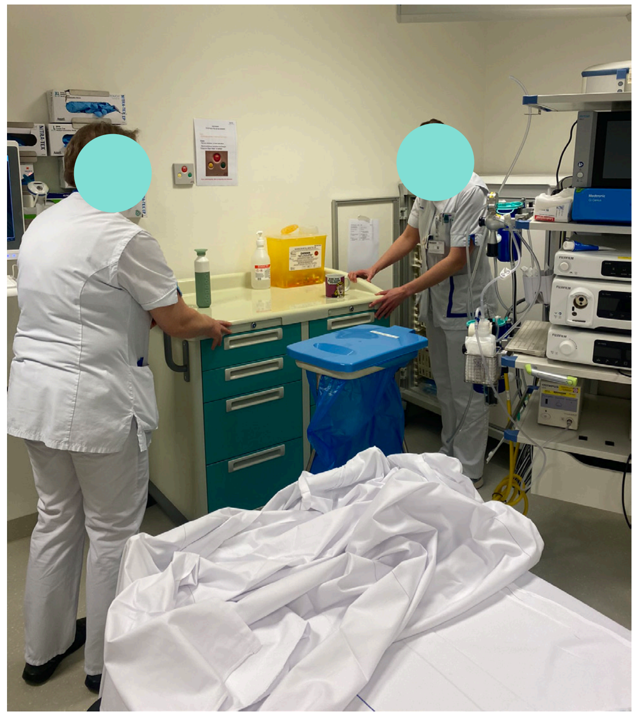
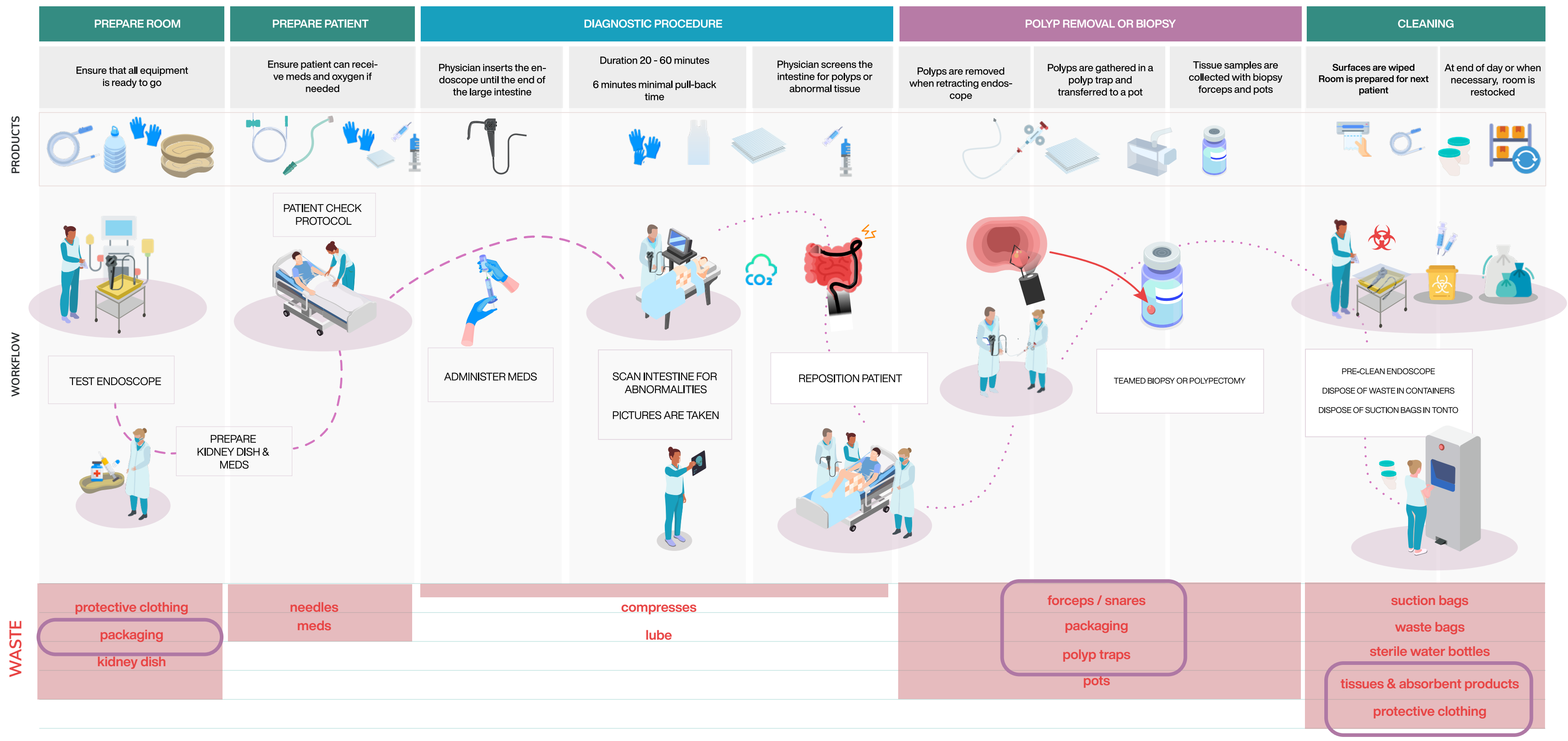


Figure 6. :Nurses deciding on a new layout during a co-creation session.

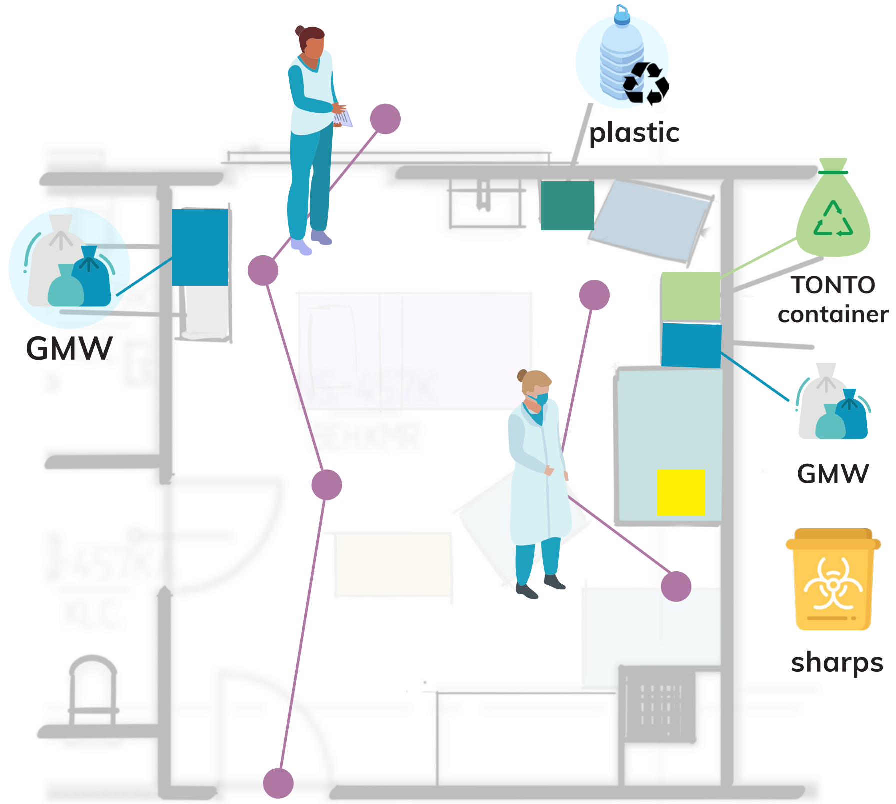
CONTAINER PLACEMENT PROPOSAL

By removing the single GMW container between the storage units, the medical supply cart can be moved slightly to the right, creating better accessibility to the sterile supply storage. Then, the foating hub of anaesthetic equipment can be moved more into the corner, creating speace between the equipment and the medical supply cart for containers.

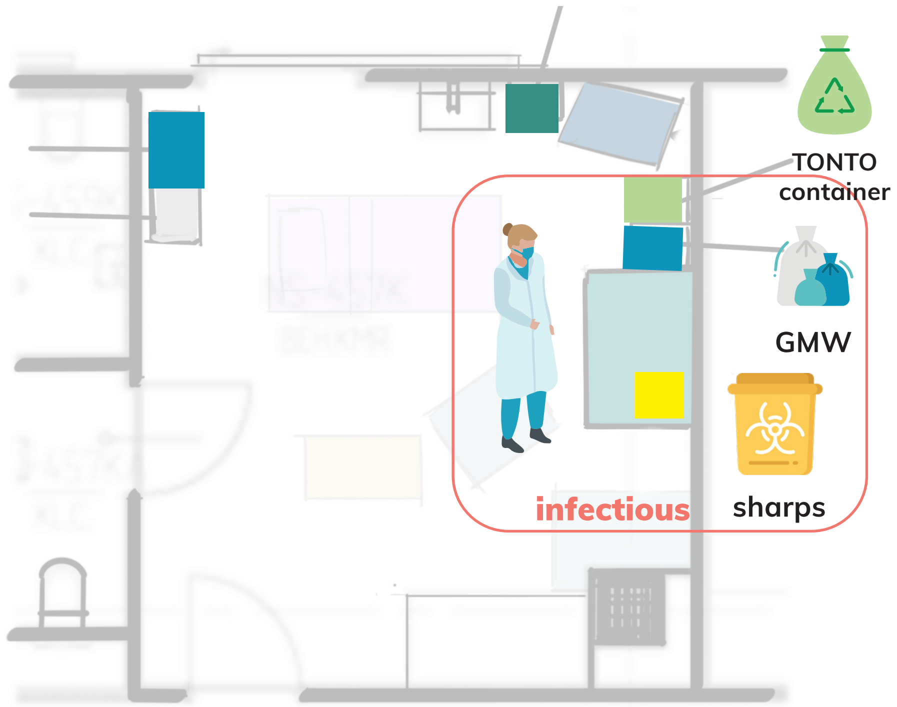
To match the nurses' workflow, the location of the containers was matched to the position of the nurse in a certain phase, also as an output of the co-creation sessions.



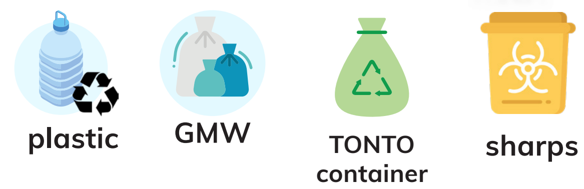
Removing packaging



Infectious waste, packaging of forceps and snares, people entering and leaving rooom > disposal of PPE



Cleaning: disposing of PPE and absorbent products, clean and infectious tubing, and sharps.



6.4

Evaluation & Validation

In this subsection the system design is validated by its desirability, feasibility and viability. Then, an estimate is made to assess the impact that this system could have and how it relates to the EMC sustainability statements. A final evaluation of the concept is done to assess if the design goal and all requirements have been met.

DESIGN GOAL

Design a system that reduces the amount of incinerated waste, creates new recyclable flows and induces permanent change in the mindset of staff.

REQUIREMENTS

user needs

room layout

regulatory

sustainability

Desirability

Implementing a waste segregation system in the endoscopy treatment room presents an opportunity to enhance waste management in EMC and align with sustainability goals.

Implementing a system which can be gradually expanded over time with small but incremental steps, reduces the pressure that comes with sudden radical change, addressing a key user need. With the foresight of the implementation of new products in the system and a circular model where materials of these products have to be kept in the loop, the endoscopy nurses will be equipped and trained to accomodate these changes, and maintain sustainable practices.

It can also increase overall awareness around waste disposal and train new morale around sustainable practices. Having a system with a clear protocol addresses the discrepancies in intrinsic motivation among staff. The endoscopy unit can cultivate a culture of environmental responsibility and contribute to long-term sustainability goals, while setting an example for other departments.

The EMC has a unique role as an academic and teaching hospital to set new standards of extensive waste segregation that align with the policy statements for sustainability in 2025, 2030 and 2050. Testing this intervention of waste segregation is necessary but can inspire other healthcare facilities to rethink existing practice.

Viability

The main goal of waste segregation is to pursue and achieve the Green Deal targets and therefore, the economic aspect of the intervention has not yet been discussed.

However, the cost of medical waste incineration per kg is generally higher than the recycling of medical waste (de Melo et al., 2021), and reducing the amount of incinerated waste can have many financial benefits. By reducing the volume of the GMW to be incinerated, in theory transportation costs could also be reduced, but the system needs to be tested and waste requantified to make hard statements about cost savings.

Feasibility

Waste segregation in the endoscopy unit already occurs for several waste streams (Appendix D). The system just presents an extension to already existing practice, but also in a manner that is better integrated in the workflow therefore can tackle the waste generated during procedures.

For colonoscopy procedures, waste segregation is possible due to the predicatabilty of the workflow, and because certain types of waste are created in different stages in the workflow. Implementing waste segregation not only creates more variety in recyclable materials, but increases awareness in staff.

Creating new waste streams is feasible in accordance with PreZero, as is demonstrated by other departments such as the operating theatre (OT). Plastics from the OT can be collected together and recycled (Appendix G). Similar pilots have been emerging in the EMC's radiology department, as well as in the ophthalmology (optic care) department in Utrecht UMC (Van Leeuwen, 2021).

That being said, microbiology analyses have to be conducted to scientifically assess the cleanliness of the new waste streams and of products that fall under the category in order to ensure that both healthcare workers and waste workers are not at increased risk of infection. Therefore, the intervention does not yet comply with the regulation of the WIP.

Impact assessment

- Increase recycling with 0,12kg (20%)
- Reducing waste with 58g (10%)

Properly disposing of sterile water bottles (80g) and H_2O tubing (55g) accounts for 135 g of plastics. The plastics part of packaging is at least 50% of the average weight of packaging in the waste audit (0,162kg), which translates to another 80g of plastic. Summing up the targeted products, they account for 225g or 0,215kg of plastics removed from the GMW, which is 40%.

TONTO can reduce the waste volume by 90%. This does not eliminate plastic materials from incineration, but definitely has the potential to reduce the emissions from transport to the incineration facility. TONTO can reduce the volume of absorbent products, which account for more than 18% of waste. If absorbent products were completely removed from the GMW and re-allocated to the TONTO, a reduction of waste volume of approximately 16% could be made, in addition to the 40% in plastics.

This combination suggests that the waste management goals can be reached. Will this intervention reduce emissions by 55% in 2030? There is insufficient information or data generation from this ideal intervention to relate it to this statement. The above is only an estimate and therefore, it should be accurately measured to present feedback to the staff for motivation.

The impact of this intervention should be further investigated in the long term, when there has been time to routinize the system. Only then can there be a reliable LCA on the recyclable flows and their overall impact to carbon emissions.

Presenting this feedback to staff can have a positive impact on their efforts and through co-creation, the system can be improved or optimized.

07

SECTION

PROJECT EVALUATION

CONCLUSIONS, RECOMMENDATIONS & REFLECTION

This last section of the report evaluates the findings and provides recommendations for further research in sustainable GI endoscopy practice. It is the concluding section of the report.

07

7.1

Summary & discussion

Project

This project was set up in pursuance of identifying opportunities for sustainable interventions in colonoscopy procedures for the EMC gastroenterology department.

Literature and emipirical research was done to understand the context from a human-centered perspective. For the identification of products and materials wasted, a waste audit was performed, keeping the HCD-approach in mind.

An explorative waste mapping study was done in EMC's gastroenterology department aiming to identify hotspots and opportunities for sustainable interventions based on different R-strategies for a CE. This was done to find an intervention aligning to their policy statements for sustainability: reduce waste with 10% and increase recycling with 20% in 2025, reduce emissions with 55% in 2030, and become a climate neutral hospital in 2050. Currently there is no waste segregation inside treatment rooms other than hazardous waste and GMW, which complicates reaching these goals.

The waste audit and context research provided a holistic overview of context factors that facilitate or challenge the implementation of R-strategies in the form of interventions.

The waste audit also provided a quantification of the products used for a single colonoscopy procedure, to illustrate the wastefulness of current practice and to sensitize staff through the visualisation of this data.

Subsequently, a material identification from the waste indicated that the extensive use of plastics across all product categories is a hotspot because of the high GWP of plastics when incinerated. Therefore, results were synthesized to formulate an intervention for reducing the volume of incinerated plastic waste and simultaneously increase recycling of current GMW. The proposal encompassed waste segregation in colonoscopy treatment rooms which was ideated in co-creation with the staff to fit the current workflow of nurses.

While it is ideal to implement higher R-strategies for designing out waste early on in the process, waste cannot be ruled out completely. Therefore, Implementing a waste segregation system in the endoscopy treatment room presents an opportunity to enhance waste management in EMC and align with sustainability goals. The proposal is a demonstration how small incremental changes within the current system boundaries can help achieve the goals of reducing waste and increase recycling.

With the foresight of the implementation of new products in the system and a circular model where materials of these products have to be kept in the loop, the endoscopy nurses will be equipped and trained to accomodate these changes, and maintain sustainable practices.

Discussion

VALUE

The value of this project is expressed through the mapping of current endoscopy practice, as was prioritized in the literature to initiate the decarbonization of healthcare strategies. Not only the outcomes, but the documentation of the methods used can plant a seed for upcoming interdisciplinary research between healthcare professionals and designers.

In addition, the sensitization of staff surrounding waste disposal was achieved through the visualisation of waste data in department meetings, as well as through direct collaboration. It shows the effectiveness of a human-centered approach in tackling the complexity of changing the system of a medical specialty like gastroenterology.

LIMITATIONS

Several limitations are inherent to the explorative nature of this study. In the waste audit, no scientific testing methods for identificaiton of the plastics were done, meaning that even if the weight percentages could be reduced from the GMW, it is no guarantee that all these plastics could fully be recycled within the proposed waste segregation system.

The waste segregation system needs additional microbial research in order to formulate new protocols that can catalyse the routinization of waste segregation. As of now, there is no way in actually knowing if the presumably clean products can cause safety problems in the reycling process. Moreover, microbial studies can also indicate other products that might now be labelled as infectious, when in fact they are not. This also presents new opportunities for increasing the recycling percentage.

7.2

Recommendations

How can this graduation project be elaborated into other research topics and improvements by EMC?

- **Perform microbial studies for differentiating non-infectious products in the current GMW stream.** By identifying which clean products become infectious by contamination with other products, waste segregation can be adapted.
- **Perform LCAs on the EMC's specific colonosocpy products** that are currently being discarded, in order to assess the true impact within the Dutch healthcare context.
- **Get in contact with the head of the Zero Waste project at PreZero** to adapt waste protocols in the endoscopy department and use the waste segregation proposal as an input.
- **Assess waste segregation viability to relate costs of the current system**.
- **Reinforce the Endoscopy Green Team with multidisciplinary actors**. The green team currently consists of a few individuals who are eager to make their workplace more sustainable. However, sustainability goals will be difficult to reach if it is only addressed as a second priority to clinical practices.
- **Invest in research in higher circular strategies, while optimizing the waste segregation inside the treatment rooms simultaneously.** One of the main takeaways of this research is that in highly complex systems, one approach is less effective than multiple. Small cumulative changes will have larger impacts.

7.3

Project reflection

This project was driven by a clear purpose, be it from the Green Deal push or intrinsic felt urgency among healthcare professionals: to create irreversible change in the transition into climate neutral healthcare (Green Deals, n.d.).

Healthcare is a complex system made out of smaller complex systems. Through this project it became clear that its complexity is often undermined, and that applying CE principles and strategies that work in other industries are almost impossible to implement because of the many regulations and focus on patient safety regarding infection risk. Not only the risk of infection, but also product liability create a downwards spiral in what should be a transition to sustainable products and services. Even with the knowledge that a disposable endoscope has up to 47 more CO_2 emissions than a reusable endoscope, from an infection risk and safety perspective, the disposable endoscope would be preferred.

The focus on a single colonoscopy procedure was already a complex system in itself, and therefore even smaller steps of the care pathway have to be analysed to start to piece together a holistic yet detailed overview of endoscopy practice.

This margin of infection risk is taken very far and even "potentially" infectious materials are incinerated. The rigor of these regulations are ingrained in the mental models of healthcare staff, resulting in everything being perceived as perceived infectious, dangerous or unfeasible because of regulations. However, with the foresight of increased healthcare costs and material scarcity, not only is it a more viable model to retain a product's value with CE strategies, but is an indispensable thing. There simply are not enough resources for healthcare systems to sustain the current model. Therefore, financial support should also be prioritized in research areas that allow for regulations to change. Complex systems are dynamic, and hence, regulations should become increasingly dynamic too.

There is a flipside. Through this project, the intrinsic motivation and eagerness for sustainable change are felt, but the problem seems to large for an individual to tackle.

The latter also calls for increased multidisciplinary cooperation. Designers can play a pivotal role in connecting the disciplines.

7.4

Personal reflection

My graduation project in endoscopy has been a final mirror that has reflected to me my capabilities as a designer. Working in a context with highly different mentalities and boundaries has made me realize the role that I can take on as a graduated design engineer in my future career to value the differences between different disciplines.

I have always taken interest in designing for complex systems and from a HCD-approach, but never in the immersive manner that this graduation project has provided me. This also led me into losing my way into little details and snowballing into more bits and pieces of a giant system. At times, I felt I was not doing a design graduation.

A key teaching moment for me was working alongside healthcare professionals in a hierarchy, which required different approaches and societal values. But also, the appreciation of the endoscopy staff of the storytelling that I could do through the visualisation of the waste and workflow.

At times I felt quite lost because of the vastness of the project, and this is my second key learning point: make the goal even more specific.

Because I had such a rich pool of context, synthesizing the findings was by far the hardest challenge of my graduation. Therefore, I felt frustrated not having the time that I planned for the creative phase in my project. However, the outcome has proved to be a necessary measure and I am happy that I could aid the Green Team in one important step towards a more sustainable endoscopy unit.

One thing that surprised me during the project is that it opened my eyes to my own behaviour and how I perceived waste and sustainability. It resonated with me that even being immersed in the context, there is always an improvement to be made in awareness. Since this was a direct project goal, I felt the value of simply being aware of your actions. Therefore, I am confident that this project and future projects of fellow graduation students and researchers, will spark the necessary change.

Through this graduation, I have gained specific insights for my career goals and the way I love to be in between disciplines as a designer.

REFERENCES

Achterberg, E., Hinfelaar, J., & Bocken, N. (2016, September). Master Circular Business with the Value Hill - Circle Economy. Circle Economy Foundation. https://www.circle-economy.com/news/master-circular-business-with-the-value-hill

ActiZ. (n.d.). Hoe staat het met: de Green Deal Duurzame Zorg? https://www.actiz.nl/hoe-staat-het-met-de-green-deal-duurzame-zorg

Adrz. (2023, November 6). Adrz - (Endel)darmkanker zorgpad. https://www.adrz.nl/onderzoeken-behandelingen/endeldarmkanker-zorgpad/

Agarwal, S., Gudi, R. D., & Saxena, P. (2022). Image classification approaches for segregation of plastic waste based on resin identification code. Transactions of the Indian National Academy of Engineering, 7(3), 739–751. https://doi.org/10.1007/s41403-022-00324-4

Anderson, J. C. (2020). Use of total underwater colonoscopy to navigate endoscopic challenges. Clinical Gastroenterology and Hepatology, 18(7), 1427–1430. https://doi.org/10.1016/j.cgh.2020.02.042

Arrotek. (n.d.). Bottlenecks, timelines, and complexity: Overcoming EU MDR Challenges | Arrotek. https://arrotek.com/bottlenecks-timelines-and-complexity-overcoming-eu-mdr-challenges/#:~:text=Challenge%203%3A%20The%20Length%20of,approaching%20deadline%20for%20MDR%20compliance.

Baca, E., Batra, N., Johnson, M. J., Sekhon, J., & Gerhardt, W. (2023, January 31). Why climate resilience is key to building the health care organization of the future. Deloitte Insights. https://www2.deloitte.com/uk/en/insights/industry/health-care/climate-change-and-health.html

Baddeley, R., Aabakken, L., Veitch, A., & Hayee, B. (2022). Green endoscopy: Counting the carbon cost of our practice. Gastroenterology, 162(6), 1556–1560. https://doi.org/10.1053/j.gastro.2022.01.057

Barlow, D. E. (2015, February 13). How endoscopes work. Clinical Gate. https://clinicalgate.com/how-endoscopes-work/

Beilenhoff, U., Biering, H., Blum, R., Brljak, J., Cimbro, M., Dumonceau, J., Hassan, C., Jung, M., Neumann, C., Pietsch, M., Pineau, L., Ponchon, T., Rejchrt, S., Rey, J., Schmidt, V., Tillett, J., & Van Hooft, J. E. (2017). Prevention of multidrug-resistant infections from contaminated duodenoscopes: Position Statement of the European Society of Gastrointestinal Endoscopy (ESGE) and European Society of Gastroenterology Nurses and Associates (ESGENA). Endoscopy, 49(11), 1098–1106. https://doi.org/10.1055/s-0043-120523

Benedettini, O. (2022). Green Servitization in the Single-Use Medical Device Industry: How Device OEMs Create Supply Chain Circularity through Reprocessing. Sustainability, 14(19), 12670. https://doi.org/10.3390/su141912670

Bevolkingsonderzoek Nederland. (2022). PROTOCOL Voor de toelating en auditing van coloscopiecentra en endoscopisten. https://www.bevolkingsonderzoeknederland.nl/media/1tdbjikr/protocol-toelating-en-auditing-cc-versie-110.pdf

Billerud. (2020). Paper choice for medical device packaging – 5 key factors to consider. https://www.billerud.com/served-industries/medical-hygiene/medical-packaging-blog/paper-choice-for-medical-device-packaging-5-key-factors-to-consider

Bretthauer, M., Hoff, G., Thiis-Evensen, E., Huppertz-Hauss, G., & Skovlund, E. (2003). Air and carbon dioxide volumes insufflated during colonoscopy. Gastrointestinal Endoscopy, 58(2), 203–206. https://doi.org/10.1067/mge.2003.340

Campbell-Lendrum, D., Neville, T., Schweizer, C., & Neira, M. (2023). Climate change and health: three grand challenges. Nature Medicine, 29(7), 1631–1638. https://doi.org/10.1038/s41591-023-02438-w

Cancer Council. (n.d.). What is a polyp? https://www.cancer.org.au/polyps

Cancer Council Australia. (2021). Cancer information and support. In Cancer Council Australia. https://www.cancer.org.au/health-professionals/optimal-cancer-care-pathways

Centraal Bureau voor de Statistiek [CBS]. (2018, April 6). Meer mensen laten ontlasting onderzoeken. Centraal Bureau Voor De Statistiek. https://www.cbs.nl/nl-nl/nieuws/2018/14/meer-mensen-laten-ontlasting-onderzoeken#:~:text=Colonoscopie,colonoscopie%20te%20hebben%20laten%20uitvoeren.

Centraal Bureau voor Statistiek [CBS]. (2009, August 13). Most people in the Netherlands live within 5 km from a hospital facility. Statistics Netherlands. https://www.cbs.nl/en-gb/news/2009/33/most-people-in-the-netherlands-live-within-5-km-from-a-hospital-facility

Choo, A. S., Narayanan, S., Srinivasan, R., & Sarkar, S. (2021). Introducing goods innovation, service innovation, or both? Investigating the tension in managing innovation revenue streams for manufacturing and service firms. Journal of Operations Management, 67(6), 704–728. https://doi.org/10.1002/joom.1136

Climate Change and Health. (2015, June 10). Operational framework for building climate resilient health systems (World Health Organization, Ed.). https://www.who.int/publications/i/item/9789241565073

Clough, J., Donnelly, L., Leddin, D., & Hayee, B. (2022). FGTwitter debate: green gastroenterology – are we nearly there yet? Frontline Gastroenterology, 14(2), 158–161. https://doi.org/10.1136/flgastro-2022-102301

Collins, J. V. (2021). Optimizing the decontamination and reprocessing of endoscopic equipment. Techniques and Innovations in Gastrointestinal Endoscopy, 23(4), 363–370. https://doi.org/10.1016/j.tige.2021.08.002

Cooperatie VGZ. (n.d.). Shared Decision Making: Samen beslissen over zorg. https://www.cooperatievgz.nl/cooperatie-vgz/over-ons/dossiers/shared-decision-making

Debnath, M., Sarder, R., Pal, L., & Hubbe, M. A. (2022). Molded pulp products for sustainable packaging: Production rate challenges and product opportunities. Bioresources, 17(2), 3810–3870. https://doi.org/10.15376/biores.17.2.debnath

Delivering the European Green Deal. (2021, July 14). European Commission. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_en

Dobson, M. (2024, February 16). Recycling codes and resin identification symbols (+free downloads). GWP Group. https://www.gwp.co.uk/guides/recycling-codes/

Donnelly, L. (2022). Green endoscopy: practical implementation. Frontline Gastroenterology, 13(e1), e7–e12. https://doi.org/10.1136/flgastro-2022-102116

DuPont. (2018). Tyvek® vs. Medical-Grade Papers. https://www.dupont.mx/news/tyvek-vs-medical-grade-papers.html#:~:text=Tyvek%C2%AE%20consistently%20outperforms%20medical,moisture%20resistance%20and%20particle%20generation.

Ellen McArthur Foundation. (2022, May 23). The technical cycle of the butterfly diagram. https://www.ellenmacarthurfoundation.org/articles/the-technical-cycle-of-the-butterfly-diagram

Erasmus MC. (n.d.). Darmkanker - Aandoening - Erasmus MC. https://www.erasmusmc.nl/nl-nl/kankerinstituut/patientenzorg/aandoeningen/darmkanker#89a702c8-c15a-4152-82fa-06dadd98b772

EUROPEAN COMMISSION. (2023). Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Regulations (EU) 2017/745 and (EU) 2017/746 as regards the transitional provisions for certain medical devices and in vitro diagnostic medical devices (Text with EEA relevance). https://health.ec.europa.eu/system/files/2023-01/mdr_proposal.pdf

FMH Medical. (n.d.). TRAINING FLEXIBELE ENDOSCOPIE [Slide show]. PE-online. https://www.pe-online.org/download.aspx?FileName=8409865_Training%20Flexibele%20Endoscopie%20accreditatie.pdf&FileKey=642b436b6379614346664f6447394e6d7555342b4e7163586e5364744d6e7157316a6e655269724e5038303d

Green Deal Duurzame Zorg. (n.d.). Green Deal Duurzame Zorg. https://www.greendealduurzamezorg.nl/

Green Deal Samen werken aan duurzame zorg (Green Deal 3.0) | Greendeals. (n.d.). https://www.greendeals.nl/green-deals/green-deal-samen-werken-aan-duurzame-zorg-green-deal-30

Green Deals. (n.d.). C-238 Green Deal: Working together towards sustainable healthcare. https://www.greendeals.nl/sites/default/files/2023-01/C-238%20Green%20Deal%20Working%20together%20towards%20sutainable%20healthcare.pdf

Harding, C., Van Loon, J., Moons, I., De Win, G., & Du Bois, E. (2021). Design opportunities to reduce waste in operating rooms. Sustainability, 13(4), 2207. https://doi.org/10.3390/su13042207

Health Care Without Harm & Arup. (2019). Health Care's Climate Footprint: how the health sector contributes to the global climate crisis and opportunities for action: Vol. Green Paper Number 1 (Climate-smart health care series). https://noharm-global.org/documents/health-care-climate-footprint-report

Henniger, D., Lux, T. J., Windsheimer, M., Brand, M., Weich, A., Kudlich, T., Schöttker, K., Hann, A., & Meining, A. (2023). Reducing scope 3 carbon emissions in gastrointestinal endoscopy: results of the prospective study of the 'Green Endoscopy Project Würzburg.' Gut, gutjnl-331024. https://doi.org/10.1136/gutjnl-2023-331024

Henniger, D., Windsheimer, M., Beck, H. C., Brand, M., Lux, T. J., Hann, A., & Meining, A. (2023). Assessment of the yearly carbon emission of a gastrointestinal endoscopy unit. Gut, 72(10), 1816–1818. https://doi.org/10.1136/gutjnl-2023-329940

Holtrop, J. S., Scherer, L. D., Matlock, D. D., Glasgow, R. E., & Green, L. A. (2021). The importance of mental models in implementation science. Frontiers in Public Health, 9. https://doi.org/10.3389/fpubh.2021.680316

Hunfeld, N., Diehl, J. C., Timmermann, M., Van Exter, P., Bouwens, J., Browne-Wilkinson, S., De Planque, C. A., & Gommers, D. (2022). Circular material flow in the intensive care unit—environmental effects and identification of hotspots. Intensive Care Medicine, 49(1), 65–74. https://doi.org/10.1007/s00134-022-06940-6

Ilić, M., & Ilić, I. (2022). Epidemiology of stomach cancer. World Journal of Gastroenterology, 28(12), 1187–1203. https://doi.org/10.3748/wjg.v28.i12.1187

Interaction Design Foundation - IxDF. (2021, June). What is Human-Centered Design (HCD)? https://www.interaction-design.org/literature/topics/human-centered-design

Johner Institut. (2022, May 25). Medical Device Regulation MDR. https://www.johner-institute.com/articles/regulatory-affairs/medical-device-regulation/

Kane, G., Bakker, C., & Balkenende, A. (2018). Towards design strategies for circular medical products. Resources, Conservation and Recycling, 135, 38–47. https://doi.org/10.1016/j.resconrec.2017.07.030

Kaplan, S., Sadler, B. L., Little, K. J., Franz, C., & Orris, P. (2012). Can sustainable hospitals help bend the health care cost curve? PubMed, 29, 1–14. https://pubmed.ncbi.nlm.nih.gov/23214181

Khalil, H., & Kynoch, K. (2021). Implementation of sustainable complex interventions in health care services: the triple C model. BMC Health Services Research, 21(1). https://doi.org/10.1186/s12913-021-06115-x

Kohli, D. R., & Baillie, J. (2019). How endoscopes work. In Elsevier eBooks (pp. 24-31.e2). https://doi.org/10.1016/b978-0-323-41509-5.00003-7

Kwakye, G., Pronovost, P. J., & Makary, M. A. (2010). Commentary: A call to go green in health care by reprocessing medical equipment. Academic Medicine, 85(3), 398–400. https://doi.org/10.1097/acm.0b013e3181cd5a71

Lee, B., Ellenbecker, M. J., & Moure-Eraso, R. (2002). Analyses of the recycling potential of medical plastic wastes. Waste Management, 22(5), 461–470. https://doi.org/10.1016/s0956-053x(02)00006-5

Lee, D. S., Kim, J. W., Lee, K. L., Kim, B. G., Kim, S. H., & Byeon, J. S. (2020). Technical feasibility of a newly designed bendable forceps for difficult endoscopic tissue samplings (with video). Surgical Endoscopy and Other Interventional Techniques, 34(10), 4692–4701. https://doi.org/10.1007/s00464-020-07784-1

López-Muñoz, P., Martín-Cabezuelo, R., Lorenzo-Zúñiga, V., Vilariño-Feltrer, G., Tort-Ausina, I., Vidaurre, A., & Pons, V. (2023). Life cycle assessment of routinely used endoscopic instruments and simple intervention to reduce our environmental impact. Gut, 72(9), 1692–1697. https://doi.org/10.1136/gutjnl-2023-329544

Maag Lever Darm Stichting. (2023a). Spijsverteringsziekten derde oorzaak van alle ziekenhuisopnamen. Maag Lever Darm Stichting. https://www.mlds.nl/nieuws/spijsverteringsziekten-derde-oorzaak-van-alle-ziekenhuisopnamen/

Maag Lever Darm Stichting. (2023b, November 8). Bevolkingsonderzoek darmkanker - Maag Lever Darm Stichting. https://www.mlds.nl/kanker/darmkanker/bevolkingsonderzoek-darmkanker/?gad_source=1&gclid=CjwKCAiAvJarBhA1EiwAGgZl0IZWZ_wXdhEIh12m42b6KAaK7f3bp09XMKJGZ38Pc4x-cKE8r31plxoCMxMQAvD_BwE

MacNeill, A., Hopf, H. W., Khanuja, A., Alizamir, S., Bilec, M. M., Eckelman, M. J., Hernandez, L. V., McGain, F., Simonsen, K., Thiel, C. L., Young, S. B., Lagasse, R. S., & Sherman, J. D. (2020). Transforming The Medical Device Industry: Road Map To A Circular Economy. Health Affairs, 39(12), 2088–2097. https://doi.org/10.1377/hlthaff.2020.01118

Maurice, J., Siau, K., Sebastian, S., Ahuja, N. K., Wesley, E., Stableforth, W., & Hayee, B. (2020). Green endoscopy: a call for sustainability in the midst of COVID-19. The Lancet Gastroenterology & Hepatology, 5(7), 636–638. https://doi.org/10.1016/s2468-1253(20)30157-6

McGill, E., Er, V., Penney, T. L., Egan, M., White, M., Meier, P., Whitehead, M., Lock, K., De Cuevas, R. A., Smith, R., Savona, N., Rutter, H., Marks, D., De Vocht, F., Cummins, S., Popay, J., & Petticrew, M. (2021). Evaluation of public health interventions from a complex systems perspective: A research methods review. Social Science & Medicine, 272, 113697. https://doi.org/10.1016/j.socscimed.2021.113697

McGrath, N., Farragher, A., Waldron, C., Keshtkar, L., Burns, A., Teahan, Á., Long, J., & Health Research Board. (2023). Cost, safety, and environmental impact of reprocessing single-use medical devices: A systematic review and meta-analysis. Dublin: Health Research Board; 2022. https://www.hrb.ie/publications

MedTech Europe. (2022, July 7). Product Liability rules and the Medical Technology Sector: MedTech Europe views on the revision of the Product Liability Directive [Press release]. https://www.medtecheurope.org/resource-library/medtech-europe-position-paper-on-the-revision-of-the-product-liability-directive/

Metabolic. (2023, March 16). SoTecIn Factory: New solutions for Europe's seven industrial value chains. https://www.metabolic.nl/projects/sotecin-factory-new-solutions-for-europes-seven-industrial-value-chains/

Milieu Centraal. (n.d.). Gemiddeld energieverbruik in Nederland. https://www.milieucentraal.nl/energie-besparen/inzicht-in-je-energierekening/gemiddeld-energieverbruik/

Ministerie van Volksgezondheid, Welzijn en Sport. (2022, June 28). Evaluatie Green Deal Duurzame Zorg. Rapport | Rijksoverheid.nl. https://www.rijksoverheid.nl/ministeries/ministerie-van-volksgezondheid-welzijn-en-sport/documenten/rapporten/2021/12/20/evaluatie-green-deal-duurzame-zorg

Ministerie van Volksgezondheid, Welzijn en Sport. (2023, November 17). Personeelstekorten in de zorg. Inspectie Gezondheidszorg En Jeugd. https://www.igj.nl/onderwerpen/personeelstekort

Namburar, S., Von Renteln, D., Damianos, J., Bradish, L., Barrett, J., Aguilera-Fish, A., Cushman-Roisin, B., & Pohl, H. (2021). Estimating the environmental impact of disposable endoscopic equipment and endoscopes. Gut, 71(7), 1326–1331. https://doi.org/10.1136/gutjnl-2021-324729

Neves, J. a. C., Roseira, J., Cunha, M. F., Pellino, G., Sampietro, G., & De Santiago, E. R. (2023). Towards a greener endoscopy: Considerations on the strategies to improve sustainability. Digestive and Liver Disease, 55(4), 429–430. https://doi.org/10.1016/j.dld.2022.12.017

NHS. (2024, January 12). Biopsy. nhs.uk. https://www.nhs.uk/conditions/biopsy/

Noordik, E., Nieuwenhuijsen, K., Varekamp, I., Van Der Klink, J. J., & Van Dijk, F. J. (2011). Exploring the return-to-work process for workers partially returned to work and partially on long-term sick leave due to common mental disorders: a qualitative study. Disability and Rehabilitation, 33(17–18), 1625–1635. https://doi.org/10.3109/09638288.2010.541547

Olympus Global. (n.d.). Structure and Components of Endoscopes. https://www.olympus-global.com/ir/data/

Overgewicht | Leeftijd en geslacht | Volwassenen. (n.d.). Volksgezondheid En Zorg. https://www.vzinfo.nl/overgewicht/leeftijd-geslacht/volwassenen#:~:text=In%202022%20had%2050%2C2,bij%20mannen%20dan%20bij%20vrouwen.

Park, S. B., & Myung, J. (2023). Gastrointestinal endoscopy's carbon footprint. Clinical Endoscopy, 56(3), 263–267. https://doi.org/10.5946/ce.2023.003

Plsek, P. E., & Greenhalgh, T. (2001). Complexity science: The challenge of complexity in health care. BMJ, 323(7313), 625–628. https://doi.org/10.1136/bmj.323.7313.625

Ramirez, B., West, D. J., & Costell, M. M. (2013). Development of a culture of sustainability in health care organizations. Journal of Health Organisation and Management, 27(5), 665–672. https://doi.org/10.1108/jhom-11-2012-0226

Ratnapalan, S., & Lang, D. (2019). Health care organizations as complex adaptive systems. The Health Care Manager, 39(1), 18–23. https://doi.org/10.1097/hcm.0000000000000284

RIVM. (n.d.). Werkgroep Infectie Preventie (WIP). https://www.rivm.nl/werkgroep-infectie-preventie-wip

RIVM. (2022). The impact of Dutch healthcare on the environment: Environmental footprint method, and examples for a health-promoting healthcare environment. In RIVM (RIVM-2022-0159). https://rivm.openrepository.com/bitstream/handle/10029/626296/2022-0159.pdf?sequence=1&isAllowed=y

Rodríguez-Jiménez, L., Romero-Martín, M., Spruell, T., Steley, Z., & Gómez-Salgado, J. (2023). The carbon footprint of healthcare settings: A systematic review. Journal of Advanced Nursing, 79(8), 2830–2844. https://doi.org/10.1111/jan.15671

Rouwkema, S. (2023). World Obesity Day 2023. Partnerschap Overgewicht Nederland. https://www.partnerschapovergewicht.nl/2023/world-obesity-day-2023/#:~:text=Op%20zaterdag%204%20maart%202023,perspectives%3A%20Let's%20talk%20about%20obesity.&text=50%25%20van%20de%20Nederlandse%20volwassenen,overgewicht%20en%2014%25%20heeft%20obesitas.

Royer, S., Ferrón, S., Wilson, S. T., & Karl, D. M. (2018). Production of methane and ethylene from plastic in the environment. PLOS ONE, 13(8), e0200574. https://doi.org/10.1371/journal.pone.0200574

Sebastian, S., Anjan, D., Robin, B., Leigh, D., Haddock, R., Arasaradnam, R., Coulter, A., Disney, B. J., Griffiths, H., Healey, C., Hilson, R., Steinbach, I., Marshall, S., Rajendran, A., Rochford, A., Thomas-Gibson, S., Siddhi, S., Stableforth, W., Wesley, E., . . . Hayee, B. (2023). Green endoscopy: British Society of Gastroenterology (BSG), Joint Accreditation Group (JAG) and Centre for Sustainable Health (CSH) joint consensus on practical measures for environmental sustainability in endoscopy. Gut, 72(1). https://doi.org/10.1136/gutjnl-2022-328460

Setoguchi, S., Leddin, D., Metz, G., & Omary, M. B. (2022). Climate Change, Health, and Health care Systems: A Global perspective. Gastroenterology, 162(6), 1549–1555. https://doi.org/10.1053/j.gastro.2022.02.037

Sherman, J. D., Thiel, C. L., MacNeill, A., Eckelman, M. J., Dubrow, R., Hopf, H. W., Lagasse, R. S., Bialowitz, J., Costello, A., McGain, F., Stancliffe, R., Anastas, P. T., Anderko, L., Baratz, M. E., Barna, S., Bhatnagar, U., Burnham, J. P., Cai, Y., Cassels-Brown, A., . . . Bilec, M. M. (2020). The Green Print: Advancement of Environmental Sustainability in Healthcare. Resources, Conservation and Recycling, 161, 104882. https://doi.org/10.1016/j.resconrec.2020.104882

Siau, K., Hayee, B., & Gayam, S. (2021). Endoscopy's current carbon footprint. Techniques and Innovations in Gastrointestinal Endoscopy, 23(4), 344–352. https://doi.org/10.1016/j.tige.2021.06.005

Siddhi, S., Dhar, A., & Sebastian, S. (2021). Best practices in environmental advocacy and research in endoscopy. Techniques and Innovations in Gastrointestinal Endoscopy, 23(4), 376–384. https://doi.org/10.1016/j.tige.2021.06.002

Singh, H., Eckelman, M. J., Berwick, D. M., & Sherman, J. D. (2022). Mandatory reporting of emissions to achieve Net-Zero health care. The New England Journal of Medicine, 387(26), 2469–2476. https://doi.org/10.1056/nejmsb2210022

Steenmeijer, M. A., Rodrigues, J. F., Mc, Z., & Loop, S. L. W. D. (2022). The environmental impact of the Dutch health-care sector beyond climate change: an input–output analysis. The Lancet Planetary Health, 6(12), e949–e957. https://doi.org/10.1016/s2542-5196(22)00244-3

Stone, C. (2022, July 5). Colonoscopy - AGA GI Patient Center. AGA GI Patient Center. https://patient-staging.gastro.org/colonoscopy/

Stuurgroep Flexibele Endoscopen Reiniging en Desinfectie [SFERD]. (2022). KWALITEITSHANDBOEK FLEXIBELE ENDOSCOPEN: Reiniging en Desinfectie. https://www.mdl.nl/sites/www.mdl.nl/files/richlijnen/SFERD%20kwaliteitshandboek%206.0%20DEF.pdf

The European Green Deal. (2021, July 14). European Commission. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

The Lancet. (2023). Climate change crisis goes critical. The Lancet Respiratory Medicine, 11(3), 213. https://doi.org/10.1016/s2213-2600(23)00056-5

Themes, U. (2021, May 9). Reprocessing and remanufacturing of Single-Use medical devices. Basicmedical Key. https://basicmedicalkey.com/reprocessing-and-remanufacturing-of-single-use-medical-devices/

TU Delft. (n.d.). Co-creation. https://www.tudelft.nl/study-climate/perspectives/co-creation

United Nations. (n.d.). Sustainable Development Goals. https://sdgs.un.org/

United Nations. (1987). Report of the World Commission on Environment and Development: Our Common Future. https://www.un.org/en/academic-impact/sustainability

US EPA. (1997). AP-42 Background Document, Section 2.3 Medical Waste Incineration. https://www3.epa.gov/ttnchie1/ap42/ch02/final/c02s03.pdf

US EPA. (2023, April 18). Understanding global warming potentials. https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

Van Deursen, L., Van Der Vaart, R., Alblas, E., Struijs, J. N., Chavannes, N. H., & Aardoom, J. J. (2023). Improving the colorectal cancer care pathway via e-health: a qualitative study among Dutch healthcare providers and managers. Supportive Care in Cancer, 31(4). https://doi.org/10.1007/s00520-023-07653-2

Vanhaecht, K. (2007). The impact of clinical pathways on the organisation of care processes.

Vereniging Gehandicaptenzorg Nederland. (2023, August 15). Miljarden nodig voor verduurzaming zorgsector. VGN. https://www.vgn.nl/nieuws/miljarden-nodig-voor-verduurzaming-zorgsector

Verma, R., Vinoda, K., Papireddy, M., & Gowda, A. (2016). Toxic Pollutants from Plastic Waste- A Review. Procedia Environmental Sciences, 35, 701–708. https://doi.org/10.1016/j.proenv.2016.07.069

Voiosu, A., De Santiago, E. R., & Voiosu, T. (2023). Getting the full picture: let's always include sustainability in trials reporting new technology! Gastrointestinal Endoscopy, 97(3), 601. https://doi.org/10.1016/j.gie.2022.09.014

VZinfo. (n.d.). Maag-, darm- en leveraandoeningen | Kosten. Volksgezondheid En Zorg. Retrieved November 16, 2023, from https://www.vzinfo.nl/maag-darm-en-leveraandoeningen-kosten

Wang, W. L., Wu, Z., Sun, Q., Wei, J., Chen, X. F., Zhou, D., Zhou, L., Xie, H., & Zheng, S. (2012). Meta-analysis: the use of carbon dioxide insufflation vs. room air insufflation for gastrointestinal endoscopy. Alimentary Pharmacology & Therapeutics, 35(10), 1145–1154. https://doi.org/10.1111/j.1365-2036.2012.05078.x

What is Human-Centered Design (HCD)? (2024, January 17). The Interaction Design Foundation. https://interaction-design.org/literature/topics/human-centered-design#what_is_human-centered_design_(hcd)?-0

Wolvetang, S., Van Dongen, J. M., Speklé, E. M., Coenen, P., & Schaafsma, F. (2022). Sick Leave Due to Stress, What are the Costs for Dutch Employers? Journal of Occupational Rehabilitation, 32(4), 764–772. https://doi.org/10.1007/s10926-022-10042-x

World Bank Group. (2024). Health and climate change. In World Bank. https://www.worldbank.org/en/topic/health/brief/health-and-climate-change#:~:text=Climate%20change%20exerts%20significant%20strains,and%20sanitation%2C%20and%20clean%20air.

World Health Organization. (2016). Operational framework for building climate resilient health systems.

World Health Organization. (2021). 2021 WHO health and climate change global survey report. https://iris.who.int/handle/10665/348068

Yamano, H., Yoshikawa, K., Kimura, T., Yamamoto, E., Harada, E., Kudou, T., Katou, R., Hayashi, Y., & Satou, K. (2010). Carbon dioxide insufflation for colonoscopy: evaluation of gas volume, abdominal pain, examination time and transcutaneous partial CO2 pressure. Journal of Gastroenterology, 45(12), 1235–1240. https://doi.org/10.1007/s00535-010-0286-5