LCA CASE STUDY
<< Hooded Sweatshirt>>

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Goal & Functional Unit

The first goal of the analysis is to identify the points within the life cycle of a hooded sweatshirt that contribute to the most environmental impact. The second goal is to see how these impacts differ based on different "alternatives" or scenarios in which the sweatshirt is produced and used.

The functional unit of the study is one hooded sweatshirt that has a weight of 750g, worn twice a week, over the course of 1 year. The sweatshirt is washed once a week (52 washes/year).

Scenarios

This case study includes five different scenarios. The base scenario and scenario 1 assess the manufacturing location alternatives, while scenarios 2-4 assess the user behavior alternatives. Each alternative takes place in one of the two potential locations in India, Maharashtra and Odisha. The alternatives vary based on the type of use, such as, size of wash load, number of washes, and the method of drying the sweatshirt.

Variation in location

Variation in user behavior

	Manufacturing	Size of Wash Load	# of Washes/year	Method of drying
Base Scenario	Maharashtra	3.8kg	52	Air dry
Scenario 1	Odisha	3.8kg	52	Air dry
Scenario 2	Maharashtra	6kg	52	Air dry
Scenario 3	Maharashtra	3.8kg	26	Air dry
Scenario 4	Maharashtra	3.8kg	52	Tumble-dryer

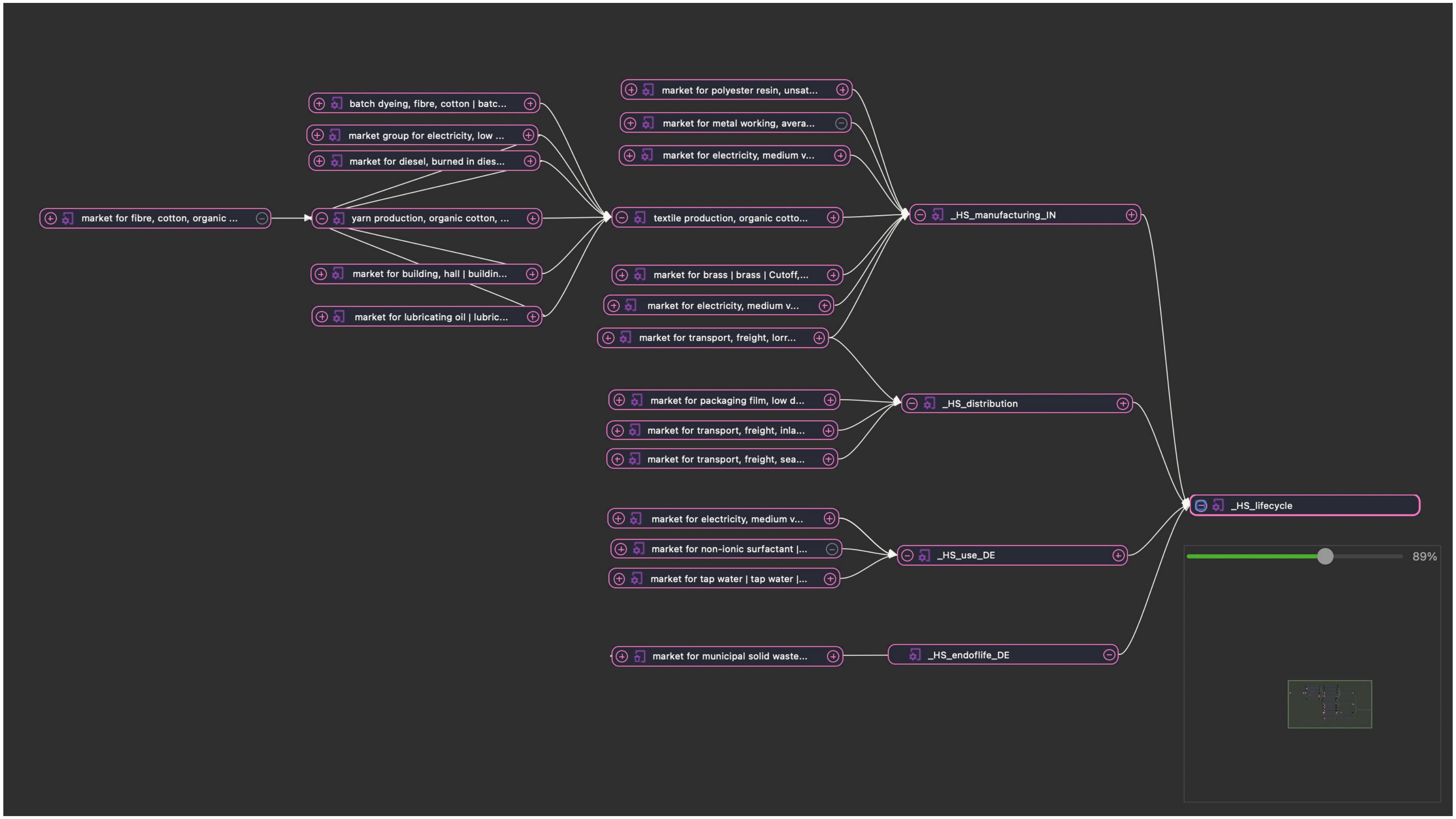
System Boundary

Within the system boundary the processes that are included are raw material extraction, production of cotton textiles, zippers, and polyester resin, manufacturing, distribution, use, and end-of-life. The geographic boundaries of these processes varies in manufacturing in India, to the use and disposal, located in Berlin.

There are no processes in the cradle-to-grave cycle that are excluded, however, there are some limitations to the boundaries. There is no recycle or re-use stage, only municipal waste. There is no differentiation between the two regions in India where raw materials are acquired, and manufacturing takes place. The only notable difference is use of the Western electrical grid in Maharashtra and the Eastern electrical grid in Odisha.

Other assumptions about the materiality, transportation, and use phase, include the percentage material composition of the sweatshirt, the length of travel from the production to manufacturing site, and the type of washing machine that is used. (See LC inventory slides 7-8 for specifics).

Life-cycle Diagram



Impact Assessment Method

For this case study the LCIA method used is the Environmental Footprint (EF) 3.0 method (adapted). According to the case study the impact categories that will be assessed are:

- Acidification (mol H+ eq)
- Climate change (kg CO2 eq)
- Ecotoxicity, freshwater (CTUe)
- Eutrophication, marine (kg N eq)
- Eutrophication, freshwater (kg P eq)
- Eutrophication, terrestrial (mol N eq)
- Human toxicity, cancer, in Comparative toxic unit for humans (CTUh)
- Human toxicity, non-cancer (CTUh)
- Ionizing radiation, human health (kBq U-235 eq)
- Land Use
- Ozone depletion (kg CFC11 eq)
- Particulate matter (disease incidence)
- Photochemical ozone formation, human health (kg NMVOC eq)
- Resource use, fossils (MJ)
- Resource use, minerals and metal (kg Sb eq)
- Water use (m3 deprived water)

Life Cycle Inventory – Raw Materials + Pre-processing

Yarn Production

Inputs

- Organic Cotton, 1.05kg for production of 1kg of yarn
- Brass, 20.52g for zipper (70% copper, 30% zinc)
- Polyester Resin, 23.24g to bind components
- Building, Hall
- Energy Input: Electricity for spinning, diesel fuel for processing equipment
- Lubricating oil for machinery
- Water for processing

Outputs

- Cotton Yarn, 1kg, 5% becomes waste during spinning
- Yarn waste, 0.05kg
- Processed Brass with components
- Waste mineral oil
- Wastewater

Textile Production

Inputs

- Cotton yarn, 1.025kg to produce 1kg of textile
- Batch Dyeing, Cotton, 1kg
- Building, Hall (larger than yarn production)
- Energy input: Electricity for knitting and dyeing, diesel fuel for processing equipment (3x more than yarn production)
- Lubricating oil for machinery

Outputs

- Cotton fabric, 2.5% becomes waste during knitting
- Textile waste, 0.025kg
- Waste mineral oil

Life Cycle Inventory – Manufacturing

Inputs

- Cotton fabric, 706.24g
- Brass zipper, 20.52g
- Polyester resin, 23.24g
- Electricity from regional grid, (Eastern or Western)
- Transport of raw materials to manufacturing, 50km
- Metal working process for zipper

Outputs

- Finished sweatshirt, 750g
- Textile waste from cutting, 11.8% of fabric input (83.34g)

Life Cycle Inventory – Distribution

Inputs

- Packaging film, low density polyethylene, 0.1kg

Transportation:

- Truck transport (1000km)
- Sea transport (11,401.18km)
- Inland waterway transport (13.31km)

Outputs

- Transported sweatshirt
- Packaging waste, 0.1kg

Life Cycle Inventory – Use

Inputs

- Electricity for washing machine (varies based on water temp.)

1) 40℃: 0.19kWh per wash
2) 60℃: 0.32kWh per wash (Base Scenario)
3) 90℃: 0.41kWh per wash

- Tumble dryer, 0.72kWh per cycle (Scenario 4)
- Tap water, 13kg per wash
- Detergent, 0.01143kg per wash

Outputs

- Washed sweatshirt
- Wastewater, 12.48L per wash
- Evaporated water, 0.52L per wash

Life Cycle Inventory – End of Life

Inputs

- Worn-out sweatshirt, 750g

Outputs

- Municipal solid waste, 750g
- No recycling or re-use available

Life Cycle Inventory – Scenario Variables

Manufacturing location:

1. Maharashtra (Western grid electricity)
2. Odisha (Eastern grid electricity)

Use behavior:

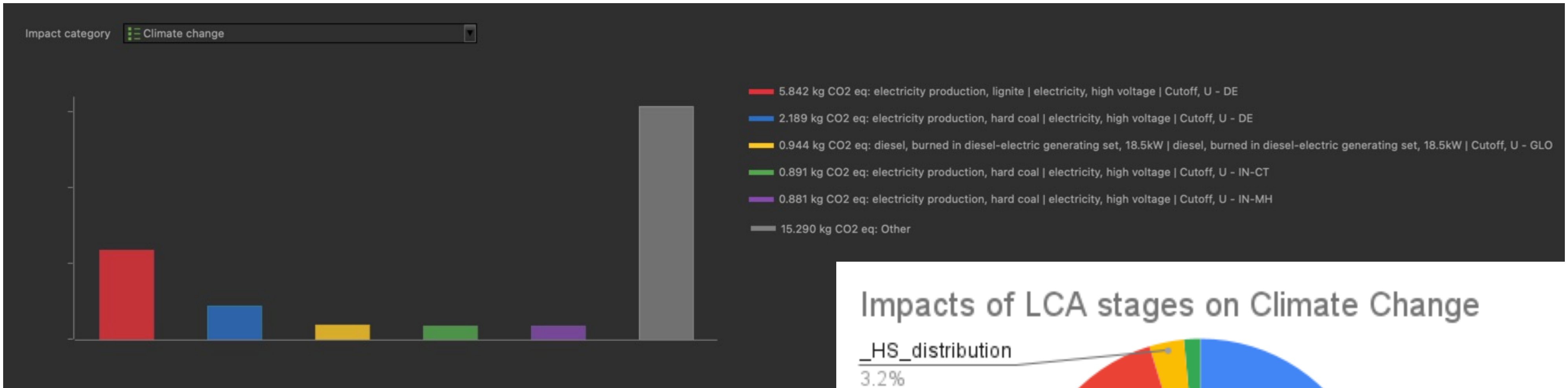
1. Base case: 3.8 kg washing load, 52 washes yearly, air drying (Base scenario)
2. Full load: 6 kg washing load, 52 washes yearly, air drying
3. Less cycles: 3.8 kg washing load, 26 washes yearly, air drying
4. Tumble-dryer: 3.8 kg washing load, 52 washes yearly, machine drying

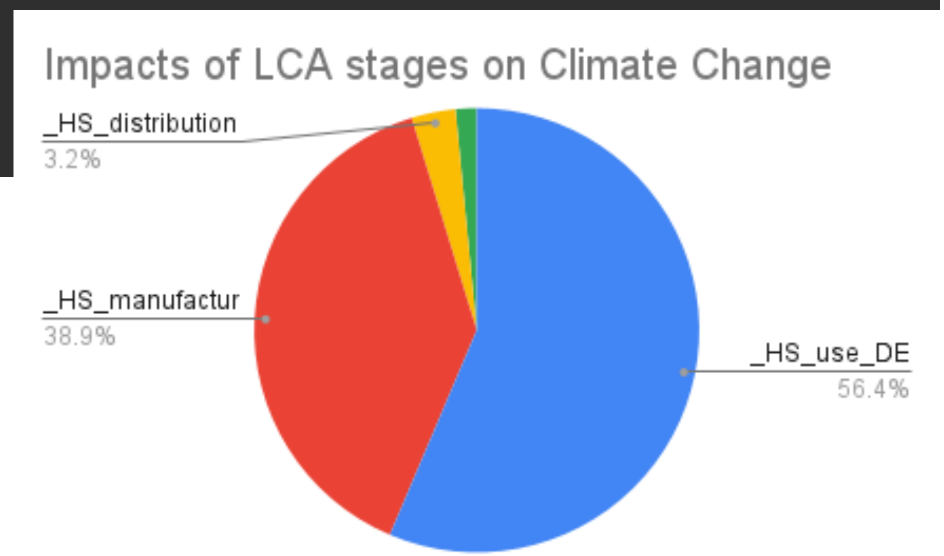
Temperature scenarios:

1. 40°C washing temperature
2. 60°C washing temperature (Base scenario)
3. 90°C washing temperature

Impact Assessment Results – Climate Change

Impact Assessment Method Used: Environmental Footprint 3.0 (adapted)

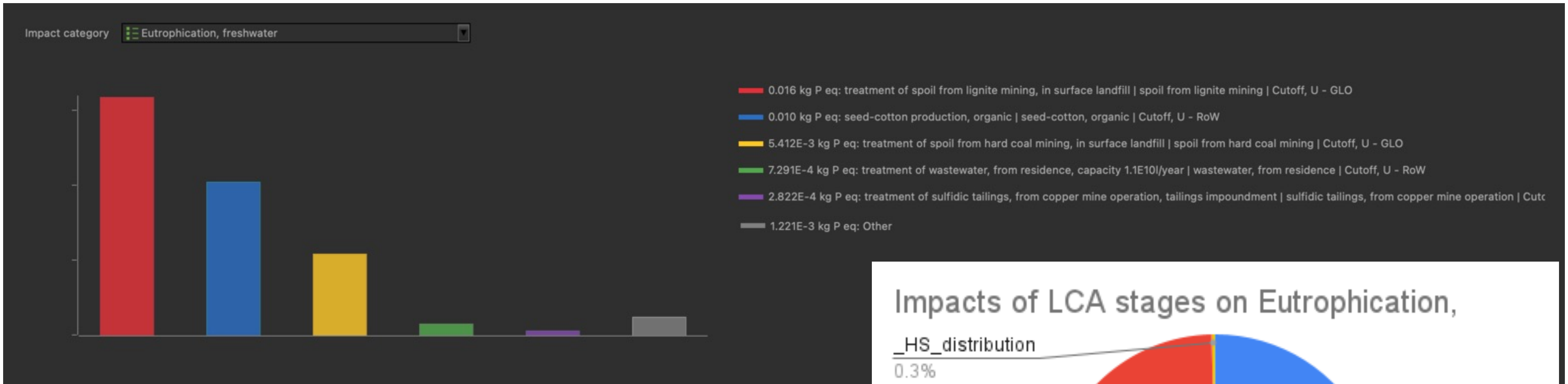


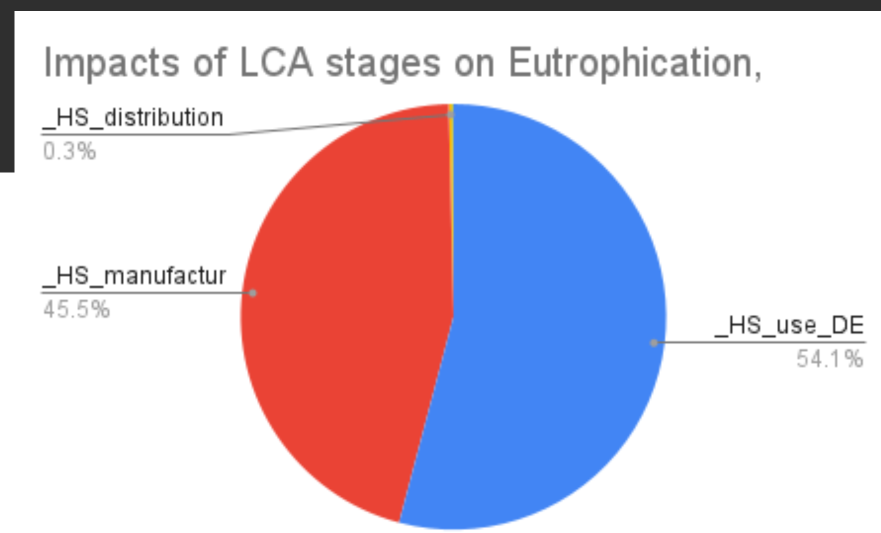


Yarn production and batch dyeing in manufacturing contributed heavily due to electrical and fuel consumption. The electrical consumption during the use phase as a result of machine washing is also a large contributor to the climate change impact category.

Impact Assessment Results – Eutrophication, Freshwater

Impact Assessment Method Used: Environmental Footprint 3.0 (adapted)

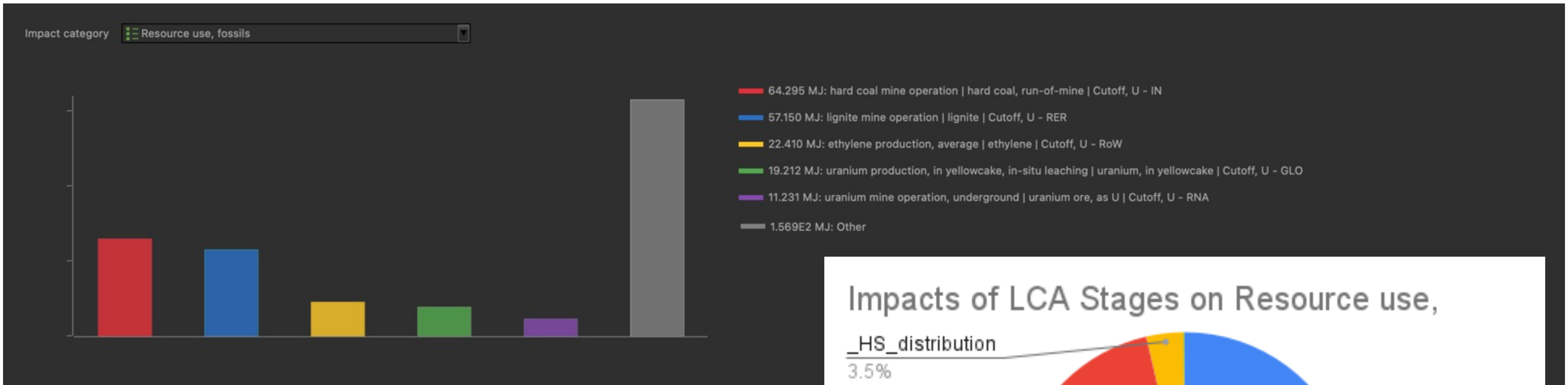


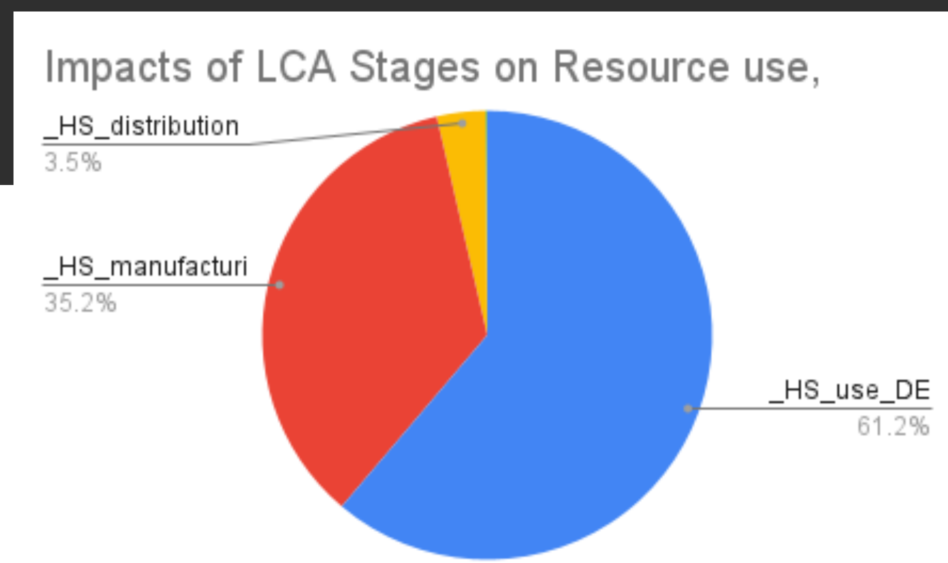


The electrical consumption required for the use phase (washing machine) makeup over half of the impact to Eutrophication. The impacts from the manufacturing phase are a result of yarn production, and primarily the cultivation of seed-cotton.

Impact Assessment Results – Resource Use, Fossils

Impact Assessment Method Used: Environmental Footprint 3.0 (adapted)

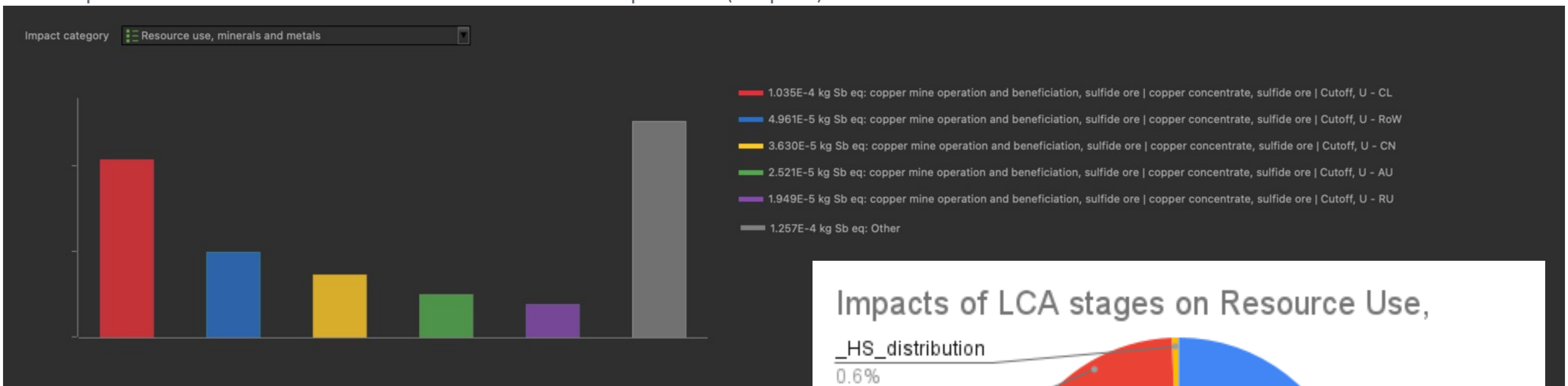




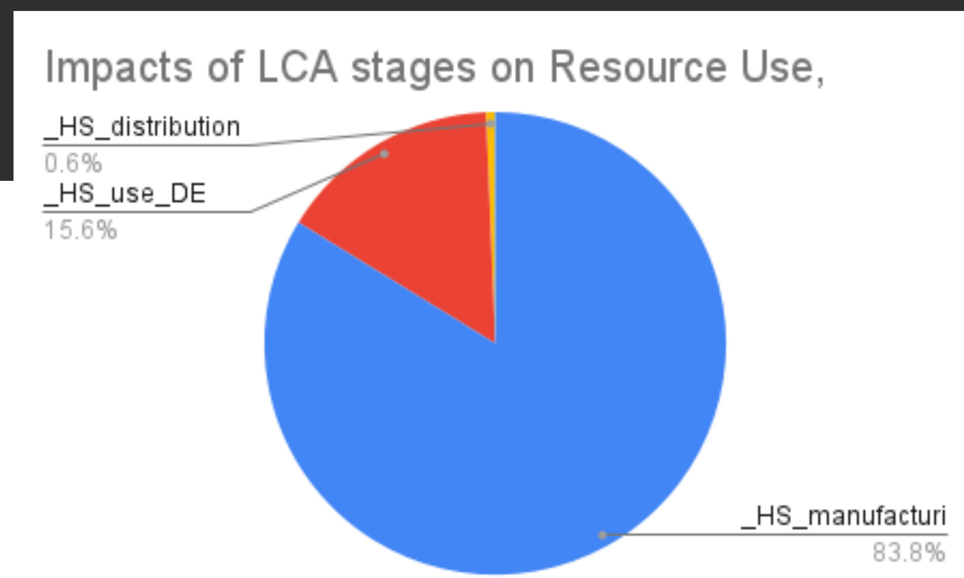
Once again, we see that the use phase is incredibly impactful, with the primary contributor being the electrical consumption required for the washing process.

Impact Assessment Results – Resource Use, Minerals and Metals

Impact Assessment Method Used: Environmental Footprint 3.0 (adapted)

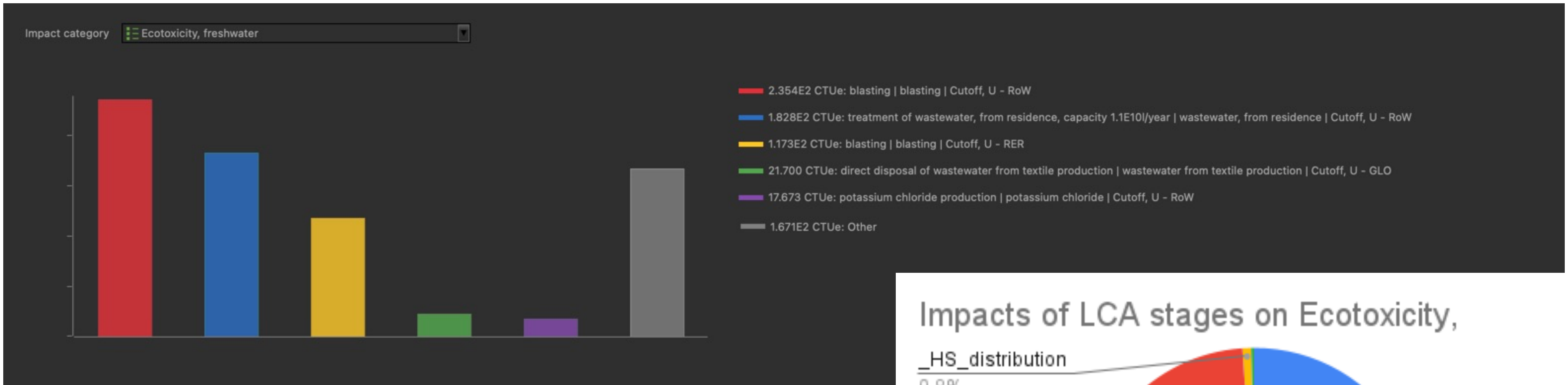


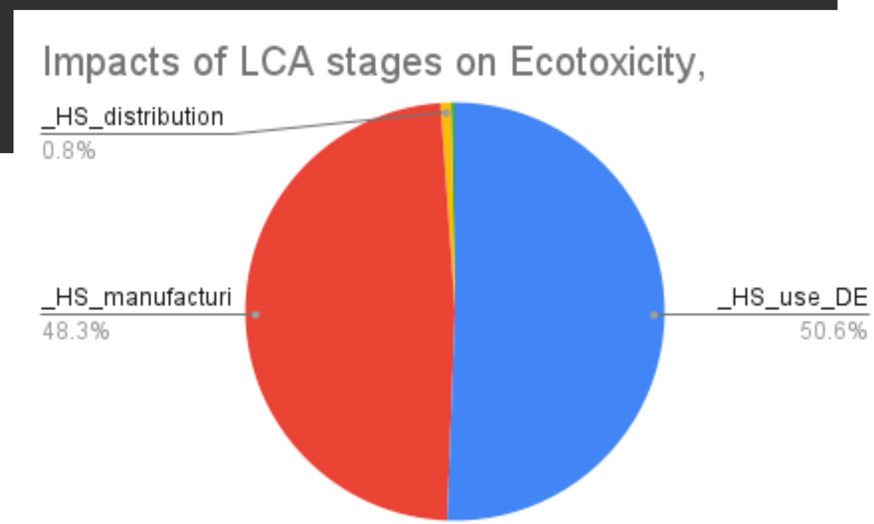
Although the use phase still represents a fair amount of the contribution to resource use of minerals and metals, the largest and most notable phase is the manufacturing phase. Particularly the production of brass and the formation of the zipper.



Impact Assessment Results – Ecotoxicity, freshwater

Impact Assessment Method Used: Environmental Footprint 3.0 (adapted)





The impact to ecotoxicity was the 5th largest contributing impact category, with the largest contributions coming from the manufacturing and use phases of the life cycle.

Interpretation of Results

Base Scenario (Maharashtra)

Significant Environmental Impact Categories:

- Climate change, 20.3%
- Eutrophication, Freshwater 17.6%
- Resource Use, Minerals and Metals, 12.8%
- Resource Use, Fossils, 12.7%

Eco hotspots:

- Electricity consumption of washing machine (42.7% contribution to climate change)
- Non-ionic surfactant used in detergent (11% contribution to climate change)
- Yarn production for cotton fabric (13.2% contribution to climate change)
- Batch dyeing processes (12.2% contribution to climate change)
- Brass production and processing for zipper (57% contribution to resource use of minerals and metals)

Interpretation of Results

Scenario 1 (Odisha)

Significant Environmental Impact Categories:

- Climate change, 20.3%
- Eutrophication, Freshwater 17.6%
- Resource Use, Minerals and Metals, 12.8%
- Resource Use, Fossils, 12.7%

Eco hotspots:

- Almost identical hotspots to the base case, as the manufacturing location change had minimal impact on overall environmental performance. The only slight difference was in the electricity mix between Western and Eastern Indian grids.

The impact categories remain virtually identical to the base case. This is because the manufacturing location had minimal influence on the overall environmental impacts, with only slight differences in regional electricity grid mixes.

Interpretation of Results

Scenario 2 (Full Load)

Significant Environmental Impact Categories:

- Climate change, 21.6% reduction
- Eutrophication, Freshwater, 19% reduction
- Resource Use, Minerals and Metals, 22.4% reduction
- Resource Use, Fossils, 5.7% reduction

Eco hotspots:

Same key hotspots as base case, but with reduced intensity:

- Washing machine electricity consumption (still dominant but lower impact due to better allocation of energy across more clothes)
- Detergent use (more efficiently distributed across a full load)
- Raw material extraction/processing hotspots remain unchanged

Interpretation of Results

Scenario 3 (26 wash cycles)

Significant Environmental Impact Categories:

- Climate change, 29.4% reduction
- Eutrophication, Freshwater, 27.7% reduction
- Resource Use, Minerals and Metals, 30.6% reduction
- Resource Use, Fossils, 7.9% reduction

Eco hotspots:

Further reductions in intensity:

- Washing machine electricity consumption (significantly lower due to halved frequency)
- Water consumption reduced
- Detergent use reduced
- Raw material extraction/processing hotspots remain unchanged

Interpretation of Results

Scenario 4 (Tumble-dryer)

Significant Environmental Impact Categories:

- Climate change, 96% increase
- Eutrophication, Freshwater, 112.7% increase
- Resource Use, Minerals and Metals, 104.1% increase
- Resource Use, Fossils, 13.6% increase

Eco hotspots:

- Tumble dryer electricity consumption (major new hotspot with substantial additional impact)
- Washing machine electricity consumption (remains a major hotspot)
- Raw material extraction/processing hotspots remain unchanged, but their relative contribution decreases as the use phase becomes even more dominant

Interpretation of Results - Continued

For all scenarios, the use phase (specifically washing machine electricity consumption) and raw materials extraction/processing, were the life cycle stages that contributed most significantly to the environmental impact categories. Depending on the scenario, the washing temperature also significantly affects the environmental impact, with higher temperatures (60°C, 90°C) creating greater impacts than lower temperatures (40°C), particularly for ionizing radiation, resource use of fossils, and climate change.

Based on the case study, Scenario 3 is the "greenest" alternative. In Scenario 3, climate change impacts are reduced by 29.4%, freshwater eutrophication is reduced by 27.7%, and fossil resource use is reduced by 30.6%.

I would recommend that in order to further reduce impacts, management would be required in user behavior, such as less frequent washes, utilize full-loads over partial loads, promote air drying, and wash at a lower temperature.

In terms of the raw material and manufacturing processes, I would recommend a focus on energy consumption reduction for the yarn and textile production, researching alternatives to brass, and exploration of circular initiatives to reduce textile waste.