H&M Conscious
- the conscious choice?

A life cycle assessment comparison between two t-shirts

AG2800 Life Cycle Assessment
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Group 7

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ABSTRACT

The frequently occurring everyday choices between environmentally-friendly stated products and their alternatives have made the authors of this report interested in what impact these choices really have. Therefore, two t-shirts have been assessed and compared, one conventional and one produced with 100 percent organic cotton. The aim is to investigate how much better the "green product" really is by performing two stand-alone life cycle assessments and compare them.

The software program SimaPro has been used, where a lot of the required datasets already existed, and the rest could be assembled with information from various reports on cotton production, retrieved from the internet. The results of the study showed that the organic t-shirt has a higher impact overall, and the important categories turned out to be *freshwater eutrophication*, *human toxicity* and *natural land transformation*. The sensitivity analysis distinguished the importance of correct water data; the water used and the environmental impact was not linear. The sensitivity analysis also showed that the use phase is important to the life cycle, which means that every consumer actually can affect the total environmental impact.

The conclusion is that the organic cotton t-shirt has got a higher environmental impact, because of the larger land requirement, solely. However, the conventional cotton t-shirt has a higher negative impact on the social aspects of the production, affecting the health of cotton workers negatively.

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1. INTRODUCTION

Every day we are faced with a number of decisions between environmentally-friendly product options and their not-so-friendly equivalents. But how do we know that the green label actually means something? Can we be certain that the extra money we spend has a positive impact and is not just something to relieve our consciences? How do we know that the assumed positive effects in the production phase of an environmental friendly product matters, looking at the product's whole lifecycle? If what happens during the use phase and waste disposal phase is what really matters, is it then unnecessary to buy a green-labelled product? This study aims to investigate one of these everyday options that the writers have encountered and if possible, give an indication to other consumers. It is safe to say that almost everyone in Sweden is familiar with the brand H&M, and the choice we focus on in this report is between a regular H&M cotton t-shirt and one from their conscious collection, made of 100 percent organic cotton.

Cotton fields are only counted for 2.5 percent of the total growing area on earth today, yet it uses up to 25 percent of the total amount of pesticides (Världsnaturfonden WWF, 2005; Organic cotton, 2016; Swerea, 2011). Further on, the fact that the cotton in a t-shirt is organic just means that the cotton has been grown and cultivated without pesticides or chemical fertilizers. However, the processes from there to the final t-shirt is the same independently of organic or conventional cotton, and they use a lot of chemicals for washing and bleaching the fabric (Karlsson, 2016).

In recent years, great progress has been made in the cotton industry, particularly in the cultivation phase, and efforts to reduce the proportion of environmentally harmful substances are highly topical today. More and more companies want to be seen as environmentally conscious, and H&M is no exception. H&M's goal until 2020, is that 100 percent of their cotton should be totally organic (H&M, 2013), the question is whether this will make any difference?

1.1. Goal of the study

All the choices we have been forced to make between a "green product" and an ordinary product have made us want to know what impact it really has, and to what extent our choices affect the environment. Our way to concretize this question is to investigate a physical product that many can relate to, namely a plain t-shirt. Therefore, we want to compare the life cycle of two t-shirts from H&M, where one is an ordinary white t-shirt and the other one is a white t-shirt from H&M´s greener collection called Conscious. Both are 100 percent cotton, but H&M Conscious is organic cotton. Since we are interested in knowing how high impact the fabric has on the whole life cycle, the study will consist of two stand-alone LCA's, where both are accounting. The aim of the project is to enable the public to make a more informed choice of which t-shirt to buy, when shopping at a H&M store. The company markets the latter t-shirt as a better, more sustainable choice, but it is also a bit more expensive. The results are intended to be used for the public when choosing which t-shirt to buy.

1.2. Scope of the study

The scope of the study includes functional unit used in calculations, system boundaries, cut-off criteria, assumptions and limitation for the study. These are presented further below.

1.2.1. Functional unit

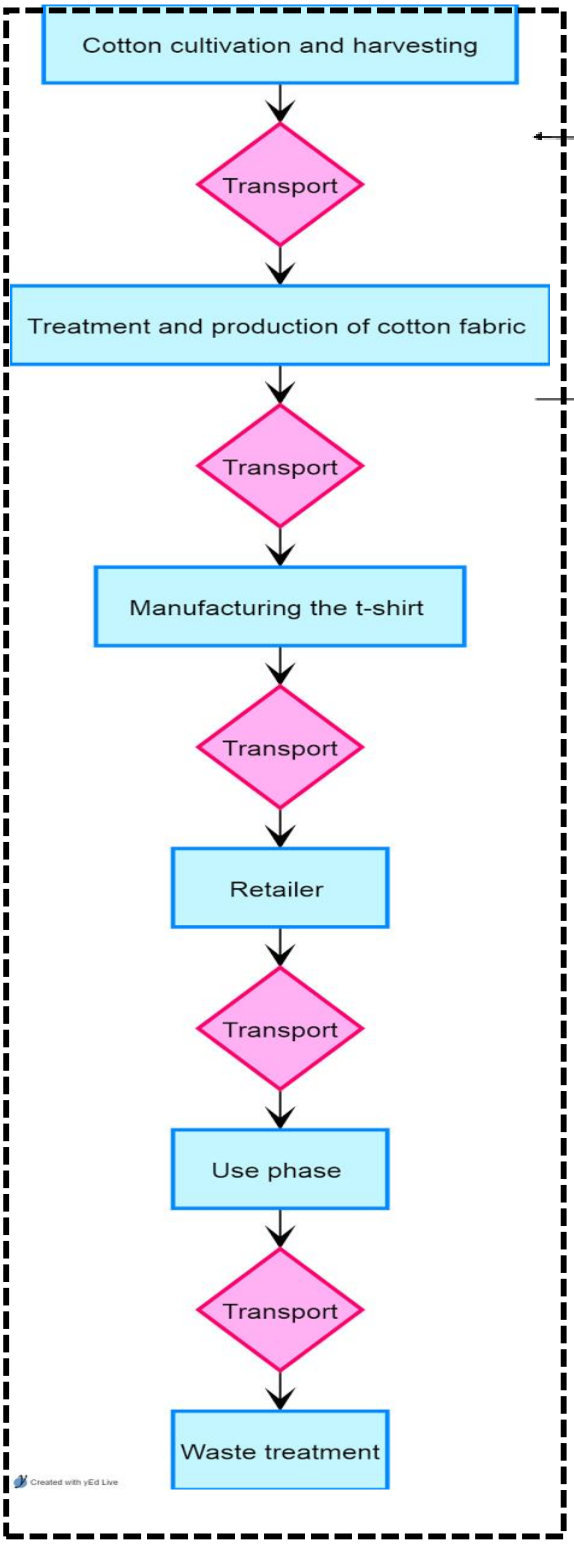
The functional unit in this LCA is 10 000 white, medium-sized t-shirts, whose purpose is to keep the carrier warm and covered during a total of 70 washes. The function of keeping warm and covered is measured in the weight of the t-shirt, namely 0,2 kg (Elander et al, 2014). We do not consider whether the t-shirts are reused during the use phase, just the total amount of washes it can undergo before breaking or in any other way become unusable.

Figure 1. Two white t-shirts -to the left one from the collection Conscious and to the right one conventional.

1.2.2. System boundaries

This is a life cycle assessment of two t-shirts from H&M, assessed from cultivation of cotton to incineration of worn out t-shirt. Processes included in the life cycle can be seen in the flowchart, below. The foreground is the processes where H&M is involved; such as retailing, and the rest of the processes are considered to be in the background. Because of the time constraint of the project, no data was able to be collected from H&M directly, and in reality every process consist of background data in this study.

The geographical boundaries in this LCA is divided into three parts; the cultivation and processing of cotton is restricted to India and China, respectively. The manufacturing of the t-shirt is restricted to Bangladesh and the selling, use and end of life is restricted to Sweden. Because of the insufficiency of data, some average data is used instead of land specific data. This approach is used in the cultivation phase, where there is no available data for India. Instead an average of the three largest cotton cultivator countries in the world, China, the U.S and India, a sort of global average, is used (United States Department of Agriculture, Economic Research Service, 2016).



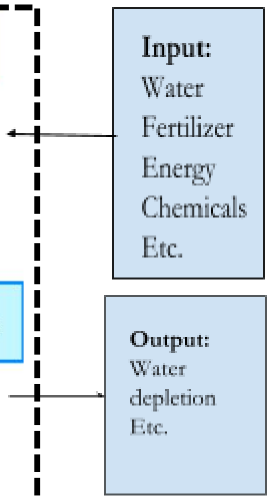


Figure 2, The life cycle of a t-shirt from cotton cultivation to waste treatment.

The data that will be collected is no more than fifteen years old, partly due to recent years´ fast development in cultivation of ecological cotton, but also depending on the data available. Given that the data is updated continuously within the subject area, old data quickly becomes incorrect. For example, land use for conventional cotton cultivation has declined by 30 percent in only 30 years (Cotton Today, 2016a). This life cycle assessment will therefore be applicable as long as there is no major development in cotton cultivation or production of the fabric and t-shirt.

1.2.3. Cut-off criteria

The cotton seeds are excluded from the process, because of the difficulty to find data, and because it is used in other products when separated from the cotton in the cotton ginning, e.g. to produce oil (Cotton Today, 2016c; Eyhron, 2005). Although, it is important to have in mind that the cotton seeds are treated differently between the two life cycles. The conventional cotton seeds are contaminated with inorganic chemicals, while the organic cotton seeds are free from those (Organic facts, 2016; Ljungström & Spångberg, 2011).

The rainwater is precluded for the reason that it does not need any undertaking to be used in the cultivation phase. Therefore, the rainwater watering the cotton does not contribute any further to the environmental impact.

Every process concerning the label and the thread is excluded, due the mass ratio between the thread, label and cotton fabric where the former two stands for a small part of the whole t-shirt. That is a probable cause not to be of any large impact in the LCA. Furthermore, neither the label nor the thread is in focus of the LCA and the processes are the same for both life cycles.

The environmental impact associated with the retailing process is cut-off from the LCA because of the small impact linked to one single t-shirt, when taking into consideration the whole lifespan of the store, its heating and lighting.

The travel made from the retailer to the household is not part of the system because it is most likely not only one t-shirt that is bought per shopping spree, which leads to an insignificant impact allocated to the t-shirt. Therefore, it is neglected in this LCA.

Concerning washing detergent added in use phase, the three biggest components were included in calculations, where a subassembly containing these was created. Additional components were assumed to be less than one percent each and therefore cut off from our calculations (Wikipedia, 2016). Collected data about the capacity of an average washing machine, see table 5b, together with the weight of one t-shirt, leads to the conclusion that approximately five percent of the washing cycle can be allocated to the t-shirt.

According to Elander et. al. (2014), almost no textiles in Sweden are recycled to be used in producing new textiles. For that reason, the recycling process is cut-off. If the recycling would increase, it would reduce the environmental impact of the cotton because of the reuse of some cotton fibre in the production of cotton fabric.

The waste treatment, when incinerating the t-shirt, heat and electricity is converted from the combusted textile. That means that some of the burden can be allocated from the t-shirt to the electricity and heat.

All the processes after incineration, e.g. landfill, is not included since landfill is not relevant for this study since instead all the material is incinerated.

1.2.4. Assumptions

- Only average data is used, since an accounting LCA is performed.
- Both conventional and organic cotton is assumed to be cultivated in India (Textile Exchange, 2016).
- Organic cotton is assumed to require three times the land area of conventional cotton (Roos & Posner, 2011).
- Both conventional and organic cotton is assumed to be harvested by machine.
- Cotton preparation is assumed to be done in China and the transportation between harvesting and preparation is included in the dataset (UNEP, 2002).
- In the manufacturing phase electricity use is included, but no heat or land occupation due to the assumption of hot climate in the manufacturing country and the fact that a factory produces a vast amount of t-shirts per year, resulting in an extremely small land area allocated to each textile.
- The manufacturing of the t-shirts is assumed to occur in Bangladesh (according to labels on the two t-shirts). The electricity mix in Bangladesh is somewhat similar to the electricity mix in Thailand, therefore it is assumed that the dataset for electricity by country mix Thailand can be used in the study without major errors. (LightCastle Blog, 2014; Marcon International, Inc., 2016)
- The cotton is assumed to be bleached (included in dataset), and no colouring process is assumed to be done since the t-shirts are white.
- Transport between material preparation in China and manufacturing of t-shirt in Bangladesh is assumed to be 1900 km and done by truck. (Distans Kina - Bangladesh, 2016)

- Next transportation step is assumed to be between Bangladesh and Rotterdam at a distance of 20 000 km, by cargo vessel. (Google Maps, 2016; H&M, 2016)
- Final transport is assumed to be by freight train, between Rotterdam and Stockholm, a distance of 1600 km. (Distans Rotterdam - Stockholm, 2016; H&M, 2015)
- Altogether, the two t-shirts are assumed to be transported the same distance and have the same weight, i.e. resulting in the same amount of emissions in the transportation phase.
- Possible emissions to air or humans during use phase are assumed to be insignificant and are therefore neglected.
- The two different t-shirts can be washed/used an equal amount of times.
- The use phase and disposal occur in Sweden.
- Washing is assumed to be done at 40 degrees Celsius for both t-shirts, according to washings instructions.
- The waste is transported from Stockholm to Högdalen, by lorry. The distance is 11 km (Distans Stockholm - Högdalen, 2016).
- The incineration results in the converted amount of 1.26 MJ electricity/kg combusted textile, Swedish electricity mixture.
- The incineration also results in the converted amount of 2.86 MJ heat/kg combusted textile, from biofuel. (Svensk fjärrvärme, 2016)

1.2.5. Limitations

It is not possible to ensure a completely representative study when the data is collected mostly from existing data sheets in the database as well as scientific reports of varying publishing dates. To improve the study, more accurate and relevant data needs to be collected, both from the databases, scientific reports as well as own-collected data. To provide the best possible LCA, the chosen sources of information has been criticized based on their origin, age and how well they correspond to other sources.

N.b. that this study only investigates the difference between an organic cotton t-shirt and a conventional t-shirt, and is not representative for comparison between other materials.

1.3. Impact categories and impact assessment method

Impact categories that are assumed to be significant for this study are: water depletion, freshwater eutrophication, freshwater ecotoxicity, natural land transformation and human toxicity. This is motivated by the fact that cotton cultivation is responsible for a relatively big amount of water and pesticides used in agriculture throughout the world. These categories will be discussed further in the analysis part.

The impact assessment method used in SimaPro is ReCiPe Midpoint (Hierarchist). The time frame for this method is based on established policies and is medium length. Just like the time frame, most issues in the method is based on established policies. The midpoint indicators are eight, and they have got a low uncertainty (Goedkoop, 2013).

Normalisation will be done to put the results in perspective, making it easier for the individual consumer to comprehend. Weighting, however, will not be performed since, again, the targeted audience of the report is the public and weighting would reduce the transparency.

2. LIFE CYCLE INVENTORY ANALYSIS

2.1. Data

From collected information it is concluded that the only differences between conventional and organic cotton t-shirts appear in the cotton cultivation phase -harvesting and every process after that is identical. The databases used in the LCA are Ecoinvent 3 - allocation, default - system and Ecoinvent 3 - allocation, default - unit, both v. 3.2 (2016).

The irrigation, fertilizers, chemicals and pesticides are modified in fabric, for both t-shirts. The irrigation for the conventional cotton is 5.726 m^3, and 17.178 m^3 for the organic cotton. Fertilizer data for the conventional cotton is from an existing process in Ecoinvent, and the fertilizer for the organic cotton is from the existing fertilizer green manure. No pesticides or artificials are present in the cultivation of organic cotton. To get an overview of the processes needed to manufacture one t-shirt, all the material and processes are stated in table 1 and table 2, for conventional and organic cotton, respectively.

Table 1. Fabric for one conventional t-shirt.

Explanation	Material/Process	Input	Output	Unit	Reference
Material developed and used in t-shirt assembly.	Fabric for one t-shirt		0.2	kg	•
Fabric. Existing assembly in Ecoinvent database, manipulated irrigation.	Textile, woven cotton {GLO}| market for | Alloc Def, S	0.22		kg	10 % spill (Strand, 2015)
Electricity used for cutting, existing assembly in Ecoinvent database.	Electricity, high voltage {TH}| market for | Alloc Def, S	0.099		MJ	Total consumption: 2.47 MJ/kg fabric, with 20 % allocated to cutting and 80 % allocated to sewing (Strand, 2015)
Process	Cotton textile waste		0.02	kg	see table 9

Table 2. Fabric for one organic t-shirt.

Explanation	Material/Process	Input	Output	Unit	Reference
Material developed and used in organic t-shirt assembly later on in the process.	Fabric for one organic t-shirt		0.2	kg	•
Fabric. Customized dataset with reference to pesticides, fertilizers and water.	Organic Textile, woven cotton {GLO}| production | Alloc Def, U*	0.22		kg	10 % spill (Strand, 2015) Green manure, land use (Cotton Today, 2016b; Swerea, 2011)
Electricity used for cutting, existing assembly in Ecoinvent database.	Electricity, high voltage {TH}| market for | Alloc Def, S	0.099		MJ	Total consumption 2.47 MJ/kg fabric, with 20 % allocated to cutting and 80 % allocated to sewing (Strand, 2015)
Process	Cotton textile waste		0.02	kg	see table 9

* Own dataset compiled from conventional with changes made concerning for example fertilizer, see appendix.

Fabric for one t-shirt is then input in an assembly, where all the processes concerning t-shirt production is included. One assembly is made for the t-shirt made from conventional cotton, table 3, and one assembly is made for the t-shirt made from organic cotton, see table 3 and 4.

Table 3. Conventional t-shirt, Material.

Explanation	Material/Process	Amount	Unit	Reference
Material	Fabric for one t-shirt	0.2	kg	See table 1
Electricity used for sewing, existing assembly in Ecoinvent database.	Electricity, high voltage {TH}| market for | Alloc Def, S	0.4	MJ	Total consumption 2.47 MJ/kg fabric, with 20 % allocated to cutting and 80 % allocated to sewing (Strand, 2015)
Transportation between fabric manufacturing in China and sewing process in Bangladesh	Transport, freight, lorry, unspecified {GLO}| market for | Alloc Def, S	380	kgkm	Approximate distance according to: (Distans Kina - Bangladesh, 2016)

Table 4. Organic t-shirt, Material.

Explanation	Material/Process	Amount	Unit	Reference
Material	Fabric for one organic t-shirt	0.2	kg	See table 2.
Electricity used for sewing, existing assembly in Ecoinvent database.	Electricity, high voltage {TH}| market for | Alloc Def, S	0.4	MJ	Total consumption 2.47 MJ/kg fabric, with 20 % allocated to cutting and 80 % allocated to sewing (Strand, 2015)
Transportation between fabric manufacturing in India and sewing in Bangladesh	Transport, freight, lorry, unspecified {GLO}| market for | Alloc Def, S	380	kgkm	Approximate distance according to: (Distans Kina - Bangladesh, 2016)

The use phase consists of washing the t-shirt and the data for the washing process is shown in table 5. To calculate average data for a washing machine, the mean value from three different washing machines were used, see table 6.

Table 5. Washing, a process that we developed on our own using existing processes in the software SimaPro.

Explanation	Material/Process	Input/Output	Unit	Reference
Process	Washing	0.2	kg	Average, assume one t-shirt stands for 5 % of one washing cycle
Material	Sodium perborate, tetrahydrate, powder {GLO}| market for | Alloc Def, S	0.19	g	7 % of detergent (Wikipedia, 2016)
Material	Sodium tripolyphosphate {GLO}| market for | Alloc Def, S	1.4	g	50 % of detergent (Wikipedia, 2016)
Material	Alkylbenzene sulfonate, linear, petrochemical {GLO}| market for | Alloc Def, S	0.42	g	15 % of detergent (Wikipedia, 2016)
Process	Tap water {Europe without Switzerland}| market for | Alloc Def, S	2.6	kg	Tap water, Swedish conditions
Process	Electricity, medium voltage {SE}| market for | Alloc Def, S	0.033	kWh	Swedish electricity mixture

Table 6. Washing machines average data, when washing in 40 degrees. Collected from three different washing machines used by the group members in this project.

Model	Capacity (kg)	Energy (kWh)	Water (litre)
ElektroHelios TF1236E	5	0.7	58
Electrolux EW1077F	6	0.60	49
Whirlpool AWE 7526	6	0.65	48
Average	5.67	0.65	52

The data for the final life cycle of a t-shirt made from conventional and organic cotton is shown in table 7 and 8.

Table 7. Life Conventional. In this life cycle we include all previous processes and materials for the conventional t-shirt.

Explanation	Material/Process	Input/Output	Unit	Reference
Assembly	Conventional Cotton T-shirt	10000	p	Functional unit is used
First part of transportation, from production Bangladesh-Rotterdam	Transport, freight, sea, transoceanic ship {GLO}| market for | Alloc Def, S	40000	tkm	Approximate distance according to Google Maps (waterway)
Second part of transportation, to retailer Rotterdam-Stockholm	Transport, freight train {Europe without Switzerland}| market for | Alloc Def, S	2800	tkm	Approximate distance according to (Distans Rotterdam - Stockholm, 2016)
Customized process for washing	WASHING	140	tkm	70 washes for 10 000 t-shirts
Waste scenario	Cotton textile waste	•	•	See table 9

Table 8. Life Organic. In this life cycle we include all previous processes and materials for the organic t-shirt.

Explanation	Material/Process	Input/Output	Unit	Reference
Assembly	T-shirt organic cotton	10000	p	Functional unit is used
First part of transportation, from production Bangladesh-Rotterdam	Transport, freight, sea, transoceanic ship {GLO}| market for | Alloc Def, S	40000	tkm	Approximate distance according to Google Maps (waterway)
Second part of transportation, to retailer Rotterdam-Stockholm	Transport, freight train {Europe without Switzerland}| market for | Alloc Def, S	2800	tkm	Approximate distance according to (Distans Rotterdam - Stockholm, 2016)
Customized process for washing	WASHING	140	tkm	70 washes for 10 000 t-shirts
Waste scenario	Cotton textile waste	•	•	See table 9

The waste treatment process used in the LCA is described in table 9, and the waste scenario is described in table 10.

Table 9. Waste treatment process.

Explanation	Material/Process	Input/Output	Unit	Reference
Waste specification	Cotton textile waste treatment	1	kg	•
Avoided burden, electricity	Electricity, high voltage {SE}| market for | Alloc Def, S	1.26	MJ	Swedish electricity mixture, Ecoinvent
Avoided burden, heat	Heat, central or small-scale, other than natural gas {SE}| heat and power co-generation, biogas, gas engine| Alloc Def, S	2.86	MJ	Typical Swedish district heating, (Svensk fjärrvärme, 2015)
Outputs to technosphere	Waste textile, soiled {CH}| treatment of, municipal incineration | Alloc Def, S	1	kg	Similar to Swedish conditions of how textiles are treated

Table 10. Waste scenario.

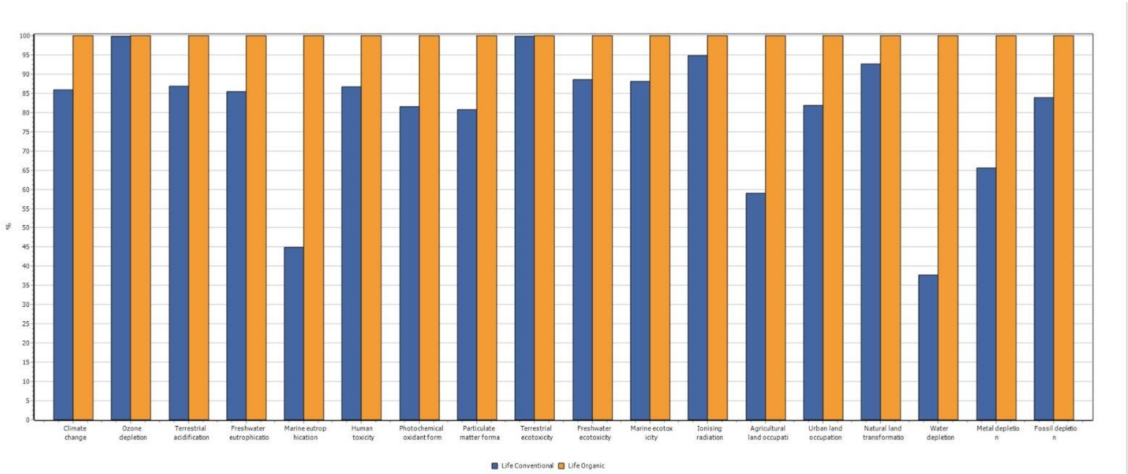
Explanation	Material/Process	Input/Output	Unit	Reference
Waste specification	Cotton textile waste	1	kg	•
The transport from central parts of Stockholm, to the incineration in Högdalen	Transport, freight, lorry, unspecified {GLO}| market for | Alloc Def, S	0.018	kgkm	The weight of a t-shirt, multiplied with the transport distance between Stockholm and Högdalen.
Waste treatment	Cotton textile waste treatment	100	%	See table 8

3. LIFE CYCLE INTERPRETATION

3.1. Results

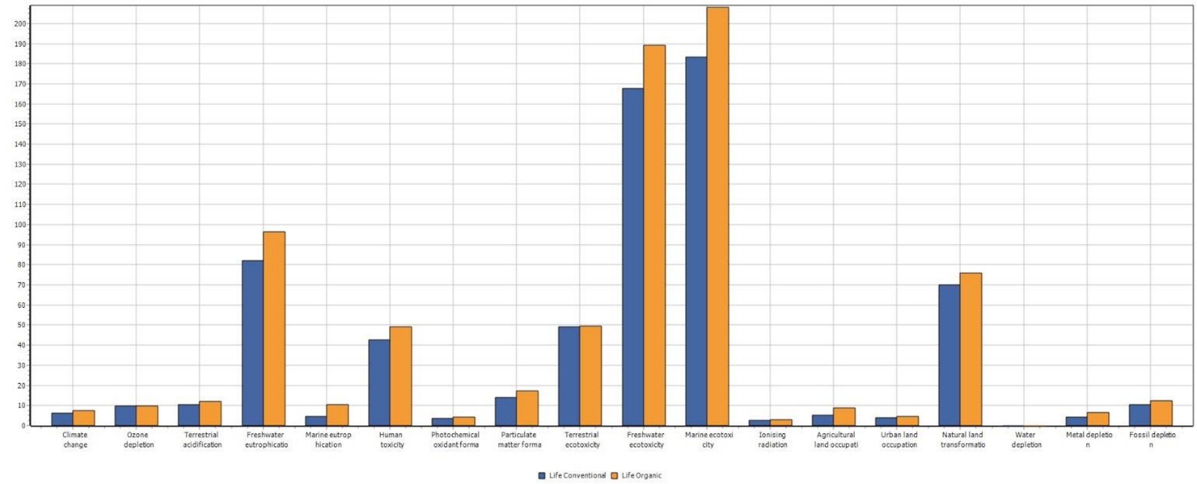
To get an overview of both life cycles, as well as how they relate to one another, the characterization chart is shown below, figure 3. The blue bars represent the impact from the life cycle of 10 000 t-shirts made from conventional cotton, and the yellow bars represent the impact from the life cycle of 10 000 t-shirts made from organic cotton.

Figure 3. Characterization of Life Conventional and Life Organic.



Interestingly, and a bit surprisingly, our study shows a bigger impact connected to the organic t-shirt in all categories. The only thing different between the two life cycles are the cultivation step, where three times more land (i.e. three times more irrigation, machine use and so on) is required, but organic fertilizers are used instead of conventional fertilizers and no pesticides are used. If we look at these results more closely, it becomes clear that the irrigation is responsible for a big share of the environmental impact, and in this sense, organic cotton is worse. However, these results need to be put in perspective, which is why we will use normalization before we draw any further conclusions.

Figure 4. Normalization of Life Conventional and Life Organic.



The normalized results compare the life cycle of 10 000 t-shirts to the environmental impact of one average European during one year. The normalization is unitless so the results indicate that the impact of 10 000 t-shirts on for example the categories freshwater ecotoxicity and marine ecotoxicity is almost two hundred times the total impact of one European during one year, which is a significant value.

As can be seen from the chart above, the important categories turn out to be *freshwater eutrophication*, *human toxicity* and *natural land transformation*. *Terrestrial ecotoxicity*, *freshwater ecotoxicity* and *marine ecotoxicity* are also high but these are systematically high when ReCiPe is used, which could indicate a systematic error as a result of an underestimated reference value. (Björklund, 2016)

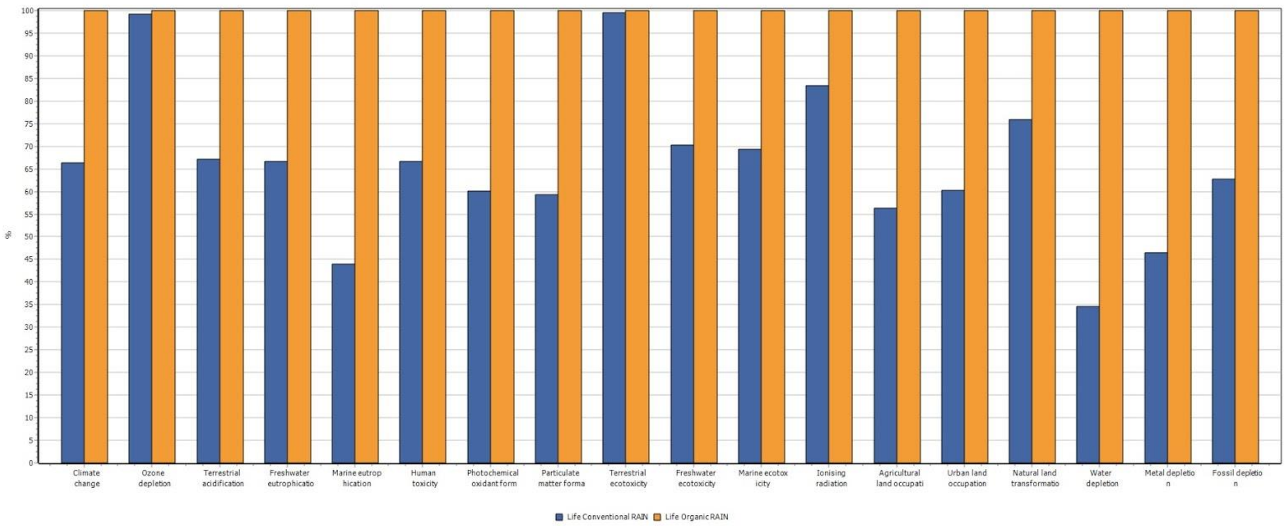
Water depletion turned out not to be important compared to one European, which reveals how much water we actually use. The fact that water depletion is completely insignificant could also be the result of some major error in the datasets. After all, there are a lot of different values on water consumption in different reports, and it would be risky to draw conclusions too fast, based on this table solely. The impact on *freshwater eutrophication* was expected to be high, because the life cycle contains a lot of substances known to increase eutrophication, e.g. nitrogen.

Marine ecotoxicity was not predicted to be important, and digging deeper into this, it turns out that the main reason for the unexpected big impact is the copper used for electricity infrastructure. One could, of course, argue that this should be outside of the system boundary. *Freshwater ecotoxicity*, *human toxicity* and *natural land transformation* also have an important environmental impact due to the same reason as *marine ecotoxicity*. The high environmental impact on the category *natural land transformation* is also a result of cotton being a rather land-consumable crop. The organic t-shirt has a higher impact on this category due the fatty acids used to produce the green manure (crops are grown to extract the fatty acids, which requires natural land to be transformed to agricultural land).

3.2. Sensitivity analysis

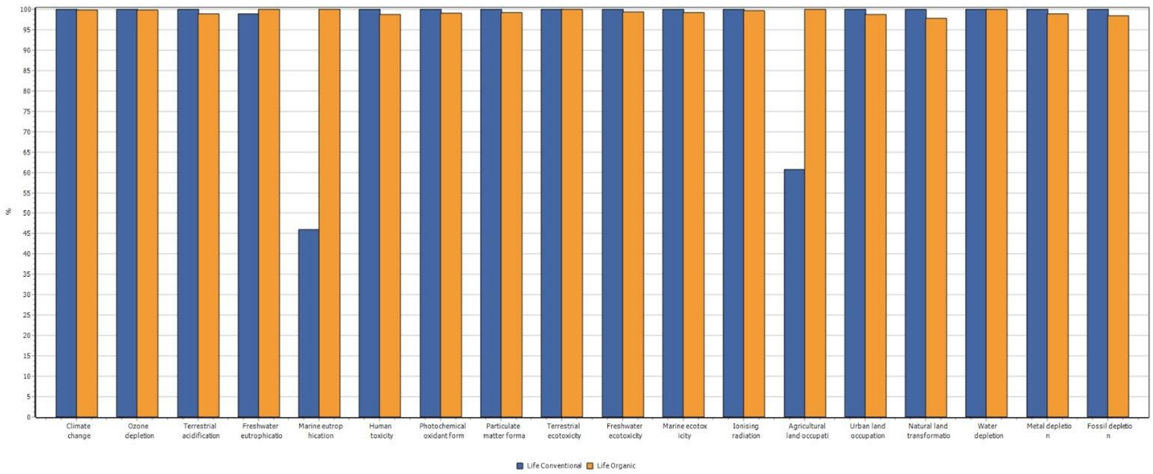
In the study, only artificial water has been accounted for, if instead the rainwater would be included as well, the environmental impact would increase. When including the rainwater, irrigation for conventional water would increase from 5.726 m^3 to 21.563 m^3. For organic cotton, corresponding increase for irrigation is 17.178 m^3 to 64.689 m^3. The result shows that the difference between the environmental impact between the two life cycles have increased. This means that the impact from irrigation is not linear when increased/reduced. From a sensitivity analysis point of view, the conclusion can be drawn that data on irrigation plays a significant role in the life cycle assessment of a cotton t-shirt.

Figure 5. Characterization of Life Conventional and Life Organic, including rainwater.



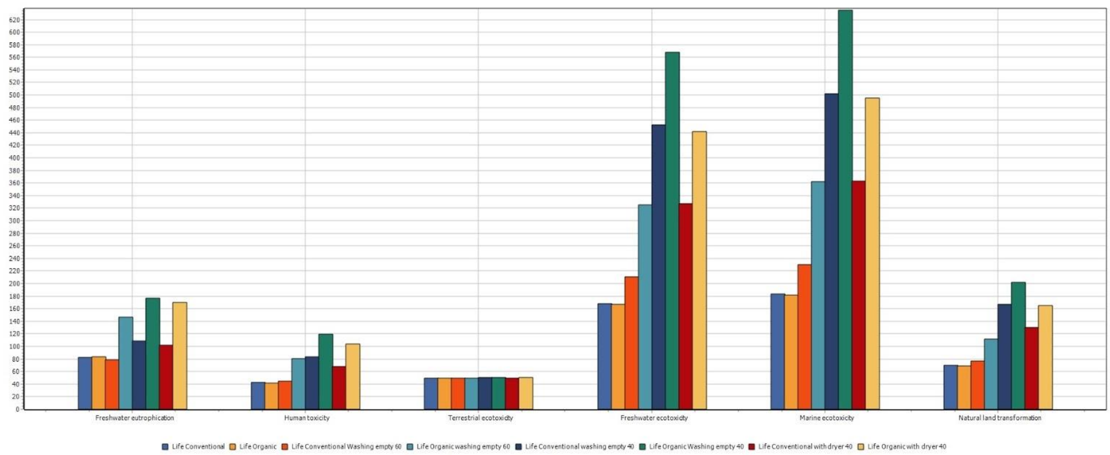
To clarify the impact from the irrigation, a sensitivity analysis was made where both cultivation phases used the same amount of irrigation, namely 5.726 m^3. The result states that, when using the same amount of water, the conventional cotton t-shirt has a higher environmental impact in almost every category, except from marine eutrophication and agricultural land occupation, see figure 6 below. This is in line with the changes made in organic cotton, were the fertilizer is changed to green manure, and some chemicals and all pesticides were deleted. The reason why the impact of an organic t-shirt is higher than the impact of a conventional t-shirt when looking at the agricultural land occupation, is because of the large land use when producing green manure, versus producing chemical fertilizers. The same goes for marine eutrophication. However, it is surprising that the vast amount of pesticides used in the conventional cotton cultivation didn't have a larger impact on for example human toxicity

Figure 6. Characterization of Life Conventional and Life Organic, when using an equal amount of water in the life cycles.



Washing an almost full machine means that only about 5 percent of the washing cycle burden has to be allocated to the t-shirt, as have been done in the charts up to now. If the t-shirt instead is washed alone, the whole burden has to be allocated to it. Also, if washing is done in 60 degrees, more energy is consumed. If the dryer is used as well, an additional amount of energy will be consumed. The result of these comparisons, with focus on the categories that has got the highest normalized environmental impact, can be seen in figure 7 below.

Figure 7. Normalization of (in the following order) Life Conventional and Life Organic when washing a fully loaded machine in 40 degrees, washing conventional vs organic in an empty machine in 60 degrees, washing conventional vs organic in an empty machine in 40 degrees and washing in a fully loaded machine in 40 degrees and then using a dryer.



Note that in this sensitivity analysis regarding the washing, only one of the t-shirts needed to be assessed, since the washing process is identical for the two t-shirts (everything from the harvesting is identical). To highlight the importance of the using phase, i.e. washing the t-shirt, both life cycles, with the four different washing scenarios, are included in figure 7. As can be seen, washing a fully loaded machine contributes to lower impact on the environment. Since washing in 60 degrees requires less water than washing in 40 degrees, see table 11, washing in 40 degrees have a higher impact on the environment concerning these categories. However, more energy is required to wash in 60 degrees, as can be seen by comparing table 6 and 11.

Table 11. Washing machines average data, when washing in 60 degrees. Collected from three different washing machines used by the group members of this project.

Model	Capacity (kg)	Energy (kWh)	Water (litre)
ElektroHelios TF1236E	5	0.94	42
Electrolux EW1077F	6	1.3	58
Whirlpool AWE7526	6	1.02	48
Average	5.67*	0.96	49.3

*Note! The reference data for the machines are for a load of approximately 5-6 kg which means that the actual value for a load of one single t-shirt is smaller.

Table 12. Dryer, program “cupboard dry”.

Model	Capacity (kg)	Energy (kWh)
ElektroHelios TK9702	7	2.17
Electrolux EDP2074PDW	7	3.77
Whirlpool DDLX 70112	7	3.46
Average	7	3.13

An important thing to consider is the question if it is better to wash colder using more/stronger detergent or to wash warmer with less detergent? One could argue that in Sweden where the energy is to a relatively high share renewable, and where eutrophicated lakes are an increasing problem, washing warmer with less chemicals is preferable. Also, water depletion is higher when washing in an empty washing machine, but this might not be a current problem in Sweden.

The study is made with the assumption that all of the t-shirts are incinerated after the use phase, but textile recycling is a topic of increasing interest in Sweden. So if a fraction of the t-shirts instead were to be recycled, the environmental impact would change. Due to the time constraint of this project, this part of the sensitivity analysis has not been performed, however, it would be an interesting investigation for further research.

4. CONCLUSIONS AND RECOMMENDATIONS

To answer the goal set up for the study, various aspects needs to be taken into consideration. SimaPro does not take into account how the humans working with the cotton are affected, and the fact is that many cotton workers die of diseases caused by the pesticides used for conventional cotton (Världsnaturfonden WWF, 2005). So on one hand, as have been said in the result section, the organic t-shirt has got a higher environmental impact during the whole life cycle due to the larger land requirements. On the other hand, the working conditions for people producing the organic t-shirt is much better.

Another thing worth mentioning is that the environmental impact is connected to different parts of the world during the different life cycle stages. Even though a significant share of the impact is related to washing the t-shirt, water use is today not a problem in Sweden, where the washing occurs in this case study. Therefore, possible environmental actions should be directed to stages where the impact is more severe.

In conclusion, the organic t-shirt has a higher impact according to this life cycle assessment. This does not necessarily mean that we regard the conventional t-shirt to be better, as have been discussed earlier, loss of human lives is not included in the calculations. However, we do think that efforts should be made to reduce the water use and increase the efficiency in organic cotton cultivation. Additionally, the washing stands for a significant share of the environmental impact and can be affected by the consumer behaviour, every time the t-shirt is washed.

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Appendix

SimaPro 8.2.0.0	product stag	Date:		2016-12-13
Project	ProjektV1torsdag17			
Product stage				
Category type	Assembly			
Status				
Products				
Conventional Cotton T-shirt	1	p	Others	
Materials/assemblies				
Fabric for one t-shirt	0,2	kg	Undefined	
Processes				
Transport, freight, lorry, unspecified {GLO}| market for | Alloc De	380	kgkm	Undefined	
Electricity, high voltage {TH}| market for | Alloc Def, S	0,4	MJ	Undefined	
Input parameters				
Calculated parameters				

Time: 14:08

Assume waste is included in the textile woven cotton assembly, OBS! No output

se.avstand.org/Kina/Bangladesh
2,47 MJ7kg tyg enl källa.

SimaPro 8.2.0.0	material	Date:	
Project	ProjektV1torsdag17		

Material

Category type	Material		
Process identifier	KTH03518000037942500012		
Type			
Process name	Fabric for one t-shirt		
Status			
Time period	Unspecified		
Geography	Unspecified		
Technology	Unspecified		
Representativeness	Unspecified		
Multiple output allocation	Unspecified		
Substitution allocation	Unspecified		
Cut off rules	Unspecified		
Capital goods	Unspecified		
Boundary with nature	Unspecified		
Infrastructure	No		
Date	2016-11-29		
Record			
Generator			
External documents			
Literature references			
Collection method			
Data treatment			
Verification			
Comment			
Allocation rules			
System description			
Products			
Fabric for one t-shirt		0,2	kg
Avoided products			
Resources			
Materials/fuels			
Conventional Textile, woven cotton {GLO}| market for | Alloc Def, U		0,22	kg
Electricity/heat			
Electricity, high voltage {TH}| market for | Alloc Def, S		0,099	MJ
Emissions to air			
Emissions to water			
Emissions to soil			
Final waste flows			
Non material emissions			
Social issues			

Economic issues

Waste to treatment

Waste textile, soiled {CH}| treatment of, municipal incineration | Allo	0,02	kg

Input parameters

Calculated parameters

2016-12-13 Time: 13:47

100 not defined Textiles

Undefined

Undefined 2,47 MJ/kg tyg enl källa.

SimaPro 8.2.0.0	process	Date:
Project	ProjektV1torsdag17	

Process

Category type	Processing
Process identifier	KTH03518000037942500011
Type	
Process name	Washing of one t-shirt
Status	
Time period	Unspecified
Geography	Unspecified
Technology	Unspecified
Representativeness	Unspecified
Multiple output allocation	Unspecified
Substitution allocation	Unspecified
Cut off rules	Unspecified
Capital goods	Unspecified
Boundary with nature	Unspecified
Infrastructure	No
Date	2016-11-29
Record	
Generator	
External documents	
Literature references	
Collection method	
Data treatment	
Verification	
Comment	
Allocation rules	
System description	

Products

WASHING	0,2	kg

Avoided products

Resources

Materials/fuels

Sodium perborate, tetrahydrate, powder {GLO}| market for | Alloc D	0,19	g
Sodium tripolyphosphate {GLO}| market for | Alloc Def, S	1,4	g
Alkylbenzene sulfonate, linear, petrochemical {GLO}| market for | Al	0,42	g
Tap water {Europe without Switzerland}| market for | Alloc Def, S	2,6	kg

Electricity/heat

Electricity, medium voltage {SE}| market for | Alloc Def, S	0,033	kWh

Emissions to air

Emissions to water

Emissions to soil

Final waste flows

Non material emissions

Social issues

Economic issues

Waste to treatment

Input parameters

Calculated parameters

2016-12-13 Time:

100 not defined Genomsnittlig maskin: assume 1 t-shirt stands for 5 % of a wash

Undefined	7 % av tvättmedel /Wiki
Undefined	50 % av tvättmedel /Wiki
Undefined	15 % av tvättmedel /Wiki
Undefined	Vatten till en t-shirt (52 l per maskin)
Undefined	Elektricitet till en t-shirt (0,65 per maskin)

SimaPro 8.2.0.0	process	Date:
Project	ProjektV1torsdag17	

Process

Category type	Waste scenario
Process identifier	KTH03518000037942500022
Type	
Process name	Cotton textile waste
Status	
Time period	Unspecified
Geography	Unspecified
Technology	Unspecified
Representativeness	Unspecified
Cut off rules	Unspecified
Capital goods	Unspecified
Boundary with nature	Unspecified
Infrastructure	No
Date	2016-12-12
Record	
Generator	
External documents	
Literature references	
Collection method	
Data treatment	
Verification	
Comment	
Allocation rules	
System description	

Waste scenario

Cotton textile waste		1	kg	

Materials/fuels

Transport, freight, lorry, unspecified {GLO}| market for | /		0,018	kgkm	

Electricity/heat

Separated waste

Cotton Textile waste treatment	All waste types			100

Remaining waste

Input parameters

Calculated parameters

2016-12-13 Time: 13:46

All waste types	Others	
Undefined		En t-shirt: 0,2 kg*11 km (Sthlm-Högdalen)