

Reducing the carbon footprint of healthcare gloves: An analysis of upstream and downstream emissions reduction scenarios

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Research Article

Keywords: Healthcare, single-use plastic, procurement, carbon footprint, reduction scenarios

Posted Date: October 6th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10958747/v1>

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Additional Declarations: No competing interests reported.

Abstract

The healthcare sector plays a pivotal role in safeguarding human health but has a substantial environmental footprint; one being the overreliance on single-use consumables like gloves, increasing the amount of waste and carbon emission from the sector. This paper explores the ways in which glove procurement, use and waste phase contribute to the sector's carbon footprint and suggests emissions reduction scenarios, in line with the climate goals. Glove procurement data was analysed from three Danish regions between the year 2019 to 2023. Approximately 845 million gloves were purchased, with 63% made from nitrile rubber, a synthetic polymer. A material flow analysis of gloves for a single year showed that 126.3 million gloves procured in 2022 had an estimated carbon emission range of 4,614t CO₂ eq to 17,225.4t CO₂ eq when incinerated. Four reduction scenarios were identified: Scenario 1, focused on how domestic production of 25% of all gloves, can achieve a 6.3% emission reduction; scenario 2 shows a potential 37% reductions through changes in consumption, while scenario 3 reported a 3.5% reduction through recycling. A combined scenario (scenario 4) can result in 46.8% emission reduction. The scenarios indicate that a combination of both upstream and downstream measures is complementary and is mostly effective when employed together.

Introduction

The healthcare sector is pivotal in safeguarding human health but has a substantial environmental footprint of nearly 4.4% of global greenhouse gas emissions (Karliner et al., 2020). One contributing factor is an over-reliance on single-use plastics, largely Personal Protective Equipment (PPE) such as gloves and masks, driven by potential but mostly unverified infection concerns or convenience (MacNeill et al., 2020; Rizan et al., 2020). Single-use plastic gloves are one of the most utilized consumable in healthcare and one of the top carbon footprint hotspots, especially post the COVID-19 pandemic (Hunfeldt et al., 2023; Rizan et al., 2021). The common glove materials used are latex and latex substitutes like nitrile (nitrile butadiene) and ethylene vinyl acetate (Co-polymer) (Ivanović et al., 2023) that have fossil-based sources, a contributor to greenhouse gas (GHG) emissions from production to the end-of-life (Joseph et al., 2021; Geyer, 2020). The over-consumption and waste patterns resemble a linear "take-make-waste" economy, an unsustainable model that contributes to ecological destruction through the depletion of natural resources, increased expenditures, generation of excess solid waste and emission of GHGs (Ramos et al., 2023; MacNeill et al., 2020).

Healthcare has been one of the few sectors exempted from plastic-related regulations like the EU's Single-Use Plastics Directive (Directive (EU) 2019/904) and from the recent UN plastic treaty negotiations. The treaty preamble argues that healthcare plastics are essential and that subjecting them to a legally binding treaty has risks that outweigh the potential harmful impacts across the product's lifecycle (Street et al., 2024). This argument overlooks the emerging evidence that plastics have additives, harmful to the human and environmental health (Wagner et al., 2024), discarded waste contaminate soil and waterways (Street et al., 2024) or fragment into microplastics whose health risks are being uncovered through ongoing research (Vethaak & Legler, 2021).

The European Union (EU) healthcare sector is among the top three of the highest emitting healthcare sectors in the world (Karliner et al., 2020). This positions the region as a priority area for targeted sector-specific emission reductions. The global roadmap to decarbonise the healthcare sector has set common but differentiated trajectories per country, to achieve the Paris Agreement aim of reducing the global average temperature rise to 1.5°C above pre-industrial levels (Health Care Climate Action, 2021). In Denmark, only 4% of the economy is circular, with 6% of the national carbon emissions coming from the healthcare sector (HealthCare Denmark, 2023). In 2023, all five Danish regions adopted a common strategy for "Green Hospitals" aimed at reducing GHG emissions by 50% in 2035 relative to 2022 (Danish regions, 2023). The strategy additionally includes a long-term strategy for climate-neutrality by 2050. It is organised in three tracks: 1) purchasing, 2) circular economy and behaviour, and 3) energy consumption, transport and buildings. With this strategy, the regions intend to implement green criteria in all tendering materials, established in accordance with market maturity and health considerations (Danish regions, 2023).

While the strategies are significant and ambitious, they lack a detailed implementation pathway, especially for plastics, which is a key contributor to carbon emissions (Ministry of Environment Denmark, 2021). This study addresses this knowledge gap by analysing the procurement data of single-use examination gloves, as they present a quantifiable intervention point, with a global replicability potential. This paper investigates glove quantities, types and consumption hotspots and applies literature-based emission factors to estimate the associated carbon emissions and identify potential reduction opportunities.

Material and methods

Glove quantities

This study analysed the procurement data of disposable examination and non-surgical gloves procured at three regions in Denmark, between the years 2019 to 2023. This time series was selected to analyse the possible impact of the COVID-19 pandemic on glove consumption and the possible future implications of the national and international guidelines on glove production and consumption in healthcare. Additionally, this was the only time series available as records could only be recovered for a maximum of five years. The procurement data was from Region Zealand, the Capital Region, and Central Region of Denmark. The three regions are part of the five administrative regions in Denmark and cover approximately 70% of the Danish inhabitants, with the Capital Region being the largest with 1.9 million inhabitants, the Central Region of Denmark at 1.4 million, and Region Zealand at 0.85 million inhabitants, as of the first quota of 2024 (Statista, 2025). These regions manage the hospitals in Denmark.

Procurement data was analysed from 55 healthcare centers, including hospitals, pharmacies, social services, pre-hospitals (emergency services), psychiatry service centers, and the regions' central administrations. The centers consisted of over 1500 departments, which were later categorized into 10 broad groupings: Medical specialties, administration, services and logistics, emergency and acute care, diagnostic and laboratory services, research, psychiatry, pharmacies, public health and social services, and unidentified departments.

A simple material flow analysis (MFA) was employed for the year, 2022, to map the flow of gloves from the regions to the healthcare centres and to the ten departments. The data used was from the year 2022, as a reference to the regional strategy to half emissions in 2035, relative to 2022. The MFA was used to highlight the departments that were not in direct patient contact, whose waste, if correctly sorted, could be recycled.

Carbon emission impact

The main glove types from the data were registered and, if the glove type could not be identified or there was missing glove type data, the 'unknown' label was used. This information was obtained from the identification code provided, either box code or product description from the suppliers. This study then estimated the carbon footprint of the total gloves based on Life Cycle Assessment (LCA) data estimates from publicly accessible carbon emission data from the glove suppliers. This was then compared with other literature studies to verify the accuracy of supplier-based LCA calculations. Only products with a calculated LCA value were used in this calculation. The exclusion criteria included products without an identification code and all other glove types other than single-use examination gloves. The referenced LCA data was presented in CO₂ emissions in kg per 1000 items, which incorporated a cradle-to-grave LCA, that consider the products lifecycle from raw material processing, production, transport and incineration, as method of disposal. The CO₂ emissions covered the product's lifecycle, regardless of where in the world they were manufactured. To determine the emissions for a single year, this study calculated the emissions per single glove type then multiplied by the total procured gloves, as shown below.

$$Emissions\ in\ a\ single\ year\ (tonnes\ CO_2e) = \left(\frac{E_n}{1,000,000} \times N_n \right) + \left(\frac{E_l}{1,000,000} \times N_l \right) + \left(\frac{E_v}{1,000,000} \times N_v \right)$$

Where E_n is carbon emissions per 1000 nitrile gloves (kg), N_n is nitrile gloves procured in that year, E_l is carbon emissions per 1000 latex gloves (kg), N_l is latex gloves procured in that year, E_v is carbon emissions per 1000 vinyl gloves (kg) and N_v is vinyl gloves procured in that year.

Scenario analysis

This study further calculated a series of simplified glove reduction scenarios focused on the changes in production (substitution), consumption, and end-of-life (recycling). These three areas were selected based on an extensive literature study and potential for significant changes. The scenarios were inspired by key literature studies (Amadei et al., 2023; Jamal et al., 2021, 2021; Rizan et al., 2021) and an analysis of the current healthcare sector. The scenarios aimed at identifying potential room for improvement and available opportunities for a shift towards reducing carbon healthcare emissions, in line with the current climate goals.

Current scenario: 2022 Emissions: Identified the glove quantities and associated emissions for a single year, 2022, to estimate emission reduction scenarios for the year 2035. The year 2022 was used as a baseline, in reference to the regional strategy to half emissions in 2035, relative to 2022.

Scenario 1: Substitution: This scenario assumes that 25% of all gloves are produced domestically, to reduce the reliance on import and the environmental footprint from overseas transportation. This scenario stems from the COVID-19 pandemic, where an overreliance on the global supply chains led to delays, shortages, low glove quality, and increased costs. Additionally, this scenario assumes a 25% emission reduction for locally produced gloves. This value is based on a cradle-to-gate LCA by ECOVAMED, a company carrying out LCAs of healthcare products, which reported that gloves produced in France and within EU had 25% lower emissions, compared to gloves produced in Malaysia and China, who are the leading glove producers (ECOVAMED, 2022).

Scenario 2: Changes in Consumption: In this scenario, a 37% glove reduction is assumed, focusing on plastic waste reduction through changes in consumption within the hospitals. The scenario is based on the results from the "Gloves Off!" campaign at public hospitals in Australia, which achieved a 37% reduction in the number of gloves through reduction in unnecessary glove use and improved hand hygiene (Wilkie-Miskin et al., 2025). This study was referenced due to their success and was based on other successful campaigns (Leonard et al., 2019; Rizan et al., 2021).

Scenario 3: Recycling: Assumes effective sorting and recycling of gloves at the non-patient contact departments and for all unused gloves, largely from stockpiles in case of emergencies, instead of incineration, which can reduce emissions by 35% (Rizan et al., 2021). These departments will be identified using the MFA results for the year 2022. The scenario assumes that the glove consumers - the healthcare workers - are trained, engaged, and change behaviors regarding glove sorting and waste management.

Scenario 4: Combined scenario: This scenario combines the results of scenario 1, 2 and 3, a combination of upstream and downstream measures, thereby assumes that all measures described above are implemented.

Results and Analysis

Current glove consumption (2019–2023)

Approximately 845 million gloves were purchased between the year 2019 and 2023 across the three Danish regions. There was a significant increase in the procurement of gloves in 2020 compared to 2019, in all the regions, a possible influence of the COVID-19 pandemic as shown in Fig. 1. The Capital Region had the highest procurement quantities with 404 million gloves, almost half of the total gloves. The region houses Copenhagen, the national capital, where more than 30% of the Danish population reside in. Glove procurement increased by 61%, from 63 million in 2019 to 102 million in 2020, followed by a 35% decline in 2022, then a slight increase in 2023 to 75 million. The Central Region experienced a similar surge, from 53 million in 2019 to 68 million gloves in 2020, a 28% increase. There was a decline each year thereafter, reaching 37 million in 2023, a 30% decline from 2019. In Region Zealand, while there was missing 2019 data, there was a significant difference between 2020 and 2023, with a 50% decrease in glove quantities, from 62.7 million in 2020 to 31.5 million in 2023. While this analysis shows the glove procurement data and patterns, it does not equate to the glove consumption as some of the gloves were stored in stockpiles to address the supply shortages while others were donated to other region and municipalities, as obligated by the Danish government (Fugmann, 2020).

Glove MFA for a single year

When looking at the combined glove flow within a year, there was a significant variability in glove procurement across the different hospital, with 144.5 million gloves procured in 2022, as shown in Fig. 2. The merged hospitals, which are a group of 2–3 different hospitals merged to improve the quality of patient care through combined expertise and resources, had the highest procurement at 24%. There were three groups of merged hospitals from the capital region and one from region Zealand. Specialised hospitals had the second largest purchase at 23% while the two main university hospitals made up 20.2% of the total gloves. The central administration, which consists of seven centres that manage the regions and were responsible for stockpiling in case of emergency and made donation to other municipalities made up 13% of the gloves bought.

When comparing between gloves procured at departments in direct versus indirect patient contact, 90% of the gloves were within the direct patient contact. Of the 144.5 million gloves, 46% were consumed at all specialised medical departments, while 18% were consumed at the emergency and acute care and 6% at the public health and social services. Other subcategories included the diagnostic and laboratory services departments at 3%, research departments at 3%, and psychiatry departments at 2%. All these departments are in direct patient contact. Outside direct patient contact, services and logistics departments had the largest consumption at 6% while research, administration and pharmacy departments constituted 2.5%, 1.1% and 0.2% respectively. The unknown locations made up 2.8% while 11.9% were assumed to either be donated or sold and therefore not possible to identify which locations they were consumed at.

Estimated carbon emission impact

Nitrile gloves were the most purchased glove type, with 533 million gloves consumed between 2019 and 2023, in all the regions, accounting for 63% of the total gloves (Fig. 3). Latex gloves made up 11%, vinyl gloves at < 1% while the unknown glove types were quite significant, at 26%. The large number of 'unknown' glove type was due to missing and/or incomplete data. The glove type data from Central Region, for the years 2020 and 2021, and the 2019 data for Region Zealand was missing. Additionally, there was a lack of precise categorization in the data provided, which made it difficult to identify the type of glove procured. For example, gloves with general descriptive words such as 'long glove' or 'blue powder-free glove' were categorised as unknown.

This study further estimated the carbon emissions for the three glove types. The metadata used during this study provided a general description of the gloves but not specific characteristics of the gloves, for example powdered or powder-free or specific brands, which differed with the referenced LCA data used for the carbon estimates. This study therefore estimated the highest and lowest possible emissions from the three main glove types: nitrile, latex, and vinyl to provide a range of the possible emissions in a year, as shown in Table 1. The emissions were calculated for a single year, 2022, a reference to the regional strategy to half emissions by 2035. The average emissions were calculated using data from literature studies and supplier data. It is worth noting that due to a lack of material identification, emissions for gloves in the "unknown" category (approx. 18.2 million gloves) remain unaccounted for, underlining a significant gap in procurement transparency. The total emission estimates for a single glove are illustrated in Table 1 and were used as a reference to calculate the overall emission from all the gloves.

Table 1
Estimated carbon emission impact for a single glove type and all gloves procured in 2022, based on LCA values from different studies and glove supplier.

Glove type	Quantities in millions (M) (2022)	Average emission for a single glove (g CO ₂ e)	Total emissions (t CO ₂ eq)	Sources	Notes
Nitrile	107,6 m	26 g CO ₂ e	2,797.8 t CO ₂ eq	(Rizan et al., 2021)	Data from literature sources
Nitrile	107,6 m	34 g CO ₂ e	3,658.8 t CO ₂ eq	(Jamal et al., 2021)	Data from literature sources
Nitrile	107,6 m	144 g CO ₂ e	15,496 t CO ₂ eq	Supplier	Highest emission value
Nitrile	107,6 m	35 g CO ₂ e	3,766.4 t CO ₂ eq	Supplier	Highest emission value
Latex	18.6 m	93 g CO ₂ e	1,731.3 t CO ₂ eq	Supplier	Highest emission value
Latex	18.6 m	45.8 g CO ₂ e	837.8 t CO ₂ eq	Supplier	Lowest emission value
Latex	18.6 m	21.04 g CO ₂ e	391 t CO ₂ eq	(Usubharatana, 2018)	Data from literature sources
Vinyl	25, 000	108 g CO ₂ e	2.7 t CO ₂ eq	Supplier	Highest emission value
Vinyl	25, 000	77 g CO ₂ e	1.9 t CO ₂ eq	Supplier	Lowest emission value
Unknown	18.3 m	-	-	-	-

The study then presented three scenarios to compare the current business-as-usual emissions from the year 2022, with future reduction scenarios for the year 2035, as shown in Fig. 4. When comparing this study's data with other studies focused on glove emissions in healthcare, we noted a significant variation in the LCA estimates, highlighting the limitations of carbon foot printing. This is because several factors are considered in estimations, calculations, and interpretation of the LCA data (Jamal et al., 2021; Patrawoot et al., 2021). For example, most of the studies calculated the carbon emission for one glove type, with the assumption that there are no significant differences between other types of gloves. This, however, differed from the data used for this study, where there were significant differences in the carbon emission of different glove types, varying from long and short gloves, powdered and powder-free, classic or sensitive. Due to the general description in our data, we used estimates from gloves with the highest and lowest emission impact.

Carbon emission reduction scenarios

In the current business-as-usual scenario for the year 2022, 126.3 million gloves had an estimated carbon emission range of 4,614 t CO₂ eq to 17,225.4t CO₂ eq when incinerated; where 107.6 million nitrile gloves had an estimated emission range of 2,798 t CO₂ eq to 15,496t CO₂ eq when incinerated while 18.6 million latex gloves emitted 391t CO₂ eq to 1,781.5t CO₂ eq and 25,000 vinyl gloves emitted an estimated 1.9t CO₂ eq to 2.7t CO₂ eq when incinerated (Fig. 4). However, 13% of all the gloves (18.2 million) were unknown and therefore not included in the calculations. In this current scenario, consumption and incineration as the end-of-life remain constant to 2035. At this rate, it is not possible to achieve the climate goal of halving the carbon emissions by 2035. The next four scenarios will explore intervention opportunities throughout the gloves' lifecycle. The different scenarios presented varying reduction rates in both glove quantities and carbon emissions.

In Scenario 1, domestic glove production can reduce emissions by 6.3% reduction by 2035 (Fig. 4). While the current EU glove production capacity does not meet the high European demand, a 25% domestic production can reduce the overreliance on import and associated environmental footprint by eliminating overseas transportation and use of low-carbon energy during production (ECOVAMED, 2022). Domestic glove production can also strengthen the health security of individual countries by reducing dependency on other countries, delays, increased costs, and interruptions in supplies, as was experienced during the COVID-19 pandemic. It is however crucial to not only reduce imports but also lower the overall domestic demand and the associated raw material requirements in production (Teixeira & Vicard, 2026).

Scenario 2 focuses on the consumption phase of gloves which offers the largest opportunity for reduction, by focusing on both glove quantities and associated carbon emissions. A 37% reduction in glove quantities and emissions can be achieved by 2035, as evidenced by the "Gloves Off" education campaign in Australia that resulted in reduced unnecessary glove use, associated carbon footprint, waste, and cost savings. Studies show that non-sterile gloves are often overused or misused, especially during and after the COVID-19 pandemic (NHS Grampian, 2025; Peters et al., 2025; Rizan et al., 2021). A study by (Sgambaro et al., 2025) noted that while healthcare staff are highly aware of the benefits of circular economy and are ready to adopt circular practices, the lack of formal learning and clear leadership undermines the potential to translate the engagement into

actionable steps. The Australian campaign addressed this through an education intervention, which was effective in addressing behaviour change and might be translated within the EU setting.

Scenario 3 focuses on the end-of-life phase, where, through effective waste sorting and recycling rather than incineration, a 3.5% reduction in emissions can be achieved by 2035. In this scenario, only gloves used for non-hazardous, non-biohazardous tasks are eligible for recycling, which are often found in specific non-patient contact departments, such as the administration, service and logistics department, pharmacy, and research departments, as identified in the MFA. They can also be found in departments in direct contact with patients, when used in interactions that do not have direct patient contact, like in cleaning and kitchen areas. This scenario is therefore dependent on proper staff training and clear segregation bins for successful recycling. While recycling is great, the amount of carbon reduced, 3.5%, is not significant enough to achieve the reduction goal.

Scenario 4 is a combined scenario, where the upstream and downstream measures are combined in scenarios 1, 2, and 3 to achieve 46.8% reductions in emissions (Fig. 4). Focusing on one part of the glove lifecycle only results in a slightly positive improvement, and the pace of change is not fast enough to align with the Paris and Glasgow climate agreements neither the Danish climate goals. It is only by incorporating other scenarios that significant change can be expected. These factors are dependent on other parameters, such as implementation of strong reduction policies; behaviour shift among the healthcare workers; and changes in consumption and procurement strategies. While all these factors cannot be 100% guaranteed, the initial steps are an effective strategy towards reducing carbon emission in healthcare.

Discussion

This study aimed to understand the glove consumption in Danish hospitals, the hotspots, and associated carbon emissions. The procurement data illustrated significant differences in glove consumption between the three Danish regions and within the hospitals. The three regions cater to approximately 4.1 million inhabitants, where 845 million gloves were consumed between 2019 and 2023. Approximately 26% of the 845 million glove types were unknown, either due to missing data or a lack of precise categorization in the procurement data, and therefore, the estimated emissions are presumed to be higher. This stresses the need for proper documentation of procurement data for not only recording past decisions, but more importantly for future decision-making and emergency preparedness (Patience Okpeke Paul et al., 2024). This study therefore underlines the need for clear, easy-to-translate and uniform procurement data for future referencing.

The large glove quantities show that the sector's volume is significant enough to steer the supply chain towards more sustainable practices (Torkki et al., 2024). It is crucial, however, to acknowledge that procuring great amounts of gloves may not equal the amount consumed during that same time. During the COVID-19 pandemic, stockpiling of PPE increased, with single-use gloves stocked in the highest amounts. This was due to shortages and delays in the supply of PPEs, a result of the overreliance on global supply chains. Since then, different countries have adopted various measures to address the PPE challenges, through measures such as a centralized purchasing system, domestic production, and stockpiling (Ivanović et al., 2023; Olatayo et al., 2021). Most European countries, the USA, Australia, among others, have set up national stockpile structures and governance, which serve as centralized repositories in case of emergencies. Denmark established the Epidemic Act that ensures a contingency stock of PPEs, with gloves having the longest stock coverage of six months, to increase security of supplies (Danish Agency for Social Security, 2023).

Stockpiling, however, can result in increased waste due to limited shelf life and expirations, leading to the gloves ending up incinerated, adding to the already large emissions in this sector. To curb this, countries such as the Netherlands and Latvia have adopted stock rotation programs through partnerships with hospitals and wholesalers to use up the supplies before expiration (Azai et al., 2025). Adoption of this strategy can reduce wastage, emissions, and financial losses. Additionally, Scenario 4, the recycling scenario, ensures that the expired gloves are recycled, where several recycling initiatives like the Zero Waste Box (Ansell, 2025) and Polycarbin's glove recycling program (EcoTek, 2025) produce new products like playground surface covers. Recycling is, however, a part of the solution and needs to be combined with other reduction strategies.

Scenario 1, is the domestic glove production, evidenced to alleviate shortages and improve the supply chain resilience, and reduce emissions during production (Department of Health, 2022). The current system is dependent on imports, with Danish import data highlighting that over 59% of examination gloves were produced and imported from only three countries: Malaysia, China, and Thailand (Danish Agency for Social Security, 2023), whose factories predominantly rely on energy generated from coal rather than renewable energy sources (Patrawoot et al., 2021). The glove production stage has been associated with the largest emission impact, up to 66.2% of the glove's entire life cycle (Wang et al., 2024). A study by Patrawoot et al., (2021) highlighted that substituting coal with natural gas reduced emissions by more than 50%. Additionally, Rizan et al., (2021) found that by manufacturing PPE in the UK, there was a carbon footprint reduction by 12%. This was due to the elimination of overseas travel and the use of renewable energy within the UK. Sea freight transportation from Asia to Europe constitutes 6–8% of the total glove footprint (ECOVAMED, 2022).

Although domestic manufacture of gloves is more sustainable, the European demand for gloves does not meet the EU production capacity, and therefore, the need for import remains. Since glove import is unavoidable, it is essential to consider the environmental performance of the supplier before purchase, to promote the purchase of sustainably made gloves. Setting CO2 requirements in tendering or purchasing gloves with documented lower lifecycle-based emissions is likely to incentivise up-scaling of domestic production in Europe and to incentivise renewable energy supply at gloves manufacturing operations in Asia. There is a need to adopt sustainable procurement practices where 'green' criteria are set for tenders and should be met by suppliers. The implementation of sustainable procurement has some limitations, as highlighted by (Torkki et al., 2024), who highlights that institutional steering without financial incentives was not an efficient enabler towards sustainable procurement. This underscores the

need for increased resources and opportunities for sustainable procurement through collaborations between different stakeholders such as procurement teams, healthcare workers, and policy makers. Implementation of circular strategies will have to go hand in hand with healthcare workers on board, in a bottom-up approach (Murugan, 2026; Olatayo et al., 2024)

Scenario 2 has shown a potential 37% decrease in glove consumption, but this must involve the healthcare workers. (Sgambaro et al., 2025) noted that while healthcare staff are highly aware of the potentials for circular economy and are ready to adopt circular practices, the lack of formal learning and clear leadership undermines the potential to translate the engagement into actionable steps. This is further echoed by (Ramos et al., 2023) who identified the hindrances for plastic reduction and effective waste sorting (scenario 3) to include potential disturbance to the workflow, inadequate sorting space, and the need for a sterile work environment. One of the potential solutions to the barriers is to apply mixed methods approaches when identifying local circular solutions to overuse, where staff experience is combined with quantitative data on material flows, to provide reduction potentials in the healthcare sector (Oturai et al., 2025). Oturai et al. underline the importance of understanding the reality in which healthcare is performed, i.e., the in-situ decision-making of acute care, uncertain procedure flows, and department/specialty dependent interpretations of hygiene guidelines that may lead to unnecessary PPE use. This approach calls for the inclusion of care staff in identifying hotspots for reduction potentials for efficient and implementable reduction initiatives. The concurrent push for circularity along the value chain, to strive for the highest CO2 emission reduction of single-use plastic gloves, can be transferred to other single-use PPE in general, such as gowns, masks, shoe covers etc., driving the general healthcare sector towards the high reduction targets.

Conclusion

With the healthcare sector facing increased pressure to become more sustainable, it is crucial to identify intervention areas and strategies towards sustainability. This study highlights that the healthcare sector's volume is significant enough to shift the supply chain towards more sustainable products and practices. The study suggests tangible pathways for reduction of CO2 from glove consumption in hospitals, illustrated in four scenarios that, when combined, suggest a potential to reduce CO2 emissions from glove consumption by 50%. From the four scenarios, both upstream and downstream measures appear complementary yet mostly effective when employed together. Incorporating the gloves' carbon footprint as an evaluation criterion in procurement scenarios, with the bidder disclosing the methods used, from cradle to grave/gate, can generate a market signal and drive eco-innovation. While there is no "Silver bullet" solution to reduce plastics in healthcare, a combination of actions, both upstream and downstream, can create a significant impact. The inclusion of various stakeholders, including healthcare workers, procurement officers, policy makers, and suppliers, will be essential for a greener healthcare sector.

Declarations

Declaration of generative AI and AI -assisted technologies in the writing process

During the preparation of this work the authors used M365 Copilot and perplexity to check and improve language in some manuscript sections such as abstract and introduction. After using these tools, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

Data availability statement

All data that support the findings of this study are included within the article. Any additional data will be made available on request.

Funding

The PhD project is partially funded by Region Zealand and the Capital region

Credit authorship contribution statement

Joy R. Ndwiga: Conceptualization, Methodology, formal analysis, data curation, writing- original draft, writing- review and editing, visualization. **Nikoline G. Oturai:** Data curation, Writing—review & editing, visualization. **Kristian Syberg:** Conceptualization, Methodology, Writing—review & editing, funding acquisition, supervision. **Thomas B. Christensen:** Conceptualization, Supervision, Validation, Writing—review & editing, Funding acquisition, supervision.

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Figures

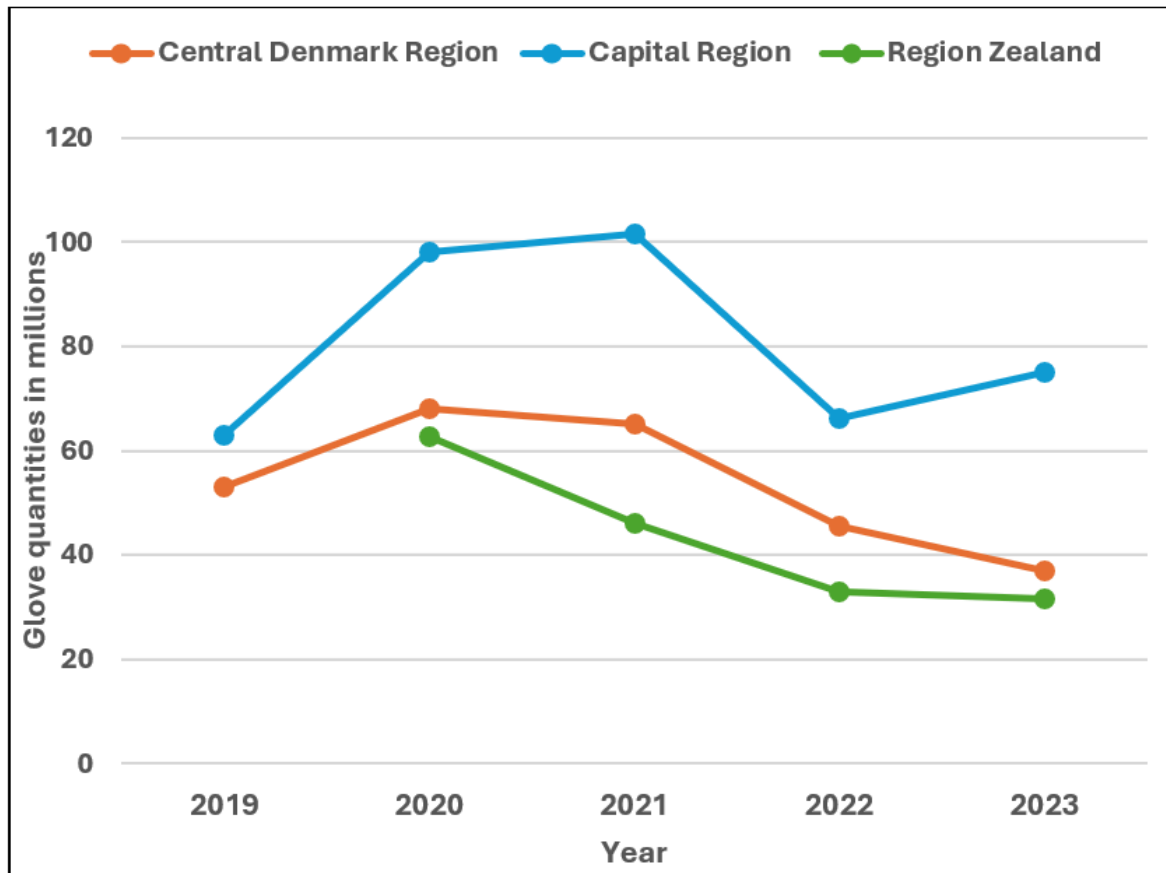


Figure 1

The quantities of gloves purchased in Central Denmark Region, Capital Region and Region Zealand, between the year 2019 to 2023.

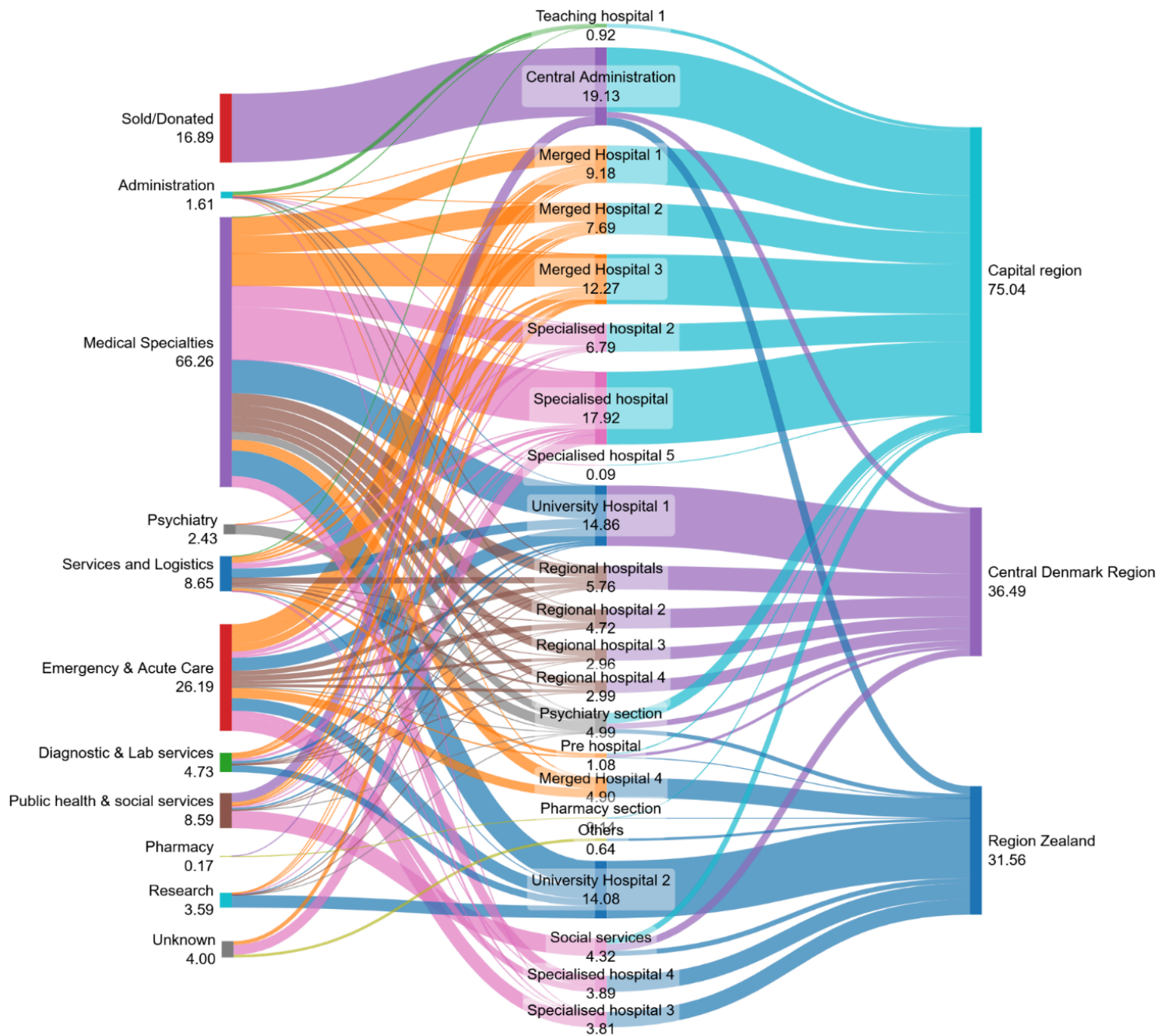


Figure 2

Material flow of gloves from specific department groups (left) to the hospitals and to the three regions for the year 2022 (Outward flow to the right). The values represent the glove counts in million. Made at SankeyMATIC.com

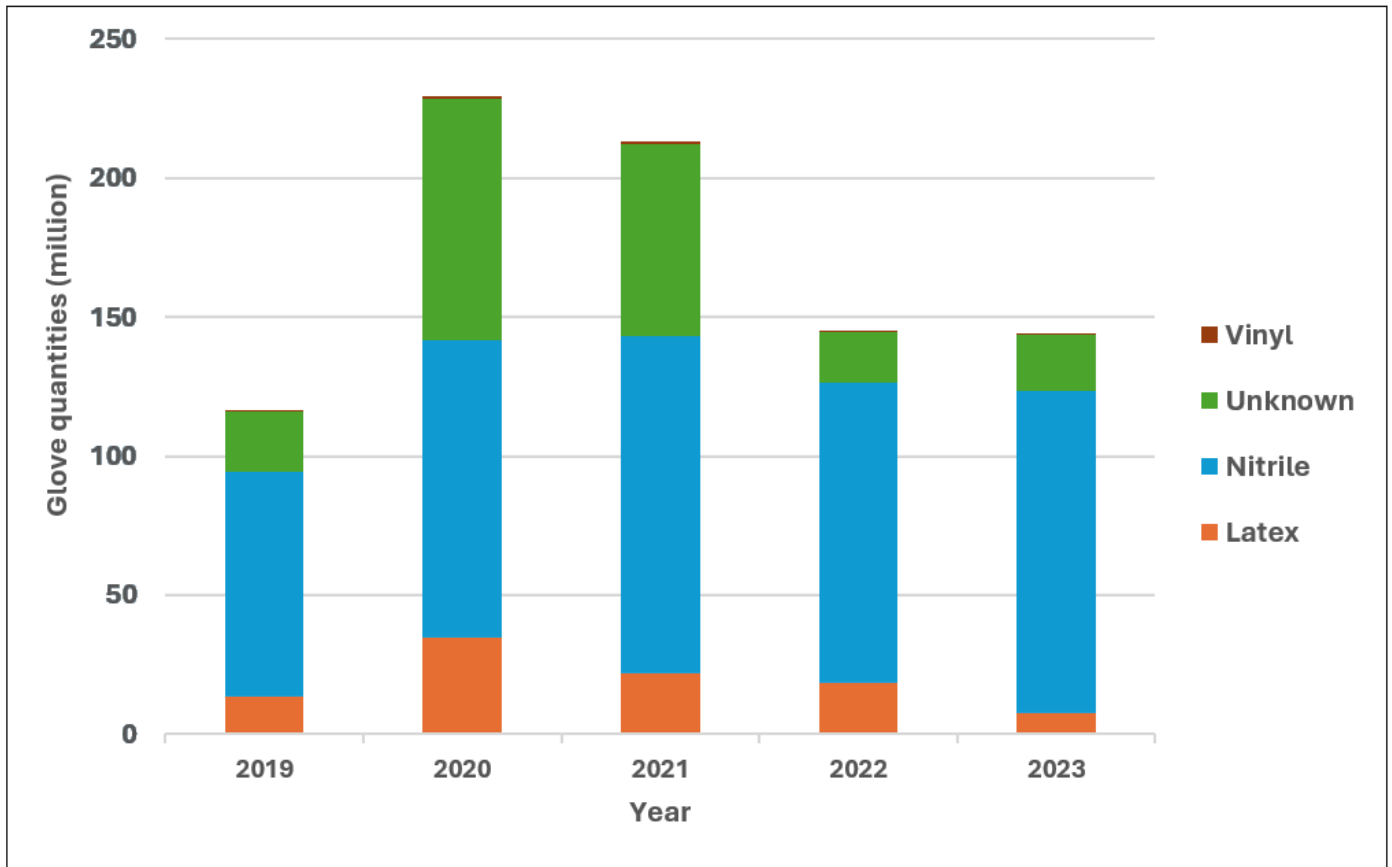


Figure 3

Type of glove materials (Nitrile, Latex and Vinyl) purchased at the regions between the year 2019 to 2023

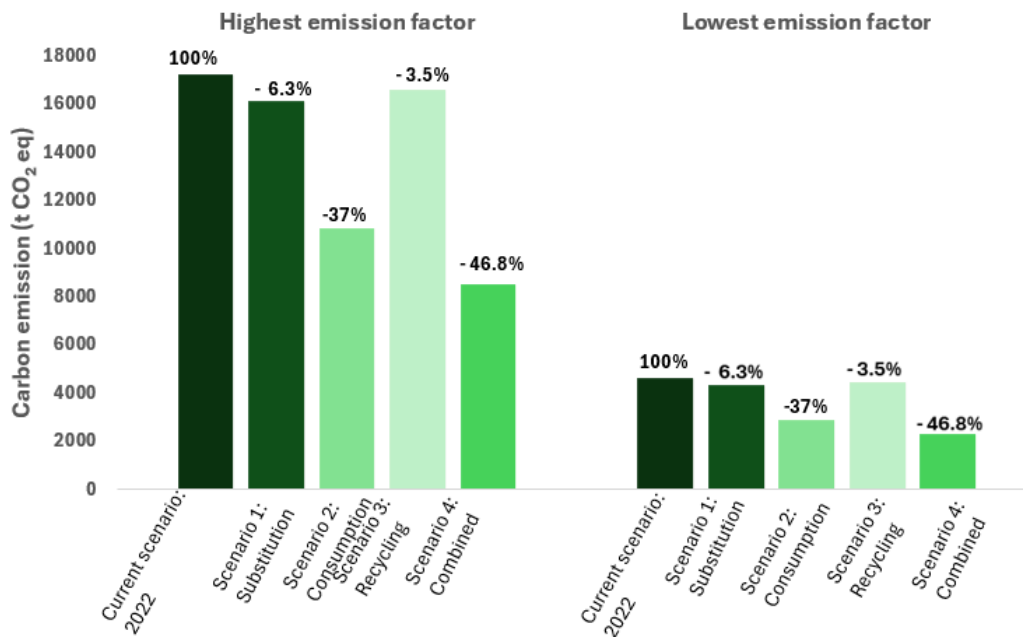


Figure 4

Bar charts illustrating the carbon emission reduction scenarios calculated from the highest emitting glove (left) and the lowest emitting glove (right) for the year 2035, in comparison to 2022 emissions. The figures present projected reduction potential focused on changes in production, consumption, the end-of-life being recycling and a combination of the four scenarios.

Supplementary Files

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- [floatimage1.png](#)