Appendices

Reuse of intubation devices as a catalyser for systemic change

Towards Circular ICUs

Alicia Ville | Master thesis | March 2022
Integrated Product Design | Delft University of Technology

Appendices Table of content

APPENDIX A

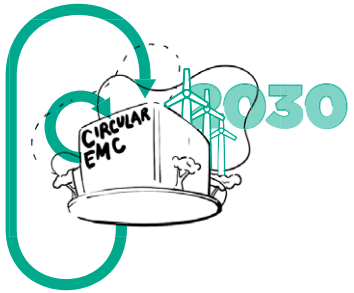
Towards Circular ICUs

Opportunities areas to catalyse circular transition or Erasmus Medical Center Intensive Care Units.

This booklet presents opportunity areas developed for Erasmus MC towards creating a circular ICU by by 2030.

Future healthcare can
heal without generating waste,
provide care while keeping resources in use,
and nurture not only human lives
but the whole ecosystem we are part of.

2030.
Imagine a future Erasmus Medical Center where ...



Devices are used for longer,
redesigned to use fewer and
cleaner resources.

Devices are reused instead of disposed
of after single-use.

Devices are procured from local
manufacturers to whom they will be
returned by the end of their use-life.
This way, devices and resource value
will be retained for longer.

Renewable energy powers the hospital
and makes Erasmus MC resilient.

Users are aware of the environmental
impact of their actions and minimize
wastefulness.

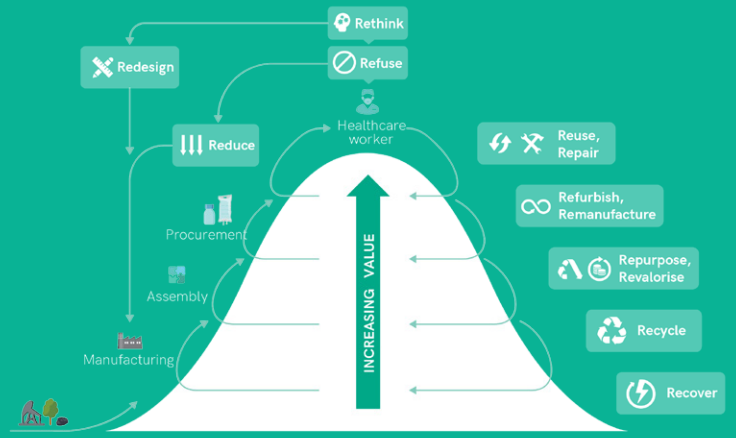
Circular ICUs

One patient day at EMC ICU is equivalent to driving 2000 km or deforesting a 200 square meter area. Compared to other parts of the hospital, the ICU produces extreme waste per patient. The transition towards a circular economy is crucial.

The circular economy is regenerative and restorative by design and is based on the following three principles: Designing out waste and pollution, keeping products and materials in use and regenerating natural systems. It would enable hospitals to retain value for longer and being less harmful to the environment.

These booklet presents opportunity areas detected throughout the graduation project which could bring Erasmus MC ICU closer to becoming circular.

Circular strategies to retain value



Refuse: Abandoning the function of redundant products

Rethink: Design towards a more intensively use product

Reduce: Increase efficiency in product manufacture or use by consuming fewer natural resources or materials

Reuse: Use of a product again for the same purpose in its original form or with little enhancement or change.

Repair: Bring a product back to working condition after failure.

Refurbish: Restore a used product to an original as-new condition.

Remanufacture: Restoring cores to original as-new condition and performance or better.

Repurpose: Use of products or parts that had have been discarded in a new product with a different function than the initial one.

Recycling: Process of material recovering for the original or other purposes.

Recover: Incineration of material with energy recovery.

Context

Systemic research of current practices and waste at Erasmus MC ICU was undertaken, to better understand the impact and complexity.

A set of opportunities areas were developed from the systemic study around intubations at Erasmus MC ICU.

A pilot proposal to reuse key intubation devices is proposed. This pilot, a first step towards circular ICUs, is only one of the many opportunities areas detected throughout the research.

A set of actions that Erasmus MC ICU could take to transition to full circularity by 2030 are summarized in this booklet, complementing the reuse pilot proposed.

Reading guide

Opportunity area. Explanation of the possible intervention.

R-strategy addressed | **Scope of action** ICU/EMC/Collabs

First the context and problem detected will be explained here.

Next, in bold, the proposed opportunity area will be presented.

Challenges addressed

- The challenges addressed
- within each proposal will be
- listed here.

Impact

- Here the different
- benefits of the proposal
- will be presented.

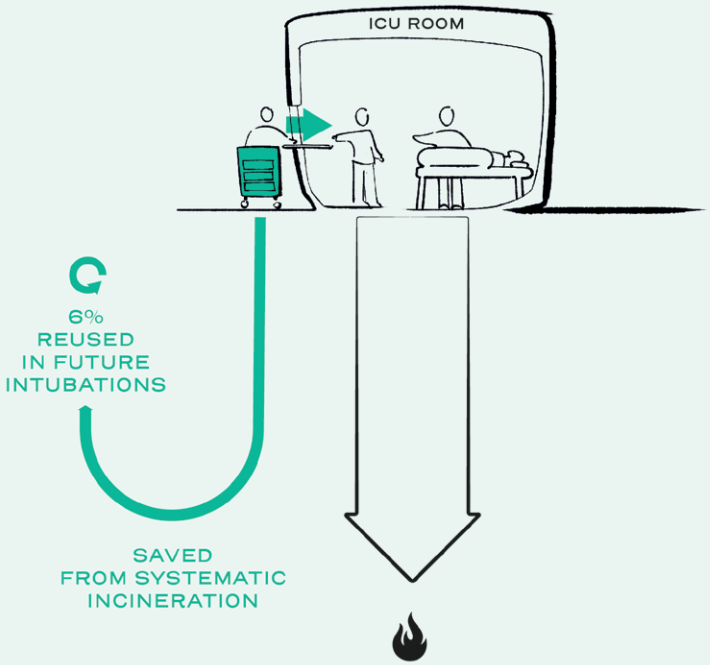
- These would look at benefits
- for people at the ICU,
- environmental impact and
- overall costs for EMC.

Stakeholders required
Here, the required stakeholders to be involved are listed

Short **Medium** **Long**

How long should this idea take to be implemented?
Here, a further explanation of each proposal timeframe estimation is provided, whether **short** (1 to 2 years), **medium** (2 to 5 years) or **long** (5 years or more)

1 EXTERNAL STORAGE



Avoid unused waste. Reduction of devices entering the room, external storage compartment in front of the ICU room.

Reduce | **Area** ICU Procedures

If devices enter in the ICU room of a patient considered infectious, they must be thrown away even if eventually not used. The unused waste was estimated at 6% through a waste observation of waste at Erasmus MC Pediatric ICU.

Currently, more devices than required are placed in the rooms during intubation procedures. As intubations need to be extremely time-efficient, the option of searching for these devices only if the necessity arise is not considered.

Adding an external storage in front of the ICU room allows devices easily accessible, still out of the room. This saves devices from incineration in case they are eventually not used.

Challenges addressed

- Unused waste

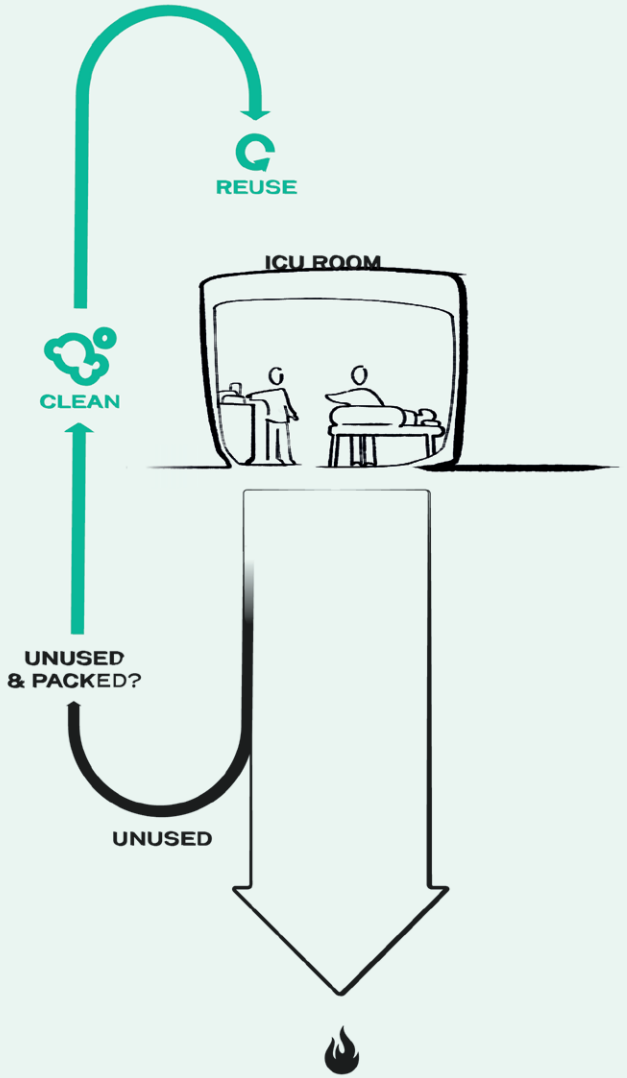
Impact

- Reduction of **waste** generated by the ICU
- **Material** reduction impact by avoiding unused devices going to waste
- **Energy** reduction used during waste incineration by reduction of the amount.
- **Pressure** reduction on doctors when deciding which devices to introduce in the room

Stakeholders required
Erasmus MC

Short term solution
Intubation trolleys are already available at the ICU, that could be placed next to the ICU rooms when needed.

2 CLEANABLE PACKAGING



Avoid unused waste. Cleaning unused devices that are still in their packaging with UV-C technology or adapting the packaging materials.

Reduce | **Area** Collaborations

Some devices that enter in the ICU room are thrown away unused and still packed. These packagings are made from materials that cannot be cleaned with the wiping system used at the ICU.

Erasmus MC could explore collaboration with manufacturers to redesign cleanable packaging, allowing cleaning and thus saving the packed devices from being thrown away unused.

Other cleaning alternatives can be also contemplated. The use of UV-C cleaning, a rather new yet certified cleaning technique, allows the cleaning of the current paper and plastic-based materials.

Challenges addressed

- Unused waste
- Slow implementation of reprocessing innovations in hospitals

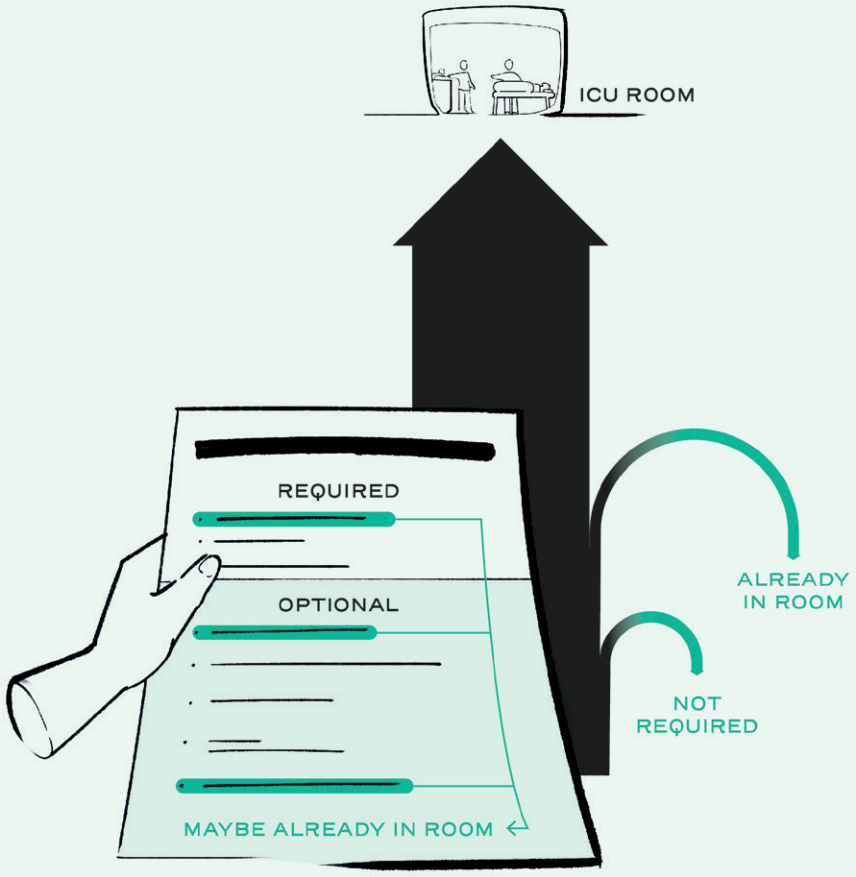
Impact

- Reduction amount of **waste** generated by the ICU
- Reduction **material** impact by avoiding unused devices going to waste and redesigning packaging
- Reduction **energy** used during waste incineration
- Avoiding **chemicals** replacing disinfectant impregnated wipes by UV-C cleaning

Stakeholders required
Erasmus MC - Manufacturers

Medium term solution
Implementation of new cleaning technology or collaboration with manufacturers towards packaging redesign are required.

3 REDESIGN PROTOCOLS



Avoid unused waste. Redesign intubation protocols to avoid redundancy.

Reduce | **Area** ICU Procedures

Rooms are filled by both care assistants and nurses. Basic devices are placed in the room in advance by care assistants, and nurses will add any additional device required for specific operations. Some devices mentioned in specific operation protocols are already available in the room. This overlap triggers the same devices to be brought twice into the room, leading to unused waste. Also, some devices mentioned in protocols are optional still always entered in the room for precaution.
A redesign of protocols that allows nurses to know which devices can be potentially already in the room can be envisioned.
Protocols could also distinguish better optional devices. Doctors could then take better decisions on what to enter in the ICU room.

Challenges addressed

- Unused waste
- Lack of communication between ICU users

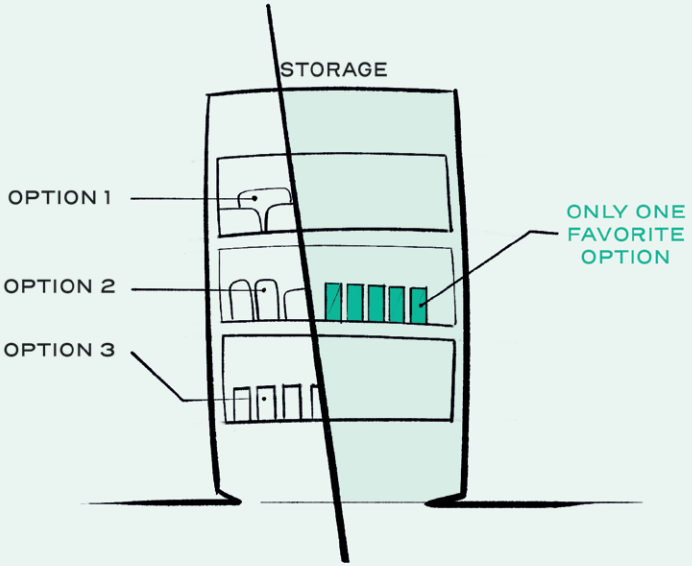
Impact

- Reduction amount of **waste** generated by the ICU
- Reduction **material** impact by avoiding unused devices going to waste
- Reduction **energy** used during waste incineration by reduction of the amount.
- Help nurses and doctors in the room filling **process**

Stakeholders required
Erasmus MC

Short term solution
Changes of the protocols can be done by Erasmus MC itself as long as they comply with regulation

4 AVOID TOO MANY OPTIONS



Avoid unsued waste by reducing the number of redundant device options at ErasmusMC ICU.

Refuse | **Area** EMC Procedures

During an interview with an ICU doctor, the interviewee discovered differen versions of the same device that she did not know were available.

Reducing redundant versions of the same device is needed to avoid less known versions going unused until expiration.

Challenges addressed

- Unused waste
- Pressure on doctors decision making with excisive choice

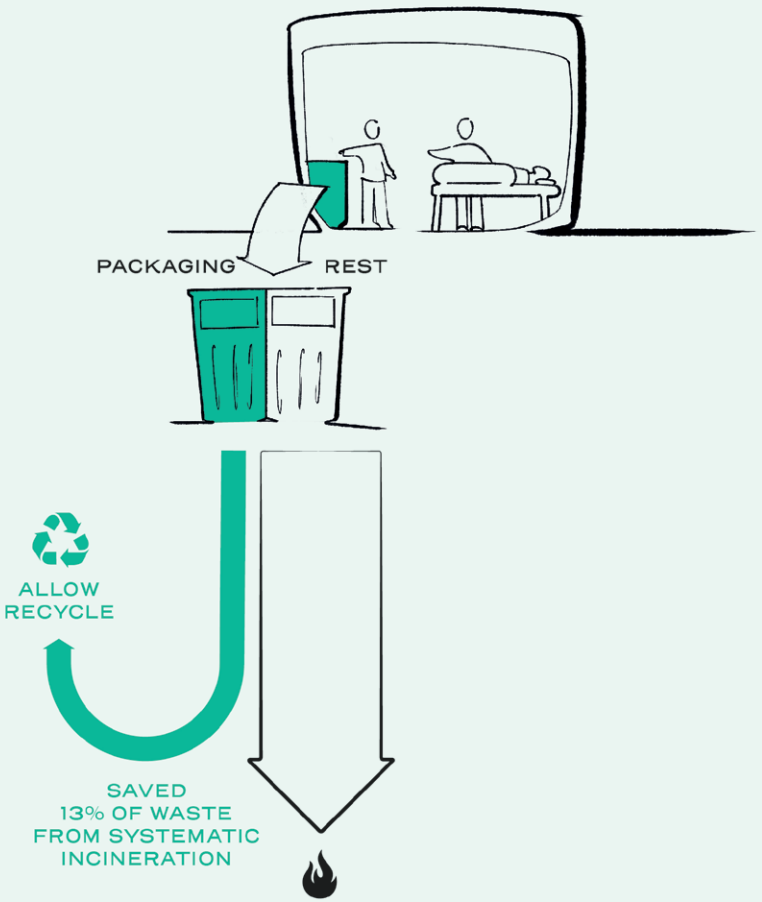
Impact

- Reduction **material** impact by avoiding waste
- Reduction **energy** used during waste incineration by reduction of the amount of waste
- Reduce hassle of current procedures and **decision makings** at EMC ICU.

Stakeholders required
Erasmus MC

Short term solution
Requires only changes within EMC procurement

5 SEPARATE PACKAGING



Allow waste separation. Redesign the waste separation process to allow separation and recycling of packaging.

Recycle | **Area** EMC Procedures

Almost everything that enters the ICU is thrown away in a single waste stream, including the device packaging. Packaging represents almost 13% of the total waste in weight during a study of Erasmus MC PICU.

Knowing that 'almost 60% of ICU general waste could be recycled' (McGain et al., 2009) it can be envisioned to separate devices packaging. Most devices packaging are made from the same range of materials (paper, laminated PA, LDPE, HDPE, etc.). The potential recyclability of these materials can be envisioned.

Challenges addressed

- Packaging waste
- Lack of waste separation within the ICU room

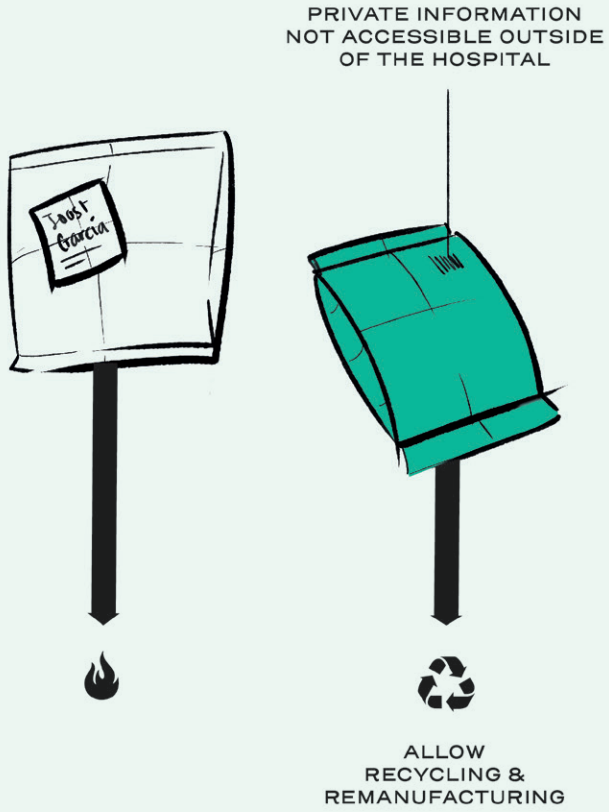
Impact

- **Material** reduction impact by avoiding incineration / allowing recyclability
- **Energy** used reduction during waste incineration by reduction of the amount of incinerable waste

Stakeholders required
Erasmus MC - Waste managament external service

Long term solution
Collaboration with waste management services complying to strict safety regulation and changes in waste logistics are required.

6 NO STICKERS



Allow waste separation. Allow post-use R-strategies by separating the waste and avoiding the use of stickers.

Remanufacture | **Area** Collaborations

Remanufacturing of single-use healthcare devices is possible. Collaboration with remanufacturers or manufacturers themselves can be envisioned to reduce Erasmus MC environmental footprint.

Devices must be separated from the main waste stream to enable remanufacturing by external stakeholders. Erasmus MC ICU must thus allow waste separation within the ICU room.

The ICU should also avoid placing stickers on products. Stickers can restrict remanufacturing technically, whereas the personal information present on stickers makes remanufacturing not possible from a regulatory point of view.

Challenges addressed

- Lack of waste separation
- Lack of post-use R-strategies implemented
- Use procedures jeopardizing the implementation of R-strategies post-use

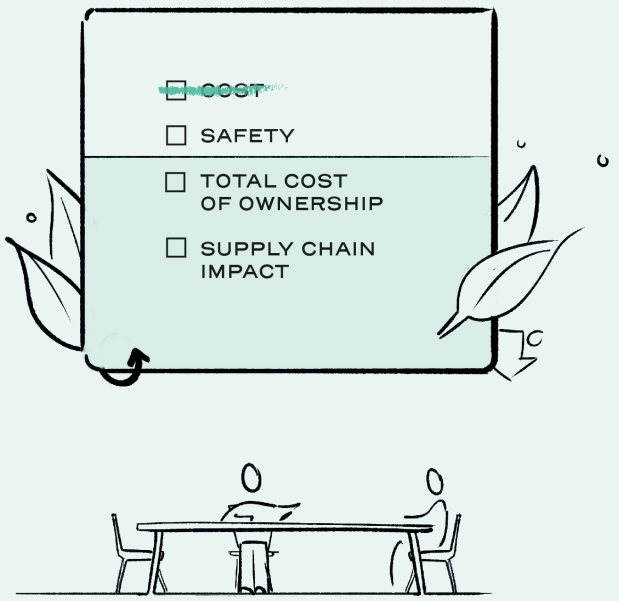
Impact

- Reduction **material** impact by avoiding incineration / allowing remanufacturing
- Reduction **energy** used during waste incineration by reduction of the amount of incinerated waste

Stakeholders required
Erasmus MC - Remanufacturer or manufacturers

Long term solution
Collaboration with waste management services and implementation of new waste streams and separation are required.

7 CONSCIOUS PROCUREMENT



Raise awareness. Enhance future responsible procurement through sustainable KPIs.

Rethink | **Area** EMC

Procurement decisions are relevant to achieve higher sustainability at Erasmus MC, as they will greatly affect the implementation of higher R strategies. However, current procurement is only based on cost and safety.

Taking into consideration the total cost of ownership of devices and their supply chain impact (CO2, land, water, toxicity, child labour) could increase hospital sustainability and the use of reusable devices.

Challenges addressed

- Current procurement KPIs prioritize disposables
- Negative connotation of sustainability in the healthcare environment
- Manufacturers pressure towards disposability

Impact

- Reduction **total cost of ownership** of devices used at Erasmus MC.
- Reduction **supply chain impact** by more responsible procurement.

Stakeholders required

Erasmus MC - Manufacturer - Regulations entities

Medium term solution

For this change to happen, Erasmus MC is dependent on manufacturing sharing additional information on their devices' life cycle. However, Erasmus MC procurement team is highly aware of this.

8 CONSCIOUS DECISION

Raise awareness. Educate Erasmus MC users of their wastefulness to reduce excessive device and clothes usage.

Refuse | **Area** Procedures at the ICU

Observations highlighted that personal protective clothing is used more than required, and devices enter into ICU rooms that are eventually not used.

Raising the awareness of ICU staff on these decisions could avoid nonessential use of resources and reduce waste.

Interviews showed that ICU user awareness is already higher than in other departments of Erasmus MC, given the volume of waste generated. But there is still room for improvement, especially around the balance between environmental impact, sustainability, and risk perception.

Challenges addressed

- Excessive use of single-use devices
- Excessive use of personal protective clothing
- Negative connotation of sustainability in the healthcare environment

Impact

- Reduction amount of **waste** generated and **resources** used by the Erasmus MC.
- Reduction **energy** used during waste incineration by reduction of the amount.

Stakeholders required
Erasmus MC

Meidum term solution
Changes in the sustainability connotation and risk perception of Erasmus MC users are needed.

Towards Circular ICUs.
Reuse of intubation devices as a catalyser for systemic change.

Alicia Ville

DESIGN FOR our future

APPENDIX B

TU Delft

IDE Master Graduation

Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT
Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME

Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy".
Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1

family name: Ville
initials: A given name: Alicia
student number: 5145481
street & no.:
zipcode & city:
country:
phone:
email:

Your master programme (only select the options that apply to you):

IDE master(s): ★ IPD ( ) DfI ( ) SPD
2nd non-IDE master:
individual programme: - - (give date of approval)
honours programme: ( ) Honours Programme Master
specialisation / annotation: ( ) Medisign
( ) Tech. in Sustainable Design
( ) Entrepeneurship

SUPERVISORY TEAM **

Fill in the required data for the supervisory team members. Please check the instructions on the right !

** chair: C. Bakker dept. / section: SDE / CPD
** mentor: J.C. Diehl dept. / section: SDE / DfS
2nd mentor: B. Sene
organisation: VanBerlo
city: Eindohven country: the Netherlands

comments (optional): Nicole Hunfeld will be the client from this graduation project. As the project leader of the Sustainability Intensive Care Unit at Erasmus MC, she will be the main contact point with Erasmus MC organization.

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v..

Second mentor only applies in case the assignment is hosted by an external organisation.

Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.

APPROVAL PROJECT BRIEF

To be filled in by the chair of the supervisory team.

chair C. Bakker date 10 - 09 - 2021 signature Conny Bakker Digitally signed by Conny Bakker Date: 2021.09.10 12:19:14 +02'00'

CHECK STUDY PROGRESS

To be filled in by the SSC E&SA (Shared Service Center, Education & Student Affairs), after approval of the project brief by the Chair. The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: 11 EC

Of which, taking the conditional requirements into account, can be part of the exam programme 11 EC

List of electives obtained before the third semester without approval of the BoE

★ YES all 1st year master courses passed

NO missing 1st year master courses are:

name J. J. de Bruin date 16 - 09 - 2021 signature

FORMAL APPROVAL GRADUATION PROJECT

To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **. Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: V APPROVED NOT APPROVED

Procedure: V APPROVED NOT APPROVED

comments

name Monique von Morgen date 28/09/2021 signature MvM

Towards greener ICUs. Designing circular intubation systems

project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 08 - 09 - 2021

02 - 03 - 2022 end date

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

The health sector is one of the major contributors to the climate crisis, the greatest health threat of the 21st century. By contributing to 4,4% of global net greenhouse gas emissions and toxic air pollutants, the sector's mission of protecting and promoting health is intrinsically jeopardized by its carbon-intensive activity [1]. Intensive Care Units (ICU) in particular, due to the constant care they provide to patients suffering severe illnesses and injuries, produce high amounts of waste. Not only do they make large use of disposables, but also do not use medical equipment until their depreciation time [2].

The Erasmus Medical Center (MC) at Rotterdam, the Netherlands, aims to innovate towards more sustainable healthcare. Transitioning from a linear to circular economy is necessary to prevent the intensive depletion of finite natural resources available and the associated negative environmental and social impacts.
The circular economy is regenerative and restorative by design and is based on the following three principles: designing out waste and pollution, keeping products and materials in use and regenerating natural systems [3]. This would enable Erasmus MC to capture and retain value for longer and thus be less harmful for the environment.

Specifically, Erasmus MC aims to start this transition by focusing on the ICU. To transition towards a Sustainable Intensive Care Unit, a collaboration with the Faculty of Industrial Design Engineering of the TUDelft was initiated. This project is part of a series of graduation projects to design sustainable solutions specifically for the Intensive Care Unit (ICU). Additionally, this project will be developed under the additional mentorship of VanBerlo, a design consultancy with previous valuable practical knowledge both on circular product design and Medesign.

The project will have to consider another wide range of actors. Figure 1 introduces stakeholders which shape the current medical ecosystem, to which great attention will be paid to integrate circular economy principles in the project. Transition towards greener ICU results in a complex challenge involving changes at different scales. These challenges range from changes within the ICU protocols itself to which the staff will need to adapt to assuring regulations compatibility.

This project focuses on the intubation process, a specific system currently used at Erasmus MC ICUs. The scope is limited by the graduation project timeframe. Specifically, this project aims to map the environmental impact of this ICU system and generate solutions towards making the process more circular.

[1] Karliner, J., Slotterback, S., Boyd, R., Ashby, B., Steele, K., & Wang, J. (2020). Health care's climate footprint: the health sector contribution and opportunities for action. European Journal of Public Health, 30, 165-843.
[2] Browne-Wilkinson, S., van Exter, P., Bouwens, J., Souder, J., & Chatel, E. (2021). Circular Intensive Care Unit - opportunities for human and planetary health. Metabolic and Erasmus MC.
[3] Morlet, A., Blériot, J., Schouteden, C., Gueye, S., Jeffries, N., Banks, I. & Gravis, L. (2019) Completing the picture. How circular economy tackles climate change. Ellen Macarthur Foundation and Material economics.

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introduction (continued): space for images

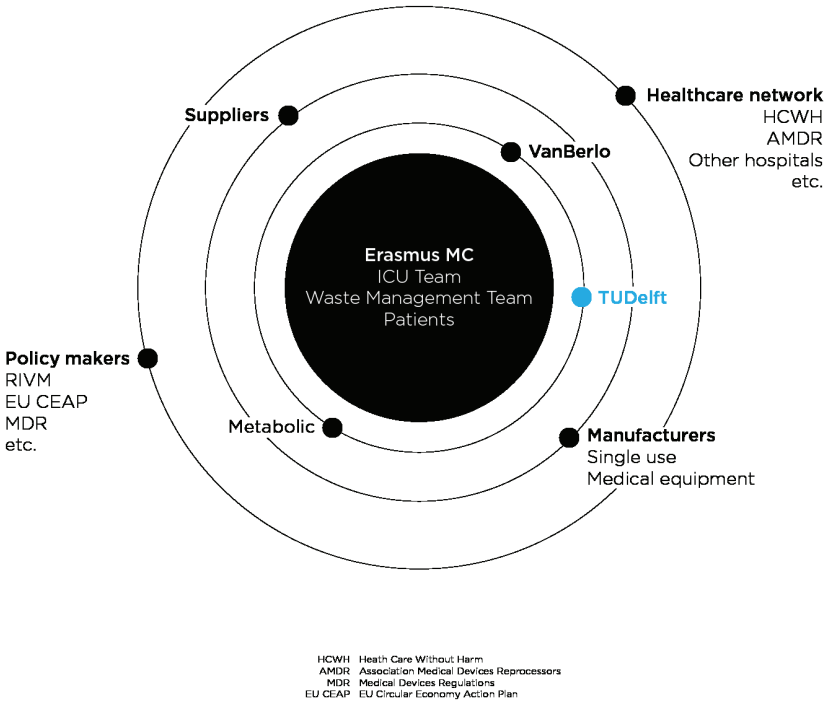


image / figure 1: Healthcare Ecosystem

image / figure 2: Intubated patient

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

The intubation done at Erasmus MC ICU involves multiple steps. Before the intubation, the patient stomach is emptied, anaesthesia is given and preoxygenation undertaken. A video-laryngoscope will then be used to support the placement of the tube into the lungs. After checking its correct positioning and fixing the tube, mechanical ventilation is used to pass air into and out of the lungs. Throughout the intubation period, periodic checking of the tube positioning is made. The patient is fed intravenously or using an additional tube inserted into the stomach. Eventually, the tube(s) may be pulled out when the patient's ability to breathe independently is back.

Throughout this system, medical equipment and disposables will be used, as well as water, medicines and energy. The intubation procedure makes use of tremendous amounts of single-use devices. Even electronics such as the video laryngoscope is thrown away, as it is an invasive procedure (introduced into the patient body). No inventory of the system's wastefulness has been made at Erasmus MC yet, neither has been it mapped.

Finally, as this system involves multiple stakeholders, from suppliers to waste managers, the complexity of the system arises even more. These stakeholders as well as the overall cost of the system have not yet being mapped either. We do also ignore which are the decision making factors when choosing the materials, products and suppliers used throughout this system.

Could we map the intubation system as a tool for discussion? Can we redesign intubation systems towards a lower environmental impact? How could Erasmus MC implements this transition to more circular intubations?

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

Using systemic design thinking, a visual map of the intubation system will be developed and used as a cocreation tool. Ideation towards more a more circular intubation will be made, and the most promising idea will be further developed so to deliver an implementation roadmap to Erasmus MC. A set of complementary recommendations on how to achieve circularity in the intubation subsystem will be also provided to Erasmus MC.

First, a literature analysis, as well as a context map, will be done to better understand the implementation of circular strategies within the healthcare ecosystem. I will define which is the role of stakeholders involved in the intubation.

Second, the system will be mapped using a systemic design approach. Water and medicines used will be out of scope. Although further definition of the map needs to be done, it would tentatively include:
- All steps of the system over time
- A cost, stakeholder and material flow
- Decision-making factors
- Potential opportunity areas

This system map will be used as a design tool. Through co-creation sessions with different stakeholders, ideas into how to turn the intubation more circular would be collected, from which the most promising one would be further developed into an implementation roadmap for Erasmus MC. Considering the requirements of the graduation project, the solution chosen should (at least partly) refer to a physical part of the system.
Finally, a set of recommendations will be proposed to Erasmus MC based on insights acquired during the graduation process on complementary alternatives to turn the intubation circular.

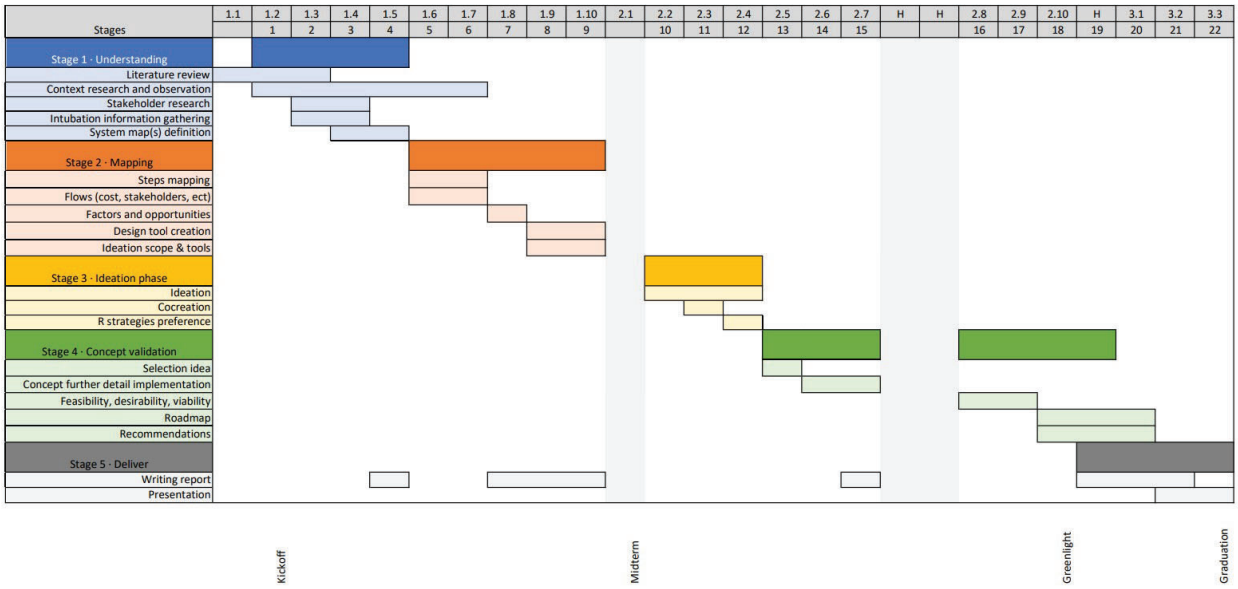
Initials & Name A Ville Student number 5145481

Title of Project Towards greener ICUs. Designing circular intubation systems

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 8 - 9 - 2021 2 - 3 - 2022 end date



The graduation project will extend over 22 weeks as I am simultaneously working as a teacher assistant at TUDelft for 4h a week, meaning that I will be dedicating 36h a week to the graduation project instead of 40h, resulting in an extension of two weeks. The project will consist of 5 phases.

Phase 1: Discovering the context and defining the system mapping that will be realized.
Phase 2: Mapping.
Phase 3: Ideate on potential solutions and strategies to turn the intubation system more circular.
Phase 4: Conceptualize the most promising idea(s) and develop a roadmap.
Phase 5: Visualize and finalize all deliverables.

Kick off meeting: 9th September 2021
Midterm presentation: 10th November 2021
Greenlight meeting: 2nd February 2022
Presentation: 2nd March 2022

Regarding my working habits, I will be working mondays and tuesdays at the convergence office (Erasmus MC, Rotterdam), wednesdays and fridays at VanBerlo Ypenburg office (The Hague) and Thursdays at the IDE Faculty, TUDelft.
I will have a weekly meeting with Nicole and JC and a bi-weekly meeting with Baptiste. I will meet the ICU green team every two weeks and my whole supervision team every month. Additional meetings will be arranged based on necessity.

Initials & Name A Ville Student number 5145481

Title of Project Towards greener ICUs. Designing circular intubation systems

MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

I believe in design as one of the most powerful tools towards designing a more sustainable future. Having been specializing in circular and sustainable design, I am enthusiastic about this project. I consider it a perfect environment to further develop my knowledge in circular design, as well as exploring new areas of design such as complex systems.

I am also intrigued to further discover the medical field complexity. I hope to define in the course of this project which are the most effective methods to evaluate and redesign a product towards a lower environmental impact. I believe the complex and regulated nature of the medical field will give me the necessary challenge to develop learnings that can be applied to almost any future project I will face.

We find ourselves in a situation where we must reduce our consumption of resources while other hospitals around the world do not have access to enough resources. The possibility of, hypothetically, learning from the current practice of countries that have access to fewer resources than we do and applying it to this project is inspiring to me.

Finally, on top of all the above-mentioned personal growth as a designer, I strongly believe that the purpose of the project will make me grow as a person. Both the impact and ambitions of this graduation seems to be optimistic and solving a problem that needs to be addressed, which brings me energy.

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.

APPENDIX C

NUMBER OF INTUBATIONS AT THE ICU PER YEAR CALCULATION

There are four areas of ICU on floor 4th and two on floor 6th. The numbers of intubations done per year were calculated by looking at how many video laryngoscopes or laryngoscopes had been procured for each area per year. Knowing that at least one of these devices would be used per intubation, we suppose that each procured video laryngoscope or laryngoscope equals one intubation. Around **565** intubations were performed per year at the ICU. The table hereunder shows the procurement numbers of both video laryngoscopes and laryngoscopes purchased in 2020 for the ICU at EMC

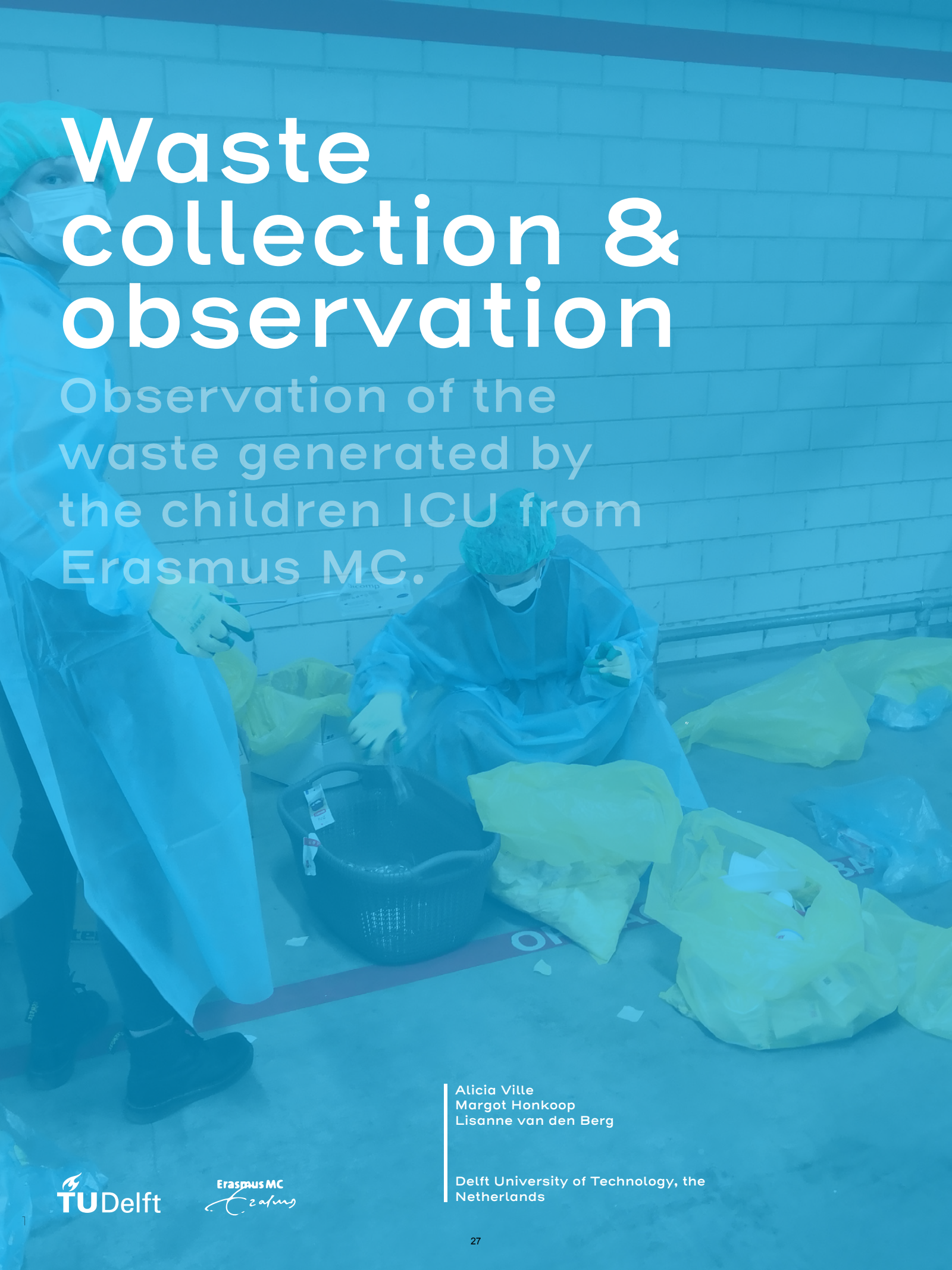
Leverancier	Artikelnaam	Pieces per pack	Units	**Total stuks**
Verathon Medical Europe BV	GlideScope Spectrum LoPro S3	10	11	110
Emdamed BV	Laryngoscope Handvat LED single use	10	11	110
Emdamed BV	Laryngoscoop blad Econ Macintosh single use maat 3	10	10	100
Emdamed BV	Laryngoscoop blad Econ Macintosh single use maat 4	10	7,5	75
Verathon Medical Europe BV	GlideScope Spectrum LoPro S4	10	6	60
Verathon Medical Europe BV	GlideScope stat GVL3	10	4	40
Medtronic Trading NL BV	VL MAC BLADE S3 X50	50	1	50
Verathon Medical Europe BV	GlideScope stat GVL4	10	2	20
			Total	565

APPENDIX D

OVERVIEW INTERVIEWS AND OBSERVATIONS

Table summarising all interviews undertaken

Who	When	Aim
Strategic buyer at the procurement team at EMC	Sep 22	Understanding the decision-making process of devices and their manufacturers at EMC. Factors used for decision making and how is sustainability assessed.
Device procurement advisor at the procurement team at EMC	Nov 2	
ICU Nurse from EMC	Sept 15	Interview and observation of preparation of the room from an intubated patient. Understanding which devices are used and disposed of. Understanding how the nurse felt emotionally about the waste generated.
	Oct 5	Observation of a room cleaning after an intubated patient had left. Understanding the quantity of waste generated per ICU room and the number of devices thrown unused.
ICU Physician from EMC	Sept 15	Guide through the ICU, steps of patient intubation to detubation, shows all different devices and storages within the ICU. Understanding the pains a physician might feel in intubating a patient and choosing devices and procedures to apply.
PhD working on the intubation period at EMC	Oct 26	Explanation of the steps and devices used during the intubated period of a patient.
Pharmacist of EMC ICU in combination with ICU Physician	Oct 4	Detailed explanation of higher value devices used throughout intubation: The video laryngoscopes and bronchoscope. Explanation reasoning behind using mostly disposable devices during intubations at EMC ICU. Explanation of the gains and pains experienced when devices were reusable.
Medical device designer at Medtronic	Oct 24	Explanation of the design process in the healthcare environment.



Waste collection & observation

Observation of the waste generated by the children ICU from Erasmus MC.

Alicia Ville
Margot Honkoop
Lisanne van den Berg

Delft University of Technology, the Netherlands

Introduction

Context

The Pediatric Intensive Care Unit (PICU) from Erasmus Medical Center (Erasmus MC) has 4 areas:

1 Short stay area
2 Conventional ICU
3 Conventional ICU
4 Long stay area

Each area has its own green container where all domestic waste generated ends up. These containers are unfilled two to three times per day.

Each area counts as well with numerous hazardous waste containers. These containers waste will not be separated because of safety reasons and available time. The procedure used to unfill these containers is different than the one followed for the green containers. Adding these into the scope of the project would increase the complexity of the same to an unreachable level. Although hazardous waste will not be analysed, we will take a picture of their content to get an indication of what is in there. We will weigh them as well.

Aim

The waste of the green containers will be analysed throughout four days. Each day, one of the unit's green containers will be analysed. On the first day, we start with unit 4 and the time needed to analyse one container will be defined. If there is enough time, more than one unit can be measured per day. To differentiate the containers from each area, a sticker will be placed on the lid of each of them when positioned emptied.

Although the morning shift starts at 7:45, separating waste will start from 8:30. All trash bags will be brought throughout the day to the collection point by the workers assigned to do so. These workers are informed by Sascha and Suzan to collect the containers from the PICU. Two shifts during night, one at 10:00am. No previous separation of the waste placed in the green containers is needed.

Setup

Apparatus

- 2 garbage bins
- 3 scales
- 1 phone camera
- 3 forceps
- 1 computer
- 12 sets of protective clothes
- 1 set of plastic bags
- 1 tape (to fix the garbage bags outside)

Procedure

ICU: Children IC; WCP: Waste collection point

[ICU] Wearing protective clothes and picking up all utensils used for the waste separation.

[ICU] Taking pictures of the specific hospital waste (blue container) present in all four areas of the ICU.

Procedure per bag:

[WCP] Weighing bag

[WCP] Identifying waste per garbage bag. One to two observant(s) separate the waste using forceps. The content will be separate between the following areas. See list of subsections in excel.

- Used (Criteria: Out of packaging*)
- Unused (Criteria: Still in packaging)

[WCP] The number of gloves and syringes separated will be counted**

[WCP] Each of aforementioned area will be placed in a different garbage bag (8 bags).

[WCP] Each bag will be weighed at the end of the day or when filled.

[WCP] Weighed garbage bags will be placed back in the containers.

* We will only consider this criterion when separating between used or unused as the circumstances does not allow us to be accompanied by an PICU worker that could give us more insights.
** The second observant would also proceed to take photos along the day and complete the excel file.

Results

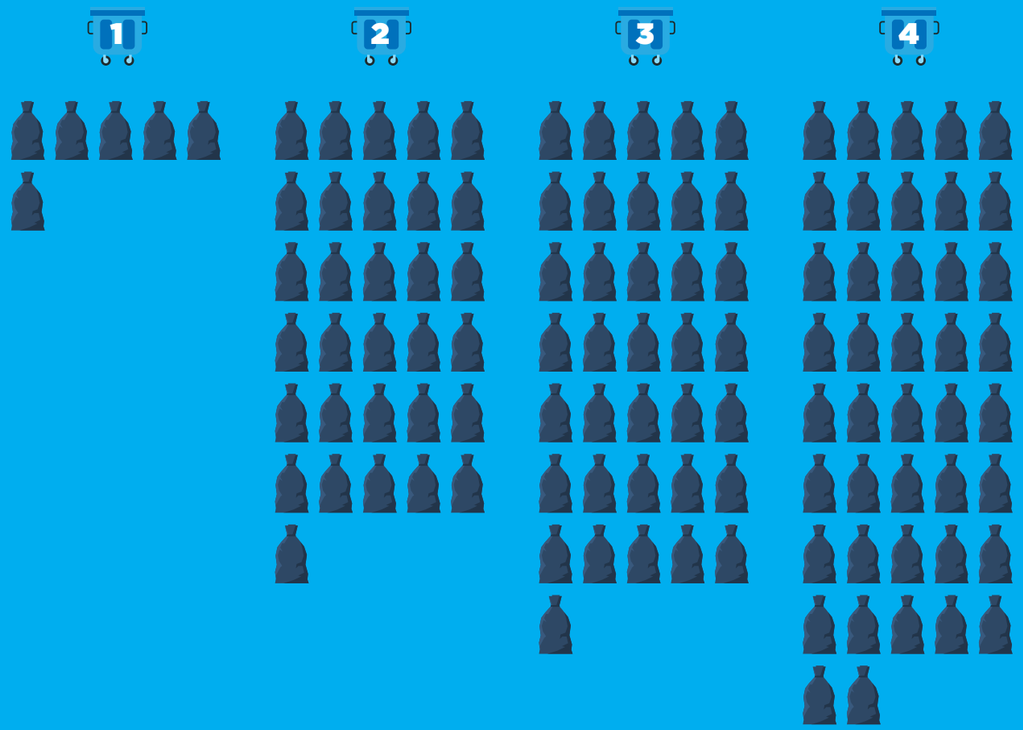


Figure 1. Trash bags per day per unit of the PICU

NB: For Unit 1, the bags might correspond to a longer period of time of between 2 to 4 days.

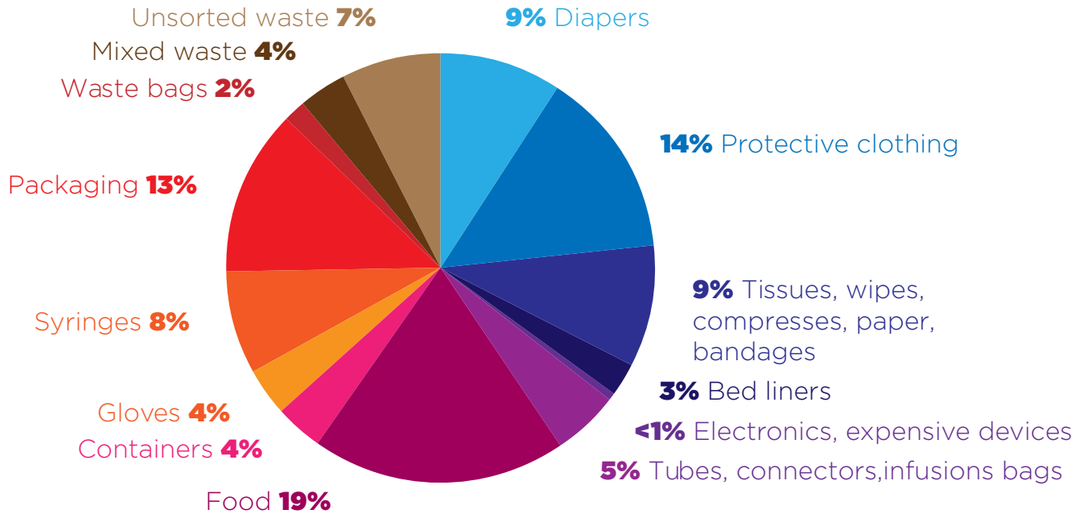


Figure 2. Waste percentages per typology

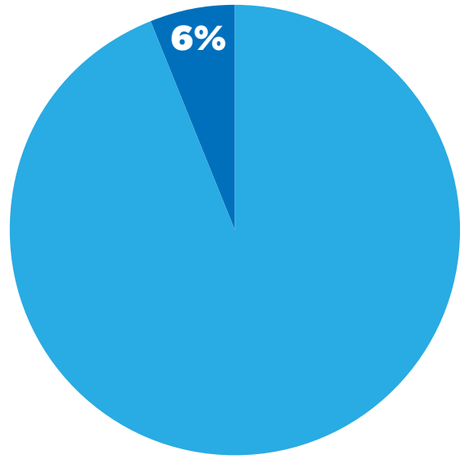
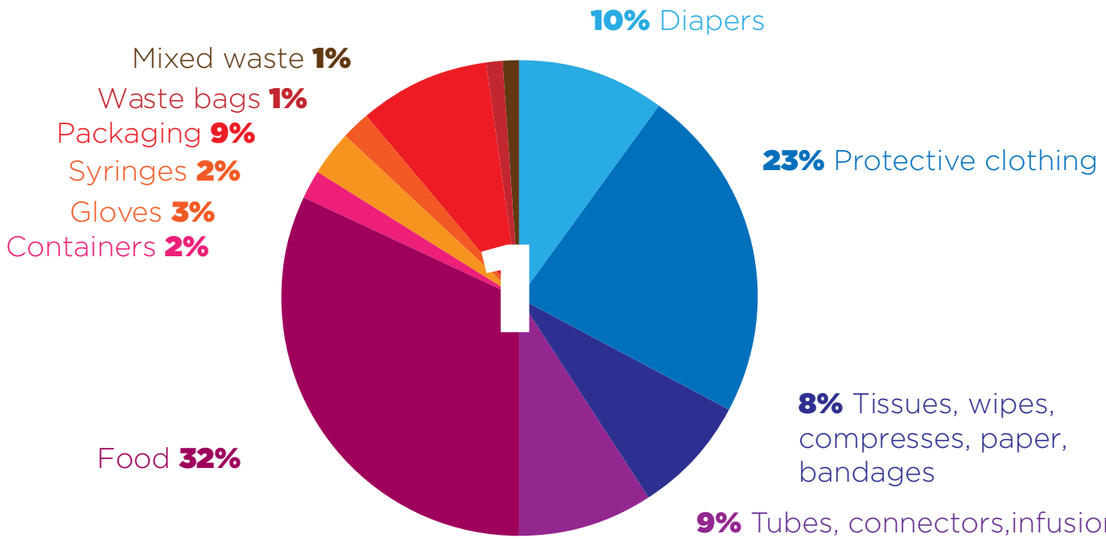
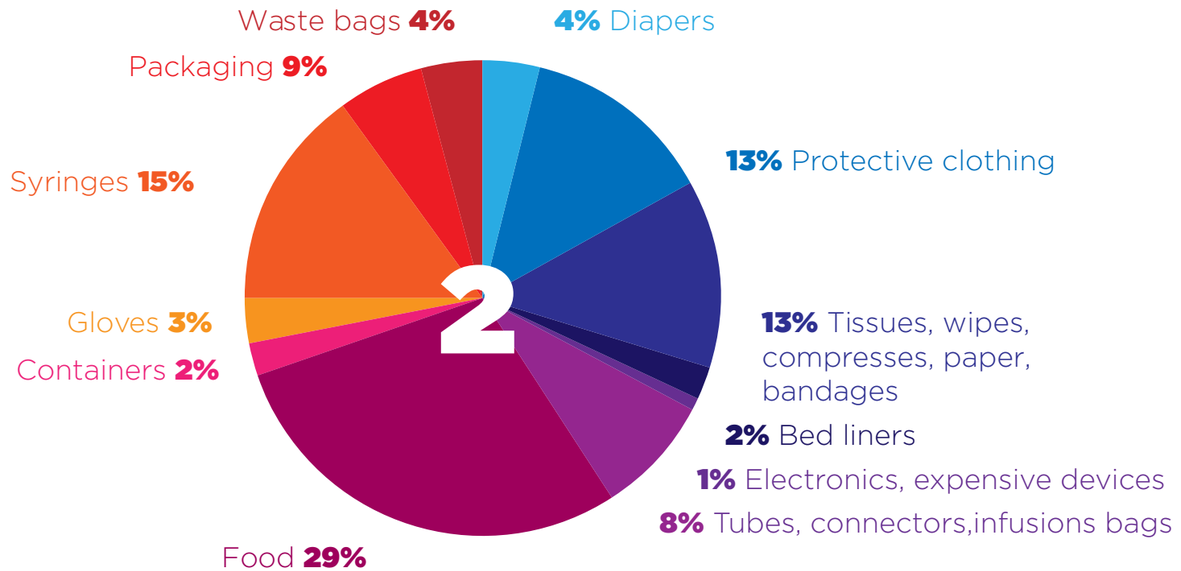


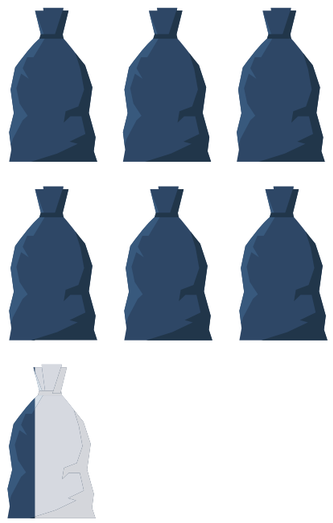
Figure 2. Unused waste percentages from the quantified items

Per unit



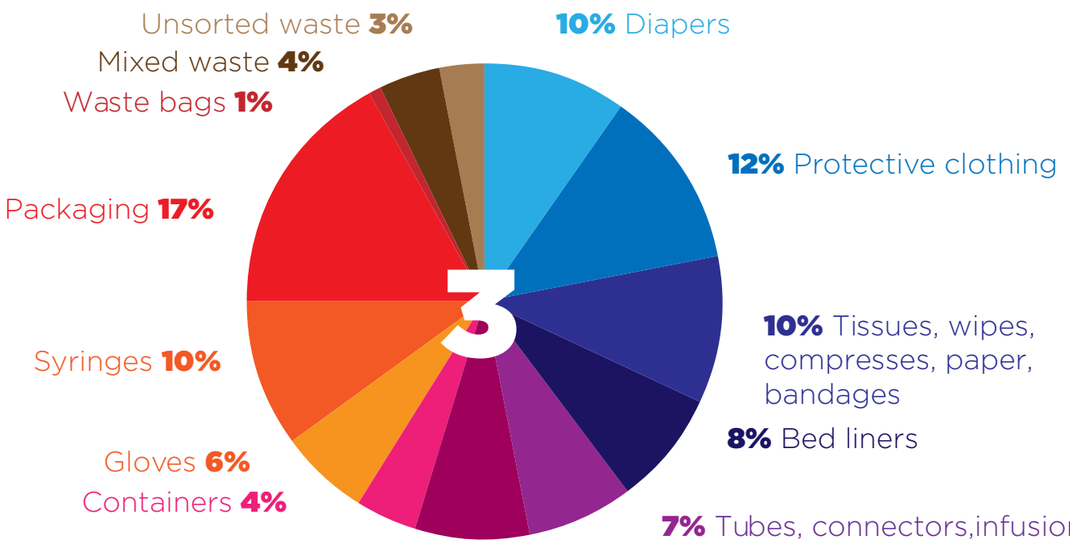


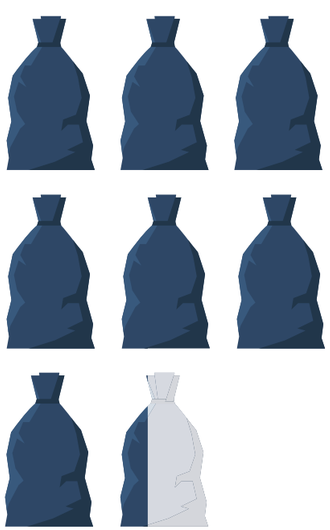
0,6 trash bags per person per day



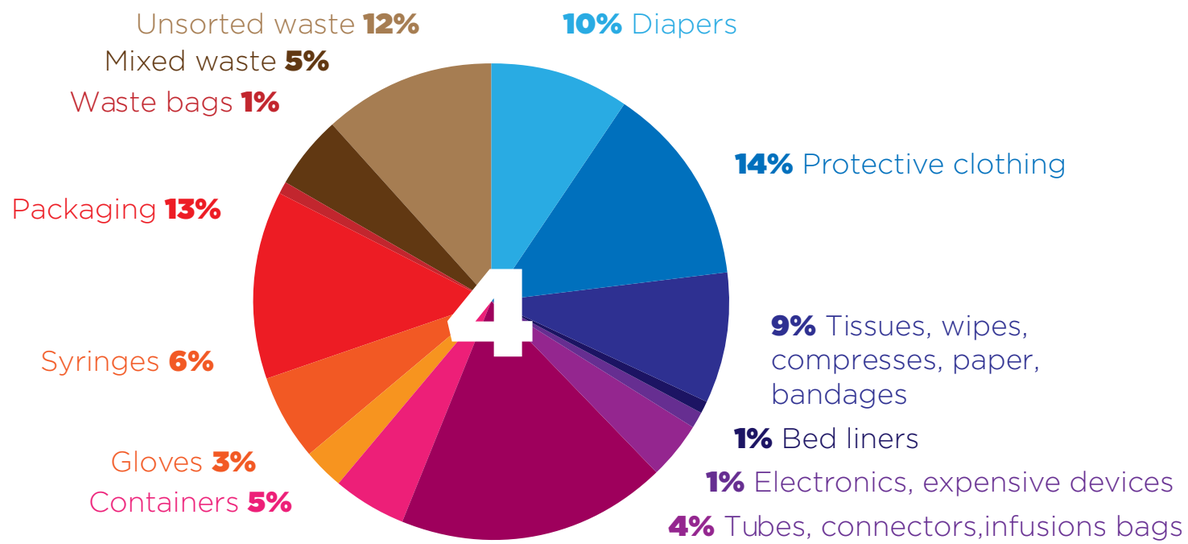
6,2 trash bags per person per day

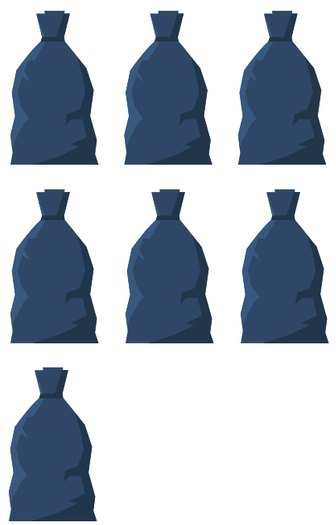
Per unit





7,2 trash bags per person per day





7 trash bags per person per day


TOT HIER HOOGTE OPSLAG


OPSLAG PLASTI


OPSLAG PLASTIC BAKJE


142
351


DANGER

Observations & Recommendations

Limitations study

- Some trash bags contained infectious materials, like blood. Due to the potential danger that this could generate to open such bags, they were consider as unsorted waste.

- A high number of syringes were found with the tubing still connected. As all syringes in this status contained some remaining liquid on the interior, the tubes were not separated, thus counted as syringe-related waste.

- First day weight result resulted slightly unprecise. Although the weighting method was corrected for the following days, these might results on some overall unprecise numbers.

- For some products it was difficult to distinquish whether they were used or unsused: gloves, syringes, some loose tubes. If there was doubt, the products were placed in the used category.

General observations

- The waste generated at area 1 is considerably less than in the other areas of the PICU.

- Gloves were found sometimes filled with liquid, therefore considered as mized waste.

- We could recognize as a pattern that some containers contained a bag we suppose came from the farmacy. This deduction was done as the bag contained mostly packaging from syringes and medication. Here, syringes and tubes are not normally present together but separated.

- Some of the waste found in the green container seemed to be products which should have been disposed differently:

A blanket was found, a supposition was done that this product could have been thrown with liners. Syringes containing blood, glass and needles which seemed hazardous were also found in the green container, although their condition seemed to indicate they should be treated as hazardous waste.

- Waste typologies come highly mixed in some bags. Food related waste can be found in trash bags next to syringes and intubation devices.

Unused devices observations

- The syringes that were thrown away unused were in the mayority containing a medication which had expired. This was not the case for the rest of the unused waste.

- Some baby food containers were found still mostly full in the containers.

- There was a high amount of unused tissues present, but all of them were out of their packages.

- From the unused waste, most is connectors Packed connectors were found in several occasions.

Recommendations

- Staff working at the PICU could be reinstruct about waste separation: This would ensure that all wastestreams are correctly separated.

- Protective clothing resulted on a big amount of the waste, reusable alternatives could be analysed.

- Unit 4 had the biggest amount of waste, studies could be undertaken to understand why is this happening and how to tackle it.

- Food was the biggest amount of waste, which was non hazardous but mixed with the rest. A separation of food waste from the hospital waste could be an alternative to look into

- Implementation of reusable hot water bags instead of filling gloves with hot water.

APPENDIX E

System direction selection

Five system directions were presented in chapter 3. One of the previously presented system direction was chosen. Further ideation focuses on the reprocessing of reusable devices. The systems were compared based on the following criteria:

Actionability: Actionability assesses if the system compels with healthcare regulations.

Scale of impact: Systems are scored depending on their reach. The higher the number of devices it can be applied to, the higher its scale of impact will be scored.

R strategy: Higher-level R strategies will be prioritized as they preserve the product's value in use. It also tells better what circularity can look like, allowing this project to be more relevant for catalyzing future transition.

Level: The system can require more or less stakeholders involvement. The less stakeholders are required, the more actionable the pilot would be.

Table: Selection between different system directions.

	Design for reuse	Design out unused	Keep in flow after use	Biobased future	Reduce use
Actionability	● ○ ○ The system might be challenging some of the current regulations.	● ● ○ The system might be challenging some of the current regulations.	● ● ○ The system might be challenging some of the current regulations	○ ○ ○ The system requires changes in the current healthcare regulation.	● ● ● The system can be done within the current regulation.
Scale of impact	● ○ ○ 80% of devices used during intubation are disposable.	○ ○ ○ 6% of waste are unused devices	● ● ○ This system could have an impact upon all non-hazardous devices, 92% of the waste	● ● ● This system could have an impact upon all devices	● ○ ○ This system could reduce unused (6%) and redundant use (unquantified)
R strategy	● ○ ○ Reuse	● ● ● Refuse	○ ○ ○ Recycle	● ○ ○ Reduce	● ○ ○ Reduce
Level	● ○ ○ The system requires changes in the procedure at EMC and EMC procurement.	● ○ ○ The system requires changes in the procedure at the ICU and involvement of manufacturers for the packaging redesign.	● ○ ○ The system requires changes in the procedure at EMC and involvement of new stakeholders	○ ○ ○ The system requires changes mostly outside of EMC, in the manufacturers.	● ● ● The system requires changes in the procedure at the ICU.
	8	6	5	4	8

APPENDIX F

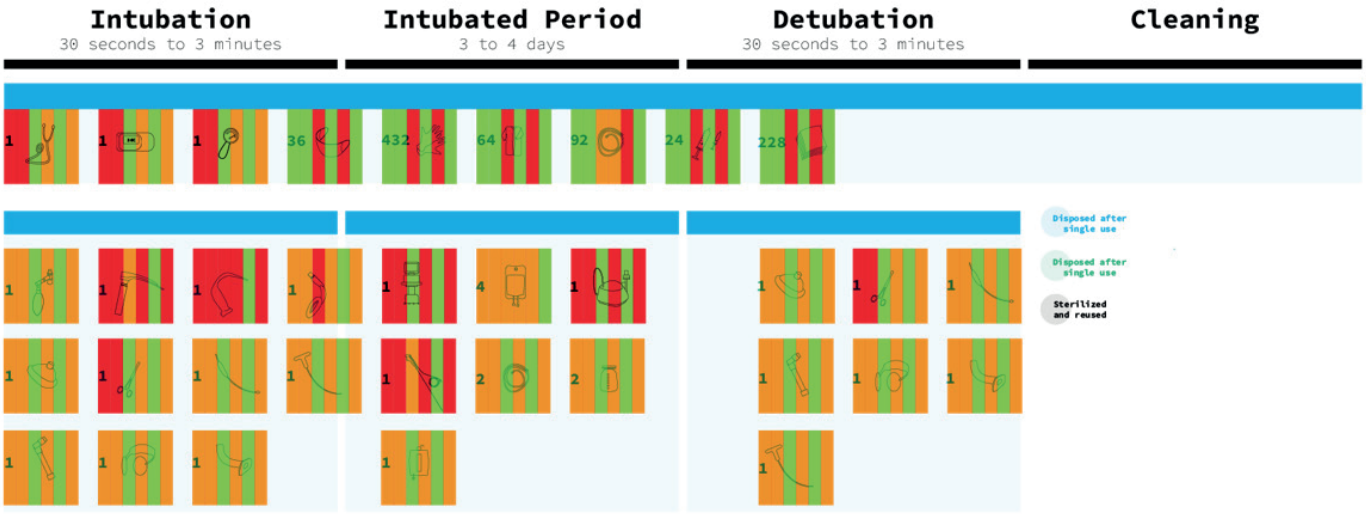
Selection of the example device

The table shows an overview of the different criteria used to evaluate which intubation devices should be selected. The system proposal is built around the mentioned product.
On the next page, we evaluated all devices mapped in the previous chapter with these criteria.

Impact	Is any material used harmful for the environment or toxic for humans? Are they associated with human rights violations? No – Moderately – Yes
Material Criticality	Is the material supply chain easily susceptible to have hiccups leading to not having the device in time and quantities needed at EMC? No criticality – Low to Medium criticality – High criticality
Lifetime	How long is the product used at EMC ICU? Single use – Only throughout the stay of a patient – Reused multiple times
Weight	How much material is used on the device? Lightweight – Moderate amount of material used – Large amount of material used
Material quantity	How many types of materials are used in the device? Monomaterial – A moderate amount of materials – A lot of different types of plastics and materials
Cost	How costly is purchasing each unit of this device to EMC? Unexpensive – Moderate price – High price
Intensity	How many units of the device are used throughout an intubation to a detubation? One – Some – A high number of units

For each device, the criteria were assessed from left to right. The colour coding can be found in the previous table. These indicators allow assessing the impactfulness of the product qualitatively environmentally. Cost, the only financial criterion included, is not represented in the map.

Assumptions or estimations on the materials, costs and weights were made. All devices had been seen beforehand. Hypotheses were based on this observation.



Three products appear as the most impactful ones from the criteria:

- Laryngoscope. EMC ICU procures 175 per year, around 10 euros per unit.
- Video laryngoscope EMC ICU procures 230 per year, around 60 euros per unit.
- Bronchoscope EMC ICU procures 110 per year, around 250 euros per unit.

Other considerations:

All these scopes are disposed of. The laryngoscopes ones after a single-use; meanwhile the bronchoscope can be used multiple times for the same patient and dispose only when the patient has left the ICU room.

The laryngoscope and the video laryngoscope are introduced in the mouth of the patient whereas the bronchoscope is placed until the lungs. Bronchoscope is consider a critical devices whereas laryngoscopes are semi-critical.

The video laryngoscope was chosen because it combines high value and semi-criticality. Lower criticality level allows the reuse system to compels to less strict regulations.

APPENDIX G

Waste quantity, CO2 footprint and cost estimations

Quantity of waste generated - estimation

	Components	Weight (kg)	Cycles
current	VL	0,064	1
	Packaging VL	0,008	1
	Total	0,072	kg
reduce	VL	0,062	1000
	Packaging VL	0,004	1
	Cover	0,008	1
	Packaging cove	0,004	1
	Blue paper cov	0,006	1
	Total	0,022062	kg
Reuse	VL body	0,064	1000
	Packaging VL	0,004	1
	blade	0,052	100
	blade packagin	0,005	1
	wipes	0,005	1
	Total	0,014584	kg

Assumptions:

- We assumed the final redesigned cover and its packaging weights to be equal to the cover test. The tested cover is currently used in the ICU but with another device.
- Numbers for the Reuse scenario were hypothesized based on the weights of the current single-use video laryngoscope.

Weight was measured with a 1g precision scale

Waste quantity per VL usage reduces from 69% and 80% on the two scenarios proposed

	WASTE (kg)		
	CURRENT	REDUCE	REUSE
Quantity waste per VL usage (kg)	0,07	0,02	0,01
Reduction compared to the current scenario		69%	80%

CO2 footprint estimations

Database:

- CO2 footprint product per material from EDUPack 2019, Sustainability Database
- CO2 kg per tkm from FastTrack LCA template
- Combustion Co2 kg/kg from EDUPack 2019, Sustainability Database

Assumptions:
Numbers that were assumed are marked in red in the tables

- The transport of the product from Canada to the Netherlands is hypothesized
- The consumption of the UV-C devices per reprocessing cycle had also to be hypothesized.
- The electricity the VL uses during the intubation procedure is not considered. It is assumed that the CO2 footprint would be the same for all scenarios.
- UV-C devices production, transport, use and end of life are not considered, as the information was not provided by the manufacturers. This would increase the CO2 footprint of both the reuse and reduce scenario.
- All VL electronics are considered as a single component. An assumption was done on the CO2 its production and combustion has.
- Devices packaging were not taken into consideration
- Chemicals in the cleaning wipes were not considered for the CO2 estimation
- Wipes and covers manufacturers transport distance were assumed, hypothesising the transport from another European country.

Uncertainties:

- The percentage of intubations where the VL would enter in contact with patient blood were not assessed. The blade would have to be disposed of in this situation, thus the CO2 footprint and waste would increase.
- The percentage of intubations where the cover would break is not included in this calculation. This would make the CO2 footprint and waste quantity of the reduced scenario increase.

	CO2 (kg)		
	CURRENT	REDUCE	REUSE
CO2 footprint estimation per VL usage (kg)	0,47	0,03	0,08
Reduction compared to the current scenario		94%	83%

CO2 footprint estimation current scenario

PRODUCTION		
Components	Weight (kg)	CO2 Footprint production (kg/kg)
Blade (ABS)	0,062	3,44
Electronics	0,004	8
Total weight	0,066	kg
Co2 footprint production per VL	0,24528	kg

TRANSPORT				
Number of products fitting in a tonne	15152	units		
Distance (km)	40	200	6000	
Medium	Truck	Train	Sea Ship	
Cost (CO2 per tkm)	0,034	0,008	0,008	
Co2 footprint transport per VL	0,00008976	0,0001056	0,003168	0,003363

End of life			
	ABS	Electronics	VL (ABS+electronics)
Incineration (combustion CO2 kg/kg)	3,1	8	
CO2 cost (weight per incineration)	0,1922	0,032	
Co2 footprint VL incineration	0,2242	kg	

CO2 Cost estimation per product per use (production + transport + incineration)	0,47284336	kg

CO2 footprint estimation reduce scenario

PRODUCTION			
Devices	Components	Weight (kg)	CO2 Footprint production (kg/kg)
VL	Blade (ABS)	0,062	3,44
	Electronics	0,004	8
Cover	PE	0,004	1,86

Total weight VL	0,066	kg	Total weight Cover	0,004	kg
Co2 footprint production per VL	0,24528	kg	Co2 footprint production per cover	0,00744	kg
Products per tonne	15151,51515	units	Products per tonne	250000	units

TRANSPORT				
	Transport			
	Medium	Truck	Train	Sea Ship
	Cost (CO2 per tkm, FastTrack LCA)	0,034	0,008	0,008
VL	Distance (km)	40	200	6000
Cover	Distance (km)	50	200	

	VL	Cover	
CO2 footprint per transport	0,00019536	0,0000132	kg

REPROCESSING	
CO2 footprint of a UV-C reprocessing cycle (kg)	0,01 kg

END OF LIFE			
	ABS	Electronics	Cover
Incineration (combustion CO2 kg/kg)	3,1	8	3,12
CO2 fooprint per component (kg)	0,1922	0,032	

CO2 fooprint incineration VL (kg)	0,2242	kg
CO2 fooprint incineration cover (kg)	0,01248	kg

Nmb of cycle reuse of VL	1000
Nmb of cycle reuse cover	1

CO2 Cost estimation per use of VL (production + transport + 1000 reprocessing + incineration)/1000	0,010469675	kg
CO2 Cost estimation of the cover per VL use (production + transport + incineration)	0,0199332	kg
Total	0,030402875	kg

PRODUCTION			
Devices	Components	Weight (kg)	CO2 Footprint production (kg/kg)
body VL	Body (PC)	0,062	4,75
	Electronics	0,004	8
wipes	PP	0,005	3,12
blade	Blade (PC)	0,05	4,75

	Body	Wipes	Blade (hard cover)	
Total weight	0,066	0,005	0,05	kg
Co2 footprint production device	0,3265	0,0156	0,2375	kg
Devices per tonne	15152	200000	20000	units

TRANSPORT				
	Medium	Truck	Train	Sea Ship
	Cost (CO2 per tkm)	0,034	0,008	0,008
Body VL	Distance (km)	40	200	6000
Wipes	Distance (km)	50	200	
Blade	Distance (km)	50	200	

	Body	Wipes	Blade	
CO2 footprint per transport	0,00336336	0,0000165	0,0002178	kg

REPROCESSING	
CO2 footprint of a UV-C reprocessing cycle of non critical devices (kg)	0,01
CO2 footprint of a UV-C reprocessing cycle of a semi critical device (kg)	0,04

END OF LIFE				
	Body		Wipes	Blade
	Body (PC)	Electronics	PP	Blade (PC)
Incineration (combustion CO2 kg/kg)	3,1	8	3,12	3,1
Cost per product	0,1922	0,032	0,0156	0,155

CO2 fooprint incineration Body VL (kg)	0,2242	kg

CO2 fooprint incineration Wipes (kg)	0,0156	kg
CO2 fooprint incineration Blade (kg)	0,155	kg

Nmb of cycle reuse of body	1000
Nmb of cycle reuse of blade	100
Nmb of cycle wipes	1

CO2 Cost estimation per use of body (production + transport + 1000 reprocessing + incineration)/1000	0,00392406
CO2 Cost estimation per use of blade (production + transport + 100 reprocessing + incineration)/1000	0,043927178
CO2 Cost estimation of the wipe per VL use (production + transport + incineration)	0,0312165
Total	0,079067738

Calculation pay-back time estimation

Database:

- Some of the devices' prices were estimated and shared from Erasmus MC procurement.

Assumptions:

- Prices of some were estimated based on online consultation and market price research.
- Nurses' and doctors' training of new devices usage are included within the procurement price

Uncertainties:

- The percentage of intubations where the VL would enter in contact with patient blood were not assessed. The blade would have to be disposed of in this situation, thus the CO2 footprint and waste would increase.
- The percentage of intubations where the cover would break is not included in this calculation. This would make the CO2 footprint and waste quantity of the reduced scenario increase.

PILOT

Devices						Energy usage per use (W)
Name	**Manufacturer - supplier**	**Lot number**	**Quantity**	**Price per lot (€)**	**Total price (€)**	
Electronics VL	GlideScope	1	8	6000	48000	100
Blade 3	GlideScope	1	20	16	320	0
Blade 4	GlideScope	1	10	16	160	0
Covers	__	24	600	305	7625	0
D60	UVSmart	1	2	4000	8000	150
Sealing machine	Gandus	1	2	4000	8000	0
Redesigned blades	__	10	10	100	100	0
Services						
Name	Provider		Quantity	Price per unit	Total price	
Doctors training			2	0	0	
Nurses training			3	0	0	
Installation					600	
R&D budget for collabs required					50000	
Non fixed resources						
	Quantity to treat	Price per kg	Employees	er hour of employe	Total price	
Nurses	0	0	0,25	20	5	
Waste management	0,01	50	0,5	20	10,5	
Electricity usage	250	0,1	0,2	20	29	
Total costs without resources					122805	
Total cost per intubation during X years					85,435	

CURRENT

Devices						Energy usage per use
Name	**Manufacturer - supplier**	**Lot number**	**Quantity**	**Price per lot**	**Total price**	
Glidescope	GlideScope	10	3000	60	90000	100
Non fixed resources						
	Quantity to treat	Price per kg	Employees	er hour of employe	Total price	
Nurses			0,1	20	2	
Waste management	0,07	50	1	20	23,5	
Electricity usage	300	0,1	0	20	30	
Total costs without resources					90055,5	
Total cost per intubation during X years					85,5185	

Extra		
Time	5	years
Intubation	600	per year

Prices		
Electricity	1,49	Eur/w

Prices per scenario		
Reuse	85,44	eur per VL
Dispose	85,52	eur per VL

APPENDIX H

Selection of the ideas
to implement on the pilot proposal

Ideas (order presented)	ICU User Interest	Implementation Speed	Circularity Demonstrator	Environmental impact (EI)
Modular VL	Already connect VL to screen, used to assemble or dissasemble products	Hyrbid devices are already available in the market	Modular would allow repairability and optimize reuse steps for each product part	Only required reprocessing steps will be applied to each part, reducing the EI
Air pipe system	Users already know this system as it is used for medicine transport	Changes in the building required		
Reusable packaging	Additional objects, additional workload			
Automated Cleaning	High interest from user interviewed	Options in the market		
Refuse additional steps	Irrelevant for users	Machine design required		
Optimize sterilization	Irrelevant for users	Machine design required		
Physical infection barrier	Visual clue simplifies process	Available in the market	Optimize reuse of modular devices	Additional part but reduces reprocessing
Product indicators	Visual clue simplifies process	Technology not yet feasible		
Alternative technology	Irrelevant for users	Available in the market	Allow larger devices reuse	Reduces reprocessing footprint

Appendix G: Selection ideation ideas with nurse

User consultation

An ideation session was undertaken with one of the potential users of the system, a nurse. During this session, the different scenarios were presented. The first impression of the nurse on the usability and implementability of the proposal was accessed, and further ideation was done on the ideas that had seemed more accepted by the interviewee. The following takeaways were extracted:

Cleaning, the main pain

The interviewee highlighted that cleaning is the part of the reusing procedure that is the least enjoyed by nurses. They are actually aware of the criticality of the procedure, which provokes stress. Cleaning is neither an enjoyable task compared to others that they find themselves more passionate to fulfil. Finally, they do not feel that reliant on their nurse formation, as cleaning is not their main expertise. as nurses do not

Already disassemble

Separating modular devices would not be a hassle as they are already performing similar tasks separating the disposable video laryngoscope from the reusable screen system.

Clear workflow

The main inconvenience of modularity would be therefore linked to knowing the procedures required for each part.
The same applies to waste separation, or to the use of hard containers.

Miro board of the collaborative ideation validation:
https://miro.com/app/board/o9J_lDH47tY=/

Details on some of the boards:

Pneumatic tube	Trolleys, stored in ICU	Robot
Waste system pipes	**How to transport devices from the ICU to the SD**	Other?

Clean in room	Packed in room, individual ontainer	Trash system
Other?	**How to handle a reusable device?**	Other?

Reuse scenario

	Prepare devices in room	**Assist** intubation	**Clean after** intubation	...	**Clean after** patient leaves room	Bring trash or devices out of the room
Current						
Proposal	Bring box	Box stays in room	Place back in box		Clean exterior box	
					Call pickup	

Automatic, liquid solution	Not cleaning at ICU at all	By hand
Other?	**How to make cleaning of reusable devices hassle free?**	Other?

APPENDIX I

Reprocessing techniques overview

	Technology	Impact	Drawbacks
Cleaning of Non Critical Devices	**Current** Wet cleaning with wipes impregnated in alcohol 70% solution	Material waste generated through wipes and packaging. Do not require energy for usage. Toxicity for humans and environement of the cleaning solution	Not automated
	Pressured water Example: VMARC bed cleaning system	Completely automated Extensive use of water	Controlled environment of bid dimensions is required. VMARC technology specialized in beds. Require a drying time
	UVC Cleaning	Require little electric resources during use. Little dimensions and thus smaller raw material use Larger scope of material disinfection posibilities (non-water proof, etc.)	Certifiifed, still most manufacturers do not include this cleaning technique within their protocol options.
High disinfection of Semi Critical Devices	Gamma technology	No wipes waste associated with the sterilization procedure. he gamma sterilization has environmental benefits in comparison to steam sterilization as no energy is required for the sterilization process itself (Leiden A. Et al. 2020)	High toxicity, needs a controlled environment and dimensions of about a whole buidling.
	Current Autoclave (steam sterilization)	Commonly used and approved by manufacturers as reprocessing technique for cirtical devices	Extensive use of water and electricity. Most plastic do not tolerate the high tempatures this sterilization technique makes use of. Dimensions are too big to be placed in the current ICU layout.
	Hydrogen Peroxide Vapor (HPV)	This steam sterilization is adapted to the specific device cleaned. The dimensions fit therefore the ICU.	Same as for the autoclave.
	UVC Radiation	No use of water, reduces the use of electricity. Available in relatively small dimentions (UVSmart, 2020) and is certified for healthcare usage.	Requires pre cleaning

APPENDIX J

Market comparison video laryngoscopes

GLIDESCOPE® VIDEO BATONS AND GVL® STATS
Verathon

Produced in ---

McGRATHTM MAC Video Laryngoscope
Medtronics

Produced

GLIDESCOPE® SPECTRUMTM TITANIUM
Verathon

futurehealthconcepts

ONTEX Reusable Video Laryngoscope
ONTEX

i-viewTM disposable
intersurgical

GLIDESCOPE® SPECTRUMTM SINGLE-USE
Verathon

Produced in Malasia
Manufacturer in Canada

KING VISION® ABLADETM
Ambu

Manufacturer in the USA

MODULAR	SCREEN - BODY - COVER	BODY - COVER	SCREEN - BODY	BODY - BLADE	BODY - BLADE	NO	SCREEN - BODY	SCREEN - BODY - COVER
REUSABLE	ALL BUT BLADE	ALL BUT BLADE	YES	YES	YES	NO	NO	ALL BUT BLADE
BATTERY	NO	YES	NO	YES	YES	YES	NO	YES
SIMILITUDE CURRENT	SIMILAR TO MC AND GLIDE	NO	SAME SHAPE DIPSOSABLE	NO	NO	NO	YES	NO
	15.000 euros + 16 blade https://www.merkala.nl/mc-grath-mac-9-x1-videolaryngoscoop.html no battery, allows use of reusable stylets	1.500 euros + 10 blade + 34 battery https://www.merkala.nl/mc-grath-mac-9-x1-videolaryngoscoop.html less than $1,000 each when purchased in bulk - Disposable blades require only an upfront purchase and range from $6 to $18 each. - Video laryngoscopes require batteries, which cost from $24 to $50. Batteries last up to 250 minutes and are typically good for up to 100 intubations	4500 euros on ebay opened..		1200 euros piece https://nl.aliexpress.com/item/1005003441832052.html?src=google&aff_fcid=d940d67a0433473ea7396ee57cbf8166-1639659831528-05324-UneMJZVf&aff_fsk=UneMJZVf&aff_platform=aaf&sk=UneMJZVf&aff_trace_key=d940d67a0433473ea7396ee57cbf8166-1639659831528-05324-UneMJZVf&terminal_id=febebe42706a4655bae84db618941fdb	120 euros each piece	65 (on ebay though)	2100 euros each piece

Table 1. **Cost Breakdown for McGRATH and GlideScope Video Laryngoscopes Over 2-Year Period**

	McGRATH units purchased	McGRATH costs	GlideScope units purchased	GlideScope costs	Difference $ (%)
Equipment	36	$54000	15	$226725	172725 (-319.86)
Blades	5501	$55010	5305	$84480	29870 (-54.30)
Batteries	104	$3526	0	No cost	–
Repairs/Losses	15[a]	$22500	3	$14000[b]	8500 (37.77)
Stylets	5501	$10177	20	$700[c]	9477 (93.12)
Total	–	$145212	–	$326305	181093 (-55.50)

[a] Lost devices
[b] Baton replacements
[c] Reusable item

lower (55.5%) for the McGRATH VL compared to the GlideScope over the 24-month period. The mean (SD) monthly costs for GlideScope VL blades were $3837 ($1050) and $3236 ($538) for years 1 and 2, respectively, vs $1652 ($663) and $2933 ($585) for the McGRATH VL blades. Most of the total cost differences were attributed to equipment and blade purchases, which were $202 595 (65.0%) higher for the GlideScope compared to the McGRATH VL. The monthly blade costs alone were higher ($P < .001$) for the GlideScope over the 2-year period; however, the McGRATH VL required use of disposable stylets at a cost of $10 177 for all endotracheal intubations, compared to $700 for the GlideScope device.

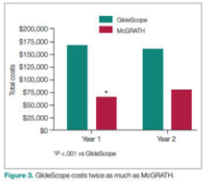


Figure 3. GlideScope costs twice as much as McGRATH.

https://cdn.mdedge.com/files/s3fs-public/JCOM02804174.PDF

This study demonstrated that over a 24-month period use of the McGRATH MAC VL resulted in a cost reduction of around 55% compared to using the GlideScope for endotracheal intubation procedures performed at a major academic center. Over the first 3 months of the COVID-19 crisis, which our study included, use of the McGRATH VL increased while GlideScope use decreased. This was most likely related to the portability and smaller size of the McGRATH, which better facilitated intubations of COVID19 patients.

APPENDIX K TEST COVER

Devices for testing

- Glidescope single use blade LoPro S4 (REF 0270-0939)
- Probetection kit PE sterile (REF 1238-02)

not available, test was done with CIV Flex Transducer cover

- Screen and connecting cables to connect the videolaryngoscope to.
- Some cleaning wipes

Own material: Balance, camera, paper, pen, fixation material, additional plastics covers, tape, hard surface to support papers if needed

Resolution The image sharpness can-not be reduce of more than 10% covering the device with a cover.	R	Spatial Frequency response (SPR)
Distortion Image distortion must be lower than 10%	R	Distortion rate (%)
Falloff Image fallodd cannot be reduced	R	Coparison lightest - darkest (%)
Chromatic aberration Not over brightness should be caused	R	Compari-son brights (%)
Depth of field should not be affected	R	

The test setup has been inspired by the test realized by the Japanese Journal of Trauma and Emergency medicine in 2010. Setup inspiration:

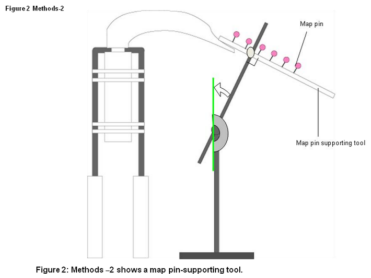
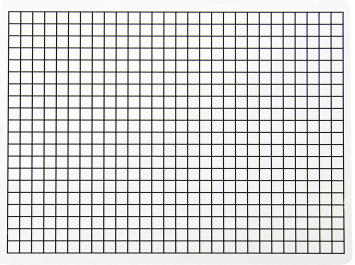
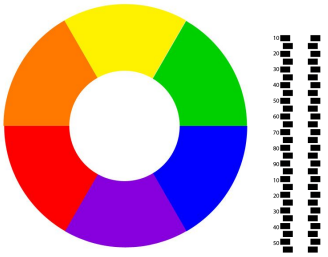


Figure 2: Methods -2 shows a map pin-supporting tool.

Printed images for comparison:



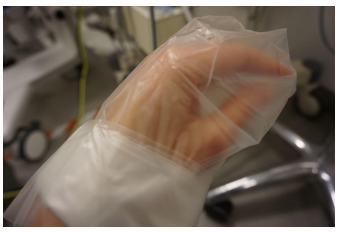


Photos from the test setup:

Results

Testing was intented to be done with a completely transparent covers, but due to lack of availability of this precise cover the day of the testing, two other cover were tested:

- CIV Flex Transducer cover, not completely transparent made from natural latex (a)




- A cover with a transparent plastic packaging was also improvised (b)

Observations

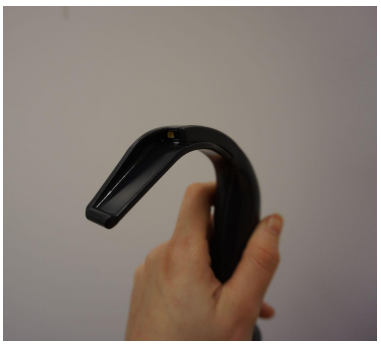
- The cover needs to make use of a highly transparent material for image to be perceptible. Natural rubber latex is not suitable as a material for the cover of the video laryngoscope.
- The cover is too big for the product, generates wrinkles which in turn generate less visibility.


- Other material seem to offer higher visibility, however the visual are from a overall lower resolution
- No distortion of the image is visible.
- The cylindrical shape of the cover does not fit the location of the camera which is located in a corner with the light.
- The higher the distance between the camera and the cover is, the lower the visibility seems to be.

Takeaways for design

- Adapted shape: The cover might need to be shaped to the videolaryngoscope shape. This is already the case done for other scopes such as the one visible here under, a Transesophageal Echocardiography (TEE). This would allow to improve the image by reducing the wrinkles and allowing the plastic to be as close as possible from the camera. Another solution could be to shrink wrap the plastic around the laryngoscope, so to make sure no distance between the camera and the product can disturb the camera vision.

- Material: Further testing needs to be done with higher transparency plastic than the latex one that was available at the ICU.




- Material: Further testing needs to be done with higher transparency plastic than the latex one that was available at the ICU.

VALIDATABLE VACUUM POWER SEALER 520

Robuuste tafelmodel valideerbare vacuüm impulssealer voor het sealen van flexibele folie-verpakkingen

De Audion Valideerbare Vacuüm Power Sealer 520 genereert een veilige en betrouwbare verpakking voor food- en non food producten. De machine is uitgerust met een eenvoudig te bedienen digitaal Audion controlepaneel. De seal- en koeltijd zijn afzonderlijk instelbaar, afhankelijk van het type materiaal. Deze machine is uitgerust met een temperatuur-regelaar en is geschikt voor gebruik in gevalideerde processen.

De machine is uitgerust met een boven en een onder sealbalk. Bij gebruik van relatief dunne laminaten kan de bovenste sealbalk gemakkelijk worden uitgeschakeld op het controlepaneel. De indrukwekkende seal-kwaliteit maakt deze machine geschikt voor vele verschillende toepassingen, ook voor gebruikers van “speciaalfolien”.

- Al onze Valideerbare Power Sealer modellen zijn compatibel met EN 868-5 and DIN 58953, part 7 normen. Onze Val PSR / Val Vac PSR series voldoen ook volledig aan de ISO 11607-2 en ISO/TS 16775
- Extra accessoires en configureerbare opties zijn beschikbaar om aan de verpakkingsvereisten van elke specifieke industrie te voldoen en uw verpakkingsproces te optimaliseren.
- Onze Power Sealer machines zijn ook beschikbaar zonder een geïntegreerde vacuüm- en gas-flush systeem, in een standaard non-valideerbare versie, evenals een heat sealer versie. Voor een overzicht van al onze Power Sealer-modellen klikt u hier

Standaard eigenschappen

- Gebruiksvriendelijk digitaal Audion controlepaneel
- Venturi vacuüm pomp
- Uitgerust met een temperatuur-regelaar
- Compact industrieel design
- Seallengte tot 520 mm
- Grote sealbalk opening: 45 mm
- Bi-actieve sealbalken, geschikt voor gelamineerde en/of dikke folies
- Voetbediening

Voordelen

- Heavy duty design
- Kan gebruikt worden in gevalideerde processen
- De VAL VAC PSR is geschikt voor het produceren van vacuüm and MAP verpakkingen (Modified Atmosphere Packaging)
- Venturi vacuüm pomp
- Sealing length 520 mm
- Grote sealbalkopening: 45 mm
- Mogelijkheid om I sealbalk uit te schakelen
- I seal programma
- Gebruiksvriendelijk digitaal controlepaneel
- Mogelijkheid om de vacuüm / begassingsfunctie uit te schakelen
- Bi-actieve sealbalken geschikt voor gelamineerde en/of dikke zakken
- Machine kan worden uitgerust met een support
- Horizontale en verticale sealpositie in combinatie met een support
- Pneumatische sluiting van de sealbalken (geen oververhitting van de elektromagneten)
- Machine gebouwd volgens de laatste richtlijnen

Accessoires

- Werktafel – Bevestigd aan de machine ter ondersteuning van de te sealen verpakking
- Support – De machine bevestigd op een support maakt het mogelijk de machine in hoogte en seal-hoek te verstellen
- Cleanroom support – Frame is stofdicht, de machinehoogte en seal-hoek zijn te verstellen. (Bag

support en/of rollerbaan optie zijn op deze support niet mogelijk)

- Bag support – Bevestigd aan het support-frame ter ondersteuning van de te sealen verpakking
- Rollerbaan – Roller conveyor bevestigd aan het support-frame zodat de machine kan worden ingezet in een semi-automatisch productie-proces. Tevens kunnen zwaardere producten gemakkelijk in de juiste seal-positie worden gerold

Opties

- Kalibratie opties – Kalibratie certificaat van Audion of van een geaccrediteerd laboratorium
- Cleanroom oplossing – Silicone-arme machine, Electrostatic Discharge aansluitingen, externe uitlaat voor het afvoeren van gebruikte perslucht buiten de ruimte
- IQ/OQ VAL – Betreft IQ/OQ check certificaat and gebruiks- en onderhoudstraining door een Audion servicemedewerker
- Bekijk verschillende Power Sealer opties in 3D in onze 3D configurator: klik
- Wilt u meer informatie ontvangen met betrekking tot een passende oplossing voor uw verpakking-vereisten: neem contact met ons op via customerservice@audion.com

Markten

- Farmaceutische industrie
- Medische industrie
- voedingsmiddelen industrie
- Industriële onderdelen
- Cleanroom omgeving

SPECIFICATIES

Product	VAL VAC PSR 520
Artikelnummer	520 MVMED-2
Seallengte	520 mm
Sealbreedte	8 mm
Type machine	Valideerbaar/kalibreerbaar/medisch, Vacuümsealer
Model	Tafel/Vloer
Covering	RVS
Mes	Ja/Nee
Voetbediening	Ja
Type folie	PA/PE, Vacuümzakken
Foliedikte	2 X 200 micron
Voltage	230V-lph-50/60 Hz
Venturi pomp	ll,3 m3/h
Persluchtaansluiting	⊠ 6 bar
Afmetingen machine	6l0 x 497 x 242 mm
Consumptie	2500 W
Type verpakking	Zak
Branche/toepassing	Farmaceutische industrie, Medische sector
Type product	Vloeistof, Granulaat, Poeder, Solide

APPENDIX M

Makrolon® 2458

Grades / Medical devices

MVR (300 °C/1.2 kg) 19 cm³/10 min; medical devices; suitable for ETO and steam sterilization at 121 °C; biocompatible according to many ISO 10993-1 test requirements; low viscosity; easy release; injection molding - melt temperature 280 - 320 °C; available in transparent and opaque colors

ISO Shortname

PC

	Property	Test Condition	Unit	Standard	typical Value
					-
Rheological properties					
C	Melt volume-flow rate	300 °C/ 1.2 kg	cm³/10 min	ISO 1133	19
	Melt mass-flow rate	300 °C/ 1.2 kg	g/10 min	ISO 1133	20
C	Molding shrinkage, parallel	60x60x2 mm/ 500 bar	%	ISO 294-4	0.65
C	Molding shrinkage, normal	60x60x2 mm/ 500 bar	%	ISO 294-4	0,70
	Molding shrinkage, parallel/normal	Value range based on general practical experience	%	b.o. ISO 2577	0.5 - 0.7
Mechanical properties (23 °C/50 % r. h.)					
C	Tensile modulus	1 mm/min	MPa	ISO 527-1,-2	2400
C	Yield stress	50 mm/min	MPa	ISO 527-1,-2	65
C	Yield strain	50 mm/min	%	ISO 527-1,-2	6.1
C	Nominal strain at break	50 mm/min	%	ISO 527-1,-2	> 50
	Stress at break	50 mm/min	MPa	ISO 527-1,-2	70
	Strain at break	50 mm/min	%	b.o. ISO 527-1,-2	130
C	Tensile creep modulus	1 h	MPa	ISO 899-1	2200
C	Tensile creep modulus	1000 h	MPa	ISO 899-1	1900
	Flexural modulus	2 mm/min	MPa	ISO 178	2350
	Flexural strength	2 mm/min	MPa	ISO 178	97
	Flexural strain at flexural strength	2 mm/min	%	ISO 178	7.1
	Flexural stress at 3.5 % strain	2 mm/min	MPa	ISO 178	73
C	Charpy impact strength	23 °C	kJ/m²	ISO 179/1eU	N
	Charpy impact strength	-60 °C	kJ/m²	ISO 179/1eU	N
	Charpy notched impact strength	23 °C/ 3 mm	kJ/m²	ISO 21305/based on ISO 179/1eA	65P
	Charpy notched impact strength	-30 °C/ 3 mm	kJ/m²	ISO 21305/based on ISO 179/1eA	14C
	Izod notched impact strength	23 °C/ 3 mm	kJ/m²	ISO 21305/based on ISO 180/A	65P
	Izod notched impact strength	-30 °C/ 3 mm	kJ/m²	ISO 21305/based on ISO 180/A	15C
C	Puncture impact properties - maximum force	23 °C	N	ISO 6603-2	5100
C	Puncture impact properties - maximum force	-30 °C	N	ISO 6603-2	6000
C	Puncture energy	23 °C	J	ISO 6603-2	55
C	Puncture energy	-30 °C	J	ISO 6603-2	65
	Ball indentation hardness		N/mm²	ISO 2039-1	115
Thermal properties					
C	Glass transition temperature	10 °C/min	°C	ISO 11357-1,-2	146
C	Temperature of deflection under load	1.80 MPa	°C	ISO 75-1,-2	125
C	Temperature of deflection under load	0.45 MPa	°C	ISO 75-1,-2	139
C	Vicat softening temperature	50 N; 50 °C/h	°C	ISO 306	145
	Vicat softening temperature	50 N; 120 °C/h	°C	ISO 306	146
C	Coefficient of linear thermal expansion, parallel	23 to 55 °C	10^{-4}/K	ISO 11359-1,-2	0.65
C	Coefficient of linear thermal expansion, normal	23 to 55 °C	10^{-4}/K	ISO 11359-1,-2	0.65
C	Oxygen index	Method A	%	ISO 4589-2	28
	Thermal conductivity, through-plane	23 °C; 50 % r. h.	W/(m·K)	ISO 8302	0.20
	Resistance to heat (ball pressure test)		°C	IEC 60695-10-2	138
	Flash ignition temperature		°C	ASTM D1929	480
	Self ignition temperature		°C	ASTM D1929	550

Makrolon® 2458

	Property	Test Condition	Unit	Standard	typical Value
Electrical properties (23 °C/50 % r. h.)					
C	Relative permittivity	100 Hz	-	IEC 60250	3.1
C	Relative permittivity	1 MHz	-	IEC 60250	3.0
C	Dissipation factor	100 Hz	10^{-4}	IEC 60250	5.0
C	Dissipation factor	1 MHz	10^{-4}	IEC 60250	90
C	Volume resistivity		Ohm·m	IEC 60093	1E14
C	Surface resistivity		Ohm	IEC 60093	1E16
C	Electrical strength	1 mm	kV/mm	IEC 60243-1	34
C	Comparative tracking index CTI	Solution A	Rating	IEC 60112	250
Other properties (23 °C)					
C	Water absorption (saturation value)	Water at 23 °C	%	ISO 62	0.30
C	Water absorption (equilibrium value)	23 °C; 50 % r. h.	%	ISO 62	0.12
C	Density		kg/m³	ISO 1183-1	1200
	Bulk density	Pellets	kg/m³	ISO 60	660
Material specific properties					
	Refractive index	Procedure A	-	ISO 489	1.586
	Haze for transparent materials	3 mm	%	ISO 14782	< 0.8
	Luminous transmittance (clear transparent materials)	1 mm	%	ISO 13468-2	89
C	Luminous transmittance (clear transparent materials)	2 mm	%	ISO 13468-2	89
	Luminous transmittance (clear transparent materials)	3 mm	%	ISO 13468-2	88
	Luminous transmittance (clear transparent materials)	4 mm	%	ISO 13468-2	87
Processing conditions for test specimens					
C	Injection molding - Melt temperature		°C	ISO 294	280
C	Injection molding - Mold temperature		°C	ISO 294	80
C	Injection molding - Injection velocity		mm/s	ISO 294	200
Recommended processing and drying conditions					
	Melt temperatures		°C	-	280 - 320
	Standard Melt temperature		°C	-	300
	Barrel Temperatures - Rear		°C	-	250 - 260
	Barrel Temperatures - Middle		°C	-	270 - 280
	Barrel Temperatures - Front		°C	-	280 - 290
	Barrel Temperatures - Nozzle		°C	-	290 - 300
	Mold Temperatures		°C	-	80 - 120
	Hold Pressure (% of injection pressure)		%	-	50 - 75
	Plastic Back Pressure (specific)		bar	-	50 - 150
	Peripheral Screw Speed		m/s	-	0.05 - 0.2
	Shot-to-Cylinder Size		%	-	30 - 70
	Dry Air Drying Temperature		°C	-	120
	Dry Air Drying Time		h	-	2-3
	Moisture Content max. (%)		%	-	<= 0,02
	Vent Depth		mm	-	0.025 - 0.075

C These property characteristics are taken from the CAMPUS plastics data bank and are based on the international catalogue of basic data for plastics according to ISO 10350.

Impact properties: N = non-break, P = partial break, C = complete break

Makrolon® 2458

Disclaimer

Typical value

These values are typical values only. Unless explicitly agreed in written form, the do not constitute a binding material specification or warranted values. Values may be affected by the design of the mold/die, the processing conditions and coloring/pigmentation of the product. Unless specified to the contrary, the property values given have been established on standardized test specimens at room temperature.

General

The manner in which you use and the purpose to which you put and utilize our products, technical assistance and information (whether verbal, written or by way of production evaluations), including any suggested formulations and recommendations are beyond our control. Therefore, it is imperative that you test our products, technical assistance, information and recommendations to determine to your own satisfaction whether our products, technical assistance and information are suitable for your intended uses and applications. This application-specific analysis must at least include testing to determine suitability from a technical as well as health, safety, and environmental standpoint. Such testing has not necessarily been done by Covestro. Unless we otherwise agree in writing, all products are sold strictly pursuant to the terms of our standard conditions of sale which are available upon request. All information and technical assistance is given without warranty or guarantee and is subject to change without notice. It is expressly understood and agreed that you assume and hereby expressly release us from all liability, in tort, contract or otherwise, incurred in connection with the use of our products, technical assistance, and information. Any statement or recommendation not contained herein is unauthorized and shall not bind us. Nothing herein shall be construed as a recommendation to use any product in conflict with any claim of any patent relative to any material or its use. No license is implied or in fact granted under the claims of any patent. With respect to health, safety and environment precautions, the relevant Material Safety Data Sheets (MSDS) and product labels must be observed prior to working with our products.

Covestro Medical Grades

For more information on Covestro products in Medical Applications, please request from your sales support contact our Guidance document: GUIDANCE ON USE OF COVESTRO PRODUCTS IN A MEDICAL APPLICATION.

Recommended Processing and Drying Conditions

Barrel temperatures are valid for a standard 3-zone barrel. Temperature set-up for different barrel types may change according to configuration. Values for hold pressure as percentage of injection pressure may vary depending on, amongst others, part geometry, injection molding machine and injection mold. Drying conditions are for dry air dryers only. Drying times and drying temperatures may differ depending on valid dryer type. Further information is provided by your local Covestro support as well as in the following brochures: Injection Molding of High Quality Molded Parts - Drying; Determining the Dryness of Makrolon by TVI Test; The fundamentals of shrinkage in thermoplastics; Shrinkage and deformation of glass fiber reinforced thermoplastics [...]. https://www.plastics.covestro.com/Library/Overview.aspx

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