

Comparing circular business models for clothing using life cycle assessment

ANNEX

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Annex 1: Results data

A comparison of the environmental impacts of wardrobes acquired using the five business models with the conventional wardrobe life cycle are presented in the LCA paper, and provided here as a data table.

Table A1: Environmental impacts of wardrobes acquired using five alternative business models and a wardrobe acquired conventionally

Impact category and unit	1. Conventional wardrobe	2. Commercial resale	3. Charity resale	4. Online resale	5. Short-term rental	6. Leasing
Global warming kg CO ₂ eq	2621.6	2006.8	2004.6	1937.4	2245.0	2124.6
Freshwater eutrophication kg P eq	1.4	1.0	1.0	1.0	1.1	1.1
Terrestrial ecotoxicity kg 1,4-DCB eq	4852.1	3724.0	3714.6	3369.7	4918.5	3881.9
Freshwater ecotoxicity kg 1,4-DCB eq	132.9	99.7	99.5	92.0	121.7	103.4
Human carcinogenic toxicity kg 1,4-DCB eq	80.1	59.9	59.7	55.6	69.1	61.8
Land use m ² a crop eq	2110.9	1611.5	1609.6	1607.8	1666.0	1729.4
Water consumption m ³	296.3	210.5	209.8	209.5	213.2	227.1

Annex 2: Life cycle inventory data for use phase

The table that follows presents the data that was implemented in the LCI to represent conventional use. The use phase is in the foreground for the LCA and the data selected, where possible, use information provided from consumer surveys that are representative for the UK population, since this is the main market of interest. Consumer survey responses are used for behavioural factors relating to the number of times garments are worn and washed, the frequency of use of machine drying and ironing, and how likely garments are to be repaired during the first, and subsequent phases of use.

To produce data for the LCI, the survey responses were combined with additional sources of data to provide quantities of materials and chemicals used and energy use for different processes. These sources are listed in the table that follows. These data were combined with the consumer survey data to get quantities used in the LCI. For example, the energy used by washing machines for the whole life of each garment was calculated with consumer data for washing frequency, combined with secondary data for energy consumption of washing machines. The typical kWh for one wash would be difficult to get from consumer surveys since this information requires a certain amount of technological understanding, and for energy consumption to be 'looked up' before the survey could be answered. This data was taken from (Energy Savings Trust, 2010) for domestic washing in the use phase. The energy (in kWh per wash) was multiplied by the average number of times that garment type would be washed during one phase of ownership, taken from survey data. The conventional use phase includes only the primary stage of use. Reuse models include only one second or subsequent stage of use. As with other processes, impact was modelled using Ecoinvent 3.7.1 in SimaPro (v9.2.0.2).

Table A2: Life Cycle Inventory for Conventional Use

Processes	Type	Quantity	Unit	Data source
Product: Coats / jackets				
Materials	1 coat / jacket, polyester wool mix	805.8	g	Weight from WRAP data average weights list
Water	Tap water (RER)	7.84	kg	Pakula and Stamminger, (2010)
Chemicals	Cleaning consumables, without water, in 13.6% solution state	6.533	ml	Mintel, (2020) Ecoinvent 3.7.1
Chemicals	PERC, Tetrachloroethylene	0.0016	Kg	PERC used per load from Laitala et al., (2018) citing Fong et al (2006) Dry cleaning frequencies assumed 40% of washes for coats / jackets
Materials	Repair textiles; woven polyester wool blend	0.9614	G	Material to match garment. Repair frequency from (WRAP, 2022a)
Materials	Repair buttons, polyester, unsaturated resin	0.1351	g	Material to match garment. Repair frequency from (WRAP, 2022a)
Transport	Passenger car	7.5	km	Estimate for UK customer transport
Transport	Regular bus	3	personkm	Estimate for UK customer transport
Transport	Freight, light commercial vehicle	0.009	tkm	Estimate for UK customer transport
Electricity	Washing	0.0764	kWh	Energy Savings Trust (2010)
Electricity	Repair (sewing machine)	0.0062	kWh	Thomas et al., (2012)
Electricity	Machine drying	0	kWh	(Energy Savings Trust, 2010)
Electricity	Ironing	0	kWh	
Electricity	Dry cleaning	0.0475	kWh	from Laitala et al., (2018) citing Fong et al (2006)
Waste	MSW treatment, sanitary landfill	0.00001	kg	Ecoinvent 3.7.1
Product: Denim jeans				

Materials	1 pair denim jeans	598	g	Weight from WRAP data average weights list
Water	Tap water (RER)	541.9	kg	Pakula and Stamminger, (2010)
Chemicals	Cleaning consumables, without water, in 13.6% solution state	451.6	ml	Mintel, (2020) Ecoinvent 3.7.1
Chemicals	PERC, Tetrachloroethylene	0	kg	PERC used in dry cleaning
Materials	Repair textiles; denim cotton	0.9389	g	Material to match garment. Repair frequency from (WRAP, 2022a)
Materials	Repair buttons, brass	0.1319	g	Material to match garment. Repair frequency from (WRAP, 2022a)
Transport	Passenger car	7.5	km	Estimate for UK customer transport
Transport	Regular bus	3	personkm	Estimate for UK customer transport
Transport	Freight, light commercial vehicle	0.009	tkm	Estimate for UK customer transport
Electricity	Washing	5.2729	kWh	Energy Savings Trust (2010)
Electricity	Repair (sewing machine)	0.0061	kWh	Thomas et al., (2012)
Electricity	Machine drying	3.4218	kWh	Energy Savings Trust (2010)
Electricity	Ironing	0	kWh	
Electricity	Dry cleaning	0	kWh	
Waste	MSW treatment, sanitary landfill	0.00001	kg	Ecoinvent 3.7.1

Product: Dresses

Materials	1 dress, jersey blend	307.2	g	Weight from WRAP data average weights list
Water	Tap water (RER)	69.5	kg	Pakula and Stamminger, (2010)
Chemicals	Cleaning consumables, without water, in 13.6% solution state	57.9	ml	Mintel, (2020) Ecoinvent 3.7.1
Chemicals	PERC, Tetrachloroethylene	0.000432	kg	PERC used per load from Laitala et al., (2018) citing Fong et al (2006) Dry cleaning frequencies assumed
Materials	Repair textiles; jersey VI, PE, CO blend	0.0010	kg	Material to match garment. Repair frequency from (WRAP, 2022a)
Materials	Repair buttons, polyester, unsaturated resin	0.0001	kg	Material to match garment. Repair frequency from (WRAP, 2022a)
Transport	Passenger car	7.5	km	Estimate for UK customer transport
Transport	Regular bus	3	personkm	Estimate for UK customer transport
Transport	Freight, light commercial vehicle	0.009	tkm	Estimate for UK customer transport
Electricity	Washing	0.6774	kWh	Energy Savings Trust (2010)
Electricity	Repair (sewing machine)	0.0065	kWh	Thomas et al., (2012)
Electricity	Machine drying	0.4391	kWh	Energy Savings Trust (2010)
Electricity	Ironing	0.093	kWh	Beton et al (2014)
Electricity	Dry cleaning	0.0134	kWh	from Laitala et al., (2018) citing Fong et al (2006)
Waste	MSW treatment, sanitary landfill	0.00001	kg	Ecoinvent 3.7.1

Product: Jumpers

Materials	1 jumper, med-heavyweight synthetic knit	344	g	Weight from WRAP data average weights list
Water	Tap water (RER)	101.7	kg	Pakula and Stamminger, (2010)
Chemicals	Cleaning consumables, without water, in 13.6% solution state	84.8	ml	Mintel, (2020) Ecoinvent 3.7.1
Chemicals	PERC, Tetrachloroethylene	0	kg	
Materials	Repair textiles; acrylic fibre, ring spun 300dtex	0.0008	kg	Material to match garment. Repair frequency from (WRAP, 2022a)
Materials	Repair buttons, polyester, unsaturated resin	0	kg	
Transport	Passenger car	7.5	km	Estimate for UK customer transport
Transport	Regular bus	3	personkm	Estimate for UK customer transport
Transport	Freight, light commercial vehicle	0.009	tkm	Estimate for UK customer transport
Electricity	Washing	0.991	kWh	Energy Savings Trust (2010)
Electricity	Repair (sewing machine)	0	kWh	(Thomas et al., 2012)

Electricity	Machine drying	0.6423	kWh	Energy Savings Trust (2010)
Electricity	Ironing	0.0678	kWh	Beton et al (2014)
Electricity	Dry cleaning	0	kWh	
Waste	MSW treatment, sanitary landfill	0.00001	kg	Ecoinvent 3.7.1

Product: Nightwear

Materials	1 pair of woven cotton pyjamas	563	g	Weight from WRAP data average weights list
Water	Tap water (RER)	496.8	kg	Pakula and Stamminger, (2010)
Chemicals	Cleaning consumables, without water, in 13.6% solution state	414	ml	Mintel, (2020) Ecoinvent 3.7.1
Chemicals	PERC, Tetrachloroethylene	0	kg	PERC used in dry cleaning
Materials	Repair textiles; lightweight cotton, woven	0.001	kg	Material to match garment. Repair frequency from (WRAP, 2022a)
Materials	Repair buttons, polyester, unsaturated resin	0.0001	kg	Material to match garment. Repair frequency from (WRAP, 2022a)
Transport	Passenger car	7.5	km	Estimate for UK customer transport
Transport	Regular bus	3	personkm	Estimate for UK customer transport
Transport	Freight, light commercial vehicle	0.009	tkm	Estimate for UK customer transport
Electricity	Washing	4.8394	kWh	Energy Savings Trust (2010)
Electricity	Repair (sewing machine)	0.0067	kWh	Thomas et al (2012)
Electricity	Machine drying	3.1366	kWh	Energy Savings Trust (2010)
Electricity	Ironing	0	kWh	
Electricity	Dry cleaning	0	kWh	
Waste	MSW treatment, sanitary landfill	0.00001	kg	Ecoinvent 3.7.1

Product: Shirts

Materials	1 shirt, woven cotton, long sleeves	182	g	Weight from WRAP data average weights list
Water	Tap water (RER)	73.6	kg	Pakula and Stamminger, (2010)
Chemicals	Cleaning consumables, without water, in 13.6% solution state	61.3	ml	Mintel, (2020) Ecoinvent 3.7.1
Chemicals	PERC, Tetrachloroethylene	0.0005	kg	PERC used per load from Laitala et al., (2018) citing Fong et al (2006) Dry cleaning frequencies assumed
Materials	Repair textiles; lightweight cotton, woven	0.001	kg	Material to match garment. Repair frequency from (WRAP, 2022a)
Materials	Repair buttons, polyester, unsaturated resin	0.0001	kg	Material to match garment. Repair frequency from (WRAP, 2022a)
Transport	Passenger car	7.5	km	Estimate for UK customer transport
Transport	Regular bus	3	personkm	Estimate for UK customer transport
Transport	Freight, light commercial vehicle	0.009	tkm	Estimate for UK customer transport
Electricity	Washing	0.7167	kWh	Energy Savings Trust (2010)
Electricity	Repair (sewing machine)	0.0056	kWh	Thomas et al (2012)
Electricity	Machine drying	0.4646	kWh	Energy Savings Trust (2010)
Electricity	Ironing	0.0981	kWh	Beton et al (2014)
Electricity	Dry cleaning	0.0142	kWh	PERC used per load from Laitala et al., (2018) citing Fong et al (2006) Dry cleaning frequencies assumed
Waste	MSW treatment, sanitary landfill	0.00001	kg	Ecoinvent 3.7.1

Product: Skirts

Materials	1 skirt, thick blend	233.5	g	Weight from WRAP data average weights list
Water	Tap water (RER)	136.7	kg	Pakula and Stamminger, (2010)
Chemicals	Cleaning consumables, without water, in 13.6% solution state	113.9	ml	Mintel, (2020) Ecoinvent 3.7.1
Chemicals	PERC, Tetrachloroethylene	0.0008	kg	PERC used per load from Laitala et al., (2018) citing Fong et al (2006) Dry cleaning frequencies assumed

Materials	Repair textiles; heavyweight woven PE, VI, PA blend	0.0012	kg	Material to match garment. Repair frequency from (WRAP, 2022a) and (Laitala et al., 2018)
Materials	Repair buttons, polyester, unsaturated resin	0.0002	kg	Material to match garment. Repair frequency from (WRAP, 2022a)
Transport	Passenger car	7.5	km	Estimate for UK customer transport
Transport	Regular bus	3	personkm	Estimate for UK customer transport
Transport	Freight, light commercial vehicle	0.009	tkm	Estimate for UK customer transport
Electricity	Washing	1.3317	kWh	Energy Savings Trust (2010)
Electricity	Repair (sewing machine)	0.0076	kWh	Thomas et al (2012)
Electricity	Machine drying	0.8632	kWh	Energy Savings Trust (2010)
Electricity	Ironing	0.1823	kWh	Beton et al (2014)
Electricity	Dry cleaning	0.0264	kWh	from Laitala et al., (2018) citing Fong et al (2006) Dry cleaning frequencies assumed
Waste	MSW treatment, sanitary landfill	0.00001	kg	Ecoinvent 3.7.1

Product: Socks

Materials	1 pair of socks, wool and nylon mix	40.5	g	Weight from WRAP data average weights list
Water	Tap water (RER)	68.3	kg	Pakula and Stamminger, (2010)
Chemicals	Cleaning consumables, without water, in 13.6% solution state	56.9	ml	Mintel, (2020) Ecoinvent 3.7.1
Chemicals	PERC, Tetrachloroethylene	0	kg	PERC used in dry cleaning
Materials	Repair textiles; wool yarn, 150dtex.	0.0005	kg	Material to match garment. Repair frequency from (WRAP, 2022a)
Transport	Passenger car	7.5	km	Estimate for UK customer transport
Transport	Regular bus	3	personkm	Estimate for UK customer transport
Transport	Freight, light commercial vehicle	0.009	tkm	Estimate for UK customer transport
Electricity	Washing	0.6654	kWh	Energy Savings Trust (2010)
Electricity	Dry cleaning	0	kWh	
Waste	MSW treatment, sanitary landfill	0.00001	kg	Ecoinvent 3.7.1

Product: Sportswear

Materials	1 sportswear garment	331.4	g	Weight from WRAP data average weights list
Water	Tap water (RER)	106.1	kg	Pakula and Stamminger, (2010)
Chemicals	Cleaning consumables, without water, in 13.6% solution state	88.4	ml	Mintel, (2020) Ecoinvent 3.7.1
Chemicals	PERC, Tetrachloroethylene	0	kg	PERC used in dry cleaning
Materials	Repair textiles; polyester fibre yarn, air jet spinning, 150dtex	0.0008	kg	Material to match garment. Repair frequency from (WRAP, 2022a)
Materials	Repair buttons, polyester, unsaturated resin	0.0001	kg	Material to match garment. Repair frequency from (WRAP, 2022a)
Transport	Passenger car	7.5	km	Estimate for UK customer transport
Transport	Regular bus	3	personkm	Estimate for UK customer transport
Transport	Freight, light commercial vehicle	0.009	tkm	Estimate for UK customer transport
Electricity	Washing	1.0332	kWh	Energy Savings Trust (2010)
Electricity	Repair (sewing machine)	0.0055	kWh	Thomas et al (2012)
Electricity	Machine drying	0.6697	kWh	Energy Savings Trust (2010)
Waste	MSW treatment, sanitary landfill	0.00001	kg	Ecoinvent 3.7.1

Product: Sweaters

Materials	1 sweater, med-heavyweight cotton knit	501.7	g	Weight from WRAP data average weights list
Water	Tap water (RER)	224.4	kg	Pakula and Stamminger, (2010)
Chemicals	Cleaning consumables, without water, in 13.6% solution state	203.7	ml	Mintel, (2020) Ecoinvent 3.7.1
Chemicals	PERC, Tetrachloroethylene	0	kg	PERC used in dry cleaning

Materials	Repair textiles; polyester fibre yarn, air jet spinning, 150dtex	0.0009	kg	Material to match garment. Repair frequency from (WRAP, 2022a)
Materials	Repair buttons, polyester, unsaturated resin	0.0001	kg	Material to match garment. Repair frequency from (WRAP, 2022a)
Transport	Passenger car	7.5	km	Estimate for UK customer transport
Transport	Regular bus	3	personkm	Estimate for UK customer transport
Transport	Freight, light commercial vehicle	0.009	tkm	Estimate for UK customer transport
Electricity	Washing	2.38	kWh	Energy Savings Trust (2010)
Electricity	Repair (sewing machine)	0.0057	kWh	Thomas et al (2012)
Electricity	Machine drying	1.5432	kWh	Energy Savings Trust (2010)
Electricity	Ironing	0.3259	kWh	Beton et al (2014)
Waste	MSW treatment, sanitary landfill	0.00001	kg	Ecoinvent 3.7.1

Product: Tops

Materials	1 top, cotton t-shirt	204.8	g	Weight from WRAP data average weights list
Water	Tap water (RER)	148.6	kg	Pakula and Stamminger, (2010)
Chemicals	Cleaning consumables, without water, in 13.6% solution state	123.8	ml	Mintel, (2020) Ecoinvent 3.7.1
Chemicals	PERC, Tetrachloroethylene	0.0009	kg	PERC used per load from Laitala et al., (2018) citing Fong et al (2006) Dry cleaning frequencies assumed
Materials	Repair textiles; cotton, ring spun 150dtex	0.0008	kg	Material to match garment. Repair frequency from (WRAP, 2022a)
Transport	Passenger car	7.5	km	Estimate for UK customer transport
Transport	Regular bus	3	personkm	Estimate for UK customer transport
Transport	Freight, light commercial vehicle	0.009	tkm	Estimate for UK customer transport
Electricity	Washing	1.4479	kWh	Energy Savings Trust (2010)
Electricity	Repair (sewing machine)	0.0052	kWh	Thomas et al (2012)
Electricity	Machine drying	0.9384	kWh	Energy Savings Trust (2010)
Electricity	Ironing	0.1982	kWh	Beton et al (2014)
Waste	MSW treatment, sanitary landfill	0.00001	kg	Ecoinvent 3.7.1

Product: Trousers

Materials	1 pair of trousers, cotton chinos	331.4	g	Weight from WRAP data average weights list
Water	Tap water	297.5	kg	Pakula and Stamminger, (2010)
Chemicals	Cleaning consumables, without water, in 13.6% solution state	247.9	ml	Mintel, (2020) Ecoinvent 3.7.1
Chemicals	PERC, Tetrachloroethylene	0.0018	kg	PERC used per load from Laitala et al., (2018) citing Fong et al (2006) Dry cleaning frequencies assumed
Materials	Repair textiles; cotton, ring spun 150dtex	0.0009	kg	Material to match garment. Repair frequency from (WRAP, 2022a)
Materials	Repair hardware, steel, low-alloyed	0.0013	Kg	Material to match garment. Repair frequency from (WRAP, 2022a)
Materials	Repair, metal working, average for manufacturing	0.0013	Kg	Material to match garment. Repair frequency from (WRAP, 2022a)
Transport	Passenger car	7.5	Km	Estimate for UK customer transport
Transport	Regular bus	3	personkm	Estimate for UK customer transport
Transport	Freight, light commercial vehicle	0.009	tkm	Estimate for UK customer transport
Electricity	Washing	1.8782	kWh	Energy Savings Trust (2010)
Electricity	Repair (sewing machine)	0.0061	kWh	Thomas et al (2012)
Electricity	Machine drying	0.3966	kWh	Energy Savings Trust (2010)
Electricity	Ironing	0.3966	kWh	Beton et al (2014)
Electricity	Dry cleaning	0.0575	kWh	Fong et al (2006)
Waste	MSW treatment, sanitary landfill	0.00001	kg	Ecoinvent 3.7.1

Product: Underwear

Materials	1 item of cotton underwear	77.26	g	Weight from WRAP data average weights list
Water	Tap water (RER)	209.6	kg	Pakula and Stamminger, (2010)
Chemicals	Cleaning consumables, without water, in 13.6% solution state	174.7	ml	Mintel, (2020) Ecoinvent 3.7.1
Transport	Passenger car	7.5	Km	Estimate for UK customer transport
Transport	Regular bus	3	personkm	Estimate for UK customer transport
Transport	Freight, light commercial vehicle	0.009	tkm	Estimate for UK customer transport
Electricity	Washing	2.042	kWh	Energy Savings Trust (2010)
Electricity	Machine drying	1.323	kWh	Energy Savings Trust (2010)
Waste	MSW treatment, sanitary landfill	0.00001	kg	Ecoinvent 3.7.1

Use of Clothing Acquired via Circular Clothing Business Models

Garment use is modelled for reuse business models, to represent the second use phase following reuse, and to represent the whole lifespan, where garments are acquired via rental or leasing, because for these business models the garments are unlikely to have had previous, first phase of use. Processes included in the LCI include transport to the consumer following acquisition. Depending on the business model, this may be consumer transport or it may also include use of postal services and couriers. Processes for cleaning including, domestic washing, and sometimes machine drying, ironing, and repair are presented, and it is assumed that secondhand clothes acquired via resale are washed the same way as if they were bought new. Dry cleaning is used occasionally for certain types of clothing (as with the primary use phase) and for certain types of business model; in particular rental models included in interviews for the research were more likely to professionally clean clothing before an is re-issued. The model acknowledges that some rental companies consciously choose lower-impact methods of cleaning and includes data for professional wet cleaning, but frequency of use of dry cleaning is modelled in line with industry averages (85% of professional cleaning was assumed to be dry cleaning). Factors related to the length and intensity of use of garments are also important and data were reviewed on garment lifespan for each type of garment, as well as how often garments of that type are likely to be worn. The type of business model results in different patterns of wear. This is especially so for rental models, since garments may be worn quite intensely over a shorter duration of lifespan, by changing hands multiple times. For certain types of garment, this should result in them being worn much more often than they would have otherwise been (Johnson and Plepys, 2021; Piontek et al., 2020).

Displacement of the sale of new garments is particularly important to the potential of reuse to provide savings (Farrant et al., 2010; Stevenson and Gmitrowicz, 2013). If displacement is not factored, then reuse is assumed to entirely replace new products and the impacts from raw materials and production of garments avoided altogether. This results in overstating the potential of reuse where purchases of secondhand items are likely to cost less than new products, and additional items are purchased.

Life cycle inventory data used for circular clothing business models

Table A3 presents data that was implemented to represent the circular clothing business models. Each model is presented in a separate column of data. The use phase is in the foreground for the LCA and the data selected, where possible, use information provided from consumer surveys that are representative for the UK population, since this is the main market of interest. Consumer survey responses are used for behavioural factors relating to the number of times garments are worn and washed, the frequency of use of machine drying and ironing, and how likely garments are to be repaired during the first, and subsequent phases of use.

The following business models are included in the table:

- CCBM1 – Commercial resale
- CCBM2 – Charity resale
- CCBM3 – Online resale
- CCBM4 – Short-term rental
- CCBM5 – Leasing

Table A3: Life cycle inventory data for circular economy clothing business models

Processes	Type of process	Quantities					Unit	Data source
		CCBM1	CCBM2	CCBM3	CCBM4	CCBM5		
Product: Coats / jackets								
Materials	1 coat / jacket, polyester wool mix	805.8	805.8	805.8	926.6*	805.8	g	Weight from WRAP data average weights list. *Weights for rental business models were increased to factor in design for durability
Chemicals	Cleaning consumables, without water, in 13.6% solution state	8.1758	7.501	9.863	0	44.850	ml	Mintel, (2020) Ecoinvent 3.7.1
Water	Tap water	9.8110	9.001	11.84	0	53.820	l	Pakula and Staminger (2010)
Electricity	Wash energy	0.0956	0.088	0.115	0	0.524	kWh	Energy Savings Trust (2010)
Electricity	Dry energy	0	0	0	0	0	kWh	Energy Savings Trust (2010)
Electricity	Iron energy	0	0	0	0	0	kWh	Beton et al (2014)
Chemicals	Dry clean PERC Tetrachloroethylene	0.0020	0.002	0.002	0.058	0.065	PERC l	PERC used per load from Laitala et al., (2018) citing Fong et al (2006)
Electricity	Dry clean energy	0.0619	0.057	0.075	1.792	2.038	kWh	Energy used from dry cleaning from Laitala et al., (2018) citing Fong et al (2006)
Electricity	Prof wet clean	0	0	0	0.121	0	kWh	Laitala et al (2018)
Electricity	Liquid CO2 clean	0	0	0	0.134	0	kWh	Laitala et al (2018)
Materials	Repair textiles	3.0235	1.893	0.7	1.576	2.061	g	Calculated
Materials	Repair hardware	0.4248	0.266	0.354	0.221	0.290	g	Calculated
Electricity	Repair	0.0196	0.012	0.016	0.010	0.013	kWh	Thomas et al (2012)
Transport	Passenger car	7.5	7.5	0.75	220.5	0.75	km	Estimate for UK customer transport
Transport	Regular bus	3.0	3	0.75	220.5	0.75	km	Estimate for UK customer transport
Transport	Freight, light commercial vehicle	0.009	0.009	0.027	7.938	0.027	tkm	Estimate for UK customer transport
Waste	Per garment, as for conventional use							
Product: Denim jeans								
Materials	1 pair of denim jeans	598	598	598	687.7*	598	g	Weight from WRAP data average weights list. *Weights for rental business models were increased to factor in design for durability
Chemicals	Cleaning consumables, without water, in 13.6% solution state	700.0	707.6	609.4	0	1443	ml	Mintel, (2020) Ecoinvent 3.7.1
Water	Tap water	840.0	849.1	731.2	0	1731	kg	Pakula and Staminger (2010)

Electricity	Wash energy	8.183	8.272	7.124	0	16.87	ml	Energy Savings Trust (2010)
Electricity	Dry energy	5.304	5.361	4.617	0	10.93	kg	Energy Savings Trust (2010)
Electricity	Iron energy	0	0	0	0	0	g	Beton et al (2014)
Chemicals	Dry clean PERC Tetrachloroethylene	0	0	0	0.001	0	g	PERC used per load from Laitala et al., (2018) citing Fong et al (2006)
Electricity	Dry clean energy	0	0	0	0.036	0	km	Energy used from dry cleaning from Laitala et al., (2018) citing Fong et al (2006)
Electricity	Prof wet clean	0	0	0	0.098	0	personkm	Laitala et al (2018)
Electricity	Liquid CO2 clean	0	0	0	1.801	0	tkm	Laitala et al (2018)
Materials	Repair textiles	3.831	2.763	1.744	0.220	2.293	kWh	Calculated
Materials	Repair hardware	0.538	0.388	0.245	0.031	0.322	kWh	Calculated
Electricity	Repair	0.025	0.018	0.011	0.001	0.015	kWh	Thomas et al (2012)
Transport	Passenger car	7.5	7.5	0.75	220.5	0.75	kWh	Estimate for UK customer transport
Transport	Regular bus	3	3	0.75	220.5	0.75	kWh	Estimate for UK customer transport
Transport	Freight, light commercial vehicle	0.009	0.009	0.027	7.938	0.027	kg	Estimate for UK customer transport
Waste	Per garment, as for conventional use							

Product: Dresses

Materials	1 dress, jersey blend	307.2	307.2	307.2	353.2*	307.2	g	Weight from WRAP data average weights list. *Weights for rental business models were increased to factor in design for durability
Chemicals	Cleaning consumables, without water, in 13.6% solution state	91.41	86.52	83.85	0	71.03	ml	Mintel, (2020) Ecoinvent 3.7.1
Water	Tap water	109.7	103.8	100.6	0	85.24	kg	Pakula and Staminger (2010)
Electricity	Wash energy	1.069	1.011	0.980	0	0.830	ml	Energy Savings Trust (2010)
Electricity	Dry energy	0.693	0.656	0.635	0	0.538	kg	Energy Savings Trust (2010)
Electricity	Iron energy	0.146	0.138	0.134	0	0.114	g	Beton et al (2014)
Chemicals	Dry clean PERC Tetrachloroethylene	0.001	0.001	0.001	0.020	0.004	g	PERC used per load from Laitala et al., (2018) citing Fong et al (2006)
Electricity	Dry clean energy	0.021	0.020	0.019	0.632	0.110	km	Energy used from dry cleaning from Laitala et al., (2018) citing Fong et al (2006)
Electricity	Prof wet clean	0	0	0	0.057	0	personkm	Laitala et al (2018)
Electricity	Liquid CO2 clean	0	0	0	0.316	0	tkm	Laitala et al (2018)
Materials	Repair textiles	3.884	2.469	1.763	2.246	2.249	kWh	Calculated
Materials	Repair hardware	0.546	0.347	0.248	0.316	0.316	kWh	Calculated

Electricity	Repair	0.025	0.016	0.011	0.015	0.015	kWh	Thomas et al (2012)
Transport	Passenger car	7.5	7.5	0.75	220.5	0.75	kWh	Estimate for UK customer transport
Transport	Regular bus	3	3	0.75	220.5	0.75	kWh	Estimate for UK customer transport
Transport	Freight, light commercial vehicle	0.009	0.009	0.027	7.938	0.027	kg	Estimate for UK customer transport
Waste	Per garment, as for conventional use							

Product: Jumpers

Materials	1 jumper, med-heavyweight synthetic knit	344	344	344	395.6*	344	g	Weight from WRAP data average weights list. *Weights for rental business models were increased to factor in design for durability
Chemicals	Cleaning consumables, without water, in 13.6% solution state	129.4	128.2	120.0	0	506.1	ml	Mintel, (2020) Ecoinvent 3.7.1
Water	Tap water	155.2	153.8	144.0	0	607.4	kg	Pakula and Staminger (2010)
Electricity	Wash energy	1.512	1.498	1.402	0	5.917	ml	Energy Savings Trust (2010)
Electricity	Dry energy	0.980	0.971	0.909	0	3.835	kg	Energy Savings Trust (2010)
Electricity	Iron energy	0.103	0.103	0.096	0	0.405	g	Beton et al (2014)
Chemicals	Dry clean PERC Tetrachloroethylene	0	0	0	0.016	0	g	PERC used per load from Laitala et al., (2018) citing Fong et al (2006)
Electricity	Dry clean energy	0	0	0	0.506	0	km	Energy used from dry cleaning from Laitala et al., (2018) citing Fong et al (2006)
Electricity	Prof wet clean	0	0	0	0.068	0	personkm	Laitala et al (2018)
Electricity	Liquid CO2 clean	0	0	0	0.682	0	tkm	Laitala et al (2018)
Materials	Repair textiles	3.944	2.303	2.712	0.461	2.410	kWh	Calculated
Materials	Repair hardware	0	0.324	0.381	0.065	0.339	kWh	Calculated
Electricity	Repair	0.026	0.015	0.018	0.003	0.016	kWh	Thomas et al (2012)
Transport	Passenger car	7.5	7.5	0.75	220.5	0.75	kWh	Estimate for UK customer transport
Transport	Regular bus	3	3	0.75	220.5	0.75	kWh	Estimate for UK customer transport
Transport	Freight, light commercial vehicle	0.009	0.009	0.027	7.938	0.027	kg	Estimate for UK customer transport
Waste	Per garment, as for conventional use							

Product: Nightwear – reuse models excluded intimate apparel, which was modelled using conventional use data for reuse wardrobes.

Product: Shirts

Materials	1 shirt, woven cotton, long sleeves	182	182	182	209.3*	182	g	Weight from WRAP data average weights list. *Weights for rental business models were increased to factor in design for durability
Chemicals	Cleaning consumables, without water, in 13.6% solution state	101.4	102.0	97.9	0	73.275	ml	Mintel, (2020) Ecoinvent 3.7.1
Water	Tap water	121.6	122.4	117.4	0	87.930	kg	Pakula and Staminger (2010)
Electricity	Wash energy	1.185	1.192	1.144	0	0.857	ml	Energy Savings Trust (2010)
Electricity	Dry energy	0.768	0.773	0.741	0	0.555	kg	Energy Savings Trust (2010)
Electricity	Iron energy	0.162	0.163	0.157	0	0.117	g	Beton et al (2014)
Chemicals	Dry clean PERC Tetrachloroethylene	0	0	0	0.009	0	g	PERC used per load from Laitala et al., (2018) citing Fong et al (2006)
Electricity	Dry clean energy	0	0	0	0.267	0	km	Energy used from dry cleaning from Laitala et al., (2018) citing Fong et al (2006)
Electricity	Prof wet clean	0	0	0	0.036	0	personkm	Laitala et al (2018)
Electricity	Liquid CO2 clean	0	0	0	0.361	0	tkm	Laitala et al (2018)
Materials	Repair textiles	4.290	2.556	2.813	1.716	2.791	kWh	Calculated
Materials	Repair hardware	1	0.359	0.395	0.241	0.392	kWh	Calculated
Electricity	Repair	0.028	0.017	0.018	0.011	0.018	kWh	Thomas et al (2012)
Transport	Passenger car	7.5	7.5	0.75	220.5	0.75	kWh	Estimate for UK customer transport
Transport	Regular bus	3	3	0.75	220.5	0.75	kWh	Estimate for UK customer transport
Transport	Freight, light commercial vehicle	0.009	0.009	0.027	7.938	0.027	kg	Estimate for UK customer transport
Waste	Per garment, as for conventional use							
Product: Skirts								
Materials	1 skirt, thick blend	233.5	233.5	233.5	268.5*	233.5	g	Weight from WRAP data average weights list. *Weights for rental business models were increased to factor in design for durability
Chemicals	Cleaning consumables, without water, in 13.6% solution state	145.8	151.2	128.5	0	123.2	ml	Mintel, (2020) Ecoinvent 3.7.1
Water	Tap water	174.9	181.5	154.2	0	147.9	kg	Pakula and Staminger (2010)
Electricity	Wash energy	1.704	1.768	1.503	0	1.441	ml	Energy Savings Trust (2010)
Electricity	Dry energy	1.105	1.146	0.974	0	0.934	kg	Energy Savings Trust (2010)
Electricity	Iron energy	0.233	0.242	0.206	0	0.197	g	Beton et al (2014)
Chemicals	Dry clean PERC Tetrachloroethylene	0	0	0	0.012	0	g	PERC used per load from Laitala et al., (2018) citing Fong et al (2006)

Electricity	Dry clean energy	0	0	0	0.390	0	km	Energy used from dry cleaning from Laitala et al., (2018) citing Fong et al (2006)
Electricity	Prof wet clean	0	0	0	0.035	0	personkm	Laitala et al (2018)
Electricity	Liquid CO2 clean	0	0	0	0.195	0	tkm	Laitala et al (2018)
Materials	Repair textiles	3.128	2.219	0.668	0.796	2.242	kWh	Calculated
Materials	Repair hardware	0	0.312	0.094	0.112	0.315	kWh	Calculated
Electricity	Repair	0.020	0.014	0.004	0.005	0.015	kWh	Thomas et al (2012)
Transport	Passenger car	7.5	7.5	0.75	220.5	0.75	kWh	Estimate for UK customer transport
Transport	Regular bus	3	3	0.75	220.5	0.75	kWh	Estimate for UK customer transport
Transport	Freight, light commercial vehicle	0.009	0.009	0.027	7.938	0.027	kg	Estimate for UK customer transport
Waste	Per garment, as for conventional use							

Product: Socks – reuse models excluded intimate apparel, which was modelled using conventional use data for reuse wardrobes.

Product: Sportswear

Materials	1 sportswear garment	331.4	331.4	331.4	381.1*	331.4	g	Weight from WRAP data average weights list. *Weights for rental business models were increased to factor in design for durability
Chemicals	Cleaning consumables, without water, in 13.6% solution state	154.1	143.8	118.9	25	71.08	ml	Mintel, (2020) Ecoinvent 3.7.1
Water	Tap water	184.9	172.6	142.6	30	85.29	kg	Pakula and Staminger (2010)
Electricity	Wash energy	1.801	1.682	1.389	0	0.831	ml	Energy Savings Trust (2010)
Electricity	Dry energy	1.167	1.090	0.901	0	0.539	kg	Energy Savings Trust (2010)
Electricity	Iron energy	0.000	0.000	0.000	0	0.000	g	Beton et al (2014)
Chemicals	Dry clean PERC Tetrachloroethylene	0	0	0	0.005	0	g	PERC used per load from Laitala et al., (2018) citing Fong et al (2006)
Electricity	Dry clean energy	0	0	0	0.170	0	km	Energy used from dry cleaning from Laitala et al., (2018) citing Fong et al (2006)
Electricity	Prof wet clean	0	0	0	0.246	0	personkm	Laitala et al (2018)
Electricity	Liquid CO2 clean	0	0	0	0.000	0	tkm	Laitala et al (2018)
Materials	Repair textiles	4.391	3.279	2.268	2.870	2.345	kWh	Calculated
Materials	Repair hardware	1	0.461	0.319	0.403	0.329	kWh	Calculated
Electricity	Repair	0.028	0.021	0.015	0.019	0.015	kWh	Thomas et al (2012)
Transport	Passenger car	7.5	7.5	0.75	220.5	0.75	kWh	Estimate for UK customer transport
Transport	Regular bus	3	3	0.75	220.5	0.75	kWh	Estimate for UK customer transport

Transport	Freight, light commercial vehicle	0.009	0.009	0.027	7.938	0.027	kg	Estimate for UK customer transport
Waste	Per garment, as for conventional use							

Product: Sweaters

Materials	1 sweater, med-heavyweight cotton knit	501.8	501.8	501.8	577.1*	501.8	g	Weight from WRAP data average weights list. *Weights for rental business models were increased to factor in design for durability
Chemicals	Cleaning consumables, without water, in 13.6% solution state	359.3	318.9	275.3	0.0	677.0	ml	Mintel, (2020) Ecoinvent 3.7.1
Water	Tap water	431.2	382.7	330.3	0.0	812.4	kg	Pakula and Staminger (2010)
Electricity	Wash energy	4.201	3.728	3.218	0	7.914	ml	Energy Savings Trust (2010)
Electricity	Dry energy	2.723	2.416	2.086	0	5.130	kg	Energy Savings Trust (2010)
Electricity	Iron energy	0.575	0.510	0.440	0	1.083	g	Beton et al (2014)
Chemicals	Dry clean PERC Tetrachloroethylene	0	0	0	0.019	0	g	PERC used per load from Laitala et al., (2018) citing Fong et al (2006)
Electricity	Dry clean energy	0	0	0	0.607	0	km	Energy used from dry cleaning from Laitala et al., (2018) citing Fong et al (2006)
Electricity	Prof wet clean	0	0	0	0.082	0	personkm	Laitala et al (2018)
Electricity	Liquid CO2 clean	0	0	0	0.819	0	tkm	Laitala et al (2018)
Materials	Repair textiles	4.433	2.823	2.355	0.468	2.728	kWh	Calculated
Materials	Repair hardware	1	0.397	0.331	0.066	0.383	kWh	Calculated
Electricity	Repair	0.029	0.018	0.015	0.003	0.018	kWh	Thomas et al (2012)
Transport	Passenger car	7.5	7.5	0.75	220.5	0.75	kWh	Estimate for UK customer transport
Transport	Regular bus	3	3	0.75	220.5	0.75	kWh	Estimate for UK customer transport
Transport	Freight, light commercial vehicle	0.009	0.009	0.027	7.938	0.027	kg	Estimate for UK customer transport
Waste	Per garment, as for conventional use							

Product: Tops

Materials	1 top, cotton t-shirt	204.8	204.8	204.8	235.5	204.8	g	Weight from WRAP data average weights list. *Weights for rental business models were increased to factor in design for durability
Chemicals	Cleaning consumables, without water, in 13.6% solution state	235.1	183.7	217.3	0.0	114.3	ml	Mintel, (2020) Ecoinvent 3.7.1
Water	Tap water	282.1	220.4	260.8	0.0	137.2	kg	Pakula and Staminger (2010)

Electricity	Wash energy	2.748	2.147	2.540	0	1.336	ml	Energy Savings Trust (2010)
Electricity	Dry energy	1.781	1.392	1.647	0	0.866	kg	Energy Savings Trust (2010)
Electricity	Iron energy	0.376	0.294	0.348	0	0.183	g	Beton et al (2014)
Chemicals	Dry clean PERC Tetrachloroethylene	0	0	0	0.007	0	g	PERC used per load from Laitala et al., (2018) citing Fong et al (2006)
Electricity	Dry clean energy	0	0	0	0.228	0	km	Energy used from dry cleaning from Laitala et al., (2018) citing Fong et al (2006)
Electricity	Prof wet clean	0	0	0	0.031	0	personkm	Laitala et al (2018)
Electricity	Liquid CO2 clean	0	0	0	0.307	0	tkm	Laitala et al (2018)
Materials	Repair textiles	4.873	2.479	2.258	0.907	2.704	kWh	Calculated
Materials	Repair hardware	1	0.348	0.317	0.127	0.380	kWh	Calculated
Electricity	Repair	0.032	0.016	0.015	0.006	0.017	kWh	Thomas et al (2012)
Transport	Passenger car	7.5	7.5	0.75	220.5	0.75	kWh	Estimate for UK customer transport
Transport	Regular bus	3	3	0.75	220.5	0.75	kWh	Estimate for UK customer transport
Transport	Freight, light commercial vehicle	0.009	0.009	0.027	7.938	0.027	kg	Estimate for UK customer transport
Waste	Per garment, as for conventional use							

Product: Trousers

Materials	1 pair of trousers, cotton chinos	331.4	331.4	331.4	381.1	331.4	g	Weight from WRAP data average weights list. *Weights for rental business models were increased to factor in design for durability
Chemicals	Cleaning consumables, without water, in 13.6% solution state	397.5	366.6	362.7	0.0	605.3	ml	Mintel, (2020) Ecoinvent 3.7.1
Water	Tap water	477.1	440.0	435.2	0.0	726.4	kg	Pakula and Staminger (2010)
Electricity	Wash energy	4.647	4.286	4.240	0	7.076	ml	Energy Savings Trust (2010)
Electricity	Dry energy	3.012	2.778	2.748	0	4.586	kg	Energy Savings Trust (2010)
Electricity	Iron energy	0.636	0.587	0.580	0	0.969	g	Beton et al (2014)
Chemicals	Dry clean PERC Tetrachloroethylene	0	0	0	0.018	0	g	PERC used per load from Laitala et al., (2018) citing Fong et al (2006)
Electricity	Dry clean energy	0	0	0	0.553	1	km	Energy used from dry cleaning from Laitala et al., (2018) citing Fong et al (2006)
Electricity	Prof wet clean	0	0	0	0.050	0	personkm	Laitala et al (2018)
Electricity	Liquid CO2 clean	0	0	0	0.276	0	tkm	Laitala et al (2018)
Materials	Repair textiles	9.017	3.123	2.672	0.246	2.397	kWh	Calculated
Materials	Repair hardware	0	0.439	0.375	0.035	0.337	kWh	Calculated

Electricity	Repair	0.058	0.020	0.017	0.002	0.016	kWh	Thomas et al (2012)
Transport	Passenger car	7.5	7.5	0.75	220.5	0.75	kWh	Estimate for UK customer transport
Transport	Regular bus	3	3	0.75	220.5	0.75	kWh	Estimate for UK customer transport
Transport	Freight, light commercial vehicle	0.009	0.009	0.027	7.938	0.027	kg	Estimate for UK customer transport
Waste	Per garment, as for conventional use							

Product: Underwear – reuse models excluded intimate apparel, which was modelled using conventional use data for reuse wardrobes.

Annex 3: Uncertainty analysis description of methods used

Aspects of data quality covered by the matrix included the representativeness of the data in terms of geography, time, and technology. Combined scores for each data item at process level made it possible to check for processes where data quality should be addressed. The scores that were provided by the data quality matrix were applied to the foreground data used for the LCA in the Simapro software, (v9.2.0.2).

Our analyses also include systematic assessment of the quality of input data to the foreground system, and presents a matrix of scores from this assessment, followed by results from a Monte Carlo analysis. Methods such as these used for tackling issues related to data quality and uncertainty are well-established and clear guidance is available on analysis of uncertainty for LCAs (European Commission, 2010; Goedkoop et al., 2016; Sadhukhan et al., 2014). Nevertheless, from the review of academic and grey literature, this is the first assessment of this type focussed on clothing CBMs.

A matrix was used to score different aspects of data quality. This method was devised in the 1990s (Weidema and Wesnæs, 1996) and has been applied successfully in LCAs since. Bamber et al., 2020 found the use of a scoring matrix was the most often used method in the published articles that they reviewed which did include an assessment of uncertainty. The design of the scoring matrix provides for an assessment of five aspects of data quality. Each indicator is represented by a 'default' lognormal distribution with each aspect of data quality scored on its contribution to the uncertainty in the data (Guo and Murphy, 2012). Each data item is given a score on each of the five aspects, ranking the data quality from 1 to 5. Table A5 details the basis for each score, under each data quality aspect (Goedkoop et al., 2016). This approach is similar to that developed for use with LCAs by (Weidema and Wesnæs, 1996), covering the same five data quality aspects. The weighting as noted in the table, is that used by the matrix in Ecoinvent (v3.7.1) as implemented by SimaPro (v9.2) (Goedkoop et al., 2016). The weighting means that a process or material that is modelled assuming different technology would have higher uncertainty than a poor data quality score on other aspects. Data from different geographical areas, and data with unknown completeness / representativeness, would contribute less uncertainty. scores were calculated using the matrix for each material flow of the use phase. Indicator scores were given separately for each of the activities of the CBMs and the flows into and out of the foreground system.

Table A4: Aspects of data quality with weighting for each score

Indicator score	1	2	3	4	5
Reliability	Verified data based on measurements	Verified data partly based on assumptions OR non-verified data based on measurements	Non-verified data partly based on qualified estimates	Qualified estimate (e.g. by industrial expert); data derived from theoretical information (stoichiometry, enthalpy, etc.)	Non-qualified estimate
	1	1.02	1.05	1.1	1.5

Indicator score	1	2	3	4	5
Completeness	Able to be based on census data for the relevant population	Data from a representative sample for the relevant population, within the cut-off limit set in goal and scope, over an adequate period to adjust for fluctuations due to seasons	Data from a representative sample for the relevant population, but with a wider CI than set in goal and scope, OR from a shorter timespan not accounting for seasonal variation	Sample data but not from a representative population, either from another place OR too small a sample to be representative	Representativeness unknown or from another, different type of place, AND from shorter periods
	1.00	1.02	1.05	1.10	1.20
Time	Less than 3 years of difference to our reference year	Less than 6 years of difference to our reference year	Less than 10 years of difference to our reference year	Less than 15 years of difference to our reference year	Age of data unknown or more than 15 years of difference to our reference year
	1.00	1.03	1.10	1.20	1.50
Geography	Data from area under study	Average data from larger area in which the area under study is included	Data from smaller area than area under study, or from similar area	Data from area with slightly similar production conditions	Data from unknown OR distinctly different area (north America instead of Middle East, OECD Europe instead of Russia)
	1.00	1.001	1.02	1.05	1.10
Technology	Data from enterprises, processes and materials under study (i.e. identical technology)	Data from processes and materials under study (i.e. identical technology) but from different enterprises	Data on related processes or materials but same technology, OR data from processes and materials under study but from different technology	Data on related processes or materials but different technology, OR data on laboratory scale processes and same technology	Data on related processes or materials but on laboratory scale of different technology
	1.00	1.05	1.20	1.50	2.00

To perform a Monte Carlo analysis, it was first necessary to select the kind of distribution for each data item, based on the distribution from the source data. In many cases the inventory data were derived from secondary literature and only a single value was available. Where this was the case, the underlying data, which was not available, was assumed to have a lognormal distribution. This assumption was used because the uncertainty factors generated using the scoring matrix default to a lognormal distribution, as the square of the geometric standard deviation. The scores from the matrix were aggregated using the weighting provided with SimaPro (v9.2) to calculate standard deviation (SD) for each data item, following the ranking and weighting provided in Table A4.

Standard deviation (SD) is the most commonly used measure of the spread of a set of observations, equal to the square root of the variance (Everitt, 2002, page 360). The formula for calculating the SD, σ , of n data points: $x_1, x_2, x_3, \dots, x_{n-1}, x_n$, with respect to their mean value, $\bar{x}$, is provided in Sadhukhan et al., (2014b, page 155):

$$\sigma = \frac{\sqrt{\sum_i (x_i - \bar{x})^2}}{n - 1}$$

With Ecoinvent (v3.7.1), default basic uncertainty factors are provided to quantify variation and stochastic error of the values due to factors such as temporal variations and incomplete information to fully describe an activity in detail (Weidema et al., 2013, see pages 74 - 75). The calculations made using the scoring matrix produce additional uncertainty factors which are summed together with the basic uncertainty factors to produce an overall, total uncertainty (Ciroth et al., 2016; Weidema et al., 2013). The six factors summed in the following equation, refer to the measurement of basic uncertainty provided by Ecoinvent (v3.7), together with factors for each aspect covered in Table A5 above; reliability, completeness, time, geography and technology:

$$\sigma^2 = \sum_{n=1}^6 \sigma_n^2$$

A coefficient of variation (CV) is also provided with the results from the MC analysis. The CV is defined as the ratio of the SD to the mean, expressed as a percentage (Everitt, 2002, page 78). The equation for the CV is therefore:

$$CV = \frac{\sigma}{\mu}$$

The CV is used to provide a measure which can be compared on a nearly like-for-like basis across environmental impact indicators, despite the wide variation between mean values. Some caution should be exercised in directly comparing the results, in particular because it should be expected that the quality of the data overall varies more widely than indicated by examining the matrix scores on their own, since the matrix scores relate only to data inputs included in the foreground system.