BEST PRACTICES OF SUSTAINABLE OPERATING FOR OR-COMPLEXES

A review towards providing an overview of Dutch initiatives in three university medical centers. Intended to clarify the best practices.

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Bachelor: Health Sciences
Date: 01-07-2022
Final version

Management summary (English version)

This thesis aims to clarify the best practices of environmentally sustainable initiatives in the operating room. Additionally, this thesis gives advice on measuring environmentally sustainable practices in the operating room by selecting Key Performance Indicators (KPIs).

Problemdefinition

The operating room (OR) is seen as one of the largest carbon dioxide (CO_2) contributors in a hospital and produces 70% of the total waste of a hospital. Several Dutch ORs have started initiatives to decarbonize the OR. However, there is a lack of overview of what the best practices are to make the OR more sustainable. Research is done to create an overview of best practices and select key performance indicators to measure the performance in environmental sustainability in the OR. Thus this thesis answers the following research question:

"What are best practices within sustainability projects in the OR-compleesx of Leiden UMC, Radboud UMC, and Amsterdam UMC?"

Approach

An overview of best practices has been made to solve the core problem. First, the current situation is worked out by means of a literature review to gain insight into the different initiatives there are and what makes them the best practices. Second, interviews have been conducted to get insight into the performance of three Dutch University Medical Centres (UMCs) and Isala hospital. Lastly, literature reviews were done on environmental sustainable key performance indicators to create tools for Isala to measure its sustainability performance in both the entire hospital and the OR-complex.

Sustainable initiatives

The overview of best practices in the 9R-framework of this research shows the initiatives ranked in the recovery options from the framework. The initiatives target different categories such as waste management and energy consumption. The data for this overview was gathered by both literature review and interviews with stakeholders from the hospitals.

Some of the most well-known initiatives are the Rethink initiatives of replacing aneastethic gases such as sevoflurane, desflurane and isoflurane in the future and use propofol and turning of all the lights, machines and other OR equipment when not in use can save expences and CO_2. Occupancy sensors, motion detectors or timers can be helpful to minimize energy waste. An ongoing trend is the replacement of single use products with re-usable ones. The re-usable options tend to be less polluting, more circular and result in less waste. Another best practice is repairing, refurbishing or remanufacturing more expensive, high-complexity equipment to extend the life of these products.

Selection of KPIs

Isala hospital has expressed the ambition to work towards a more data-driven way of becoming sustainable. In addition, to determine if a sustainable strategy is working and results in positive results the progress should be monitored. The selected KPIs indicate the

performance for sustainability, as stated in the Green Deal sustainable care and can be used as a translation of the (future) sustainability goals set by the board of Isala.

The KPIs target four topics: Energy, Emissions, Circularity (waste management), and procurement. To provide more insight and a better overview of the sustainability performance the KPIs can be put into a performance dashboard. The KPIs enable measurement to understand both the current situation but will mainly help determine the hotspots and progress. Implementing them into a performance dashboard will provide insights into the performance of sustainable activities.

Conclusion

The result of this thesis provides a starting point for Isala to make their OR and hospital more sustainable by measuring and monitoring their sustainable performance and learning from best practices. However, Isala must set clear goals in order for the KPIs to be effective. Implementing the best practices and measuring their environmental performance will help the hospital reach the goals of the Green Deal. Becoming more sustainable will take a lot of time, effort, and money from the hospital. Besides that, all the activities should be measured and mapped, so that they can be improved and further researched. Considering future research, the number of KPIs can still be expanded to measure more specifically.

This research has shown that few hard figures are available yet. Eventhough there are already a lot of sustainable initiatives in hospitals and especially in the OR targeting the reduction of waste. Therefore, an important future research implication is that hospitals, just like Isala hospital, have to measure and monitor sustainability performance better to determine what the best practices are and how well they are reducing their emissions. With hard figures, initiatives can be compared with each other in the most expressive way to determine what best practice are in the several circular categories. Isala hospital is quite ambitious regarding sustainability, but is not yet tackling the problem in a methodological way for which the adviced KPIs can bring guidance until other research has brought answers to the comparisons between initiatives.

Management summary (Dutch version)

Het doel van deze thesis is het onderzoeken van de 'best practices' van ecologisch duurzame initiatieven in de operatiekamer. Alsmede het geven van advies over het meten van duurzame milieu 'practices' in de operatiekamer door het selecteren van 'key performance indicators'.

Probleem definitie

De operatiekamer (OK) wordt gezien als een van de grootste bijdragers in de CO_2 uitstoot van een ziekenhuis en de OK produceert 70% van het totale afval van een ziekenhuis. Verschillende Nederlandse OK's zijn initiatieven gestart om de uitstoot van CO_2 te verminderen. Er ontbreekt echter een overzicht van wat de 'best practices' zijn om de OK te verduurzamen. Er is onderzoek gedaan om een overzicht van 'best practices' te creëren en 'key performance indicators' te selecteren om de prestaties op het gebied van ecologische duurzaamheid in de OK te meten. Deze thesis beantwoordt dus de volgende onderzoeksvraag:

"Wat zijn 'best practices' binnen duurzaamheidsprojecten in het OK-complex van Leiden UMC, Radboud UMC en Amsterdam UMC?"

Methode

Om het kernprobleem op te lossen is een overzicht gemaakt van 'best practices'. Eerst is de huidige situatie uitgewerkt door middel van literatuuronderzoek om inzicht te krijgen in de verschillende initiatieven, die er zijn en wat heb tot een 'best practices' maakt. Ten tweede zijn er interviews afgenomen om inzicht te krijgen in het functioneren van drie Nederlandse University Medical Centres (UMC's) en het Isala. Ten slotte zijn er literatuuronderzoeken uitgevoerd naar ecologische duurzame 'key-performance indicators' om indicaties te creëren waarmee Isala haar duurzaamheidsprestaties in zowel het hele ziekenhuis als het OK-complex kan meten.

Duurzame initiatieven

Het overzicht van 'best practices' in het 9R-raamwerk van dit onderzoek toont de initiatieven gerangschikt in de herstelmogelijkheden uit het raamwerk. De initiatieven zijn gericht op verschillende categorieën, zoals afvalbeheer en energieverbruik. De gegevens voor dit overzicht zijn verzameld door zowel literatuuronderzoek als interviews met 'stakeholders' uit de ziekenhuizen.

Enkele van de meest bekende initiatieven zijn de Rethink-initiatieven om anesthesiegassen zoals sevofluraan, desfluraan en isofluraan in de toekomst te vervangen en propofol te gebruiken en alle lichten, machines en andere OK-apparatuur uit te schakelen wanneer ze niet in gebruik zijn, dit kan kosten en CO_2 besparen. Aanwezigheidssensoren, bewegingsdetectoren of timers kunnen nuttig zijn om energieverspilling te minimaliseren. Een aanhoudende trend is de vervanging van producten voor eenmalig gebruik door herbruikbare. De herbruikbare opties zijn doorgaans minder vervuilend, meer circulair en resulteren in minder afval. Een andere best practice is het repareren, opknappen of herfabriceren van duurdere, complexere apparatuur om de levensduur van deze producten te verlengen.

Selectie van KPI's

Isala heeft de ambitie om te werken aan een meer evidence based manier van verduurzamen. Om te bepalen of een duurzame strategie werkt en positieve resultaten oplevert, moet bovendien de voortgang worden gecontroleerd. De geselecteerde Key Performance Indicators (KPI's) weergeven de prestatie op duurzaamheid, zoals vermeld in de Green Deal duurzame zorg en kunnen worden gebruikt als 'vertaling' van de (toekomstige) duurzaamheidsdoelen die het bestuur van Isala stelt.

De KPI's richten zich op vier thema's: Energie, Emissies, Circulariteit (afvalbeheer) en Inkoop. Om meer inzicht en een beter overzicht te geven van de 'sustainability performance' kunnen de KPI's in een 'performancedashboard' worden gezet. De KPI's maken het meten van duurzaamheid mogelijk, om zowel de huidige situatie te begrijpen, maar ook als ondersteuning bij het bepalen van de hotspots en voortgang. Door ze te implementeren in een prestatiedashboard krijgt u inzicht in de prestaties van duurzame activiteiten.

Conclusie

Het resultaat van deze thesis biedt een startpunt voor het Isala om hun OK en ziekenhuis groener te maken, door hun 'sustainability performance' te meten en te monitoren. Ook helpt het bij het leren van de 'best practices'. Om de KPI's effectief te laten zijn, moet Isala echter duidelijke doelen stellen. Door de best practices te implementeren en hun milieuprestaties te meten, kan het ziekenhuis de doelstellingen van de Green Deal bereiken. Verduurzamen kost het ziekenhuis veel tijd, moeite en geld. Daarnaast moeten alle activiteiten gemeten en in kaart gebracht worden, zodat ze verbeterd en verder onderzocht kunnen worden. Mogelijkheden voor toekomstig onderzoek omvat het uitbreiden van het aantal KPI's om zo specifiekere metingen te doen.

Uit dit onderzoek blijkt dat er nog weinig harde cijfers beschikbaar zijn. Ziekenhuisenen vooral de OK hebben al veel duurzame initiatieven gericht op het terugdringen van verspilling. Daarom is een belangrijke implicatie voor toekomstig onderzoek dat ziekenhuizen, net als het Isala, duurzaamheidsprestaties beter gaan meten en monitoren om te bepalen wat de beste praktijken zijn en hoe goed ze hun uitstoot verminderen. Met harde cijfers kunnen initiatieven op de meest impactvolle manier met elkaar vergeleken worden om te bepalen wat de best practice zijn in de verschillende circulaire categorieën. Isala ziekenhuis is behoorlijk ambitieus op het gebied van duurzaamheid, maar pakt het probleem nog niet methodologisch aan waarvoor de geadviseerde KPI's houvast kunnen bieden totdat ander onderzoek antwoorden heeft gegeven op de vergelijkingen tussen initiatieven.

Acknowledgments

The past five months in writing my thesis was one of the best experiences of my career which included learning, experiencing and exploring the 'working' world and implementing the knowledge obtained in the previous two-and-a-half years of my bachelor studies at the University of Twente.

This thesis would not have been possible without the assistance and contributions of a number of people to whom I owe acknowledge.

Firstly, I am wholeheartedly thankful to my supervisor Jacqueline Bosker from Isala hospital for believing in me and offering the freedom in finding a thesis topic at Isala. Jacqueline, thank you for supporting me during my time at Isala and introducing me to so many stakeholders. I have really enjoyed working with you. I would also like to extend my thanksgiving to Christa Baas-Albers for always being so approachable and helping me with your insights.

Next, I would like to express my gratitude to my university supervisors prof. dr. ir. Erwin W. Hans and dr. Patricia B. Rogetzer for your support and reassurance that have helped me to get into the right mindset. Patricia, thank you for your valuable insights. Erwin, thank you for this opportunity to do my thesis in sustainability in health care.

I am incredibly grateful to my parents for providing me with this opportunity to pursue my degree in Health Sciences at the UT. Thanks to my boyfriend for being my backbone through this whole adventure.

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List of abbreviations

Carbon dioxide (CO_2)
Carbon dioxide-equivalents (CO_2-eq)
Greenhouse Gas (GHG)
Health Carbon Footprint (HCF)
Key Performance Indicator (KPI)
Life Cycle Analysis (LCA)
Operating room (OR)
Organisation for Economic Co-operation and Development (OECD)
Research question (RQ)
The International Organization for Standardization (ISO)
The National Health Service (NHS)
The United Nations' Sustainable Development Goals (SDGs)
United Kingdom (UK)
University Medical Center (UMC)
World Health Organisation (WHO)

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1. Introduction

This chapter delves deeper into the context of the Dutch hospitals' journey to sustainability and expands on the challenges and practices that form the foundation for this research. The goal of this research is to create an overview of sustainable initiatives in the operating room (OR), collect data from these initiatives and derive best practices. This chapter introduces the research that is carried out at three Dutch hospitals: Radboud University Medical Center (UMC), Amsterdam UMC, and Leiden UMC with support from Isala Hospital in Zwolle. Section 1.1 introduces the topic, Section 1.2 presents the problem definition with the accompanying problem identification, problem cluster, action and core problems, and problem-solving approach. Thereafter, Section 1.3 outlines the research questions of this research. Section 1.4 provides an overview of the deliverables of this research.

1.1 Introduction to the topic

The health care industry is one of the most polluting service sectors in the industrialized world [1]. More than 7% of the total carbon dioxide (CO_2) emissions in the Netherlands are caused by the health care industry. Some of these emissions come directly from hospitals, others originate from the supply chain of the health care goods and services [2]. If the health care industry was a country, it would be the fifth-biggest CO_2 emitting country in the world. If operations continue to go on like this, the pollution that comes from health care can triple between now and 2050 [3]. All these CO_2 emissions contribute to climate change, which harms both our current and future health [4]. Reducing the carbon footprint of the health care industry will moderate the incidence of human disease and therefore also contribute to the prevention of health risks. Reducing the emissions by switching to thinking more circular instead of consuming and throwing away will contribute to a more safe and healthy world. By signing the Green Deal for sustainable care, various hospitals have taken on a best-efforts obligation to reduce CO_2 emissions and with that give increasing priority to circularity [5].

The CO_2 emissions of hospitals and other care facilities are the sum of various sources, making sustainability within hospitals a broad and challenging concept. Sustainability in hospitals is not only about the use of more sustainable materials, but also about housing, airflow, energy consumption, waste separation, anaesthetic gases, and transport of materials and patients [6]. More and more sustainability projects are being started in Dutch hospitals, but there is no overview of which hospital is doing what. Many hospitals, both top clinical and UMCs, have signed the Green Deal whereafter they started so-called Green Teams to work more sustainably. Green Teams consist of health care professionals who research within their department or hospital how they can make their area of expertise more sustainable.

Currently, there is a Dutch national Green Team for the ORs in which various UMCs work together to share some of their sustainable practices. There is no cooperation yet for researching common "best" practices together. This leads to a lack of overview of what exactly is being researched and what is successful in terms of CO_2 reduction. This knowledge gap hinders the continuous improvement in the field of sustainability in the OR.

In this research, the sustainability practices of three UMCs are assessed in addition to practices from literature. The focus on UMCs was made due to the results of initial unstructured interviews with a diverse group of stakeholders such as hospitals, manufacturers and health care purchasing organizations. The outcome of these interviews

was that UMCs are generally already further in their development of sustainable practices compared to most categorical, topclinical, and general hospitals. In this thesis, the focus primarily lies on environmental sustainability. The environmentally sustainable initiatives from three UMCs OR-complexes (also called surgical complexes) are included in this review, these are Radboud UMC, Amsterdam UMC, and Leiden UMC. Additionally environmentally sustainable initiatives from literature and Isala Hospital are taken into account.

This report is written in cooperation with Isala Hospital in Zwolle. This hospital has, just like the three included UMCs, signed the Green Deal for sustainable care and is looking for ways to lower their CO_2 emission and work more circularly. This report aims to create more clarity on what practices are already done in the medical area and which ones are the most successful in terms of CO_2 reduction and circularity. With this knowledge, Isala wants to implement more sustainable practices in their hospital.

1.2 Problem definition

The OR is seen as one of the largest CO_2 contributors in a hospital and is also referred to as the "waste factory" of a hospital [7]. Surgical complexes use a relatively large amount of material, including a large number of disposable products. As a result, they produce a lot of waste. There has been a 15% annual increase in the waste produced by hospitals, part of this is due to the trend of using disposable medical products [8]. Approximately 20% to 30% of all hospital supplies and 70% of its total waste volume originate from ORs [9, 10]. Next to the high amount of waste, ORs contribute emissions through anaesthetic gases, energy-intensive medical equipment and lighting, and a 24/7 operating schedule [11]. Unlike other departments parts of the operating complex, the Emergency Room and radiology department must be working 24/7. Due to the significant contribution to the health care system's environmental footprint, the OR is considered to be an important target for sustainability initiatives [7].

In Figure 1 the problem cluster of environmental sustainability in the OR states that the core problem behind the action problem "no continuous improvement in environmental sustainability" is "no overview of what the best solutions are for the OR". Several sustainable initiatives (such as reduction in sevoflurane, a polluting inhalation anaesthetics, and the use of reusable OK hats) have already been started for Dutch ORs, but at this time there is no overview of what the "best" solutions or practices are to make the OR more sustainable. The lack of overview is due to the indistinctness of which hospital is doing what. Additionally, there has not been a comparison of the results of these practices. It is expected that Isala hospital will benefit from gaining a better overview of the best solutions and thus making their hospital more sustainable. Some initiatives target the separation of waste (e.g. Amsterdam UMC), others, for instance, target the reduction in the amount of waste (as can be seen in the use of reusables instead of disposables). Environmental sustainability initiatives pose many challenges since they alter standard procedures for infection control, policy and regulatory restrictions, and a cultural shift in the system itself [12, 13].

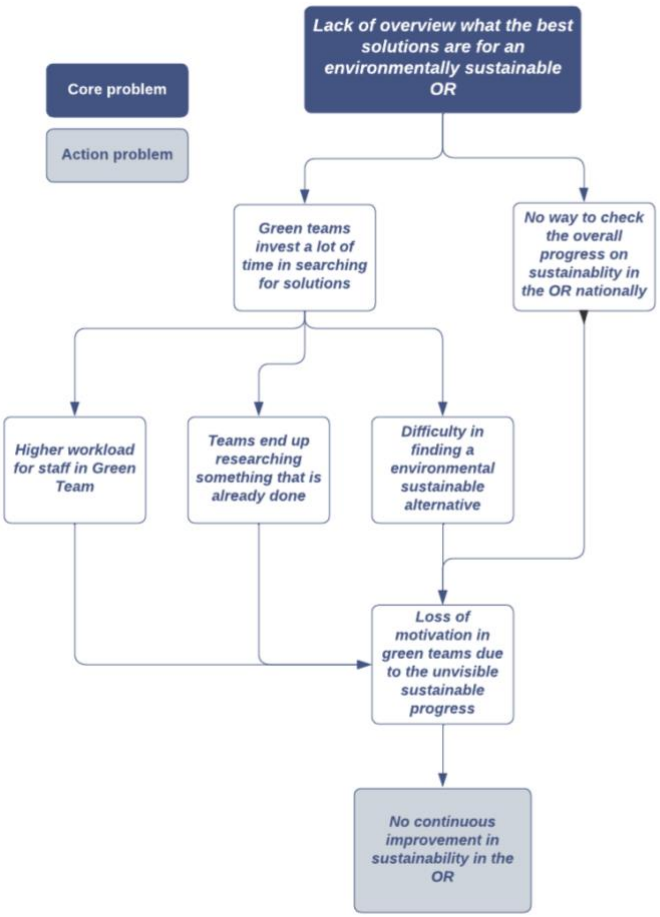

Figure 1: Problem Cluster

1.3 Research objective

The goal of this research is to solve the core problem of unclarity in the best practices for an environmentally sustainable OR-complex. The definition of best practices used in this thesis is that best practices comprise the most recent, relevant, and helpful methods, interventions, procedures, or techniques based on high-quality evidence [14]. A best practice should be implemented to improve a patient's individual health outcomes, the quality of care, and strengthen the health care system [15]. Best practices in the health care field are a set of guidelines, ethics, or ideas that represent the most efficient or prudent course of action in a situation [16]. In the case of environmental sustainability projects in the OR, a best practice should be a project that is the most helpful in reducing the CO_2 footprint of the OR and therefore the most sustainable. The focus of this research is to create clarity in successful environmentally sustainable practices in other hospitals and how to measure these practices by identifying key performance indicators (KPIs).

Main RQ: "What are best practices within sustainability projects in the OR-complex of Leiden UMC, Radboud UMC, and Amsterdam UMC?"

Furthermore, the main research questions is further decomposed into two main research objectives consisting of sub-research questions:

Research Objective 1 (RO1):

- To investigate the current practices of OECD countries in literature and those of three UMCs from both literature and interviews.
- To compare the current practices based on circularity by ranking the practices within the 9R framework of circularity.

RQ1- What are the environmentally sustainable practices in hospitals from OECD countries already done in the OR-complex that can be found in literature?
RQ2- What are the environmentally sustainable practices done in the OR-complex of Leiden UMC, Radboud UMC, and Amsterdam UMC?

Research Objective 2 (RO2):

- To design a performance dashboard for environmental sustainability, KPIs are selected from literature
- To investigate which existing environmentally sustainable practices are applicable in the OR-complex of Isala

RQ3- What KPIs can be used to measure sustainability performance and should be selected for Isala?
RQ4- What are the current and future environmental sustainability projects in the OR-complex of Isala hospital?

The sub-research questions above were developed in order to merge and contribute to conclusive advice. RQ1 and RQ3 will be answered using secondary sources (published literature), whereas RQ2 is a combination of interviews and literature. RQ4 is completely based on the outcomes of interviews. The sub-questions are answered sequentially during the research and presented in this report.

1.4 Report outline

This report serves as an advisory report for a possible implementation of sustainable practices and performance indicators in the OR. This report will first map the current practices from a literature review and the practices used in the three selected UMCs and Isala hospital. After having provided an overview, KPIs are selected to be able to compare sustainable practices in the future. The results of these KPIs highlight the best practices for CO_2 reduction and circularity. Ultimately, this report considers that it can provide advice on the best solutions for sustainability practices in the OR. This will create more clarity and lead to continuous improvement in sustainability in the OR. Table 1 shows the structure of the thesis report derived from the research.

Chapter	Research questions (if applicable)
1. Introduction	
2. Theoretical Framework	
3. Methodology	
4. Sustainable initiatives in the OR	RQ1- What are the environmentally sustainable practices in hospitals from OECD countries already done in the OR-complex that can be found in literature?

	RQ2- What are the environmentally sustainable practices done in the OR-complex of Leiden UMC, Radboud UMC, and Amsterdam UMC? RQ4- What are the current and future environmental sustainability projects in the OR-complex of Isala hospital?
5. Key performance for a "Green OR in Isala"	RQ3- What KPIs can be used to measure sustainability performance and should be selected for Isala?
6. Discussion	
7. Conclusion	

Table 1: Report outline

1.5 Summary Chapter 1

In the beginning of this chapter, a small introduction has been given about the pollution from healthcare and in specific that of the OR-complex. After that, a problem description has been described, in which the core problem has been formulated. The aim of the research is to create an overview of best practices of environmentally sustainable practices in the operating room and give insight in measuring performance by selecting key performance indicators. To solve the core problem a set of research questions has been developed. At the end of the chapter, the outline of the report is described to show what can be expected in this thesis.

2. Theoretical Framework

In this chapter, the relevant literature regarding sustainability in the OR and the amount of pollution from hospitals will be elaborated on concerning forming a theoretical background for this bachelor thesis. First, the literature about the polluting effects of health care and in particular the OR will be discussed. Second, sustainable policy in the Netherlands and hospitals will be discussed. Last, the literature about the R-ladder of circularity, Lansink's ladder and the Triple Bottom Line is discussed.

2.1 Pollution from health care

The health care sector is socio-economically important and causes a significant amount of CO_2 emissions. The majority of the health carbon footprint (HCF) finds its origin along the supply chain. The footprint, as calculated in the study of Pichler et al. [1], accounts for CO_2 emissions that occur anywhere along the global supply chain of goods and services purchased by the health care system. In this study, the Netherlands has an 8.1% share of the total national carbon footprint, which is the highest HCF of the OECD countries included in this study. The health care sector can therefore be a major contributor to the reduction of CO_2 emissions [1]. According to the Gupta report of 2019, the approximation of the total carbon footprint of health care in the Netherlands accounts for 7% [17]. The percentage of estimated CO_2 emission share of Dutch health care differs between 7% (the result of the Gupta Report) and 8.1% (the result of the study by Pichler et al. [1]).

By signing the Green Deal for sustainable care, various hospitals have taken on a best-efforts obligation to reduce CO_2 emissions and prioritize circularity. The goal is to realize a CO_2-neutral health care sector by 2050 [5]. This requires that the CO_2 footprint is reduced by 7 to

8.1% per year in the coming years. Due to the negative effects that climate change has on global health, there is a burden of responsibility for health systems. The carbon footprint expresses the amount of greenhouse gases (GHG) emitted in CO_2-equivalents (abbreviated to CO_2-eq). There are three scopes that are taken into account when calculating the emissions for the footprint. The first scope are emissions that fall under the direct control of the facility. The second scope takes emissions into account that derive from electricity purchased by the facility. The third scope includes all other indirect emissions [18].

The health care infrastructure has a big influence on the GHG-emissions. Hospitals have a high demand for heating, electricity, transport, lighting, ventilation, air conditioning, and electric and electronic equipment [19]. Next to this, hospitals are also major consumers of medical goods and equipment, which are often produced under polluting conditions. These hospitals all create significant amounts of all types of waste. This waste ranges from food to pharmaceuticals to plastics [6]. Simply put, there are two types of waste that a hospital produces: hazardous and domestic waste. To convince hospitals to implement more sustainable and circular practices, the practices should mostly be cost-saving and therefore financially attractive [20]. This indicates a trade-off between environmental and economic benefits, which is in line with the triple bottom line of sustainability. This concept is eleborated on in section 2.4. Additionally, environmental practices can motivate the health care workforce and build employee morale [21].

OR-complexes are the biggest polluters within a hospital since they consume three to six times more energy per square foot than any other department in the hospital. Next to this, 30% of the total waste and two-thirds of biohazardous waste result from the OR [22]. The OR is a challenging environment to experiment with new techniques since there are high standards in infection prevention amongst other quality and safety measures [7].

2.2 Environmental policy in health care

In 2015 the Paris Agreement was signed by 196 parties at COP 21 in Paris [23]. It was signed to combat climate change internationally and to limit global warming. To achieve this goal, all participating countries must lower their emission levels by 28% in 2025, 45% in 2030, and to nearly zero Greenhouse Gas (GHG) emissions by 2050. Climate change is driven by GHG emissions. CO_2 makes up most of the GHG emissions, which is why interventions that combat climate change target a reduction in CO_2 emissions [24]. On average 4-5% of the total GHG emissions of a country, and even more than 7% in the Netherlands, come from the health care sector. Therefore, health care needs to play a central role in combatting climate change [1].

In reaction to the Paris Agreement and the Gupta report, the Dutch Ministry of Health, wellbeing, and sports together with various health care organizations came up with the Green Deal for sustainable care [5, 17, 23]. The Green Deal is about the contribution of the health care sector toward improving the environment. It targets reducing CO_2 emissions, reducing pharmaceutical residues in surface- and groundwater, and stimulates a circular economy. Additionally, its goal is to create a health care environment that invites healthy behavior [5].

The main priority of the Dutch health care industry will remain to deliver high-quality care, but increasing priority must be given to sustainability.

In the United Kingdom, there has been a CO_2 reduction strategy for the health care sector in place since 1992 [17, 25]. Yearly, the CO_2 footprint of the health care industry there is calculated by the National Health Service (NHS). The structured approach in this country can be an example of innovative, inspiring work since they have been the first OECD country to estimate their CO_2 footprint [25]. The NHS method used in the United Kingdom is also used in the report of Gupta for calculating the CO_2 footprint of the Dutch health care sector. The Dutch calculation must be seen more like an estimation than a calculation [17]. However, even with this limitation this report has made sustainability a priority in Dutch health care and has shown the necessity to tackle this issue.

Environmental policy in Dutch hospitals is mainly based on the International Organization for Standardization (ISO) 14000 series, the Environmental Thermometer for Care, and the United Nations' Sustainable Development Goals (SDGs). Various ISO standards from the ISO 14000 series are used in the environmental policy [26]. The most commonly used standard in hospital environmental policy is the ISO 14001 standard, which is used to set up and certify environmental management systems. Hospitals use the environmental thermometer for care because they find it to work clearer and more concisely. The thermometer gives medals for doing more than what is asked for by environmental legislation, for example, sustainable procurement and transparent reporting [5].

2.3 Circularity

Circularity is considered an economic model in which, among other aspects, waste is being reused again and again [27]. Therefore, the Circular Economy is described as being an economic system in which waste is prevented, minimized, or even completely reused [28]. Circularity is not only about reusing waste; the definition of the Ellen MacArthur Foundation clarifies it as being restorative or regenerative by intention and design [29]. The circular economic model is opposed to the linear economic model of consumption, which is based on the ‘take, make, dispose’ philosophy. Circularity does contribute to sustainability, but while circularity focuses on the resource cycle, sustainability is considered to be broader [30].

The enthusiasm for circularity is high in the Netherlands and growing worldwide [30, 31]. Circularity is seen as a solution for the shortages of supplies in supply chains and the environmental pressure of the extraction of natural resources. Circularity does not only take the CO_2 emission reduction into account but also the environmental impact of products or services during their life cycle [28]. Life cycle assessment is a method to determine the total environmental impact of a product during its entire life cycle [32]. The entire life cycle includes the process from extracting the necessary raw materials to production, packaging, transport, use, and waste processing. An LCA is necessary to determine whether something is socially and environmentally responsible to purchase and use. It is an assessment that captures all emissions from ‘cradle to grave’ [18].

The transition towards a circular economy is a long process, wherein it is important to continuously monitor the progress [30]. The goal of monitoring is to assess the feasibility of the desired effects. The goal of circularity in the OR of a hospital, and therefore its

contribution to environmental sustainability must be clarified for it to take place. To be able to compare a new intervention with the old way, a base year must be set and the environmental impact must be calculated for both old and new interventions [4].

The 9Rs framework for circularity stands for Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle and Recover [30]. The first R is the most circular and the last Rs are less circular. The rule of thumb to take into account with this framework is that the higher the level of circularity, the fewer natural resources are used and the less environmental pressure the product chain results in. This framework by Potting et al. (2017) results in a strategy to ensure that the materials and products retain their highest value possible and stay relevant towards the end of their life. The 9R framework is a circularity ladder, which focuses on product chains. This means a product is tracked from the extraction of natural resources to the waste treatment [33].

Refuse, Rethink and Reduce form the shortest loop in the R-framework (see Figure 2), they ensure smarter product use and manufacturing which results in the elimination of waste. In the shortest loop, fewer primary materials are required because they can be used for a longer period, this leads to a reduction in environmental pressure of resource extraction [30, 33]. The medium loops of the R-model are Reuse, Repair, Refurbish, Remanufacture and Repurpose (see Figure 2). The main goal of these recovery options is to extend the lifespan of products and parts. Products are recovered and used in another way [30, 33]. The longest loops in the R-framework are Recycle and Recovery (see Figure 23). They require some sort of process to reuse materials and create new value. Most of the time the processed materials do not result in a high-end product, but they are used again [30, 33].

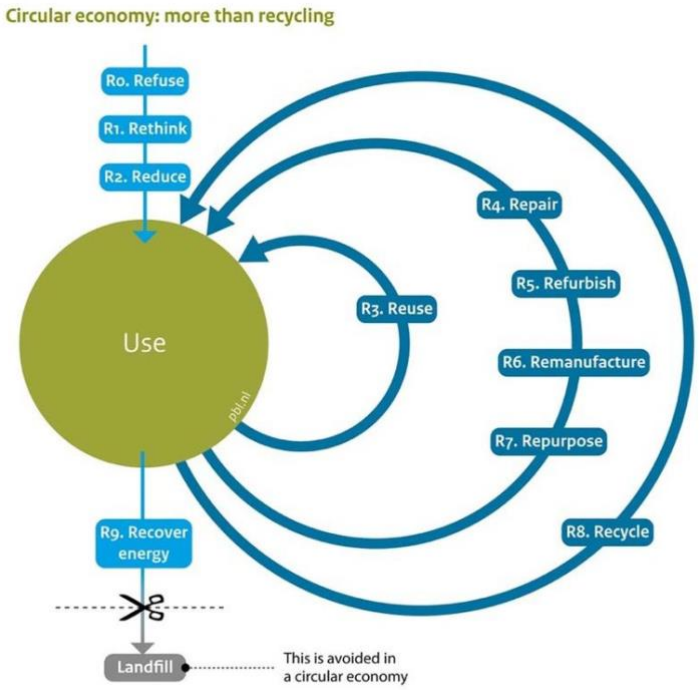

Figure 2: R-ladder of circularity strategies by PBL [30]

Environmentally friendly health care has gained momentum in the health industry [34]. In health care, there has been an adoption of circular practices. The COVID-19 pandemic has stimulated this, one of the examples is that disposable face masks were re-used after sterilization. The shortage in face masks during the pandemic led to health care institutions seeking an approach to reuse facemasks instead of buying new masks [35]. A well-known circular practice in health care is the recovery option rethink of inhalation anaesthetics [36]. Since total elimination of their use is presumably not possible, a reduction in use and a more efficient way of inhaled anaesthetic delivery have been shown to be possible in combination with an intravenous anaesthetic [36-40].

The ladder of Lansink is a sequence of preference for waste management and resource conservation options, it is also called a waste hierarchy. This waste hierarchy specifies the ranking of how to reduce and manage waste, from most beneficial to least beneficial actions. The ladder of Lansink as developed in 1979 consists of the following steps: Reduce, Reuse, Recycling, Energy Recovery, Incineration, and Landfill (see Figure 3). The ladder stimulates a circular economy and promotes sustainability because it offers opportunities for waste minimization [33]. Compared with the 9R framework of circularity strategies, the ladder of Lansink considers priority ranks in waste through five stages instead of 9, the most preferred being prevention and the least being disposal. The essential principle in circular waste management policymaking is “reduce” [41]. The R-based principles of the circular economy are highly related to the waste hierarchy. The difference between the two models is that the ladder of Lansink still allows disposal and the R-framework does not. Since it is not yet clear if the total refusal of all types of waste is possible in health care, this waste hierarchy might be better suited for this industry [33]. Circular strategies and the ladder of Lansink share similar goals in waste management by reducing the environmental impact, mitigate resource depletion and avoiding waste incineration [33, 42].

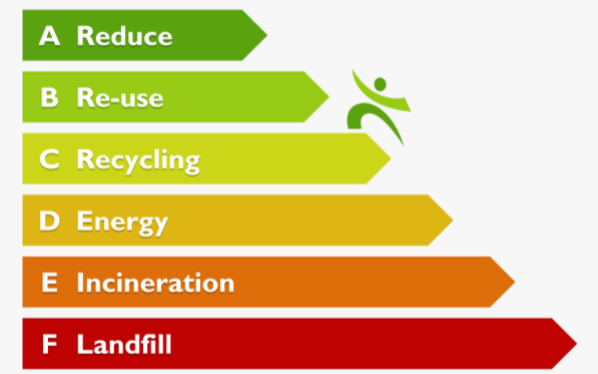

Figure 3: Waste Hierarchy Lansink’s ladder [43]

2.4 Sustainability

Sustainability is a word and concept which is used in a variety of ways and there are different interpretations. Sustainability is treated superficially, but for most industries that take the subject seriously, the concept of sustainability embraces efficient use of resources, continual social progress, stable economic growth, and the eradication of poverty [44].
The triple bottom line is one of the most widely known definitions of sustainability. This definition focuses on three pillars: social (people), economic (profit) and environment (planet)

[45]. The meaning of sustainability is thus not restricted to the environmental (planet) aspect, but also comprises economic and social elements (see Figure 4). The concept is that organizations should focus as much on the social and environmental pillars as on the economic pillar.

Figure 4: The Triple Bottom Line [46]

The triple bottom line has, in theory, equal emphasis on each pillar, however, there often is a trade-off between the pillars. Environmental initiatives can lead to economic barriers, such as a higher cost of a product. This can lead to an economic-environment trade-off where the willingness to pay extra for a planet-friendly product is central. Likewise, environmental sustainability focuses on improving human welfare, which is more focused on the social pillar of the triple bottom line. An environment-social tradeoff could therefore be protecting the sources of raw materials used for human needs and ensuring that the sinks for human wastes are not exceeded to prevent harm to humans. Environmental sustainability seeks to sustain global life-support systems indefinitely [47]. The focus of studies on sustainable health care is therefore mostly focused on decarbonizing the health system to prevent climate change and the harm that comes with that [34]. Simply put, environmental sustainability is concerned with reducing the environmental footprint by minimizing the negative impact on the environment. The three pillars together aim for sustainability which enhances the quality of life as stated in Figure 4.

2.5 Summary Chapter 2

The second chapter aims to provide a theoretical framework to build on in the following chapters. The health care sector causes a significant amount of CO_2 emissions and therefore the Green Deal for sustainable care has been signed by various hospitals [5]. The environmental impact of health care is measured in the carbon footprint, which expresses the number of greenhouse gases emitted in CO_2-equivalents. Carbon footprints are primarily based on estimations rather than on calculations [17].

Circularity is seen as a solution for the shortages of supplies in supply chains (such as for health care) and the environmental pressure of the extraction of natural resources. Circularity does not only take the CO_2 emission reduction into account but also the environmental impact of products or services during their life cycle [28]. The 9R-framework is a circularity ladder, with on top a high level of circularity with few natural resources and less environmental pressure and on the bottom a low level of circularity. The goal is to eliminate

waste. The ladder of Lansink is a sequence of preference for waste management and resource conservation options. It specifies how to reduce and manage waste, from most beneficial to least beneficial actions [33].

The triple bottom line is one of the most widely known definitions of sustainability. This definition focuses on three pillars: social (people), economic (profit), and environment (planet) [45]. Environmental sustainability seeks to sustain global life-support systems indefinitely [47]. The focus of studies on sustainable healthcare is therefore mostly focused on decarbonizing the health system to prevent climate change and the harm that comes with that [34].

3. Methodology

In this third chapter, the research methodology for the bachelor thesis is discussed. The research approach, case description, data collection methods, data analysis, and research ethics are discussed.

3.1 Research approach

This thesis zooms in on the different initiatives that are already in use in OECD countries and three different UMCs, with the purpose to create an overview and determine their environmental sustainability performance.

So far, overview studies on the effects of sustainable initiatives in the Netherlands seem to be close to non-existent. This study aims to create an overview of the sustainable initiatives in the OR, collect data from these initiatives and estimate their degree of sustainability by putting the initiatives into the 9R framework. The objective of this study is to identify leading, safe and efficient practices to promote environmentally friendly and efficient efforts in surgical health care. This study aims to focus on both circularity and CO_2 reduction since these are the two most important greening measurement outcomes found in the literature [48, 49]. Studying the different sustainable initiatives may provide relevant insights for both the future development of sustainable health care and the theoretical results of CO_2 emissions reduction. For this purpose, the overview and recommendation from this thesis can serve as a guideline for Isala hospital and other hospitals to understand what initiatives have the best effect and therefore get inspired on what sustainable initiatives they can implement and/or further develop. Additionally, this study aims to identify general environmentally sustainable KPIs for projects in the OR and other hospital departments.

To answer the main research question: *"What are the best practices within sustainability projects in the ORs of Leiden UMC, Radboud UMC, and Amsterdam UMC?"*, a qualitative deductive exploratory research approach is used. A combination of methods is needed to gain in-depth knowledge about the current situation regarding various sustainable projects in hospitals, map the existing sustainability projects, and derive KPIs. Therefore, this study is a combination of a descriptive case study and a systematic review, that attempts to extend and strengthen current knowledge on sustainability in health care in the Netherlands. The research is carried out based on unstructured in-depth interviews with stakeholders of the various UMCs, Isala hospital, data analysis, and literature review. The environmental data on the sustainable practices from the hospitals are provided by the hospitals themselves.

To understand whether the sustainable practices are performing well, to quantify this performance measurement tools are needed. To indicate the performance of sustainability KPIs can be used. The KPIs are selected and formulated to fit into the 9R-framework and ladder of Lansink. Therefore they include both indicators for circular performance and for reducing their carbon footprint. These two main themes are chosen because an initiative that is very environmentally sustainable in CO_2 reduction does not necessarily have to contribute to circularity [30, 48]. The selected KPIs aim to improve the homogeneity in the assessment methods, provide objective evidence of the performance, and therefore offer a comparison. The KPIs are used to advise Isala on what to implement in their hospital and what to measure.

3.2 Data collection and analysis

Multiple methods were used to collect data, namely gathering data through literature review, semi-structured interviews, and data provided by the UMCs of their own practices. This collection of methods provides a comprehensive view of the sustainability initiatives of the three UMCs.

First, a literature review on relevant theories was performed in order to get more knowledge on the subject and create a theoretical framework on which to build on in this thesis. For the theoretical framework a combination of both scientific sources and websites is used. To create the overview on best practices in the OR a literature review was done, combined with five interviews. For the fifth chapter a literature review was done to set KPIs for the collected environmental data from the sustainable practices. The selection of the KPIs from literature is done by comparing the possible indicators to the internal documentation of Isala hospital on their waste and sustainability management.

Interviews with the hospitals were conducted during April and May of 2022. The interviewees from the hospitals were initially contacted by e-mail which included the aim of the research followed by the aim of the interview. All interviewees were asked to sign an informed consent form. The aim of the interviews was to to create an overview of the initiatives in the three UMCs and Isala and to determine what practices could be implemented in Isala hospital. Another objective of these interviews was to understand what research and data collection already has been done and will be done in the future. The interviews were held via Teams, Zoom, and via phone call. The interviewees all work in the health care sector, at the three included UMCs or Isala hospital either as health care professionals, purchaser or supplier. To collect data as effectively as possible from the interviewees, an interview guide was developed with different themes. The names and functions of the interviewees are held confidential, but are known by the researcher. The developed interview guide for the UMCs can be found in Appendix A and the interview guide for Isala can be found in Appendix B.

After speaking with several stakeholders I made a research approach in which I would interview the UMCs with the intention of gathering data from the sustainable initiatives that I could compare with each other by performing statistical analysis. After the first interview I came to the conclusion that this would not be possible and changed my research approach. The interview with Amsterdam UMC has therefore had a different interview scheme. Instead of ranking the initiatives of the UMCs, I decided to make an overview of both results from interviews and literature.

All three UMCs and Isala hospital are focused on becoming more sustainable and expressed the ambition to make their initiatives more measurable even though they did not yet all do so. The interviewees from both the UMCs and Isala interviewed in this thesis explained how they have included sustainability in their daily operations and why they did or did not do certain projects. The diversity of respondents ensures that a diverse group of workers is heard, which results in a higher level of reliability. At both the Amsterdam, Leiden UMC and Isala hospital an anesthesiologist was interviewed of whom two are involved in the national Green Team OR.

4. Sustainable initiatives in the OR

In this chapter the current practices of sustainability initiatives in OECD countries are discussed and put into the 9R-framework. The initial interview plan was to interview the UMCs with the intention to compare the sustainable initiaitves with data provided by the hospitals and come to best practices by statistical analysis. After the first interview I came to the conclusion that this would not be possible and changed my research approach. The interview with Amsterdam UMC has therefore had a different interview scheme.

The practices from the UMCs and Isala are discussed answer the following sub-questions:

- *RQ1- What are the environmentally sustainable practices in hospitals from OECD countries already done in the OR-complex that can be found in literature?*
- *RQ2- What are the environmentally sustainable practices done in the OR-complex of Leiden UMC, Radboud UMC, and Amsterdam UMC?*
- *RQ4- What are the current and future environmental sustainability projects in the OR-complex of Isala hospital?*

4.1 Sustainable targets in the OR

Even though health care environmental emissions are estimated to be high, exact estimates with methodological standardization are rare. The first country to report its health care emissions is the United Kingdom (UK) [25]. The National Health Service (NHS) England has made a national-level benchmarking system to report its greenhouse gas emissions from health care activities. Several other OECD countries have performed national estimates of health care emissions. However, the Netherlands has not yet done so. The United States of America has performed such an estimate in both 2009 and 2016. The national estimates of health care emissions were first calculated in Sweden in 2017, Canada in 2018, Austria in 2020, China in 2019, and Australia in 2018 [50]. These countries, unlike the UK, do not have an ongoing initiative to mitigate and measure carbon emission progress. To reduce the ecological footprint of the health care industry there is a variety of measures that can be used. The implementation of sustainable initiatives can result in financial, ecological and quality improvement for the health care industry [51].

Due to the increasing amount of waste produced by ORs, there are a lot of initiatives worldwide focusing on this problem [7, 9, 11, 27, 41]. Generally, there is a high generation of waste from high-income countries, however, the amount differs from country to country [41]. Initiatives focusing on sustainable waste management take circularity and with this the R-ladder into account. However, the health care industry with its single-use disposables is still quite linear. It is part of the “take-make-waste” economy in which products are made to be

used once and disposed of after single use. This linear economic model is unsustainable and exploits raw materials. A circular economic model for health care would be more sustainable since it maximizes resource productivity, minimizes waste, and benefits a resilient supply chain [52].

Studies have demonstrated that there is potential in recycling some of this OR waste [53-55]. Waste that comes from the OR is often misqualified as hazardous or infectious waste which cannot be recycled and is costly to process and digest. Misqualification is due to ignorance and ambiguity among personnel [56]. Additionally, there is strict legislation on health care waste management, which often counteracts with recycling [9]. According to the WHO the majority of health care waste, around 85%, is non-hazardous and has therefore potential to be recycled [56]. Separating this waste has several advantages, the first being that non-hazardous waste processing is eight times cheaper than hazardous or infectious waste [57]. Non-hazardous waste also needs a less energy-intensive treatment than infectious waste. Another advantage of waste separation is that non-hazardous waste can be recycled separately, because within this waste category there is a possibility to also have for example plastic, paper and residual waste [53]. Recycling waste has the potential to reduce the ecological footprint of the OR [58]. Due to the absolute need for sterility in the OR, there will probably always be a higher amount of waste resulting from the OR than from other hospital departments [7]. However, the use of reusables instead of disposables could tackle this high amount. All supplies and equipment currently used in most of the OR in the OECD countries are sealed in mostly disposable packaging which contributes to the high amount of waste from the OR [59].

To achieve the best environmental outcome, the first step in waste management should be to limit waste altogether as stated at the top of Lansink's ladder, the second is recycling, and lastly is the diversion to the landfill [33]. Environmental initiatives in the OR come across the challenge of legislation, targeting infection control, health and safety legislation, environment and waste legislation, and transport legislation [12]. Since waste management in hospitals has a high cost, it is of big importance to consider the feasibility of OR greening. To encourage environmentally sustainable waste management the interventions should be cost-effective [9].

Instead of using disposable medical and surgical devices in the OR there are many reusable options, which include metal instruments, basins, gowns and drapes [37]. Reuse of devices causes a reduction in the number of devices needed. Reusing mostly has an effect on the life-span and amount of waste. The main counter-argument to the use of reusable products is the potential infection risk, but with infection control standards for sterilization tools are eligible for reuse. Some products, however, are difficult to clean. For these products, recycling to recover the raw materials may be the best options [60].

Segregation of waste and therefore the possibility to recycle is highly dependent on appropriate use of the waste containers by health care personnel [6]. The appropriate disposal of waste is also important for safety. Countries such as the UK and Australia thereupon have colour coding systems for OR waste management, to clarify what category of waste should go in which container. There is, however, no international standardisation in colour schemes [6, 9]. Plastic waste represents the majority of the recyclable waste, up to

84% of the plastics generated in the OR is potentially recyclable [55]. Overall, improvement in recycling facilities together with education will help create awareness [6]. Reduction of waste is the best way to improve the OR's environmental footprint, next to this it is also cost-saving [58, 61].

A quarter of all OR waste is generated by anaesthetics [62-64]. The anaesthesisa department is the highest generator of hazardous waste [20]. Aneastethic gases such as sevoflurane, desflurane and isoflurane are recognized GHGs [41]. Initiatives thus focus on reducing the use of these anaesthetic gases as a greening initiatives. The three included UMCs have already implemented a strategy in their sustainability approach to reduce the use of these anaesthetic gases. In the future they want to completely rethink anesthethic medications and stop using anaesthetic gases and work propofol instead. Just as anaesthetic gases, medication/drug waste is an expensive and polluting type of waste. The estimated yearly cost of preventable OR drug waste was 185,250 US dollars per hospital in 2016 [40]. Lots of medications such as propofol are bad for the environment since they do not degrade and require incineration to be fully destroyed [39].

4.2 Sustainable initiatives of Leiden UMC

The operating room complex of Leiden UMC has gotten a silver score in the environmental thermometer health care sector. In 2017, the hospital had performed an LCA and CO_2 footprint map of their OR-complex [65]. From this analysis it was concluded that the total emissions from their OR-complex are 4.55 kilotons of CO_2-eq per year. Disposables were the biggest impact category, followed by pharmaceuticals [Source]. In the accompanying report several short and long-term recommendations were listed [65]. Leiden UMC has already started to implement some of the recommendations such as no standard use of inhalation anaesthetics and better separation of waste. No new carbon footprint mapping has been performed since then [66, 67].

In 2017, the annual emissions of inhalation anaesthetics was 35 tons of CO_2-eq. After the CO_2 footprint of 2017, they have started reducing inhalation anaesthetics, especially sevoflurane. They are now using intravenous anaesthetics such as propofol. Sevoflurane consumption halved because of this change in 2021, which saves 12,500 kg CO_2-eq. With this reduction in use comes a financial savings of € 20,000 on an annual basis [68]. To achieve this reduction, LUMC uses the strategy of awareness. They believe critical indication and more efficient administration can reduce use even further. In the future, the hospital wants to use an extraction filter (CONTRAfluran), which captures anaesthetic gases that can be recycled in the factory [67]. The usage of such a filter is a best practice.

Air treatment produced 715 tons of CO_2-eq, 90% of the total energy consumption [65]. Due to technical complications, the time that the air treatment is on cannot be reduced. However, green energy is used. The switch of energy to more renewable sources can be seen as a best practice. By implementing more efficient air treatment systems, a best practice, that are only switched on when the OR is in use, a reduction of 25 to 30 percent of the CO_2 footprint of the LUMC's OR is expected to be achievable [67].

The entire LUMC produced 2.1 kilotons of waste in 2017. 170,000 kg (8%) of all that hospital waste comes from the OR, this accounts for 750 tons of CO_2-eq. They try to reduce this

number by better separation of waste but also to move from disposables to reusables. Both of this initiatives can be considered a best practice. Currently, they separate about 28% of their total waste [65]. Within their sustainability strategy, they work with the R-framework, prevention is seen as the most efficient way of reducing waste. LUMC has been the pioneer of a nationally reusable surgical jacket project in the last year, this would result in 66% less CO_2 emission than using a disposable jacket [66, 67]. Another project within LUMC is the reduction of the number of instruments on surgical nets. With this project, the weight of the contents of the trays is reduced by 31%. This causes less waste but also fewer instruments need to be sterilized [68]. Reducing this number of instruments on a surgical tray can be viewed as a best practice.

4.3 Sustainable initiatives of Radboud UMC

Radboud UMC has started its own sustainability program in 2017 with the ambition: 'Radboud UMC will have the greenest OR in Europe in 2022'. In the first calculation of the CO_2 footprint in 2016, Radboud had an emission of 61.080 tons of CO_2. In 2020 this had already been reduced by 25%, but there was still an annual emission of 40.784 tons of CO_2 [69]. Since 2016 a lot of sustainability projects have been launched, such as reduction in the use of harmful anaesthetic gases and omitting the swivel on breathing tubes [70]. Both of which can be viewed as a best practice.Currently, 80% of the non-biohazardous waste is being separated. The separation of waste has led to different waste streams, but not to a reduction in kilograms of waste [71]. To reduce the amount of waste, especially that of blue wrap the packaging material used for surgical trays to keep them sterile, Radboud UMC is working with a packing robot. This robot uses 15% less material and is, therefore, more efficient compared to packing something by hand [72]. This blue wrap, also called polypropylene wrap, is collected separately so that it can be recycled. The use of a packing robot can be seen as a best practice.

Since 2014, already before the green deal, Radboud UMC started using reusable blood pressure bands. This can be seen as both a financial and environmental improvement project and a best practice. Since 2014, 40,000 blood pressure bands have been saved per year. Just as Leiden, Radboud is looking into a size reduction for surgical nets. Next to reduction, they are looking into working with fewer sets to prevent unnecessary substitutions and expiration of sterilization dates [70]. To reduce the energy use in the OR-complex, the air-handling is switched off at night between 19.00 and 7.00 in the ORs that are not in use. Next to this, other equipment is consciously switched off during this time [69]. This initiative focusing on reducing energy is a best practice.

4.4 Sustainable initiatives of Amsterdam UMC

One of the first steps in Amsterdam's sustainability agenda was the greening of the energy sources. In 2014, the switch from oil to natural gas took place, resulting in a CO_2 reduction of 30% at the time. The sustainability policy for the hospital is made based on ISO 14001. The AMC has gotten a silver score in the environmental thermometer health care sector. In 2019 AMC's total CO_2 footprint was 70,457 tons of CO_2-eq [73].

Just as Leiden UMC and Radboud UMC, there is a reduction project in the use of harmful inhalation anaesthetics. This replacement of inhalation anaesthetics with intravenous anaesthetics is a best practice. The project in Amsterdam saves an estimated 9 up to 300 kg

CO_2-eq. A similar project is the reduction in oxygen tanks. Using an already 'open' one instead of using a full tank each time has led to a CO_2 reduction of 80% [74].

Amsterdam UMC separates biohazardous waste but also paper, blue wrap and plastic packaging [74]. The exact percentage for separation is not exactly known. Blue wraps are about 10% of the waste and plastic bottles, metal packaging, and drink cartons about 20%. 10% of total OR waste is disposable coats, however Amsterdam is doing a pilot with washable OR jackets. They are already using reusable, washable OR hats which is another best practice. They went from using 100,000 disposable hats per year to 500 washable ones, the hats can be washed 150 to 200 times. Using washable instead of disposable has led to a CO_2 reduction of 60% [75].

To reduce the energy-use in the OR-complex there is an optimization of the air treatment. 15 of the 20 ORs are switched off at night. They are using LED lamps and optimize the planning of surgeries that need a certain amount of air treatment [74, 75].

4.5 Sustainable initiatives of Isala hospital

Isala hospital in Zwolle is ambitious regarding sustainablity, but is not yet very sustainable. They have a lot of sustainable plans and are looking for successful projects to implement. The projects described in this section are named in internal documents provided by Isala and the results of an interview with an anaesthesiologist.

The most well-known project is that of the reduction in use of the cellulose mat. It is a hospital-wide project. In the OR, the use of cellulose mats has been reduced by 50%. The OR-complex used to use 60,000 of these mats on a yearly basis and in 2021 they have reduced this to only 25,000-30,000 [76]. Just like the three UMCs, Isala has future plans to capture anaesthetic gases from releasing into the atmosphere and is starting to educate its personnel into refusing anaesthetic gases and working with propofol instead, which is more environmentally friendly [77].

Isala is already partly using reusable washable OR jackets, they still have some disposable ones for back-up and for specific sizes. The extra waterproof OR jackets are not reusable, just as the OR hats. In the last years the switch has been made to purchase more reusable instruments and products and less single-use equipment [77].

The hospital is looking into reducing the amount of medication that has a big environmental impact and replacing the medication with one that is more friendly to the environment. To tackle the medication waste stream Isala wants to evaluate the amount of medication prescribed after surgery. The correct amount will reduce the number of medication that is thrown away [77].

In March 2022 Isala switched waste processors to be able to separate waste into more categories. The waste processors sends yearly reports on the number of kilograms of waste in each category and location [76]. To prevent wasted energy Isala is currently looking into a nightmode for their OR-complex. This nightmode would mean shutting of the lights and machinery during the night when the ORs are not in use. This nightmode would be an addition on top of the already sustainable facility projects, such as changing lights to LED [77].

Table 2 below shows initiatives from both OECD countries and UMCs in the Nederlands. The initiatives have been put in the order of the most environmental sustainable to the least. This table can be seen as an overview of the results form the literature study and interviews.

Goal	Recovery options	Current initiatives of OECD countries and UMCs in the Netherlands
Smarter product use and manufacture	R0 Refuse	There are not yet best practices in this category.
	R1 Rethink	Examples of rethought practices: - Use of handdryers or hand sanitizers for non-surgical handwashing instead of paper towels [58]. - The three UMCs want to replace aneastethic gases such as sevoflurane, desflurane and isoflurane in the future and use propofol [66, 67, 70, 74].
	R2 Reduce	Examples of reducing product use: - Redesign of surgical kits with only necessary equipment. LUMC has also studied this and has reduced the amount of instruments on their surgical trays [68]. - Packaging material can be reduced with the use of the packaging robot R-APPIT. This robot cuts the packaging material to size on the basis of the instrument nets to be packed. Radboud reduces packaging material by an average of 15% by implementing this robot [72]. - Instead of a different composition, medical instruments could also be packaged individually instead of in a complete set. This intervention is not preferred due to the increase in the amount of wrapping which would lead to more wrapping waste. If biodegradable wraps were to be used it could be an environmentally friendly option [58]. - Use of smaller bottles of medication, such as propofol 20 millilitresbottles instead of 50-100 millilitre bottles with [39]. Less propofol has to be thrown away. - Using 'starter packs' for new medication, so that only a short supply of treatment is wasted if the patient doesn't tolerate it [78]. Examples for reducing energy consumption: - Changing the OR lighting towards LED lights, this can save up to 49% of energy. Next to the decrease in energy needed for the lighting the switch towards LED lighting reduces the amount of cooling needed for the OR [79].

Goal	Recovery options	Current initiatives of OECD countries and UMCs in the Netherlands
		- Turning of all the lights, machines and other OR equipment when not in use can save $33,000 and reduce 234.3 metric tons of CO_2 emissions per year according to a US study which focuses on simple changes [58]. Occupancy sensors, motion detectors or timers can be helpful to minimize energy waste. - The best practice for fluid waste management would be a closed collection system. This system collects fluids when created and discharge them into the sanitary sewer. The intervention has shown to reduce exposure of personnel to infectious fluids. Additionally, it reduces the amount of infectious fluid waste, which saves energy [79].
Extend lifespan of product and its parts	R3 Re-Use	Examples of reusable initiatives are: - Reusable surgical linens instead of disposable linens. Targets a high volume of waste. Most hospitals fortunately already use reusable linens [80]. - Switching to reusable surgical gowns instead of disposables [80, 81]. - Sharp containers often are single-use, however, reusable sharp containers produce less waste and save money [57, 82].
	R4 Repair	Repair tends to be performed on devices that already have a long life and high-cost, such as medical imaging equipment, monitors and machines [60].
	R5 Refurbish	Examples of refurbished products are: - High-complexity, high-cost equipment: o Medical imaging equipment; o Patient monitors; o Anesthesia machines; o Furniture [83]. - Small-medium complexity equipment: o Replacing staples or screws o Sharpening blades [83].
	R6 Remanufacture	Remanufactured product must have the same or greater quality than the original product [60]. Examples of remanufactured products are: - Medical imaging equipment; - Patient monitors;

Goal	Recovery options		Current initiatives of OECD countries and UMCs in the Netherlands
			- Anesthesia machines; - Furniture [61].
	R7	Repurpose	Examples of repurposed practices are: - Mop heads from medical textiles; - Blankets from washable OR jackets [42] - Repurposing of waste medicine wrappers as efficient low-cost electrode material [84].
Useful application of materials	R8 Recycle		Examples for recycling practices are: - Increase the number of bins for waste as well as designing signs and posters of where what waste needs to go to. Inadequate recycling facilities is the greatest barrier to recycling in the OR [38]. - Awareness through eduction for recycling and segregating waste seems to improve long-term behaviour [85-87]. - Seperating waste produced prior to a patient entering the OR [13, 61]. - Introduction of glass-only disposal boxes in the OR, non-infectious, non-sharps can then be collected in this box instead of going into the sharps container [9, 53].
	R9 Recover		Recovery of waste water to clean and re-use this water. On-site waste water treatment could be done with the use of a pharmafilter [88, 89]. Energy recovery from medical waste disposal due to high heat value of medical waste [90].

Table 2: Sustainable initiatives of the Dutch ORs and OECD countries in the 9R framework [30]

4.6 Summary Chapter 4

The most CO_2 reducing projects in hospitals are on top of the ladder of Lansink and the 9R-framework. In this chapter all included initiatives from literature and the interviews with the hospitals are put into the 9R-framework. There were not yet best practices found in the first category of this framework "Refuse".

The carbon footprint of the OR can be reduced by choosing for various best practices such as intravenous anaesthetics instead of inhalation anaesthetics. The three UMCs want to replace aneastethic gases such as sevoflurane, desflurane and isoflurane in the future and use propofol [66, 67, 70, 74]. In addition, energy can be reduced by working with a night schedule, saving energy also has financial advantages [58].

The most well-known project in Isala hospital is the reduction in use of the cellulose mat. It is a hospital-wide project. In the OR, the use of cellulose mats has been reduced by 50%. Another best practice in reduction is the reduction in the amount of instruments on the surgical trays of Leiden UMC [68]. Packaging material can be reduced with the use of the packaging robot R-APPIT. Radboud saves an average of 15% of packaging material of the instruments by implementing this robot [72].

One of the current trends in sustainability practices in hospitals is the switch of re-usable instead of disposables. Both Amsterdam UMC and Leiden UMC have started pilots on re-usable OR jackets and hats, which saves a lot of waste and CO_2 [74]. This switch is not only a way of reducing waste but can also be seen as a circular practise.

5. Key performance for a "Green OR in Isala"

In this fifth chapter, the performance measurement for environmental sustainability is discussed. First the criteria the KPIs are determined, this is done by answering the following sub-question: *RQ3- What KPIs can be used to measure sustainability performance and should be selected for Isala?* Second, the selected KPIs are discussed after which the validation is explained.

Isala hospital has expressed the ambition to work towards a more data-driven way of becoming sustainable. In addition, to determine if a sustainable strategy is working and results in positive results the progress should be monitored. This thesis proposes to measure sustainability performance with Key Performace Indicators (KPIs), since literature states that an appropriate set of KPIs improve the efficiency, effectiveness and transparency of an organization [91, 92]. The goal is that the selected KPIs indicate the performance for sustainability, as stated in the Green Deal sustainable care. The focus is on two goals: CO_2 reduction and improving circularity [5]. The selected KPIs can be used as a translation of the (future) sustainability goals set by the board of Isala. The definition used for a KPI in this thesis is that it is a quantifiable measure used to evaluate the success of sustainable initiatives [93].

5.1 KPI criteria

The KPI should be at the intersection of delivery from an actor or department to the organization. The indicators should translate the goals from the organization, set by the board, toward the work floor [94]. Performance measurement gives opportunities to review past and present initiatives [91]. The KPIs are used to quantify this performance. Furthermore, measuring gives insight into the performance of initiatives towards the goals [95]. Lastly measuring can provide directions for decision-making for Isala hospital [96]. The result from the measurement gives insight into how successful the initiatives are.

The challenge of measuring within sustainability is that there is no homogeneity in scopes and outputs, which results in not being able to compare the outcomes of sustainability measurements. This is due to the different scopes and standard units studies and hospitals use. Additionally, carbon footprints are also difficult to compare due to the heterogeneity in assessment methods, e.g. not all carbon footprint calculations take all three GHG emission scopes into account.

Even though the performance indicators can be very intuitive, the development and their implementation represent a challenging task. The structure and number of KPIs are significantly different depending on purpose and intent. Next to this, KPIs are dependent on the supplied data. Every environmentally sustainable KPI has to be comparable in time, with those of similar hospitals. For that reason, certain KPIs have no special meaning by themselves if the goal or scope to be pursued is not defined.

The list of criteria used to select the environmentally sustainable KPIs derives from literature [97]. The 22 aspects can be subjective but they were used as a gatekeeper to select effective KPIs that provide the needed information. The list of criteria can be found in *Appendix C.*

5.2 Selected KPIs

The selected KPIs aim to improve the homogeneity in the assessment methods, provide objective evidence of the performance and therefore offer a comparison. The first step in environmental performance measurement would be to have a total HCF of the entire hospital, the next step would be a carbon footprint calculation of the operating complex preferably of all three scopes. With these two numbers, Isala will be able to monitor the emissions from the different sources in CO2-eq. Tracking the progress of environmental sustainability helps to focus on the efforts and increase awareness. The direct pay-off is reduced emissions and costs, which can help strengthen the competitiveness of the hospital.

For waste management, the selected KPIs target the minimization of waste and the ability to recycle by separating waste. The required data for these KPIs targeting waste can be obtained from the documents supplied by the waste processor with the compositions of the waste delivered. Reducing waste both helps lower the environmental footprint of the OR and saves costs since processing waste is very expensive [9].

Sustainable procurement is included in the selected KPIs because reducing the environmental impacts of a hospital starts by their supply chains [98]. It is the responsibility of the department purchasing medical equipment to identify suppliers who are environmental friendly, have low-impact on emissions and are circular. The department can be seen as a

gatekeeper to prevent unsustainable equipment, therefore the KPIs target the performance in sustainable suppliers.

The following goals are recommended to be set by the board of Isala in relation to the Green Deal of sustainable care. The percentages of savings should be selected by the board. The goals, as described in *Table 3,* would be the base of the KPIs, as described in *Table 4,* for measuring environmental sustainability:

Theme	**Goal**
Energy efficiency	In 2030 Isala is x% more energy-efficient compared to 2025.
CO_2 emission	In 2030 Isala hospital has reduced its CO_2 emissions by 49% [5].
Sustainable energy	In 2030 X% of all the energy needs to be provided by sustainable sources.
Circular economy	The share of waste in 2030 which cannot be reused or recycled is maxium x%, and a minimum of x% of materials needs to be reused.

Table 3: Environmental sustainability goals for Isala

The selected KPIs in Table 4 below target four topics: Energy, Emissions, Circularity (waste management) and procurement. The KPIs enable measurement to understand both the current situation and determine the hotspots of emissions and progress. Each topic consists of at least one and maximum five indicators. A description of each of the outcomes of the indicators is given next to the unit and sources.

The outcomes of KPIs can be visualy displayed in a performance dashboard. A KPI dashboard can act as a summary of core business objectives, or more specific outcomes like sustainability targets of the OR, and can be used to more efficiently track general progress toward set goals, analyze potential trends and generally make more informed data-driven decisions [91].

Topic	**KPI**	**Description**	**Unit**	**Sources**
Energy	Energy consumption (per department)	Energy consumption	kWh/year or kWh/month	[99]
	Yearly energy savings	Energy saved due to implemented improvements	% of energy saved	[99]
	Gas consumption (per department)	Gas consumption	m^3/year	[99]
	Yearly gas savings	Gas saved due to implemented improvements %	% of gas saved	[99]
	Amount of sustainable energy used	Energy from sustainable sources	% of sustainable energy	[99]
Emissions	Carbon footprint of hospital per scope	GHG emissions of the hospital per scope	CO_2-eq	[100]
	Total carbon footprint of hospital	Total GHG emissions of the hospital	CO_2-eq	[100]

Topic	KPI	Description	Unit	Sources
	Carbon footprint of OR-complex per scope	GHG emissions of the OR-complex per scope	CO_2-eq	[100]
	Total carbon footprint of OR-complex	Total GHG emissions of the OR-complex per scope	CO_2-eq	[100]
Circularity	Total waste per department	Total waste per category: - Plastic - Hospital specific waste - Hospital residual waste - Paper (+ confidential paper) - Glass - Medication	Kilograms (kg)	[101]
	Division of waste categories	Distribution of waste types	% of total kilograms waste per category	[101]
	Division of disposal methods of waste	Distribution of disposal methods: - Recycling - Incineration - Landfill - Chemical-physical treatment	% of total kilograms of the waste per disposal method	[101]
	Recycling of materials [101]	Maps the amount of non-recyclable materials used	% of non-renewable materials	[101]
		Maps the amount of recyclable materials used	% of recycled materials used	[101]
		Distribution of much of the products is actually being recycled or has the potential to	Product recycling rate %	[101]
		Distribution of much of the packaging material is actually being recycled or has the potential to	Packaging materials recycling rate %	[101]
Procurement	Sustainable supply [101]	Amount of suppliers already checked for sustainability performance	% of suppliers reviewed in the context of sustainability	[101]

Topic	KPI	Description	Unit	Sources
		Amount of suppliers with whom is cooperated that meet the requirements for sustainability	% of suppliers that comply with established sustainability strategy	[101]

Table 4: List of selected KPIs

5.3 KPI validation

A validation of KPIs was done to be able to tell of the selected KPIs measure what they should measure according to the needs of Isala hospital. For this validation both a presentation to Isala hospital was given and short meetings with stakeholders were held where they could give their opinion. The stakeholders were positive on the KPIs, one of the reasons given for this was that the central research question of this thesis was incorporated into them. Next to this, these KPIs can serve as a tool for translating sustainability policy to the workplace since it clarifies the need for sustainability.

There was also some criticism on the number of KPIs and the kind of KPIs. The number of KPIs selected in this thesis is 18, which is seen as quite a lot. Stakeholders therefore suggested to reduce this number to make it a bit more manageable. The selected KPIs are mostly productivity KPIs, meaning that they al result in quantitative data. Stakeholders expressed the need for more clearity on what these numbers mean. When implementing these KPIs Isala hospital can take a critical view on what KPIs are the most important in reducing the number of KPIs. Additionally, Isala hospitals should listen to the need of their staff when implementing the KPIs. If there is need for more open or qualitative KPIs to clarify the need of sustainability, these KPIs should be included.

5.4 Summary Chapter 5

Isala hospital has expressed the ambition to work towards a more data-driven way of becoming sustainable. To measure sustainability performance KPIs are selected to improve the efficiency, effectiveness and transparency of sustainability practices in Isala hospital. After reviewing internal documentation of waste management by Isala and a literature review on sustainability KPIs 18 KPIs were selected. The goals, as described in *Table 3,* are the base of the KPIs. The list of criteria used to select the environmentally sustainable KPIs derives from literature [97]. The selected KPIs indicate the performance for sustainability, as stated in the Green Deal sustainable care.

The selected KPIs target four topics: Energy, Emissions, Circularity (waste management) and procurement. The KPIs enable measurement to understand both the current situation and determine the hotspots of emissions and progress. All KPIs measure productivity and result in quantitative data.

6. Discussion

6.1 Recommendations

The overview of environmentally sustainable OR initiatives and selected KPIs contribute to having insight into how to make the OR-complex of Isala more environmentally sustainable and what indicators to use to measure and monitor the progress. The data the KPIs provide are transferrable to a performance dashboard that shows the progress in sustainability. A dashboard can provide an overview on which the board of Isala, the manager of the OR, and the Green Team OR of Isala can make decisions. Due to the lack of data, this dashboard could not be filled in but it would be advised to do so when data is calculated.

To reduce GHG emissions in the health care industry and make the industry more environmentally sustainable the first recommendation for Isala is to identify and quantify the sources of the carbon footprint of the hospital [1, 2, 50]. Measuring the GHG emissions, especially CO_2 emissions, and therefore understanding the current situation will help identify the most polluting actions also called hotspots. When these hotspots are known specific initiatives can be selected or developed that target these and reduce the ones that have the biggest impact. Next to this measuring, the GHG emissions can help to successfully reach the goal of international and Dutch climate policy, such as the Green Deal for sustainable care. When the numbers are known progress can be tracked and a comparison can be made.

For monitoring a yearly carbon footprint calculation is recommended, since a carbon footprint can give insights into all the scopes. Management guru Peter Drucker once stated "(only) what gets measured, gets managed", since Isala wants to translate the theme of sustainability into their identity they should measure and monitor their progress [102]. Next to the yearly carbon footprint measurement, it is recommended to track projects from a starting point to an evaluation point. The project or pilot should start with a baseline measurement, where the units of outcomes must be determined. The KPIs selected in Chapter 5 "Key performance for a 'Green OR Isala'" can be used for measuring and monitoring. At the evaluation point of a project or pilot, a final or control measurement should be performed according to the units of outcomes determined in the baseline measurement. Measuring the performance of a project gives strength to the project, is good for motivation under personnel, creates awareness, and convinces management of the success [94]. Making a hospital more sustainable cannot happen overnight and requires commitment from all layers of management and departments, wherefore measurement and monitoring are vital [102].

The Coronavirus disease 2019 (COVID-19) pandemic and the war in Ukraine have shown that the linear supply chain of health care systems is vulnerable to disruption and demand fluctuations [4, 98]. Transformation of the health care industry to a more circular economy and supply chain would increase the chance to achieve the climate goals and be more resilient to external influences such as a pandemic. Next to this, a more circular health care industry is more likely to achieve the goal of providing more and more complex care in the future with low-emissions [52]. To realize this transformation towards more circular equipment, more reusable equipment should be purchased since several studies comparing single-use versus reusable equipment reveal that single-use disposables typically result in higher global GHG emissions on a life-cycle basis [35, 50, 58, 80]. Although single device acquisition costs for single-use disposables are often lower, reusable equipment distributes the cost over many uses and typically renders the lifetime cost of reusables substantially lower than that of single-

use disposables [52]. The costs of purchasing reusables will therefore be higher, but they will also last longer so that the costs are spread out over several years. The higher purchasing costs lead to a trade-off that the hospital should make between economic and environmental benefits as stated in the triple bottom line [44].

The entire health care industry, including suppliers and hospitals, are responsible in tackling the carbon footprint of this industry. However without guidance and rules from the government it is unrealistic to believe this industry will change into a more circular one and will reduce their emissions radically. Next to this, there is currently no surveillance or inspection in what products are sustainable. This thesis therefore recommends to develop a database of all healthcare goods with their CO_2 footprint. The footprint of all products and goods in this database should be calculated in the same way and take into consideration the same scopes. This unambiguity will help to make better comparisons between product groups and to identify hotspots in emissions.

With the results of this thesis, Isala has a starting point for greening their OR and measuring and monitoring their sustainable performance. The overview in best practices for the OR can inspire the hospital in taking more steps in making the hospital more sustainable. The selected KPI's can be easily used as a template for measuring and monitoring the performance of other departments in Isala or for the entire hospital.

6.2 Future research directions

The lack of clear mandates and boundaries have contributed to a cautious attitude toward implementing sustainable practices in health care. Due to the lack of clear and consistent guidelines, there is confusion around standards for reusing and recycling products. This confusion has led to health care professionals using only single-use disposable equipment to avoid potential errors and liability [52]. The mandates and boundaries amongst reusing and recycling and the implications of infection prevention and quality and safety of care should therefore be researched further.

The lack of data on the Dutch UMCs initiatives has led to a limited comparison in this research, but brings to light a need of the entire healthcare industry. This need is calculation and measurement of GHG emissions from products and therefore practices. It is uncertain to what extent the initiatives are circular or CO_2 emission reducing when data is missing. Thus, it would be recommended to measure the performance of these initiatives, to clarify their success. The lack of data in initiatives mostly is due to the lack of data on health care goods and products. It is currently unknown how much GHG is emissioned to produce, transport and use a certain product. To be able to calculate the emissions of iniatives it is first needed to calculate the emissions from specific products. This research should be done worldwide, in order to save time and money in making an overview of the emissions of all healthcare products.

Out of the literature review came that there are not yet succesful initiatives targeting Refusal of the 9R-framework. This lack of initiatives gives an indication for future research since it is the most circular option of the 9R-framework. Additionally, a lot of the initiatives found in literature and resulting from the interview target the lower R's of the 9R-framework and the

bottom of the ladder of lansink. This is an implication to research more 'higher' ranked initiatives.

6.3 Limitations

During this research, it emerged that the three included Dutch UMCs did not yet perform all measurements of emissions. This lack of data has resulted in no comparison between the initiatives. Some of the internal documents supplied by the UMCs did not contain the methodology of calculation or the source of the core data used. Resolving this issue of incomplete data took time and some data was not available at all. The real success of the initiatives from the other hospitals is therefore unknown, which can influence whether or not they are best practices.

The time available for writing this thesis is limited, therefore the scope of this research was limited to the OR-complex of a hospital, initiatives of only three UMCs were included and the number of interviews held was limited.

7. Conclusion

The problem identified at Isala was the uncontinuous improvement in environmental sustainability due to the lack of overview of best practices in Dutch ORs. The problem is not only topical at Isala hospital, but also for many other Dutch hospitals. Hospitals are groping in the dark when it comes to sustainability. It is known that they have to become more sustainable, but there is little to no guidance of how to achieve this. There are many initiatives in making hospitals and the OR-complex more sustainable, with most of the initiatives focusing on recycling and other large circles in the 9R-framework. However it is often unclear how successful the initiatives are in reducing GHG emissions. Next to this, there is little to none initiatives in the smaller circles of the framework such as Refuse or Rethink. This could be partly due to the lack of knowledge in this area, since the sustainability approach in the Netherlands and other OECD countries is often still underdeveloped.

Many 'measurements' in research are estimates, just as a lot of measurements in the Netherlands are estimates. With this estimates, not much can be done. The impact of healthcare has to be systematically measured before hotspots can derive on which initiatives can target. The cost of research and sustainability measures and the amount of time it takes to develop successful initiatives is holding back progress in this area.

Understanding and measuring the environmentally sustainable performance of these initiatives is essential to identify best practices to improve the environmentally sustainability of the OR. The 9R-framework by Potting et al. (2017) is used to display various best practices from both literature and the 3 UMCs. By selecting environmental KPIs, initiatives can be assessed on both CO_2 reduction and circularity.

The main research question: "What are best practices within sustainability projects in the OR-complex of Leiden UMC, Radboud UMC, and Amsterdam UMC and how can hospitals monitor their success?" is answered using the four sub-research questions below.

RQ1- What are the environmentally sustainable practices in hospitals from OECD countries already done in the OR-complex that can be found in literature?
RQ2- What are the environmentally sustainable practices done in the OR-complex of Leiden UMC, Radboud UMC, and Amsterdam UMC?

Chapter 4 discusses the best practices from the literature and the current practices from the UMCs using the 9R-framework and ladder of Lansink. By creating an overview of the initiatives in Chapter 4, the first two sub-research questions are answered. The current (best) practices mostly focus on the medium and longest R-loops (Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, and Recovery) and on the second to the fifth step of the ladder (Reuse, Recycling, Energy Recovery, Incineration, and Landfill). The main goal of these recovery options is to extend the lifespan of the equipment. Equipment is recovered and used in another way. The first step of the two theories, refuse and reduce, is the most circular and environmentally sustainable but there are not yet many best practices in health care that aim to refuse. The three UMCs largely focus on the same hotspots in CO_2 reduction but come up with different solutions. In addition, the UMCs differ in the amount of emissions measured, even though all three focus on waste minimization and energy reduction.

RQ3- What KPIs can be used to measure sustainability performance and should be selected for Isala?
Performance measurement gives opportunities to review past and present initiatives [91]. Therefore KPIs are selected to quantify the environmental sustainability performance of hospitals. Furthermore, measuring gives insight into the performance of initiatives towards the goals for GHG emission reduction. The selected KPIs all focus on the goals of the Green Deal as a basis for making Isala more sustaintable. The outputs are in percentages to compare different years, waste is measured in kilograms, and GHG emissions are measured in CO_2-eq. Chapter 5 discusses the KPIs, their formulas and outcomes.

RQ4- What are the current and future environmental sustainability projects in the OR-complex of Isala hospital?
Isala hospital in Zwolle is ambitious regarding sustainablity, but is not yet very sustainable.
The most well-known project is that of the reduction in use of the cellulose mat. It is a hospital-wide project. In the OR, the use of cellulose mats has been reduced by 50%. Just like the three UMCs, Isala has future plans to capture anaesthetic gases from releasing into the atmosphere and is starting to educate its personnel into refusing anaesthetic gases and working with propofol instead.

Isala is already partly using reusable washable OR jackets, they still have some disposable ones for back-up and for specific sizes. The hospital is looking into reducing the amount of medication that has a big environmental impact and replacing the medication with one that is more friendly to the environment. In March 2022 Isala switched waste processors to be able to separate waste into more categories.

The main question of this research was *"What are best practices within sustainability projects in the OR-complexes of Leiden UMC, Radboud UMC, and Amsterdam UMC?"* This research has shown that few hard figures are available yet. Eventhough there are already a lot of sustainable initiatives in hospitals and especially in the OR targeting the reduction of waste.

Therefore, an important future research implication is that hospitals, just like Isala hospital, have to measure and monitor sustainability performance better to determine what the best practices are and how well they are reducing their emissions. With hard figures, initiatives can be compared with each other in the most expressive way to determine what best practice are in the several circular categories. Isala hospital is quite ambitious regarding sustainability, but is not yet tackling the problem in a methodological way for which the adviced KPIs can bring guidance until other research has brought answers to the comparisons between initiatives.

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Appendices

Appendix A. – Interview script for UMCs

Interviewschema Duurzaamheidsprojecten OK
Datum:
Tijd:
Aanwezigen:

Introductie:

- Voorstellen: 20-jarige bachelor studente Gezondheidswetenschappen komt uit Friesland woont nu in Twente, afstudeerstage en onderzoek op het gebied van duurzaamheid in ziekenhuizen. Doel van onderzoek is om de iniatieven te bundelen en tot een best practice te komen. Uiteindelijk een advies uit te brengen aan het Isala.
- Doel interview: het in kaart brengen van verschillende 'environmentally sustainable' initiatieven op de OK's van verschillende Nederlandse Universitair Medisch Centra.
- De resultaten uit dit interview wil ik gaan gebruiken in mijn scriptie waarin ik advies uit ga brengen aan het Isala over duurzaamheidsprojecten op de OK. Gegevens die ik gebruik in mijn scriptie zal ik zo veel mogelijk anonimiseren.
- Deelname aan dit interview is geheel vrijwillig en u kant te allen tijde aangeven dat u wilt stoppen of weigeren een vraat te beantwoorden. Het interview zal ongeveer een half uur duren
- Zijn er nog vragen voor we beginnen?
- Geeft u toestemming voor het interview?

Kunt u zichzelf kort voorstellen?
Wat zijn je werkzaamheden binnen het UMC ….?

- Functie
- Rol binnen duurzaamheid
- Evt. projecten

In hoeverre speelt het thema duurzaamheid in het UMC?

- Specifiek op de OK
- Green deal
- CO_2 & circulariteit

Wat verstaat het UMC onder duurzaamheidsprojecten?

- Hoe te meten?
- Hoe bedacht?
- Verschil t.o.v. andere ziekenhuizen

Welke duurzaamheidsprojecten doen jullie al en wat willen jullie nog gaan doen?

- Hoe gemeten/bepaald
    - LCA

        - Carbon footprint

Wat zijn volgens het UMC de grootste vervuilers?

- Hoe wordt dit gemeten?
- Hoe wordt initiatief gemeten?

Wat doet het UMC qua afvalmanagement?

- Scheiden van afval
- Specifiek op de OK

Wat doet het UMC op het gebied van energie besparing?

- Groene energie
- Stand-by

Appendix B. – Interview script for Isala

Interviewschema Duurzaamheidsprojecten OK
Datum:
Tijd:
Aanwezigen:

Introductie:

- Voorstellen: 20-jarige bachelor studente Gezondheidswetenschappen komt uit Friesland woont nu in Twente, afstudeerstage en onderzoek op het gebied van duurzaamheid in ziekenhuizen. Doel van onderzoek is om de iniatieven te bundelen en tot een best practice te komen. Uiteindelijk een advies uit te brengen aan het Isala.
- Doel interview: het in kaart brengen van verschillende 'environmentally sustainable' initiatieven op de OK van het Isala en welke initiatieven vanuit de literatuur gebruikt zouden kunnen worden.
- De resultaten uit dit interview wil ik gaan gebruiken in mijn scriptie waarin ik advies uit ga brengen aan het Isala over duurzaamheidsprojecten op de OK. Gegevens die ik gebruik in mijn scriptie zal ik zo veel mogelijk anonimiseren.
- Deelname aan dit interview is geheel vrijwillig en u kant te allen tijde aangeven dat u wilt stoppen of weigeren een vraat te beantwoorden. Het interview zal ongeveer een half uur duren
- Zijn er nog vragen voor we beginnen?
- Geeft u toestemming voor het interview?

Kunt u zichzelf kort voorstellen?
Wat zijn je werkzaamheden binnen het ziekenhuis ….?

- Functie
- Rol binnen duurzaamheid
- Evt. projecten

In hoeverre speelt het thema duurzaamheid in het ziekenhuis?

- Specifiek op de OK
- Green deal
- CO_2 & circulariteit
- Meetbaarheid

Welke duurzaamheidsprojecten doen jullie al en wat willen jullie nog gaan doen?

- Hoe gemeten/bepaald
    - LCA
    - Carbon footprint

Wat doet het ziekenhuis qua afvalmanagement?

- Scheiden van afval
- Specifiek op de OK
- Reusables versus disposables

Wat doet het ziekenhuis op het gebied van energie besparing?

- Groene energie
- Stand-by

Appendix C. – Key Performance Indicator List

1. Performance measures should be derived from strategy
2. Performance measures should be simple to understand
3. Performance measures should provide timely and accurate feedback
4. Performance measures should be based on quantities that can be influenced, or controlled, by the user alone or in co-operation with others
5. Performance measures should reflect the "business process" – i.e. both the supplier and customer should be involved in the definition of the measure
6. Performance measures should relate to specific goals (targets)
7. Performance measures should be relevant
8. Performance measures should be part of a closed management loop
9. Performance measures should be clearly defined
10. Performance measures should have visual impact
11. Performance measures should focus on improvement
12. Performance measures should be consistent (in that they maintain their significance as time goes by)
13. Performance measures should provide fast feedback
14. Performance measures should have an explicit purpose
15. Performance measures should be based on an explicitly defined formula and source of data
16. Performance measures should employ ratios rather than absolute numbers
17. Performance measures should use data which are automatically collected as part of a process whenever possible
18. Performance measures should be reported in a simple, consistent format
19. Performance measures should be based on trends rather than snapshots
20. Performance measures should provide information
21. Performance measures should be precise – be exact about what is being measured
22. Performance measures should be objective – not based on opinion

The list of criteria for KPIs used in this thesis is reprinted from ''Designing performance measures: a structured approach,'' by A. Neely et al., 1997, International Journal of Operations & Production Management, 17(11), p. 1137. Copyright 1997 by MCB University Press [97].

Appendix D. Search Query sustainable initiatives hospitals

In Chapter 4 an overview of sustainable initiatives was made in the format of the 9R-framework. This overview was made by doing a literature review. In the table below the search query of finding this literature can be found.

Sub-topic	Search terms English
Sustainability in healthcare	(Sustainable OR "climate-smart") AND (Healthcare OR "Health care "OR hospital OR "medical centre")
	("Health Care Carbon Footprint" OR HCF)
	(Sustainable OR Environmental OR Green) AND (surgical OR operating OR "operating-room" OR "operating-complex") AND (practices OR initiatives OR projects)
Waste management in healthcare	(Operating OR surgical OR "operating room" OR hospital) AND (Waste OR Garbage OR "Thrown away")

Table 5: search query sustainable initiatives hospitals

The literature study was carried out by searching in different scientific databases. The most used database is Scopus, second is Pubmed and third is HealthAffairs. Some of the articles were found with snowballing. After a key document was found the references in the document were tracked down. Snowballing was used especially when doing the literature review for the sustainable initiatives overview in Chapter 4.

Appendix E. Search Query sustainable key performance indicators

In Chapter 5 KPIs and their criteria were selected after doing a literature reviewIn the table below the search query of finding this literature can be found.

Sub-topic	Search terms English
KPIs	(Sustainable OR Environmental OR Green) AND ("Key Performance Indicators" OR KPI OR Metrics)
KPI criteria	(Criteria) AND ("Key Performance Indicators" OR KPI OR Metrics) AND (Sustainable OR Environmental OR Green)

Table 6: search query sustainable key performance indicators