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Brown and Wilmanns Environmental, LLC

Greenhouse Gas, Energy and Water Impact Assessment for Rit Dye All Purpose Dye and Fixative:

Results, Methodology & Sources

by

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for

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Summary Results

This study compares the relative environmental impacts of dyeing a T-shirt with purchasing a new T-shirt, modeling the behavior of a consumer who does not want to wear a faded T-shirt.

The study evaluates water consumption (liters), energy use (megajoules), and greenhouse gas emissions (kgCO_2e) over the life span of the original and consequentially dyed T-shirt's life compared to buying new T-shirts.

The functional unit of this study was laundering a T-shirt 49 times (Average number of launderings for a T-shirt before end of life)[i]

Three models were considered:

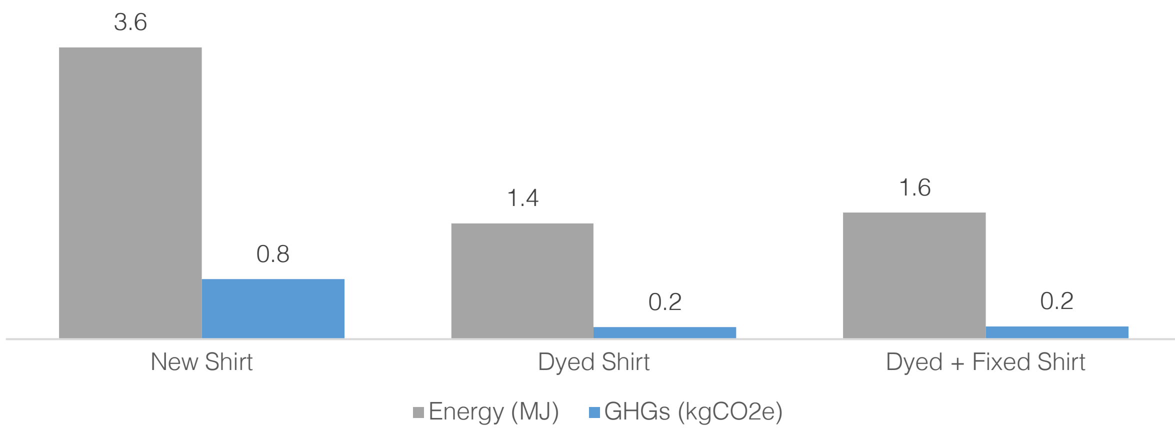
- The T-shirt was re-dyed at 13 (weighted average of Rit Dye survey – see page 5) launderings – this number was derived from a survey of current Rit Dye costumers (see page 5).
- A T-shirt replacement vs. re-dye at 20 launderings.
- A T-shirt replacement vs. re-dye at 25 launderings.

Findings based on the Rit Dye consumer survey are presented below.

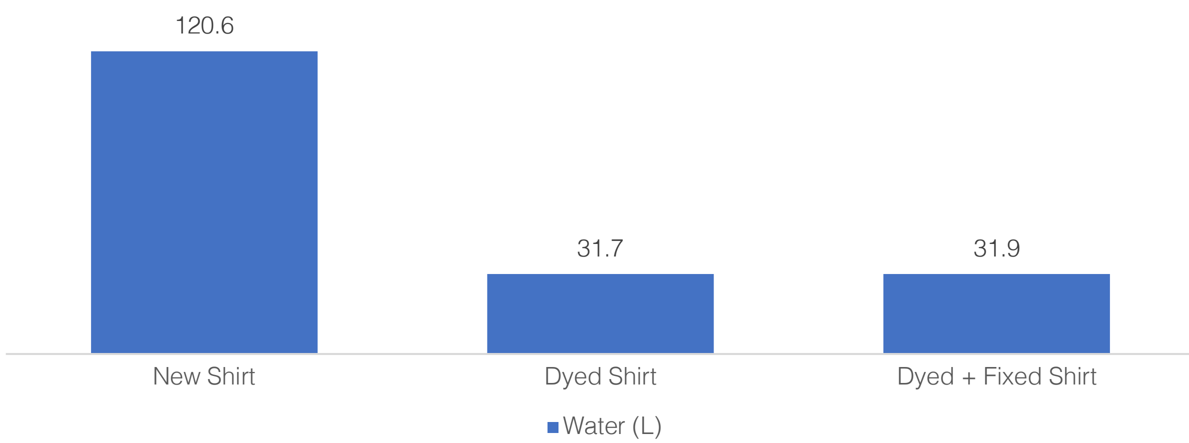
Relative Resource Consumption and Emissions of Purchasing a New T-Shirt and a New T-Shirt laundered 49 times based on Rit Dye survey Findings (other models findings later in this report)

	Dyed T-Shirt	Dyed + Fixed T-Shirt
Energy (MJ)	-61%	-57%
GHGs (kgCO_2e)	-80%	-79%
Water (L)	-74%	-74%

Total Energy Demand and GHG Emissions



Total Water Consumption



Methodology

The methodology used in this LCA defines the scope as the material and energy inputs, packaging inputs, transportation of Rit Dye products, the dyeing process, washing and drying of clothes, and end of life disposal.

Assessment Methods

We used the ecoinvent Version 3.9 Cut Off life cycle assessment database as our primary data source, accessed via openLCA Version 2.0.1 life cycle assessment software. All calculations related to the dyeing and the total impacts were completed in Excel.[ii] The Cut Off database allowed for associating each unit process with all appropriate emissions. Where co-products exist, use of the APOS (at point of substitution) or consequential databases may result in an allocation of additional emissions to the co-products and credit for substituting a co-product where it might displace another material (for example, if wind energy was used in production, a substitution credit might be taken for displacing electricity generated from coal).

"Energy Demand" represents the total energy (in MJ) demanded from non-renewable energy sources (coal, natural gas, crude oil, lignite, and uranium). Life cycle impact (LCI) results were generated using the cumulative energy demand (CED) method published by the ecoinvent Centre.[iii]

"GHG Emissions" represents the 100-year Global Warming Potential (GWP in g CO_2 equivalents). All GWP100 impacts generated from Ecoinvent follow the IPCC 2021 GWP 100a methodology.[iv]

"Water Consumption" is based on total water consumption as opposed to total water use. All water consumption impacts generated from ecoinvent represent the water depletion potential (WDP) derived using the ReCiPe 2016 Midpoint (H) methodology.[v]

Functional Unit

The functional unit of this study is 49 T-shirt launderings. The number of shirts included in the study depends on each scenario and the assumed washes per T-shirt and number of times a T-shirt is dyed.

Project Measurements

BWE measured and weighed one cotton T-shirt in size Large (sample T-shirt). The seam lengths were measured for input into the T-shirt manufacturing assessment. The weight of the T-shirt was used to determine the input cotton quantity. The weight of the size Large T-shirt matches closely the values quoted on Rit Dye's website.

Rit Dye Survey

Rit Dye conducted a survey of their users to collect general demographic information as well as information related to how their consumers use the dye products. This project uses the dyeing information as the basis for washing and dyeing variables. We considered four of the survey questions for this study:

1. Do you use Rit ColorStay Dye Fixative after dyeing?
2. Which method do you use to solid dye garments?
3. On average, how many wash cycles does it take before you notice color fading on clothing that was dyed using Rit Dye?
4. On average, how many wash cycles does it take before you notice color fading on clothing that was dyed commercially?

The results are as follows:

1. About 20% of respondents use it always and 35% use it sometimes.
    a. This shows us that the fixative is regularly used and should be considered as part of this study.
2. About 45% use the Bucket or Sink method, 25% use a Washing Machine method, and 29% use the Stove Top method. (Rounding completes the last 1%)
    a. All methods have been considered in this study.

3. About 22% say after 1-5 washes, 37% say after 6-10 washes, 25% say after 11-19 washes, and 17% say 20+ washes.
    a. A weighted average of 11 washes per dye job before fading and redyeing is assumed.
4. About 13% say after 1-5 washes, 25% say after 6-10 washes, 28% say after 11-19 washes, and 34% say 20+ washes.
    a. A weighted average of 15 washes per commercial dye/new shirt before the shirt is either dyed or disposed.

Data Sources by Life Cycle Stage and Assumptions

1. Material Production

The market-based values from the ecoinvent Ver. 3.9 Cut Off database were applied. Market-based values are unit process values that include multiple life cycle stages rolled up into one unit process, including but not limited to: extraction, processing, and transportation. Market-based unit processes are designed to give a more complete snapshot of the process without the practitioner estimating the additional processes and introducing their own uncertainties and potential inconsistencies. The end point of these processes is 1 kg of material ready to be manufactured into a final product.

The materials evaluated using market-based unit processes include:

- Cotton
- Naphthalene sulfonic acid (direct dye substitute)
- Anthraquinone (acid color substitute)
- Fatty alcohol (anti foam substitute)
- Carboxymethyl cellulose powder
- Sodium chloride powder
- Sodium sulfate (sodium lauryl sulfate substitute)
- EDTA (sequestering agent substitute)
- P-chlorophenol (preservative substitute)
- Polymer foaming (polymer substitute)

For the cotton production, we calculated a combination of the material production, weaving, and dyeing processes. ecoinvent has market-based unit processes for all three steps. [ii]

To account for cutting losses, we assumed an 80% efficiency value of inbound fabric to final T-shirt.

2. Sewing

All seam lengths were measured on the sample T-shirt. A commercial sewing machine, Juki DDL 8700, was used for stitch length, speed and energy demand.[vi] The energy demand was calculated from this information and the GREET model was used to provide the electricity emission data. [ix] Impacts for energy demand and associated GHG's were added to the model. Water consumption was excluded.

3. Packaging Materials Production

The market-based values from ecoinvent Ver. 3.9 Cut Off database were applied.[ii] Market-based values are unit process values that include multiple life cycle stages rolled up into one unit process including but not limited to: extraction, processing, and transportation. Market-based unit processes are designed to give a more complete snapshot of the process without the practitioner estimating the additional processes and introducing their own uncertainties and potential inconsistencies. The end point of these processes is 1 kg of material ready to be manufactured into a final product.

The materials evaluated using market-based unit processes include:

- High density polyethylene
- Polypropylene
- Polyethylene terephthalate
- Polyethylene linear low density
- Corrugated board box
- Paper

4. Transportation

Only transportation directly related to Rit Dye's products were considered. Two methods for transportation were considered depending on the origin and destinations.

- Two locations in the US: Google Maps was used to gather transportation distance and it was assumed that all transport was by truck. Depending on the type of truck specified by Rit Dye, the following two trucks were used:
  - Semi truck: Lorry freight, 7.5-16 metric tonnes EURO6 emissions standards
  - LTL: Lorry freight, 3.5-7.5 metric tonnes EURO6 emissions standards
- Locations outside of the US: Great circle distance equation was used with an estimate of the different modes of transport (rail, sea, truck, air). This considers the latitude and longitude of cities and draws straight between the locations. This method may over- or underestimate emissions based on the actual modes of transport and the transfer stops in between.
  - Assumed 80% of the distance was by sea and 20% of the distance was by truck.

Transportation associated with the purchase of the T-shirt or dye has been omitted. It is assumed that these will be similar and insignificant.

5. Laundering

After wearing washing and drying of the T-shirt was looked at as three different methods. The first method was based on the Rit Dye survey. The number of launderings reported before the T-shirt starts fading are below in the following table.

	# of Launderings
New T-shirt	15
Dyed T-shirt	11
Dyed + fixative T-shirt	17

The second and third are fixed numbers of launderings regardless of whether it is a new or dyed shirt. The number of launderings considered are 20 and 25 respectively.

Information about laundering came from the US Environmental Protection Agency (EPA) unless noted otherwise:[vii]

- A person creates 1/3 of a wash per day
    - Assuming a shirt is 25% of that
- Water consumption
    - Conventional top loader: 37.8gal/load
    - Conventional front loader: 18.8gal/load
    - Assumed 50/50 split: 2.12 gal for a shirt
- Energy type assumptions[viii]

	Washer		Dryer	
	% used	Efficiencies	% used	Efficiencies
Natural gas	30%	75%	25%	75%
Electric	70%	100%	75%	100%

- Emissions
    - Natural gas and electricity emissions are taken from GREET.[ix]

The same washing process is used when needed in dyeing.

6. Dyeing and Fixing Processes

The instructions on the Rit Dye website were followed and ratioed by the results from the survey. The instructions for dyeing and fixing are the same so it is assumed that the impact for either is the same.

Types of Dyeing	Percent
bucket/sink	45%
washing machine	25%
stove top	29%

One cup of salt was considered in the dye process.

- Bucket Dyeing/Fixing

  Based on Rit Dye's instructions, bucket dyeing only has water in a bucket with salt. No additional launderings were considered.

- Washing Machine Dyeing/Fixing

  Based on Rit Dye's instructions, 3 rounds of the washing machine running with one cup of salt was considered. The three rounds of the washing machine were for: dyeing, setting the dye, and washing the machine for regular use. The same washing machine information was used as if one was laundering a load of clothes.

- Stove Dyeing/Fixing

  Based on Rit Dye's instructions, water was heated for dyeing on the stove top, a cup of salt for the dyeing process, and one round in the washing machine to set the dye were considered. Assuming an electric stovetop, the energy demand was calculated, and the associated emissions were taken from GREET.x It is assumed that the water takes 10 minutes to get to the right temperature, then the dye process takes 45 minutes. One round in the washing machine to set the dye is included.

We assume that each shirt can be dyed 3 times or a shirt can be dyed and fixed 2 times before the shirt would need to be replaced. This is regardless of the number of washes assumed before the shirt starts fading.

7. End of Life

The shirts were disposed of based on the EPA's Waste Management values.x

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Detailed Results

The impacts associated with three laundering scenarios that were evaluated are presented in this section. All absolute values have been normalized to the number of launderings.

The comparison scenario used in each of the three scenarios below consists of one purchased T-shirt, which was dyed or dyed and fixed.

Scenario 1: Number of Launderings Based on Customer Survey Results:

In this scenario, four new T-shirts are purchased.

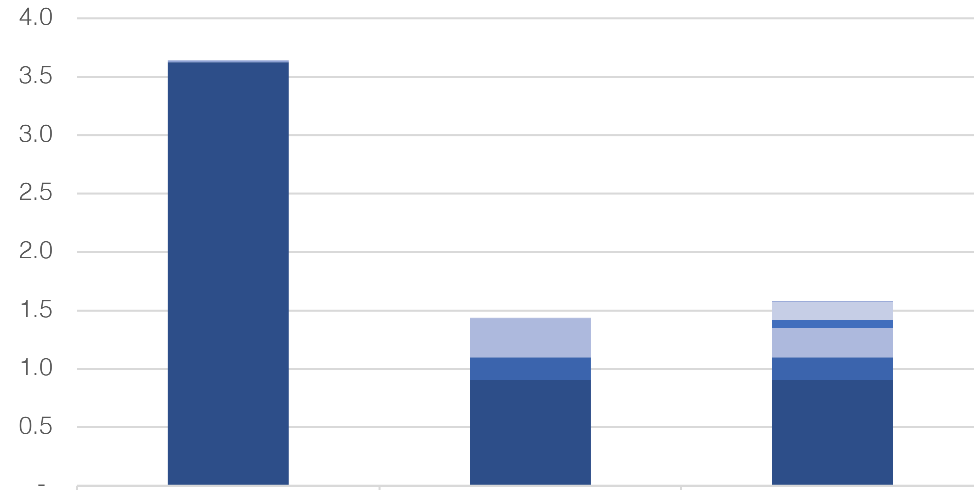
Absolute Impacts

	New	Dyed	Dyed + Fixed
Energy (MJ)	3.64	1.44	1.58
GHGs ($kgCO_2e$)	0.75	0.15	0.16
Water (L)	120.59	31.74	31.86

Relative Impacts of Scenario 1 to Dyed or Dyed + Fixed Methods

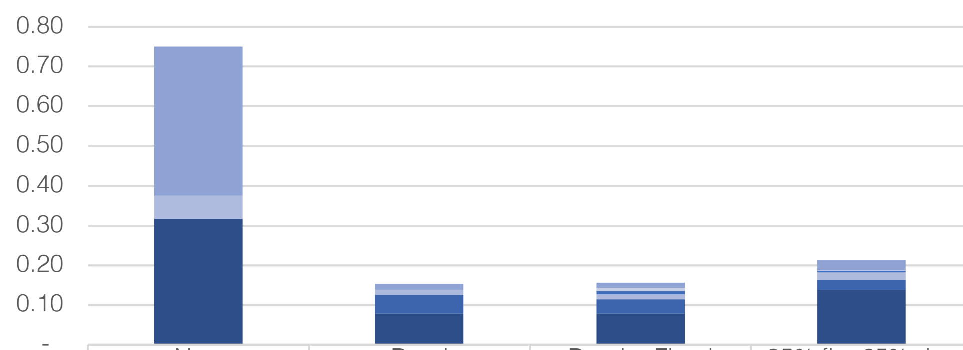
	Dyed	Dyed + Fixed
Energy (MJ)	-61%	-57%
GHGs ($kgCO_2e$)	-80%	-79%
Water (L)	-74%	-74%

Energy Demand (MJ)

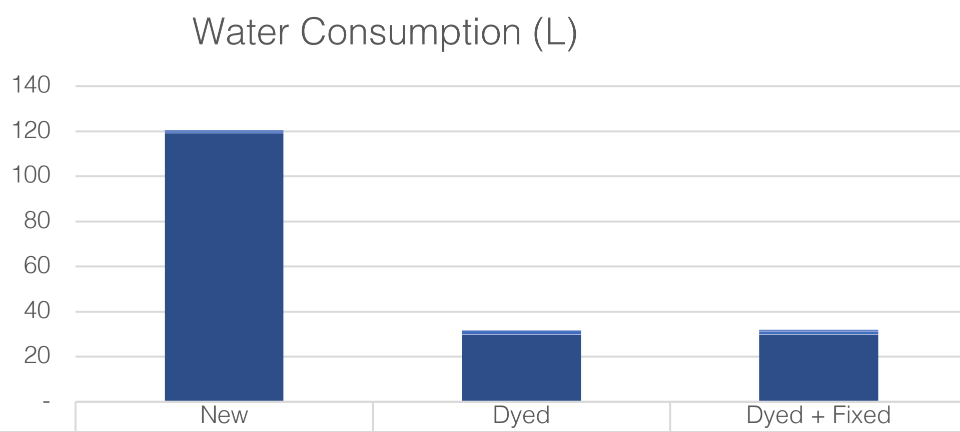


	New	Dyed	Dyed + Fixed
Landfill	0.01	0.00	0.00
Fixing			0.15
Fix Prod/Trans/Pack		-	0.07
Dyeing		0.34	0.25
Dye Prod/Trans/Pack		0.19	0.19
Production	3.63	0.91	0.91

GHG Emissions (kg CO_2e)



	New	Dyed	Dyed + Fixed	35% fix+65% dye
Landfill	0.37	0.01	0.01	0.03
Fixing		-	0.01	0.00
Fix Prod/Trans/Pack			0.01	0.00
Dyeing	0.06	0.01	0.01	0.02
Dye Prod/Trans/Pack		0.05	0.03	0.02
Production	0.32	0.08	0.08	0.14



	New	Dyed	Dyed + Fixed
Landfill	1.53	0.38	0.38
Fixing	-	-	0.40
Fix Prod/Trans/Pack	-	-	0.07
Dyeing	-	1.38	1.04
Dye Prod/Trans/Pack	-	0.21	0.21
Production	119.06	29.77	29.77

Scenario 2: 20 Launderings between re-dye vs. new shirt purchase:

This scenario assumes three new T-shirts are purchased and will go through 20 launderings before fading.

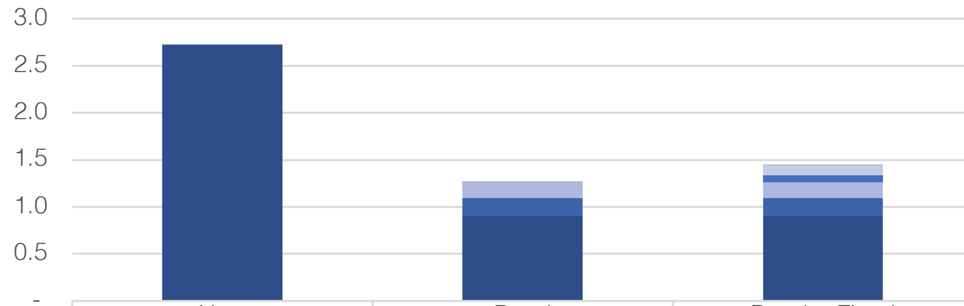
Absolute Emissions

	New	Dyed	Dyed + Fixed
Energy (MJ)	2.73	1.27	1.45
GHGs (kgCO2e)	0.28	0.13	0.14
Water (L)	90.45	31.05	31.38

Relative Impacts of Scenario 2 to Dyed or Dyed + Fixed Methods

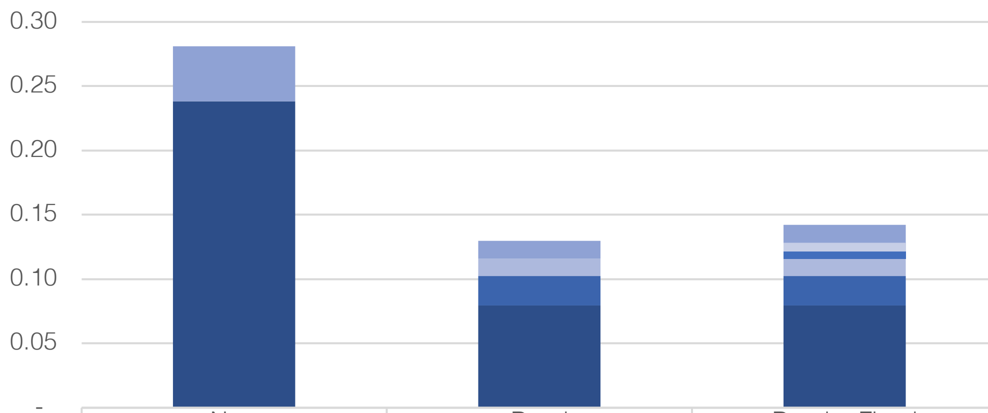
	Dyed	Dyed + Fixed
Energy (MJ)	-54%	-47%
GHGs (kgCO2e)	-54%	-49%
Water (L)	-66%	-65%

Energy Demand (MJ)

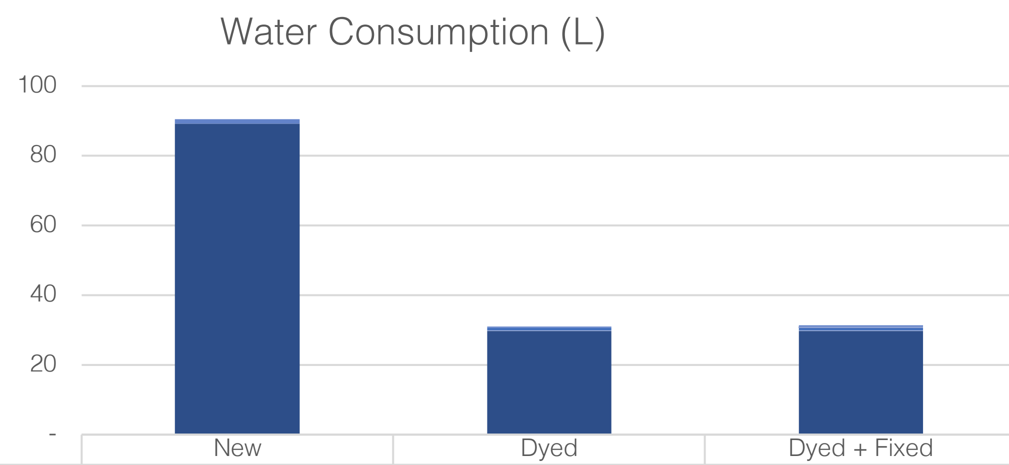


	New	Dyed	Dyed + Fixed
Landfill	0.01	0.00	0.00
Fixing			0.10
Fix Prod/Trans/Pack		-	0.07
Dyeing		0.17	0.17
Dye Prod/Trans/Pack		0.19	0.19
Production	2.72	0.91	0.91

GHG Emissions (kg CO_2e)



	New	Dyed	Dyed + Fixed
Landfill	0.04	0.01	0.01
Fixing		-	0.01
Fix Prod/Trans/Pack			0.01
Dyeing		0.01	0.01
Dye Prod/Trans/Pack		0.02	0.02
Production	0.24	0.08	0.08



	New	Dyed	Dyed + Fixed
Landfill	1.15	0.38	0.38
Fixing	-	-	0.27
Fix Prod/Trans/Pack	-	-	0.07
Dyeing	-	0.69	0.69
Dye Prod/Trans/Pack	-	0.21	0.21
Production	89.30	29.77	29.77

Scenario 3: 25 Launderings between re-dye vs. new shirt purchase

In this scenario we assume that two new T-shirts are purchased and will go through 25 launderings before fading.

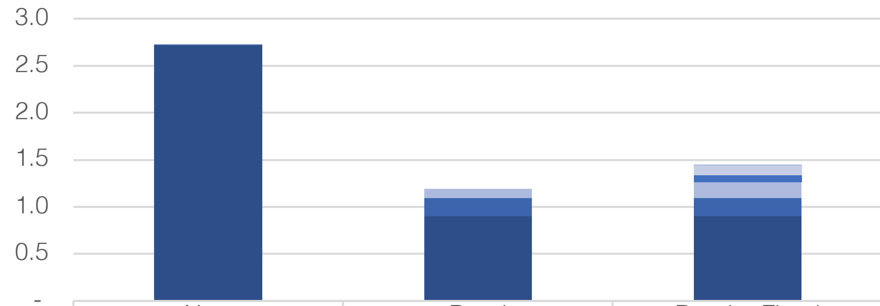
Absolute Emissions

	New	Dyed	Dyed + Fixed
Energy (MJ)	2.73	1.18	1.45
GHGs (kgCO_2e)	0.28	0.12	0.14
Water (L)	90.55	31.53	32.24

Relative Impacts of Scenario 3 to Dyed or Dyed + Fixed Methods

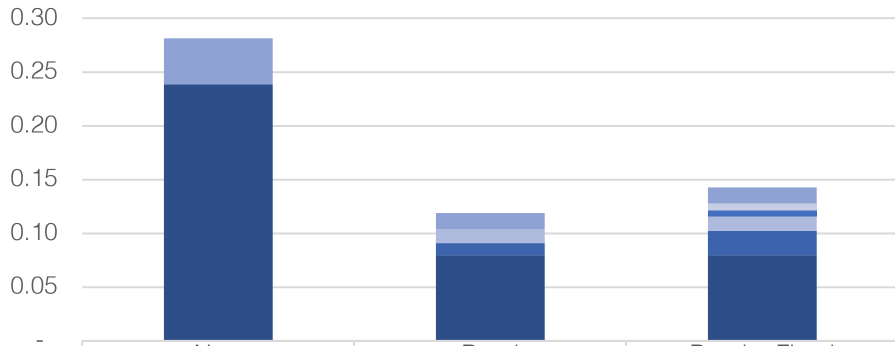
	Dyed	Dyed + Fixed
Energy (MJ)	-57%	-47%
GHGs (kgCO_2e)	-58%	-49%
Water (L)	-65%	-64%

Energy Demand (MJ)



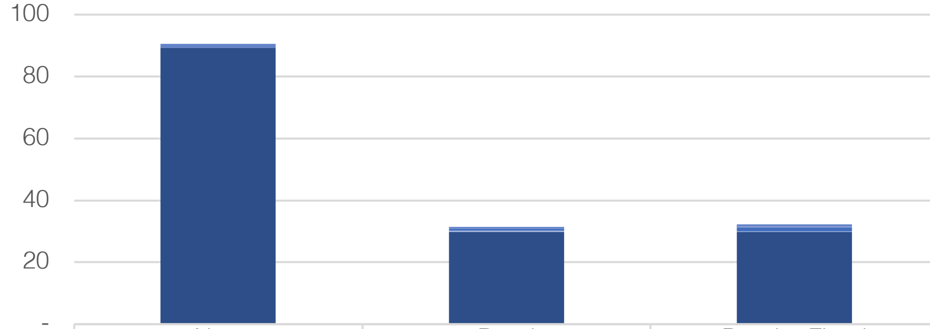
	New	Dyed	Dyed + Fixed
Landfill	0.01	0.00	0.00
Fixing			0.10
Fix Prod/Trans/Pack		-	0.07
Dyeing		0.08	0.17
Dye Prod/Trans/Pack		0.19	0.19
Production	2.72	0.91	0.91

GHG Emissions (kg CO2e)



	New	Dyed	Dyed + Fixed
Landfill	0.04	0.01	0.01
Fixing		-	0.01
Fix Prod/Trans/Pack			0.01
Dyeing		0.01	0.01
Dye Prod/Trans/Pack		0.01	0.02
Production	0.24	0.08	0.08

Water Consumption (L)



	New	Dyed	Dyed + Fixed
Landfill	1.25	0.72	0.59
Fixing	-	-	0.41
Fix Prod/Trans/Pack	-	-	0.10
Dyeing	-	0.65	1.06
Dye Prod/Trans/Pack	-	0.39	0.32
Production	89.30	29.77	29.77

Adjustments to the Statement of Work

There were no adjustments to the SOW.

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