Research paper
6th PLATE 2025 Conference
Aalborg, Denmark, 2-4 July 2025

The Laundry Care LCA project

Stefano Zuin[a], Vsevolod Dengin[b], Valentina Perzolla[a], Francesca Bisaro[a], Mario Michele Pipita[a], Alberto Azzano[a], Fabio Garzena[a], Elisa Stabon[a]

a) Electrolux Italia S.p.A., Porcia (PN), Italy
b) AB Electrolux, Stockholm, Sweden

Keywords: LCA; garment; lifetime; care index; washing cycles

Abstract: The fashion industry is increasingly scrutinized for the environmental footprint it generates. Despite this, less attention is placed on the possibility to reduce part of this footprint thanks to attitudes and daily actions that users can take in their homes. A life cycle assessment of three selected garments was performed to analyze the potential environmental benefits of an extended usage of garments thanks to the utilization of different washing treatments. Results showed that the garment production phase has consistently the highest impact. Within the use stage, the relevance of wash cycles was investigated by comparing various cycles in both the European and North America regions, and by highlighting the contribution of different energy mixes and detergent types. The data demonstrated that washing machine users can reduce the impact of garments by, for example, washing them at lower temperature, as this results in slower deterioration. Therefore, the environmental impacts per wear of garments can be reduced by around 50% by doubling the expected number of garments uses.

Introduction

Impacts connected to garments production are high, thus it is important to keep items in use for longer to postpone the moment when there is a need to purchase new ones. However, in recent years several surveys and research emphasized that people tend to buy more clothes while using them for a lower number of times (Ellen MacArthur Foundation, 2017). Despite these considerations seem to be widely accepted, only limited effort has been made to verify how relevant would it be to extend the lifetime of garment in terms of environmental impact.

This paper presents a life cycle assessment (LCA) based method used by the Group which the authors are part of to quantify the reduction of the garments environmental impacts. This reduction was exclusively achieved through the extension of the garment lifetime due to the use of gentler washing treatments.

Materials and method

Researchers performed a LCA of t-shirt, polo, and jeans to quantify the potential environmental benefits of a prolonged lifetime of garments by comparing two scenarios: a baseline scenario (BS), where the selected garment is worn and then washed X times, and an extended scenario (ES), where the same garment is worn X*t times, with X*t > X. In this context, t represents the Care Index indicator developed by the company R&D department. The developed LCA model (Care LCA) was created using the SimaPro 9.5 LCA software and Ecoinvent 3.9 database.

Garment Longevity Assessment

To measure garment longevity, an internal protocol called the "Care Index method" that provides a numerical output was developed over several years of research and development. Currently, its use is intended solely for internal evaluation of the Group's appliances. The Care Index is an internal indicator that allows to compare the gentleness of two different washing treatments and quantify the corresponding impact on clothes deterioration, affecting their lifespan. In practical terms, the index compares the number of laundry cycles required to reach a specific level of color change - correlated to clothes end of life - against a reference washing program. To run this test, researchers developed a protocol that utilizes a variety of fabrics, each intentionally dyed and printed to mirror different clothing types - i.e. t-shirt, polo-shirt and jeans - and common dye varieties found in the market. The investigation focused on a 4 kg daily load.
Through extensive laboratory testing, different scenarios where fabrics underwent a sequence of washing treatments were considered and

color changes were measured at various intervals. The color degradation was evaluated using the standard Gray Scale methodology and regularly monitored during the testing phase. Reference standards for this assessment were the ISO 105-A05:1996 and the ISO 105-J03:2009. The fabrics end-of-life was considered to be reached when the defined level of color degradation was achieved. The definition of the end-of-life threshold was assessed through an internal panel test involving more than 600 panellists worldwide.
The Care Index was then used for comparing the Extended (ES) and the Baseline Scenarios (BS). A garment life is doubled, when the Care Index equals 2.
Assuming that:

Baseline Scenarios = 52 washes
Extended Scenarios = 104 washes
Care Index = 104/52 = 2

The Index is later used as an input for the Care LCA to indicate clothes longevity in the use phase.

Care LCA measurement
The Care LCA was created to model all phases of garments life cycle to quantify the clothes environmental impact. The functional unit was defined by including, for all garments in scope (i.e., t-shirt, polo and jeans), the service provided, garment weight and size, composition (i.e., conventional cotton, organic cotton, and polyester fibers), the expected usage and service duration. All life cycle stages of garment were considered (from cradle to grave), i.e., production of garment raw materials (polyester and cotton fibers), production of finished garment (spinning, knitting, weaving, dyeing, finishing and final assembly process), transports of raw materials and intermediates included, distribution of finished garment, use phase (washing cycles and drying at ambient air), and end of life scenario. Secondary data from PEFCR Apparel and Footwear (2022) and default scenario from EU PEF (Zampori and Pant, 2019) were used for modelling all life cycle stages, while the Group primary data were used for modelling the use phase, as showed in table 1. European Cotton Normal and North America Hot cycle are more intensive (i.e. higher temperature) compered to Cotton Extra Light and Cold cycle in the respective region. Concerning the washing of garments, a mass allocation is used according to the laundry load of washing machine considered (4 kg). The formulation of the liquid detergent was modelled according to the AISE recommendation (AISE, 2019), whilst the powder detergent was modelled according to the AHAM recommendation (AHAM, 2013).

Wash cycle	Elect. [kWh]	Liquid det [ml]	Powder det [g]	Water [L]
Extra Light	0.11	33		37.5
Normal	0.67	44		49.2
Cold	0.23		63	40.3
Hot	1.64		63	56.2

Table 1. Wash cycles, 4 kg laundry load. Cotton Extra Light and Normal are EU wash cycles. Cold and Hot NA cycles.

Four impact assessment categories were considered: Global Warming Potential in kg CO2-eq (GWP100; IPCC, 2021), the water footprint (WF) in m3 water-eq according to the AWARE methodology, the Ecotoxicity freshwater (EcoTox) in CTUe according to the USEtox model 2.1, and Fossil resource use in MJ, according to CML methodology (ADP-fossil).

Results
The environmental impact of garment longevity is reported in the tables below, where the two scenarios are compared via the Care LCA method. For this evaluation, number of wears equals number of washes. Table 2 and 3 report the GWP impact of a cotton T-shirt and Jeans, respectively, both washed with the selected washing cycles, in an EU scenario. Table 4 reports the Ecotoxicity, freshwater impact of cotton jeans washed with the selected washing cycles within a North American scenario.

			GWP [kgCO2eq]			
	N° of wears	**EU wash cycle**	**P**	**D**	**U**	**EoL**
BS	52	Cotton Normal	6.18	1.16	0.71	0.10
ES	104	Cotton Extra Light	6.18	1.16	0.53	0.10

Table 2. GWP impacts of life cycle of T-shirt. P=Production; D=distribution; U=Use phase; EoL=End of Life.

			GWP [kgCO2eq]			
	N° of wears	**EU wash cycle**	**P**	**D**	**U**	**EoL**
BS	20	Cotton Normal	22.3	1.28	1.00	0.35
ES	40	Cotton Extra Light	22.3	1.28	0.75	0.35

Table 3. GWP impacts of life cycle of Jeans. P=Production; D=distribution; U=Use phase; EoL=End of Life.

			EcoTox [CTUe]			
	N° of wears	**NA wash cycles**	**P**	**D**	**U**	**EoL**
BS	20	Hot	784.1	10.2	22.0	1
ES	30	Cold	784.1	10.2	23.3	1

Table 4. Ecotoxicty freshwater impacts of life cycle of Jeans. P=Production; D=distribution; U=Use phase; EoL=End of Life.

The production phase of garment presents the highest impact for all impact categories, independently from the type of garment selected. In fact, in all tables above, production values were consistently the highest when compared to the other phases. Depending on the considered impact category, then, distribution (for GWP) or use phase (Ecotoxicity, freshwater) have the second greatest impact.
To better understand where the high impacts of the production are coming from, the relevance of the individual production steps for all impact categories were analyzed. Table 5 shows, as an example, the contribution in percentage (%) of various production processes to the four impact categories for conventional cotton jeans.

	Fiber	Yarn	Fabric	Dyeing Finish.
GWP	16.8	30.3	33.7	19.2
EcoTox	27.7	34.5	33.3	4.5
ADP	13.6	28.3	33.1	25
WF	29.5	36.1	34.3	0.1

Table 5. Contribution analysis (%) of cotton Jeans pant 's production processes.

Based on available secondary data, the fabric and yarn production are the most relevant steps in the jeans manufacturing, because if summed up they contribute more than 60% to the impacts, followed by fiber production.

An insight on the use phase is highlighted in table 6 and 7, based on the NA Cold and Hot wash cycles.

	Elec	Tap water	Det	Water drained
GWP	67.2	4.1	27.1	1.6
EcoTox	26.8	2.7	50.5	20.1
ADP	74	3.2	23	0.9

Table 6. Contribution analysis (%) of use stage. Hot wash cycle.

	Elec	Tap water	Det	Water drained
GWP	23	7.3	66.9	2.9
EcoTox	5.2	2.7	71.6	20.4
ADP	28	6.3	64	1.7

Table 7. Contribution analysis (%) of use stage. Cold wash cycle.

The GWP and ADP fossil impact categories are strongly affected by the electricity when the garment is washed with the Hot wash cycle, followed by the detergent (i.e., the electricity contributes with 67.2% for the GWP, while the detergent contributes with 27.1%). On the contrary, when the garment is washed with the Cold wash, the detergent is more relevant than the electricity (i.e., the detergent contributes 66.9% for the GWP, while the electricity contributes 23.0%). Also, the detergent strongly affects the EcoTox freshwater impact category, as it is responsible for 50.5% of the impact with a Hot cycle, and for 71.6% with a Cold wash cycle.
In the sensitivity analysis, the contribution of different energy mixes was investigated. Figures 1 and 2 show the results of GWP for a conventional cotton Polo shirt when the shirt is used and washed 52 times with Normal cycle (fig. 1) and Extra Light (fig. 2) cycle in selected EU countries (DE, IT, SE, FR and PL) that are market relevant for the Group.

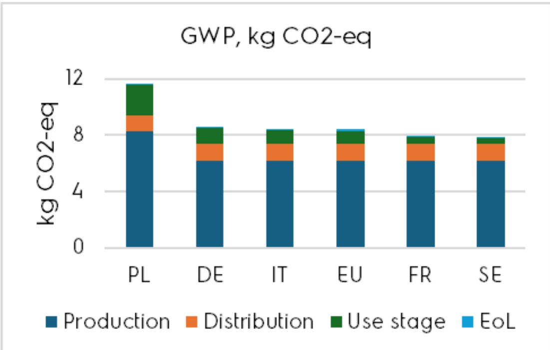

Figure 1. Sensitivity analysis on different energy mix. GWP impacts of conventional cotton Polo shirt, washed 52 times, with Normal wash cycles in different EU countries.

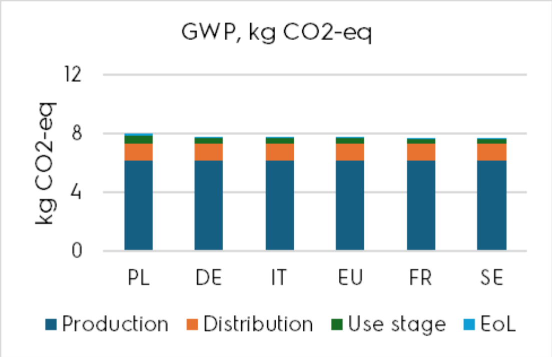

Figure 2. Sensitivity analysis on different energy mix. GWP impacts of conventional cotton Polo shirt, washed 52 times, with extra light wash cycles in different EU countries.

The GWP impact of the Polo shirt is differently affected by the countries when the shirt is washed with the two treatments. For instance, Poland (PL) and Sweden (SE), the two countries with the most different energy mix, when Normal cycle is used, the GWP is equal to 11.66 kg CO2-eq and 7.85 kg CO2-eq, respectively. It means that the overall climate change impact of a Polo shirt is decreased by around 14% when washing in SE compared to washing it in PL. If we compare PL with the average EU, the total climate change impact is 11.66 kg CO2-eq versus 8.39 kg CO-eq (9% of difference). Those changes for the GWP impact are less evident when the Polo shirt is washed with Extra Light cycle, because this cycle is less energy intensive when compared to the Normal cycle, therefore it is less sensible to climate change variations.
In order to understand the benefit on the overall impact of a prolonged use of clothing items, a different parameter was calculated: the *impact per wear*. This parameter takes into consideration the whole contributions of different phases to the impact category together with the number of uses during the use phase. An example of measurement of this parameter is reported below (Figure 3), where the jeans impact per wear for a European scenario is visible. Again, the wash cycles Cotton Normal represents the BS and the Extra Light represents the ES.

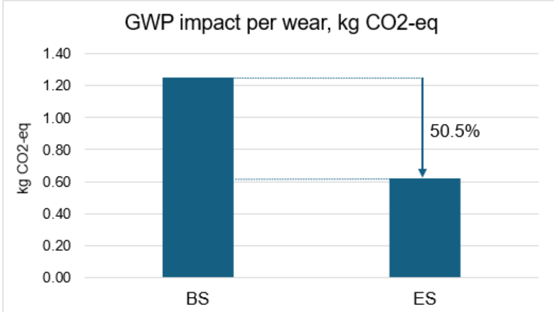

Figure 3. GWP impact per wear for the jeans using EU scenario

As already seen in Table 3, the total GWP is 22.97 kg CO2-eq for the BS, and 22.72 kg CO2-eq for the ES. Assuming that the number of wears until the end of life is 52 in the BS whilst it is 104 in the ES, it means to have a Care Index equal to 2. In other words, this means doubling the life of the item when using the Cotton Extra Light instead of the Cotton Normal.
This type of assessment can be done per each category can be placed in relationship with the number of uses and defined as *impact per wear*. By increasing the number of uses, the environmental burden can be spread over a greater number of uses resulting in a reduction of the overall impact. Similar approaches have been already proposed by institutes and researchers in the field of fashion (Bates Kassatly, 2024). For the jeans in the European scenario, the GWP impact per wear can be reduced by around 50% when the item is worn 52 times more than the BS.

Conclusion

This study illustrates the environmental impacts of the life cycle phases of three garments. It also provides an insight on how much consumers could decrease their garments impact on the planet. Since this LCA approach includes all lifecycle stages, from fiber sourcing to garment disposal, it stresses the importance of extending the life of garments during the so-called *Use Phase*, where washing machines can play a key role. The message is that the longer the garments are used for, the easier it will be to amortize their environmental impact. Indeed, adopting low washing temperatures, such as cold washes, promotes clothes longevity while contemporarily requiring lower energy consumptions. The LCA method presented in this paper was verified by a third-party according to the ISO 14040-44 for supporting the Group within its sustainability strategy.

References

AHAM, Association of Home Appliance Manufacturers. (2013). *Performance Evaluation Procedures for Household Clothes Washers. AHAM HLW-1-2013.*

AISE, International Association for Soaps, Detergents and Maintenance Products (2019). *Product Environmental Footprint Category Rules (PEFCR). Household Heavy Duty Liquid Laundry Detergents (HDLLD) for machine wash*. September 2019. Version 1.2

Bates Kassatly, V. (2024). Sustainable Fashion - Could it all be in the hands of the Consumer? *Veronica Bates Kassatly.* https://www.veronicabateskassatly.com/read/sustainable-fashion-could-it-all-be-in-the-hands-of-the-consumer

Ellen MacArthur Foundation. (2017). *A new textiles economy: Redesigning fashion's future.* A New Textiles Economy: Redesigning Fashion's Future

IPCC. (2021). *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Climate Change 2021: The Physical Science Basis

Quantis. (2022). *Product Environmental Footprint Category Rules (PEFCR) for Apparel and Footwear. Draft. Version 1.3* – First draft PEFCR, 28 March 2022.

Zampori, L., & Pant, R. (2019). *Suggestions for updating the Product Environmental Footprint (PEF) method, EUR 29682 EN, Publications Office of the European Union, Luxembourg, 2019, https://dx.doi.org/10.2760/424613. JRC115959.*