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*Supplementary Information for:*

# Factors Allowing Users to Influence the Environmental Performance of Their T-Shirt

**Mélanie Schmutz, Roland Hischier and Claudia Som ***

Empa, Swiss Federal Laboratories for Materials Science and Technology, Technology and Society Laboratory, 9014 St. Gallen, Switzerland; melanie.schmutz@empa.ch (M.S.), roland.hischier@empa.ch (R.H.),
* Correspondence: claudia.som@empa.ch

## 1. LCI datasets

### *1.1. Basic scenario*

Table S1 represents the datasets used from ecoinvent v3.6 [1] for the LCA calculations of each step of the production of a 154g T-Shirt. The yarn production and fabric production had to be adapted to our topic at hand (Table S2 and S3). For the yarn production, a global market data for cotton yarn exists. However, this dataset includes various types of yarns, such as cotton yarn for knitting and for weaving. As we were interested only in knitted yarn, we decided to create a global market data for yarn for knitting only. For the fabric production, in order to be consistent with the new dataset created for the yarn for knitting (Table S2), the dataset "market for textile, knit cotton" was modified (Table S3) by replacing its yarn input by the new created yarn for knitting dataset.

**Table S1.** Inputs for the production phase of a 154g T-Shirt.

| Inputs for the production phase | Datasets used | Amount |
|---|---|---|
| Fiber production | fibre, cotton//[GLO] market for fibre, cotton | 0.2640 kg |
| Yarn production | yarn, cotton//[GLO] market for yarn production, ring spinning, for knitting_modified | 0.2078 kg |
| Fabric production | textile, knit cotton//[GLO] market for textile, knit cotton_modified | 0.2038 kg |
| Batch Dyeing | batch dyeing, fibre, cotton//[GLO] market for batch dyeing, fibre, cotton | 0.1851 kg |
| Finishing | finishing, textile, knit cotton//[GLO] market for finishing, textile, knit cotton | 0.1833 kg |
| Assembly | electricity, low voltage//[GLO] market group for electricity, low voltage | 0.1534 kWh [2] |

For the yarn production, we created a dataset "yarn, cotton//[GLO] market for yarn production, ring spinning, for knitting_modified". To do so, 1.000005 kg (representing losses during transport) of "yarn, cotton//[GLO] yarn production, ring spinning, for knitting" was used as input. Then, for the transport the same mean of transport and distances were used as in the following dataset: "yarn, cotton//[GLO] market for yarn, cotton". The used datasets can be seen in Table S2.

**Table 2.** Input for 1kg of "yarn, cotton//[GLO] market for yarn production, ring spinning, for knitting_modified".

| Inputs for 1 kg of global market data for yarn for knitting_modified | Datasets used | Amount |
|---|---|---|
| Cotton yarn for knitting | yarn, cotton//[GLO] yarn production, ring spinning, for knitting | 1.000005 kg |
| Transport | transport, freight, aircraft, unspecified//[GLO] market for transport, freight, aircraft, unspecified | 0.0511 ton*km |
| | transport, freight, light commercial vehicle//[GLO] market group for transport, freight, light commercial vehicle | 0.0246 ton*km |
| | transport, freight, lorry, unspecified//[GLO] market group for transport, freight, lorry, unspecified | 0.386 ton*km |
| | transport, freight, sea, container ship//[GLO] market for transport, freight, sea, container ship | 1.14 ton*km |

For the Fabric production, we had as well to make some adaptations. We used the "textile, knit cotton//[GLO] market for textile, knit cotton" dataset as basis and replaced its cotton yarn by the new created dataset from Table S2.

The datasets for the distribution were based on the work of Hischier et al. (2018) representing an average transport mode from the production site to the point of sale (Table S3).

**Table S3.** Inputs for the distribution step of the T-Shirt.

| Input for the distribution | Datasets used | Amount |
|---|---|---|
| Production from production site to the point of sale [3] | transport, freight, lorry >32 metric ton, EURO3//[RER] market for transport, freight, lorry >32 metric ton, EURO3 | 0.0385 ton*km |
| | transport, freight, sea, container ship//[GLO] market for transport, freight, sea, container ship | 3.4804 ton*km |
| | transport, freight, lorry >32 metric ton, EURO6//[RER] market for transport, freight, lorry >32 metric ton, EURO6 | 0.1694 ton*km |
| | transport, freight, lorry >32 metric ton, EURO4//[RER] market for transport, freight, lorry >32 metric ton, EURO4 | 0.4312 ton*km |
| | transport, freight, light commercial vehicle//[GLO] market group for transport, freight, light commercial vehicle | 0.0154 ton*km |

For the use phase, the cotton T-Shirt is washed in a washing machine at 40°C (Table S4). As the washing machine is half-full (3.5 kg), the weight of the cotton T-Shirt corresponds to 4.4 % of the washing load. Thus, the impact of 1 washing cycle for 1 cotton T-Shirt corresponds to the impact of 1 washing cycle times 0.044.

**Table S4.** Inputs for the use phase of the T-Shirt and used datasets.

| Input for use phase | Datasets used | Amount |
|---|---|---|
| 1 Washing cycle at 40°C [2] | tap water//[CH] market for tap water | 49.9 kg [2] |
| | electricity, low voltage//[CH] market for electricity, low voltage | 0.6 kWh [2] |
| | wastewater, from residence//[CH] market for wastewater, from residence | 0.0499 $m^3$ |
| Detergent for 1 washing cycle [4] | water, deionised//[RoW] water production, deionised | 0.00425 kg |
| | soda ash, dense//[GLO] modified Solvay process, Hou's process | 0.0255 kg |
| | sodium percarbonate, powder//[RER] market for sodium percarbonate, powder | 0.00142 kg |
| | layered sodium silicate, SKS-6, powder//[GLO] market for layered sodium silicate, SKS-6, powder | 0.00142 kg |
| | ethylenediamine//[RER] market for ethylenediamine | 0.00142 kg |
| | polycarboxylates, 40% active substance//[RER] market for polycarboxylates, 40% active substance | 0.0085 kg |
| | zeolite, powder//[GLO] market for zeolite, powder | 0.0085 kg |
| | sodium sulfate, anhydrite//[GLO] activated silica production | 0.0085 kg |
| | carboxymethyl cellulose, powder//[GLO] market for carboxymethyl cellulose, powder | 0.00106 kg |
| | citric acid//[GLO] market for citric acid | 0.00106 kg |
| | sodium hydroxide, without water, in 50% solution state//[GLO] market for sodium hydroxide, without water, in 50% solution state | 0.00106 kg |
| | sodium chloride, powder//[GLO] market for sodium chloride, powder | 0.00106 kg |
| | sulfuric acid//[RER] market for sulfuric acid | 0.0085 kg |
| | fatty alcohol sulfate//[GLO] market for fatty alcohol sulfate | 0.00638 kg |
| | ethoxylated alcohol (AE3)//[RER] market for ethoxylated alcohol (AE3) | 0.00319 kg |
| | ethoxylated alcohol (AE7)//[RER] market for ethoxylated alcohol (AE7) | 0.00319 kg |
| | transport, freight, lorry 16-32 metric ton, EURO4//[RER] market for transport, freight, lorry 16-32 metric ton, EURO4 | 0.0404 ton*km |
| | transport, freight, sea, container ship//[GLO] market for transport, freight, sea, container ship | 1.21 ton*km |

*1.2. Fiber production: other fibers*

For the comparison, we used as a functional unit 264 g of fiber, representing the amount of cotton fiber required for manufacturing a cotton T-Shirt of 154 g. In other words, we assumed that the amount of fiber for manufacturing a T-Shirt is independent of the type of fiber material. The datasets used can be seen in Table S5. As nylon and polyacrylic fibers do not have direct datasets in the ecoinvent database, we took as a basis the fiber production dataset of polyester, where the PET fraction (1.02 kg of PET needed for producing 1 kg of fiber) of the dataset was replaced by "nylon 6//[RER] market for nylon 6" and "acrylonitrile//[GLO] market for acrylonitrile" for the nylon fiber and the polyacrylic fiber, respectively. This assumes that the process of the fiber production is similar for these three synthetic fibers, which is justified as the fiber extrusion is a function of the extrusion energy of the polymer [5].

**Table S5.** Inputs for the comparison of fiber production other than cotton and used datasets.

| Input for fiber production | Datasets used | Amount |
|---|---|---|
| Silk | reeled raw silk hank//[GLO] market for reeled raw silk hank | 0.264 kg |
| Polyester | fibre, polyester//[GLO] market for fibre, polyester | 0.264 kg |
| Flax | fibre, flax//[GLO] market for fibre, flax | 0.264 kg |
| Viscose | fibre, viscose//[GLO] market for fibre, viscose | 0.264 kg |
| Wool | sheep fleece in the grease//[GLO] market for sheep fleece in the grease | 0.264 kg |
| Nylon | fibre, polyester//[GLO] market for fibre, polyester_modified with Nylon 6 | 0.264 kg |
| Polyacryl | fibre, polyester//[GLO] market for fibre, polyester_modified with polyacryl | 0.264 kg |

*1.3. Use phase scenarios*

Table S6 and S7 show the datasets and inputs used for the calculation of the "lower washing temperature (30 °C)", "higher washing temperature (60°C)" and the scenario drying with a "Tumbler".

**Table S6.** Inputs for the use phase scenarios with different washing temperatures and used datasets.

| Input for washing temperatures | Datasets used | Amount |
|---|---|---|
| 1 washing cycle at 30 °C [2] | tap water//[CH] market for tap water | 51.9 kg |
| | electricity, low voltage//[CH] market for electricity, low voltage | 0.4 kWh |
| | wastewater, from residence//[CH] market for wastewater, from residence | 0.0519 $m^3$ |
| 1 washing cycle at 60 °C [2] | tap water//[CH] market for tap water | 52.3 kg |
| | electricity, low voltage//[CH] market for electricity, low voltage | 1.1 kWh |
| | wastewater, from residence//[CH] market for wastewater, from residence | 0.0523 $m^3$ |

**Table S7.** Inputs for the use phase scenarios with different mean of drying (tumbler) and used datasets.

| Input for the use of a Tumbler | Datasets used | Amount |
|---|---|---|
| 1 use of Tumbler [2] | electricity, low voltage//[CH] market for electricity, low voltage | 1.483333333 kWh |

For the variable "fullness of the washing machine" we had to assume that the amount of water and the amount of electricity needed for 1 washing cycle was independent of the load of the washing machine, as only data for a half-full washing machine could be found [2]. This means that the same inputs as in Table S4 are used. The difference comes however from the percentage of the T-Shirt's weight relative to the washing machine load. For the full washing machine (7 kg), the T-Shirt corresponds to 2.2 % of the washing load. Thus, the impact of 1 washing cycle for 1 T-Shirt corresponds to the impact of 1 washing cycle times 0.022. When the T-Shirt is washed alone, the T-Shirt corresponds to 100 % of the washing load. This means that the impact of 1 washing cycle is completely due to the washing of the T-Shirt.

In order to have an idea of the impact of a T-Shirt that is used less than it expected lifetime (here corresponding to 44 washing cycles), we looked at a scenario where the T-Shirt's lifetime was divided by 4 (corresponding to 11 washing cycles). If we assume that the T-Shirt is washed once a week, this would mean that the T-Shirt would be kept for 3 months (one season). This is believed to be a potential use behavior, which would be in accordance with the trend of fast-fashion. In order to be able to compare this scenario

with the basic scenario, we had to calculate the number of T-Shirts (with a lifespan of 11 washing cycles) needed to fulfill the lifespan aspect of our functional unit, corresponding as mentioned to 44 washing cycles. This means that four T-Shirts need to be produced as in Table S1 and that the total number of washing cycles corresponds to 44 washing cycles (11 * 4 = 44). The washing cycles are calculated according to Table S4.

## References

1. Centre, E. ecoinvent data v3.6 - recycled-content system model - available at www.ecoinvent.org. Zürich, ecoinvent Association.
2. Lehmann, A.; Roffeis, M.; Finkbeiner, M. Ökobilanzielle Bewertung des Lebensweges eines handelsüblichen weißen Baumwolle T-Shirts in Deutschland. **2019**.
3. Hischier, R. Car vs. Packaging — A First, Simple (Environmental) Sustainability Assessment of Our Changing Shopping Behaviour. **2018**, doi:10.3390/su10093061.
4. Golsteijn, L.; Menkveld, R.; King, H.; Schneider, C.; Schowanek, D.; Nissen, S. A compilation of life cycle studies for six household detergent product categories in Europe: the basis for product - specific A.I.S.E. Charter Advanced Sustainability Profiles. *Environ. Sci. Eur.* **2015**, doi:10.1186/s12302-015-0055-4.
5. Van Der Velden, N.M.; Patel, M.K.; Vogtländer, J.G. LCA benchmarking study on textiles made of cotton, polyester, nylon, acryl, or elastane. *Int. J. Life Cycle Assess.* **2014**, *19*, 331–356, doi:10.1007/s11367-013-0626-9.