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A LCA comparison between single-use and Revolution-ZERO reusable face masks

Goal

To compare the environmental impacts of using single-use (surgical masks) and Revolution-ZERO reusable face masks provided by Rutherford Research Limited.

Scope

Four scenarios of face mask use were analysed in this comparative study:

***Table 1**: Summary of scenarios compared in the comparative study.*

Scenario Number	Mask Type	Mask Treatment	Number of Masks Equivalent to the Number of Reuses per Reusable Mask
1	Surgical Mask – air freight from China	Disposed at the end of use	36
2	Surgical Mask – ship freight from China	Disposed at the end of use	36
3	Surgical Mask – from Turkey	Disposed at the end of use	36
4	Revolution-ZERO (RZ) Reusable Mask	Machine washing, 36 washes*	1

*Rutherford Healthcare masks are washable up to 40 times, a lost rate of 10% was assumed to obtain the average number of reuse.

The **functional unit** (FU) employed for the analysis is **36 mask uses**, the assumed average reuse amount per reusable mask. A cradle-to-grave study approach was used for this comparison. The scope of the study included the material sourcing of the face masks, transport to the manufacture facility, the manufacture of face masks, transport to the UK, face mask use and its final disposal (**Figure 1**).

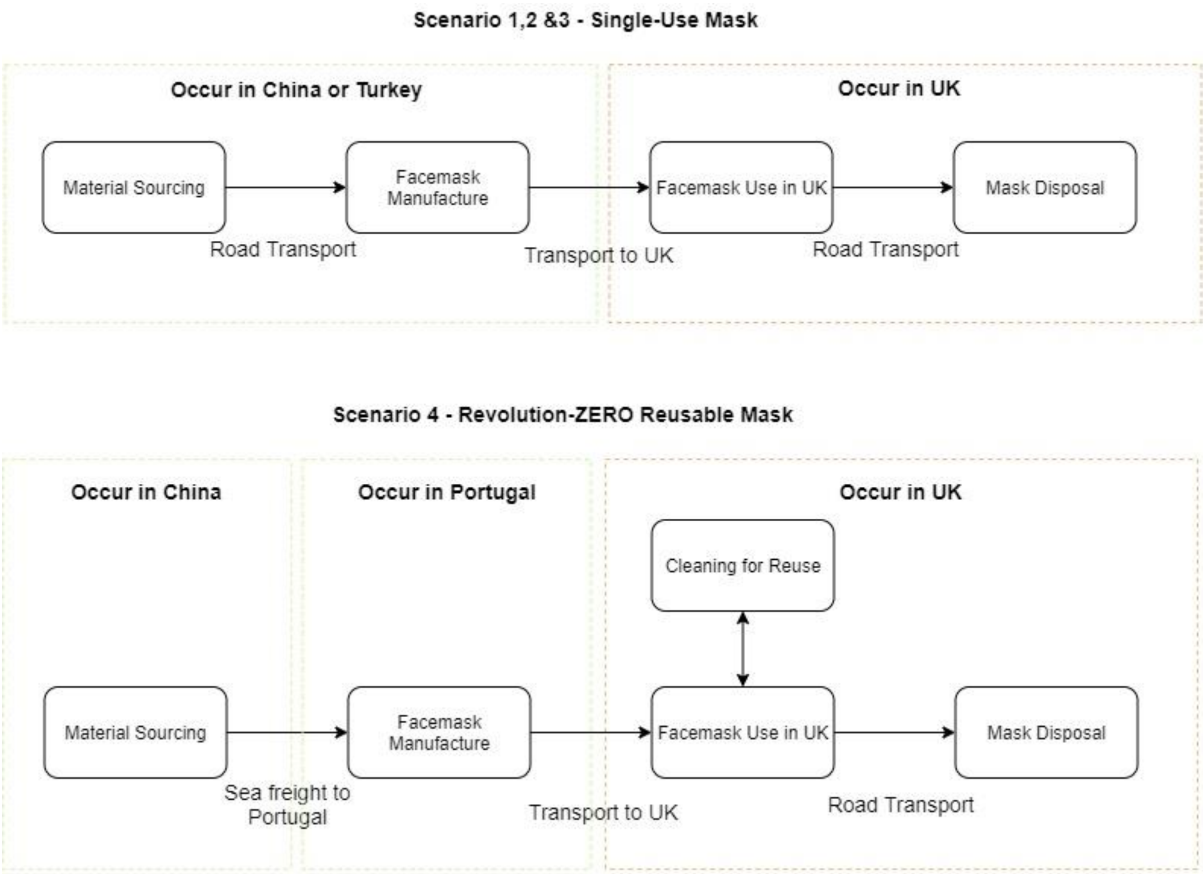

***Figure 1**: Cradle-to-grave system boundaries for each face mask use scenario.*

Manufacturing assumptions

It was assumed that the face masks (both single-use and reusable) were manufactured in China before being transported by airfreight to the UK. The materials and energy assumed to be required for the major manufacturing process of face masks and filters are summarised in **Table 2 and Table 3**. The emissions associated with the life cycle of factory machines were also not modelled. This was because installed equipment is assumed to have a long lifespan, thirty years on average (Erumban, 2008). The emissions and environmental impacts associated with the fabrication and decommission of equipment would be allocated proportionally over their lifespan, and was, therefore, assumed to be negligible.

Table 2: *Material of construction and mass used to model each product.*

Product / Component	Material	Area (m2)	Length (m)	Mass (g)	Source / Reference
(S1-3) Single-Use Mask					
Layer 1	PP (non-woven)	0.029	-	0.638	95mask, (2020) and Thomasnet (2020) provided the components and dimensions of a surgical mask.
Layer 2	Cellulosic fabric	0.029	-	0.725	
Layer 3	PP (non-woven)	0.029	-	0.638	
Nose Wire	HDPE	-	0.098	0.231	
Ear Loops	Polyetherimide (elastic material)	-	0.185 (each)	0.444	
Total				2.68	
(S4) RZ Reusable Mask		N/A	N/A		
Material	Polyester			9.14	Provided by Rutherford Healthcare
Nose Wire	Aluminium			0.044	
Ear Loops	Elastodien			0.033	
Total				9.91	

Table 3: *Electricity assumptions for the manufacture of masks and filters.*

Product / Component	Electricity Consumption (Wh/mask)	Reference Values	Assumption / Reference
(S1-3) Single-Use Mask			
Mask Body Forming	0.556	4 kW, 110 – 160 pcs/min	Reference values were taken from Testex, (no date) website on surgical mask production line. It was assumed the thorough put of mask was 120pc/min (240pc/min of ear loops).
Ear Loops Cutting	0.694	0.5 kW, 120 – 240 pcs/min	
Ultrasonic Welding	0.167	1.2 kW	
Total	0.792		
(S4) RZ Reusable Mask			
Laying, Cutting and Sewing	34.2	2.38 kWh/kg	(Moazzem et al., 2018)
Total	34.2		

Packaging assumptions

Packaging configurations were assumed based on product specifications shown on retailers' websites (Amazon, 2020; LANS Grupo, 2020). **Table 4** details the assumptions made in calculating the packaging weight of each packaging component.

Table 4: *Packaging assumptions for each scenario.*

	Packaging Configuration	Component / Material	Component Weight (kg)	Total Mass per FU (kt)	Assumptions / Reference
(S1-3) Single-Use Facemask	50pcs/box 40boxes/carton (2000pcs/carton)	Box – Cardboard Carton – Cardboard	0.0535 2.50	1060 30.9	LANS Grupo, (2020) provided dimensions and weight of each packaging component.
(S4) RZ Reusable Facemasks	Individually wrapped 1500pcs/carton	Wrap – LDPE Carton - Cardboard	0.00335 2.50	0.454 0.226	0.09m² surface area and 40 micron thickness of LDPE sheet was assumed to provide the weight per component. Assumed same size carton used, number of pcs per carton was calculated based on facemask surface area differences.

Transport assumptions

Tables 5 to 7 presents the transport assumptions use for this study. It was assumed that single-use masks materials were sourced locally to where they were manufactured but for the RZ reusable mask, materials were assumed to be sourced from China.

Table 5: *Transport assumptions for masks for all Scenarios 1 and 2.*

	Mode of Transport	Distance (km)	Notes
Materials to Manufacturing Facility & Facility to Terminal	Truck	100	Assumed materials sourced locally
China to UK	Air Freight Or Sea Freight	7800 Or 22000	(Entfernungsrechner, 2020)
Mask Distribution	Truck	300	Assumed distribution start from one UK Terminal
Mask to Disposal Sites	Truck	100	Assumed local authority collection for disposal

Table 6: *Transport assumptions for masks for all Scenarios 3.*

	Mode of Transport	Distance (km)	Notes
Materials to Manufacturing Facility & Facility to Terminal	Truck	100	Assumed materials sourced locally
Turkey to UK	Truck	5600	(Entfernungsrechner, 2020)
Mask Distribution	Truck	300	Assumed distribution start from one UK Terminal
Mask to Disposal Sites	Truck	100	Assumed local authority collection for disposal

Table 7: *Transport assumptions for masks for all Scenarios 4.*

	Mode of Transport	Distance (km)	Notes
Materials to Manufacturing Facility	Sea Freight and Truck	22000 and 100	Assumed materials sourced from China
Portugal to UK	Truck	2286	Provided by Rutherford Healthcare
Mask Distribution	Truck	300	Assumed distribution start from one UK Terminal
Mask to Disposal Sites	Truck	100	Assumed local authority collection for disposal

Machine washing assumptions (Scenario 4)

Walser et al. (2011) evaluated the environmental impact of t-shirts, with consideration for the “low”, “medium,” and “high” environmental awareness of their wearers, which influences the choice of washing machine category, the quantity of detergent used, and the temperature of the wash. Acknowledging that the ability to own a highly efficient washing machine is also dependent on household income, it was assumed that “low-medium” scenario is more probable for the UK public. This study used the parameters assumed by Walser et al. (2011) in their “low” and a 60°C full-load wash scenario, to allocate the amount of cleaning resources required to clean each face mask.

Table 6: *Requirements for the machine-washing of face masks for Scenario 4.*

Cleaning Components	**Per Machine Wash of 6 Kg Load** (Walser et al., 2011)	**Per Mask Per Wash**	**Total per FU**
Soap	67.5g	0.134g	4.82
Water	63L	0.125L	4.5 L
Electricity (Wash and Dry)	3.22kWh	6.39Wh	0.23kWh

Disposal assumptions

Waste arising from the use of single-use face masks was modelled for disposal through landfill and/or incineration: 43% landfill, 41% incineration with energy recovery, and 16% incineration only. This was based on UK statistics on waste supplied by the Department for Environment, Food & Rural Affairs [Defra] (2019). Landfill and incineration were chosen as the disposal methods, because these are the typical waste destinations for household waste. Single-use face masks are not currently recycled, while textiles are currently unlikely to be recycled. Although packaging can be recycled, plastic film packing, modelled as wrapping for reusable and single-use filters, is not conventionally recycled. Cardboard is widely recycled; however, this was not modelled due to insufficient data from GaBi (Sphera, 2020a) and EcoInvent databases (Ecoinvent, 2019).

For Scenarios 4, 90% of reusable masks were assumed to be collected for recycling as part of the take back scheme offered by Rutherford Research Limited, whilst 10% was assumed lost and therefore would end up in the general waste stream like single-use face masks. The recycling process was assumed to require 2 kW to recycle the polyester material into fibres intended for PPE manufacture; aluminium was assumed separated from the masks and was directed to recycling elsewhere; and the elastic material was assumed stored by the company. Since recycling materials provided additional functionalities to the product system, the Resource Use and Emission Profile formula developed by the Joint Research Centre (EC-JRC, 2012) was applied. It envisaged allocation of environmental impacts based on price ratio between recycled and virgin materials: for polyester fibre, 1:1 (assumed by Rutherford Research Limited), and aluminium, 0.76:1 (ratio provided by GaBi database) were assumed respectively.

Results

The comparative study was modelled on GaBi Software (Sphera, 2020b), the life cycle impact assessment (LCIA) method used to assess each scenario's environmental impact was the Environmental Footprint (EF) 3.0 methodology (Zampori and Pant, 2019). The LCIA results were compared across the different scenarios. A summary of environmental impact results is presented in **Table 8**. The results show that Scenario 4, the Rutherford Healthcare mask life cycle generated the lowest environmental impact in all impact categories, except the impact associated with water usage and ionising radiation.

Figure 2 highlights the hot-spot analysis carried out on the Climate Change results generated by each scenario. The results show that the mode of transport is an important factor to consider when lowering the carbon footprint of a mask; air freighting of single-use masks from China to UK generated highest impact towards Climate Changes as compared to sea freighting from China and road transporting from Turkey. The contribution of "Mask Manufacture" of single-use masks is also higher than of the reusable mask, which can be attributed to the higher number of masks required in Scenarios 1 to 3.

Table 8: *Overall environmental impact results for each face mask scenario. Green indicates the lowest results generated; red indicates the highest results generated.*

	S1: 36 Single-Use Masks (air freight from China)	S2: 36 Single-Use Masks (sea freight from China)	S3: 36 Single-Use Masks (from Turkey)	S4: 1 x Rutherford Healthcare Mask, washed 36 times
EF 3.0 Acidification terrestrial and freshwater [Mole of H+ eq.]	4.54E-03	2.51E-03	1.67E-03	3.17E-04
EF 3.0 Cancer human health effects [CTUh]	2.16E-10	1.76E-10	1.60E-10	5.11E-11
EF 3.0 Climate change [kg CO2 eq.]	1.15E+00	5.80E-01	5.56E-01	1.43E-01
EF 3.0 Ecotoxicity freshwater [CTUe]	1.61E+01	1.19E+01	1.19E+01	2.18E+00
EF 3.0 Eutrophication freshwater [kg P eq.]	4.37E-05	3.91E-05	3.57E-05	6.19E-06
EF 3.0 Eutrophication marine [kg N eq.]	1.51E-03	5.81E-04	3.75E-04	1.40E-04
EF 3.0 Eutrophication terrestrial [Mole of N eq.]	1.62E-02	6.15E-03	3.84E-03	9.94E-04
EF 3.0 Ionising radiation - human health [kBq U235 eq.]	4.84E-02	1.33E-02	1.12E-02	1.92E-02
EF 3.0 Land Use [Pt]	4.71E+00	3.72E+00	4.16E+00	1.03E+00
EF 3.0 Non-cancer human health effects [CTUh]	1.34E-08	6.15E-09	5.92E-09	1.57E-09
EF 3.0 Ozone depletion [kg CFC-11 eq.]	1.48E-07	1.81E-08	1.66E-08	1.50E-09
EF 3.0 Photochemical ozone formation - human health [kg NMVOC eq.]	4.34E-03	1.72E-03	1.15E-03	2.46E-04
EF 3.0 Resource use, energy carriers [MJ]	1.69E+01	9.07E+00	8.85E+00	2.46E+00
EF 3.0 Resource use, mineral and metals [kg Sb eq.]	3.46E-06	3.04E-06	3.56E-06	6.34E-07
EF 3.0 Respiratory inorganics [Disease incidences]	2.57E-08	2.12E-08	1.89E-08	3.19E-09
EF 3.0 Water scarcity [m³ world equiv.]	1.11E-01	1.05E-01	1.11E-01	2.48E-01

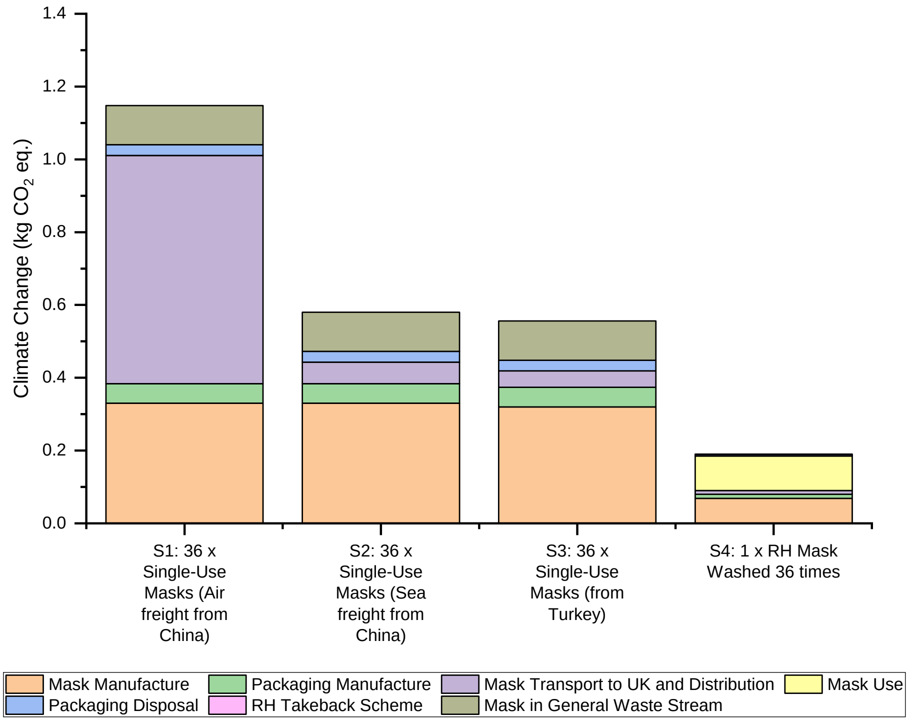

Figure 2*: Climate change results generated for each scenario of facemask use.*

The reusable face mask scenario is associated with substantial amounts of water usage as compared to single-use masks. **Figure 3** illustrates the processes that contribute to Water Scarcity. Scenario 4 contributed highly to this impact category, when compared to the use of single-use face masks. This is attributed to water requirements for washing the mask in “Mask Use”. Note that “Mask Use” considers the washing process and all other processes associated with washing, this includes energy generation for heat and production of soap. Since the study assumed a machine washing approach that is deemed to be low in efficiency, water requirements can be foreseen to lower when a more efficient washing machine is employed. Hot-spot analysis also showed that electricity usage for washing reusable masks attributed most towards ionising radiation and therefore the reason why S4 generated higher ionising radiation results to S2 and S3. Higher resource use – minerals and metals exhibited by S4 can be attributed to

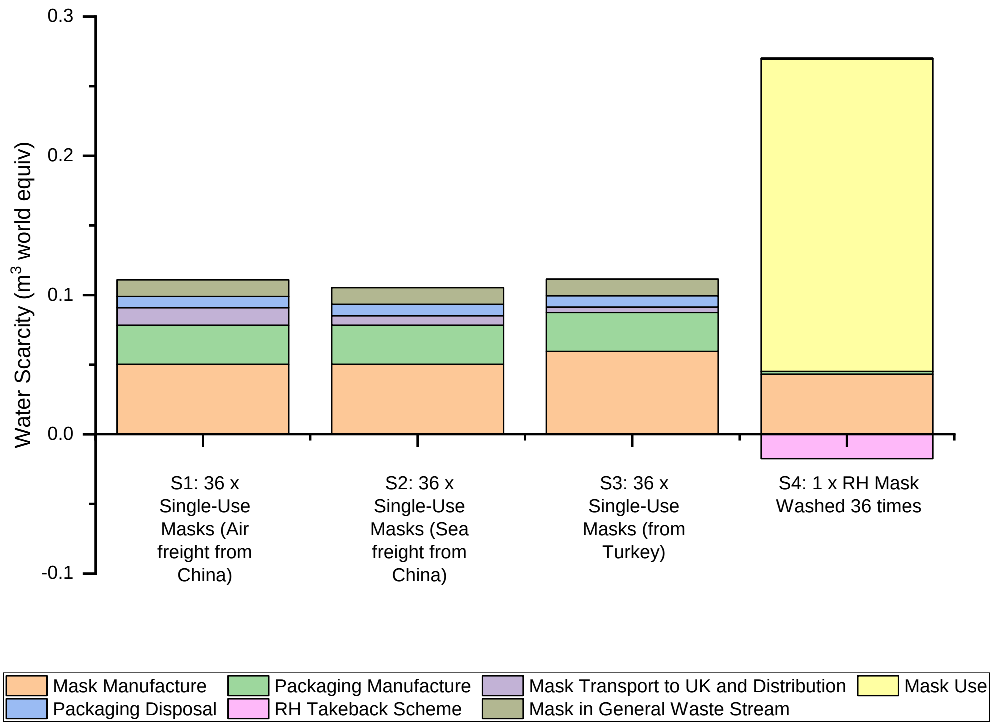

***Figure 3:** Water Scarcity results generated by each face mask scenario.*

Conclusion

The comparative study results show that using reusable face masks is the most favourable method of using face masks from an environmental perspective.