Tracing Carbon Footprint: A Lifecycle Analysis of ISOL8 Healthcare's Disposable Theatre Apparel in the UK Healthcare Sector

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Introduction
The threat of climate change has made many businesses look closely at how they can reduce their environmental footprint, especially their CO_2 and equivalent (CO_2e) emissions. The healthcare sector is no exception, with operating theatres and other medical settings drawing particular concern due to their reliance on single-use medical consumables.

The health and care system in England is responsible for an estimated 4-5% of the country's overall carbon footprint, with over half (62%) originating from its supply chain [2]. This highlights the importance of identifying which products contribute the most to CO_2e emissions and understanding their role in the system's overall carbon output.

The National Health Service (NHS) of the United Kingdom has committed to a net-zero greenhouse gas emissions goal by 2045, encompassing both direct emissions (Scope 1), indirect emissions from energy procurement (Scope 2), as well as all greenhouse gas emissions originating from its extensive supply chain (Scope 3) [1]. Specifically, for the emissions that the NHS can directly influence (NHS Carbon Footprint Plus), the organization aims to reach an 80% reduction between 2036 to 2039, and a net-zero target by 2045 [1].

Building on the need to understand product-specific contributions to emissions, this study aims to fill the information gap by undertaking a comprehensive assessment of the carbon emissions generated through the supply chain of ISOL8 Healthcare's range of disposable theatre apparel. We will trace the life-cycle of our products, starting from the manufacturing of the raw material, assembly, followed by transportation to Europe, and finally, distribution to end-users.

Understanding our emissions is important for several reasons. Firstly, by comprehending the emissions of our disposable single-use product range throughout the entire supply chain, we can identify which stages of the product life cycle produce the most emissions. This insight will guide us to strategies with the greatest potential for reducing carbon output. Secondly, gaining clarity on emissions per product provides actionable insights on how best to offset these impacts. Lastly, this knowledge can help hospital trusts to make more informed and sustainable choices in their operations.

Background
Disposable theatre apparel, such as surgical gowns, face masks, and headwear, is often made from SMS, a composite material made from layers of Spunbond, Melt-blown, and Spunbond. Polypropylene, a derivative of crude oil, is the primary raw material used in the manufacture of SMS.

The COVID-19 pandemic has increased attention over the carbon footprint of personal protective equipment (PPE), such as masks and gowns. One research noted that a single-use surgical face mask generates approximately 59 grams of CO_2e greenhouse gas

emissions [3]. A separate study used a life cycle assessment methodology to evaluate the environmental impact of various face masks over a 306-day period, revealing that each mask emits around 7 grams of CO_2e [4]. Furthermore, an analysis focusing on the transportation of masks from China quantified the emissions at 0.45kg of CO_2e per functional unit (FU), defined as equipping one person with a mask for a month. Over 90% of the emissions are generated during production and less than 10% during transport [5].
Similarly, various studies analysed the environmental impact of surgical and isolation gowns. One comprehensive study examined factors such as material composition, packaging, manufacturing location, sterilization methods, and disposal practices. It estimated that the CO_2 emissions for producing 1,000 surgical gowns are 1.636 kg [6], or 1.63kg per gown. Another study on disposable isolation gowns found that manufacturing and delivering 1,000 such gowns resulted in 300 kg of CO_2 emissions, and the packaging accounted for an additional 6.95 kg of emissions [7]. Both studies did not provide the specific calculations that were made to reach these figures. Another Comparative Life Cycle Assessment study analysed reusable and disposable isolation gowns, specifically focusing on isolation gowns. It identified manufacturing and raw materials as the most significant contributors to CO_2 emissions, and the worst-case and best-case total emissions are calculated at 163 kg and 65.5 kg of CO_2 per 100 gowns, respectively [8].

While existing research provides valuable insights into particular segments of the carbon emissions chain, a more nuanced and comprehensive understanding can help suppliers with targeted interventions that can most effectively mitigate the environmental impact of these healthcare products.

Method
To comprehensively evaluate ISOL8 Healthcare's greenhouse emissions, we calculate the emissions that are generated per product. The disposable product range that we analyse in this study, consist of three categories of sterile gowns, non-sterile gowns, face masks, theatre headwear, warming jackets and shoe covers.

Fig 1. Overview of ISOL8 Healthcare's disposable products

A cradle-to-customer lifecycle analysis is undertaken for each product within ISOL8's product range. This supply chain can be segmented into distinct stages, as illustrated below.

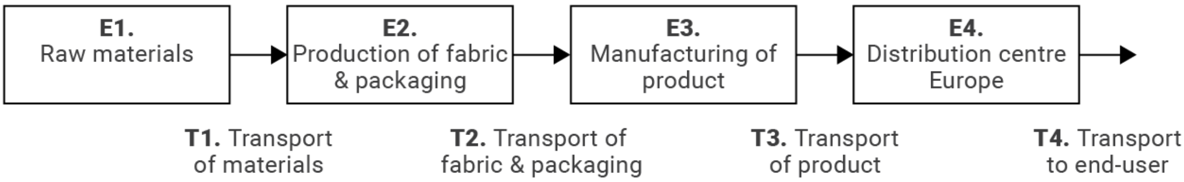

Fig 2. Steps in ISOL8 Healthcare's supply chain

We employ a step-wise approach to quantify emissions at each stage. The aggregate emissions for each product are subsequently derived from the sum of emissions at these individual stages. We assess the carbon emissions per individual item for surgical gowns, patient gowns, medical gowns, and warming jackets. For surgical masks, the emissions are calculated based on a 50-piece box; for theatre caps, a 100-piece box; and for shoe covers, a bag containing 100 pieces. For accuracy, we use the emission conversion factors for Company Reporting from the UK Department for Energy and Net Zero [9].

Reduction and offsetting emissions
In addition to quantifying emissions, we also assess ISOL8's strategies for emission reduction and offsetting, calculating their specific impact on the carbon footprint of each product. Moreover, we evaluate which prospective actions hold the most promise for further diminishing our overall emissions.

Limitations
The end-of-life stage is excluded in this analysis due to the variability in disposal practices, which are ultimately determined by the end user. Although the recycling potential for these materials remains limited, certain hospital trusts do engage in the recycling of components, such as surgical gowns.

E1. *Raw Materials*
The number of raw materials per product are quantified by disassembling the product, measuring its constituent parts, and determining the amount of raw material needed for each part. Common materials include polypropylene and cotton for the products, and paper and polyethylene for the packaging. The CO_2e emissions are then calculated based on latest available per kg emission factors that are generated to make each material.

T1. *Transport of raw materials*
Emissions are calculated by determining the energy required to transport a standard 40ft container filled with raw materials. Given the prevalent use of diesel in heavy freight, energy consumption is converted to diesel usage, which is then multiplied by average diesel emissions to estimate CO_2e.

E2. *Production of fabric & packaging*
The range of fabrics produced include SMS, SMMS, and SFS variants, whereas packaging materials are sourced from separate facilities. CO_2e emissions are quantified by multiplying the energy consumed for each material's production by its respective quantity, adjusted for the ratio of energy derived from fossil versus renewable sources at each plant.

T2. *Transport of fabric & packaging*
Fabrics and packaging are produced at three different locations. Emissions for each route are estimated based on a full-container model, with diesel-powered trucks assumed for transportation.

E3. *Manufacturing of product*
The emissions at this stage are calculated by measuring the total energy consumed in cleanroom operations, cutting, ultrasonic welding, packaging sealing, and sterilization. This is then adjusted for the energy mix—fossil fuels versus renewables—at the manufacturing facility.

***T3.** Transport of product*

The emissions are determined by accounting for the road miles to the port, the sea miles, and the road transport to the UK distribution centre. Emissions generated during loading and offloading are incorporated, using CarbonCare's online tool [10] for sea transport.

***E4.** UK distribution centre*

Emissions generated in the UK distribution centre are not included to the emissions per product. This distinction is made because the emissions arise from commuting, heating, and electricity use for lighting and the operation of warehouse machinery. While these emissions are part of ISOL8's supply chain emissions, it would be difficult to attribute this to emissions per specific product.
CO_2e emissions are derived by quantifying the energy uses from these sources and accounting for the proportion of energy originating from fossil versus renewable sources.

***T4.** Transport to end-user*

Products are dispatched from the UK warehouse to the end-user by diesel trucks. The routes are optimized for efficiency through the United Pallet Network. CO_2e emissions are calculated based on the average truck load and transporting distance.

Results

The table below offers a detailed breakdown of the CO_2e emissions generated per product.

			CO_2e emissions in kg							
		Pieces	**E1.**	**T1.**	**E2.**	**T2.**	**E3.**	**T3.**	**T4.**	**Total**
Product	**Elemental standard surgical gown**	1	0.5257	0.0010	0.0788	0.0003	0.1793	0.0289	0.1698	**0.9838**
	Elemental reinforced surgical gown	1	0.5556	0.0011	0.0876	0.0004	0.1794	0.0321	0.1698	**1.0260**
	Supreme impervious surgical gown	1	0.6144	0.0011	0.1167	0.0004	0.1793	0.0333	0.1698	**1.1150**
	Patient gown	1	0.2023	0.0003	0.0452	0.0002	0.1029	0.0137	0.0849	**0.4495**
	SMS Medical gown	1	0.3152	0.0005	0.0664	0.0002	0.1032	0.0192	0.0849	**0.5896**
	FLUIDSAFE Surgical mask (Type IIR)	50	0.5258	0.0035	0.0426	0.0010	0.2869	0.0384	0.1769	**1.0752**
	Standard theatre cap (tie-back)	100	1.0624	0.0036	0.1052	0.0014	0.2747	0.0968	0.7861	**2.3301**
	Warming jacket	1	0.2720	0.0007	0.0520	0.0003	0.1584	0.0120	0.0849	**0.5804**
	Shoe covers	100	1.3394	0.0064	0.1291	0.0027	0.0567	0.0702	0.3144	**1.9190**

Table 1. Emissions generated per product in CO_2e per kg

In addition to these findings, CO_2e emissions from the UK distribution centre (E4.) accounted for 8,224 kg in the year 2022. 63% of these emissions was due to employee commuting, 12% from heating, and 25% was attributed to electricity consumption, which includes machinery operations.

Among the individual products, surgical gowns generate the most emissions, predominantly due to the use of raw materials (E1) for fabric and specialized packaging. Other products with high emissions are shoe covers and standard theatre caps, which are quantified per 100 pieces. Most of the emissions stem from the use of fabric. For standard theatre caps, the emissions generated during transport to the end-user (T4.) are higher because fewer boxes can be transported per pallet compared to other products.

Steps in the supply chain with the highest emissions are the use of raw materials (E1.), manufacturing of products (E3.), and transportation to the end user (T4.), respectively. The majority of the emissions from raw materials come from the production of polypropylene required for fabric. Paper production for inner packaging and cartons is the second-largest contributor.
In the manufacturing stage (E3), over half of the emissions are generated by the use of cleanrooms, primarily due to electricity use for fans and lighting. Other parts where more emissions are generated are during sterilization and heat-sealing of packaging.
Transportation to the end user (T4) generates a relative high number of emissions due to high distances being covered by truck over land, and palletized delivery, which limits the number of products that can be transported per truck. Comparatively, land transportation emits significantly more than maritime shipping; for instance, transporting goods 100 miles by truck produces approximately the same emissions as shipping them 3,300 miles by sea [5].

ISOL8 has implemented measures to reduce its emissions across different steps of the supply chain. Our sourcing strategy prioritizes factories located within a 150-mile radius of the manufacturing unit, thus minimizing emissions from raw material and fabric transportation (T1., T2.). Starting in 2022, we adopted direct shipping routes and switched to carton-based loading instead of pallets for transportation to the UK distribution centre (T3). These measures have successfully reduced CO_2e emissions by 20% and 25%, respectively [11].

Compared to existing literature, ISOL8's emissions for various products like face masks, isolation gowns, and surgical gowns are generally within a comparable range. Specifically, the emissions per surgical gown from ISOL8 stand at approximately 1kg, which is slightly lower than the 1.63kg reported in previous studies. Our isolation gowns also align closely with literature data, registering 0.58 kg per gown as compared to a range of 0.307 to 1.63 kg in existing sources. Notably, CO_2e emissions from ISOL8's face masks are lower, measuring at 0.0107 kg in contrast to the 0.059 and 0.45 kg documented in the literature. These discrepancies can largely be attributed to ISOL8's optimized low-mileage transportation routes and, to a lesser extent, the use of alternative materials. For instance, the surgical gowns in our study utilized polypropylene (PP), as opposed to the polyethylene terephthalate (PET) used in referenced literature, which inherently has a higher CO_2e emission rate.

Moreover, ISOL8 has a Carbon Neutrality Program that correlates with the volume of product usage [12]. Through this program, we invest in verified carbon offset projects that neutralize the CO_2e emissions generated by each product. This results in reducing the carbon footprint of each individual product to zero.

Discussion
The variation in emissions compared to the literature underscore the need for additional research in this domain. Our detailed breakdown of emissions at different stages of the supply chain can offer valuable insights for other companies seeking to quantify and understand their environmental impact. This could facilitate more targeted interventions at specific steps in the supply chain.

This study demonstrates a methodology for translating carbon footprints into per-product emissions. When this data is combined with the total number of products distributed, it provides actionable insights for effective emission offsetting. This could serve as a foundational framework for both buyers and sellers to collaborate on offsetting emissions based on product usage, thereby working collectively towards achieving net-zero emissions.

Conclusion

ISOL8's emissions proof to be in similar range, or slightly lower than, those reported in existing literature for comparable products like gowns and face masks. The lower emissions can largely be credited to optimized transportation routes and strategic material choices.

The most significant contributors to emissions within the ISOL8 supply chain include the use of raw materials, particularly polypropylene for fabric, the energy-intensive manufacturing processes, especially those involving cleanrooms, and the distribution to end-users. Therefore, targeted efforts to reduce emissions for ISOL8 could be most impactful in these specific areas. Strategies may include sourcing recycled polypropylene, reducing overall energy consumption, and transitioning to renewable energy sources during manufacturing.

Our study provides a practical method for calculating carbon emissions per product. Combined with sales data, this allows for precise offsetting strategies. This can be an important step for buyers and sellers alike to collaboratively achieve net-zero emissions based on product usage.

Literature

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