Ecodesign in the Textile Sector

Unit 06: Life Cycle Assessment in the textile sector.

Elisa Tumminello elisa.tumminello@centrocot.it

Paolo Ghezzo paolo.ghezzo@centrocot.it

At the end of this unit, the student will be able to:

- Know the LCA applied to the textile sector. Know the legislation
- Have an overview of the studies done.
- Know a specific comparative LCA and an EPD (tutorial).

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6.1. Introduction

Over the last few years, different methodologies have been implemented to identify study and evaluate the environmental impacts associated with the life of a product, service or organization.

From the concept of "sustainable development", according to which the spheres of economic, social and environmental development must be integrated, the philosophy of thought called Life Cycle Thinking is born. The new idea compare to the past is to consider a product as a set of operations, flows of materials and energy (input and output), associated with all the steps of its life cycle, from design to its end of life. From this concept, the Life Cycle Assessment (LCA) methodology is developed as the main operational tool.

Despite its priority role at the economic level, the textile sector is strongly concerned about sustainability. Today it's the second most polluting industry in the world second only to that of oil and for this reason, therefore, its understanding and evaluation is very important.

The Life Cycle Assessment (LCA) is part of new methodological tools, developed with the aim of analyzing and subsequently making human activities sustainable, developing above all preventive measures.

LCA is a structured, complete and standardized method, which aims to estimate the effects and potential impacts on the environment and health related to the life cycle of a "product".

Depending on the purpose of the study and the objectives to be pursued, an LCA can be conducted in a more or less detailed manner. Conducting a full LCA can sometimes be very expensive both in terms of time and money. Furthermore, most often there is a need to adapt the LCA to the specific situation under consideration. In response to these considerations, various activities were born at the international level with the aim of identifying methods to simplify the LCA methodology, to make it faster and less expensive, without renouncing the fundamental characteristics of a Life Cycle Assessment (Figure 1). Complete, without losing the accuracy and reliability of the results.

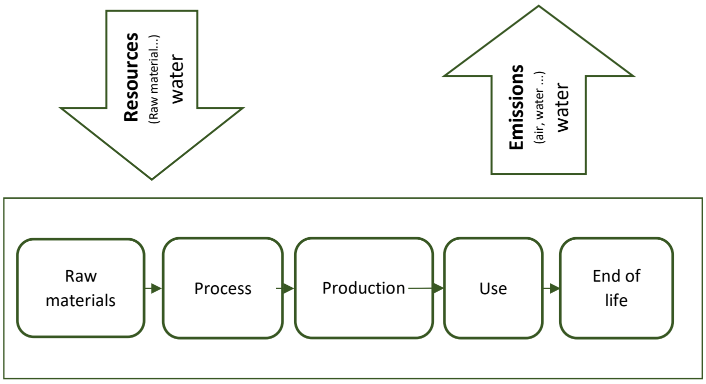

Figure 1: Life cycle phases.

This is possible by intervening on two levels:

- at the process level: creating software tools that help the realization of a Life Cycle Assessment.
- at the methodology level: limiting the objectives or eliminating life cycle phases, reducing the amount of data required accordingly:
  - Gate to gate (from the gate to the gate) that focuses only on the production phase.
  - Cradle to gate (from the cradle to the gate) considers the first two phases of the life cycle ie extraction, transformation and production.
  - Cradle to grave (from the cradle to the grave) considers the life cycle as a whole.

Simplification interventions can be summarized in some main categories:

- Elimination of UPSTREAM flows (upstream of the company), or the exclusion of all processes due to suppliers' activities, relative to the production of raw materials. Manufacturing of the finished product, use and end of life are included.
- Elimination of DOWNSTREAM flows (downstream of the company), where processes that include transport, use and end of life of the product are excluded.
- Elimination of UPSTREAM and DOWNSTREAM flows, as such, limiting itself to the gate - to - gate analysis related to the company’s process activities alone.
- Focusing of the study on specific environmental impacts, considering, therefore, only the data related to them.
- Limitation or elimination of the impact assessment phase focusing the study on data collection and identification of improvement options.
- Use of qualitatively estimated data when it is not possible to find detailed quantitative data.
- • Use of surrogate data, related to processes similar to real ones, when real data are not available.

- • Limitation of inventory data with threshold values, thus considering only the materials that present a significant percentage compared to the total mass. The simplification method must be chosen carefully based on the specific objectives that are proposed.

Below are the three main types of LCA and what may be their most common applications:

- *Simplified LCA*
  It is used in the case where decisions have to be made for the development of new products and services, especially when these systems are not complex.
- *Screening LCA*
  This type is used when the key actions for environmental improvement in the life cycle of products must be identified. The main feature is to use data already available from databases or estimated with approximation. From the results obtained, and following a sensitivity analysis, we identify the critical data on which quality improvement is needed. It is a quick system to allow the assessment of the really important aspects of the life cycle, on which to focus attention.
- *Detailed LCA*

  A detailed study is necessary in all those cases that require a complete evaluation. Data quality improvement is foreseen and the study will include the collection and use of specific data of the case in question, ie primary data. Small flows of materials are also considered, so that the level of detail becomes finer.

The textile and clothing industry has a greater environmental impact than other sectors. It is therefore of primary importance to understand what consequences this sector can bring to the LCA methodology. It provides an assessment of the environmental impacts associated with the analysis of the life cycle of a product.

It is therefore important to consider the total impact that a product has in the course of its life, which should not be limited to the simple production of the fabric. If much data is available for the first part of the production process, this is not the case for less common fabrics and especially for the later stages of life such as the production of clothing, consumer use and disposal. Defining significant elements of the last steps is important for obtaining reliable LCA data.

With this information, we can develop a first understanding of the impact of these elements on the environment and then indicate how these can be lowered and contained.

Currently, understanding the current extent of LCA textile data and determining weaknesses in the application of LCA provides useful information on where to focus future efforts.

6.2. Life Cycle Assessment process

The SETAC (Society of Environmental Toxicology and Chemistry) in a 1993 study provided a definition of the LCA methodology, that is still valid and widely used: "*An LCA is an objective process of assessing energy and environmental loads related to a process or a activity, carried out through the identification of energy and used materials and waste released into the environment. The assessment includes the entire life cycle of the process or activity, including the extraction and processing of raw materials, manufacturing, transportation, distribution, use, reuse, recycling and final disposal* ".

A more recent definition can be found in the UNI EN ISO 14040 (2006): "*The LCA deals with environmental aspects and potential environmental impacts throughout the product life cycle, from the acquisition of raw materials through manufacturing and use, until end of life treatment, recycling and final disposal* ".

As shown in the basic module, the International Organization for Standardization (ISO) in the publication of ISO 14000 standards (14040 and 14044), defines and develops an LCA study through a four-step main articulation:

1. Definition of the objective and of the scope (Goal and scope definition) - is the first fundamental step that establishes the reasons for which the analysis is conducted, the intended use of the results obtained and the type of public to whom they are intended. It represents the preliminary phase of an LCA study: it is necessary to define the processes that are part of the life cycle of the system that is going to be analyzed and identify the boundaries.

The scope should be sufficiently well defined, in order to ensure that the breadth, depth and detail of the study are compatible with the final objective established and sufficient to achieve it.

2. Analysis of the inventory (Life Cycle Inventory) - compilation of a budget of inputs (materials, energy and natural resources) and outputs (emissions in air, water and soil) relevant to the system.
It includes data collection and calculation procedures, which allow to quantify the types of interaction that the system has with the environment.

3. Impact Assessment (Life Cycle Impact Assessment) - potential, direct and indirect environmental associated with these inputs and outputs.
It is a quantitative and / or qualitative technical process that assesses the environmental impact of the life cycle and during which the environmental consequences generated by the system under study are analyzed. This phase aims to evaluate the potential environmental impacts caused by the processes, products or activities under study, using the information gathered during the inventory phase.

Each environmental impact is associated with one or more environmental effects and it is the executor of the study who is responsible for the choice of the level of detail and the impacts to be evaluated, in line with the objectives and scope defined during the first phase of the study.

Among the various impact categories used in this phase of the LCA, the following should be mentioned:

- Climate Change potential [kg CO2 eq]
- Acidification potential [kg SO2 eq]
- Eutrophication potential [kg PO43- eq]
- Ozone formation potential [kg CFC11 eq]
- Photochemical smog [NMVOC]
- Water consumption [l]
- Consumption of renewable and non-renewable resources [kg]
- Consumption of renewable and non-renewable energy resources [MJ]

4. Analysis of the results (Life Cycle Interpretation) - of the two previous phases and the definition of the possible lines of intervention.

The collected data are analyzed in order to obtain specific interpretations that must be used to improve the environmental performance of the analyzed system / product. The purpose of this phase is therefore to present the results of the previous phases as clearly and comprehensively as possible, in support of the decision-making process for the preparation and programming of the improvement measures.

The aims set in the initial phase of the study are embodied in the actions that are defined following the data interpretation phase. Furthermore, in this phase, it may be necessary to carry out a review of some fundamental steps of the study (such as the field of application, the type and quality of the data collected) in order to achieve the defined objective.

The critical review of the data collected is a process aimed at verifying whether a study complies with the requirements regarding methodology, data, interpretation and whether it is consistent with the principles of the UNI EN ISO 14040 standard. Critical review usually improves understanding and increasing the credibility of the study, especially if set as a participatory process involving stakeholders. The review is mandatory when the results are intended for external use and in the case of comparative studies between several systems / products. The review can be carried out:

- Re-examination by an internal or external expert (must know the requirements of the LAC and have the appropriate technical and scientific expertise).
- Organization of a discussion panel led by an external and independent expert, composed of at least three members. Based on the objective, application or available budget, the chairperson of the committee involves any other expert auditors; as stakeholders of non-governmental and non-governmental institutions, competitors, companies and businesses.

The purposes of a life cycle assessment are profoundly different depending on the scope and objectives for which it is undertaken. For the same reason, useful information that can be obtained, such as the potential use of results, varies from context to context. In general, two macro areas of application are identified: the management of individual companies and the management of socio - economic systems or the government of the territory.

Through an LCA study it is possible to obtain an improvement in the environmental performance of products at various levels of life (identifying critical points that can be improved), supporting decisions taken by proven / public companies, governmental and non-governmental institutions, designing products, service processes that are eco - friendly (eco - design). It is possible to communicate the environmental benefits of a product through an Environmental Product Declaration (EPD), to optimally manage public services and finally to evaluate the different environmental policies and buy them with new alternative solutions through the replacement / reduction of hazardous substances or the choice of materials.

The primary reason and therefore the final purpose of this type of analysis is to contribute, with robust and verifiable quantitative data, to direct decision makers' choices towards solutions that reduce environmental impacts in a significant way so as to decouple the growth of wellbeing from environmental degradation. Furthermore, problem displacements are prevented from one part of the system to another or between several systems, the function of the system is put at the center of analysis, allows comparisons between different ways of satisfying the same function, standard procedure with the same scientific basis and it allows to manage in a rational framework a large amount of environmental data and information.

These advantages mean that the LCA method has become, over time, a useful and supportive tool for decision - makers, for companies that want to improve their processes / products by differentiating themselves in a very competitive market, for the eco - design sector and for environmental certifications of product and activity.

6.3. Metodology

The information obtained in the inventory phase is subdivided into four macro categories that recall the phases of the life cycle:

- Production - This involves the impacts associated with the purchase of raw materials and production processes. This data is separated into different studies and is reflected in the summary data contained in the appendix. However, we will then consider a single figure that allows better comparisons;
- Use - Includes impacts associated with use and maintenance. For clothing items it refers, generally to washing, drying and ironing;

- Other impacts - Other activities such as transportation, storage and sale are considered. (We must consider the fact that some LCAs are included as parts of other phases);
- Disposal / End of Life - Encloses the impacts of end-of-life activities (eg disposal, incineration, reuse or recycling);

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The collected data are separated as described above, where it is possible, but the differences between the studies and the collection methodology does not guarantee a constant and consistent division of the data. The methodology used serves to provide an adequate compactness of the reports so as to obtain a verifiable quantitative comparison useful for the definition of the environmental impact and, consequently, the relevant recommendations to reduce it.

For example, considering a 100% cotton T-shirt for a functional unit, the category of environmental impact related to the greenhouse effect [kg CO_2 eq] will measure the greenhouse emissions produced by the cultivation of cotton, from spinning, from weaving and from all the processes that lead to the production of the finished garment. The distribution and use phase are also included up to the final disposal of the article itself.

6.4. LCA Case study

This section illustrates the most common impacts associated with the textile industry, various aspects of production will be examined as context.
First of all, it is appropriate to start with a brief outline of the types of fibers used. Textile fibers are substances with a filamentous aspect that lend themselves to being spun and woven, by virtue of their morphology and their mechanical characteristics of resistance, elasticity and flexibility. They can be present in nature or be produced by man through chemical processes of transformation or synthesis. It is therefore possible to classify them according to their origin in two distinct types: natural fibers and tecnofibre. The former come from the plant world (cotton, linen, hemp) or animal (from

hair bulb, like wool, or obtained by secretion, such as silk) and do not need any change in chemical synthesis to be transformed.

The latter are instead made by man (man made) through chemical processes of transformation or synthesis. By virtue of this, the chemical fibers can be further divided into two categories: artificial and synthetic. Artificial fibers are obtained from raw materials already present in nature and subjected to simple processes of chemical transformation, such as wood cellulose and cotton linters (an artificial fiber obtained in this way is rayon). Synthetic fibers are instead obtained through more complex chemical synthesis processes and originate from the polymers, ie synthesis chains of chemical molecules such as polyacrylates, polyamides, polyester, although they are better known by their respective commercial names: Nylon, Dacron, Terital etc .

The modern textile industry uses a great variety of materials, some of natural origin, others artificial. Both the production / cultivation and the subsequent processing of these materials are very varied and consequently can involve a great variety of potential impacts.

While natural fibers, such as cotton and wool, require less energy than synthetic fibers, such as polyester, on the other hand, the amount of water used to produce them is greater, although data vary according to different factors. A semi-synthetic regenerated fabric, like viscose, has intermediate consumption values compared to the two types of previous fibers: it comes from a renewable source that needs water but at the same time requires energy for the synthesis process to which it must be subjected .

The study illustrated in the following table, qualitatively compares the impacts of these tissues, referring to five environmental factors: the use of energy, the use of water, the emissions of greenhouse gases, water discharges and land consumption.

Decreasing environmetal impacts ↓

Energy use	Water use	Greenhouse emission	Waste water	Land use
Acrilyc Nylon Polyester/PTT *Regenerated cellulose (Viscose, Modal)* PLA/Cotton/Lyocel Wool *Raffia natural fibers* (nettle, hemp, flax)	Cotton Silk Nylon *Regenerated cellulose* Acrilyc Hemp Wool	Nylon *Sinthetics* Polyester Lyocell PLA Viscose Modal Cotton	Wool Regenerated cellulose Raffia natural fibers *Nylon* *Polyester*	Wool Ramiè Cotton Flax Hemp Viscose and Modal Iuta PLA Lyocell

		Raffia natural fibers Polyester	*Raffia natural fibers* Wool		*(Sinthetics)*

Source [Defra 2010]

Table 01:comparison of fabrics impacts

It is clear that there is no fiber that has a lower environmental impact in all the categories listed. This involves the need to resort to compromises. The fibers that usually have lower values are of natural origin obtained from hemp, branches and nettles. Although the data are qualitative, they give an idea of the possible environmental benefits deriving from the use of emerging fabrics as an alternative. Emerging fibers are often considered to be more environmentally friendly than existing fibers. In any case, if we also consider other factors, such as economic ones and customers' tastes, they have limited their use to produce fabrics.

Summary of the LCA studies on clothing

The following are LCA studies on clothing items, related to the most important environmental indicators such as primary energy consumption.

Textiles environmental evaluation, EDIPTEX, 2007

The EDIPTEX study is an example of data completeness, designed to test database capacity and methodology and to generate useful information on the life cycles of different garments.

The study compared four common garments with different fabrics using a cradle-to-grave LCA: a T-shirt, a jogging suit, a work jacket and a blouse.

For each chapter a life cycle model was developed, including the acquisition, production, use and disposal of raw materials, in order to obtain data on the consequences of the variation of the life cycle and the identification of practices which can reduce environmental impacts.

The particularity of this study is the willingness to include the analysis of particulars (for example the pesticides of drainage) that allow to further evaluate the environmental impacts of each garment.

T-shirt:

The T-shirt is made of 100% cotton, has been subjected to the typical phase of use, washing and drying. The main environmental impacts are found in the consumption of energy during the use phase, resulting from the washing and drying. Then there is the consumption of pesticides, artificial fertilizers, dyeing and finishing process. The greatest impact associated with toxicity is to be found in the culture phase for the chemicals used.

The studies have produced useful suggestions to avoid high environmental impact: organic cotton production, less washing work associated with less impurities in detergents, avoid drying and ironing, preferring disposal in incineration plants to recover energy.

Jogging suit:

The analyzed jogging suit consisted of two components made of nylon and cotton. References to nylon data are less accurate. Also in this case the use includes washing and drying. The major environmental impacts derive from the toxicity of the chemical products used in the production of cotton and from the consumption of energy linked both to the production of nylon and to the use phase of the garment. Possible alternative scenarios include elements very similar to the previous case with the addition of suggestions related to the production of nylon that include improved techniques to minimize energy consumption.

Work jacket:

The work jacket was made of 35% cotton and 65% polyester. The fact that this garment was used for industrial and non-domestic cleaning has allowed to increase the environmental impacts, in particular as regards the consumption of energy.

In this case, the recommended adjustments to reduce the impact on the environment are linked to the choice of producers to use organic materials and to choose other options in the end-of-life process. This garment is potentially ready for an ecological labeling.

Blouse:

Because of the unavailability of some data and countless hypotheses on the life cycle, the study of this head was considered the least accurate. The analyzed shirt was made using viscose for 70%, nylon for 25% and elastane for 5%. The high energy costs during the production and disposal phase are the most impacting factor for the environment.

The use phase, in this case, does not have a high influence since the washing was performed at a low temperature (40 ° C) and without drying. This is the most desirable option for the use phase of a garment.

LCA Comparative: flax shirt vs cotton shirt, BIOIS, 2007LCA

This LCA study compares the environmental impacts of the life cycle of two very similar products: a linen shirt and a cotton shirt.

As other studies have shown, the use phase requires the greatest use of water and energy (for both about 80%), although the cotton shirt involves a reduced consumption of energy (about 1/6) given that in the phase of ironing the linen shirt requires a greater and more intense use.

Although, by taking the individual stages of the life cycle, the linen shirt has less or equal impact. For example, during production, CO2 emissions and eutrophic impacts were very similar. The toxicity of water and the amount used to produce the linen shirt are 1/8 compared to cotton.

However, energy consumption during the use phase remains very high, although it can be reduced with different habits (ironing). Again, it is advisable to reduce fertilizers, pesticides and chemicals that are harmful to the environment, as well as more efficient production methods.

It can be said that, overall, the linen shirt has a lower environmental impact.

LCA: Women's knitted polyester blouse, Franklin Associates, 1993

Although this study was conducted in 1993, it is still valid and cited as an example. Consider the LCA of a women's polyester shirt.

The figures on energy use are very similar to those studied recently. The consumer use phase consumes 82% of the total energy, for precision with a 2: 1 ratio between washing and drying. The rest of the energy used is attributable to production and disposal. The conclusions to reduce the environmental impact include the possibility of improving the washing and drying habits.

Jeans's environmental product declaration, ADEME / BIOIS, 2006

This study follows the life cycle of a pair of five-pocket jeans (600g of denim, 37.5g of cotton fabric, 10.4g of double thread, 3.6 g of rivets and 14g of buttons). In particular, data from US production were considered as the real data of the countries of origin (Uzbekistan, India and Egypt) were not available.

Also in this case, the main environmental impacts in use are in terms of energy consumption, toxicity and water consumption. Significant impacts are also found in the cotton growing phase.

This study also produces an internet tool in which consumers can compare different items (eg washing and ironing) and assess how they can influence environmental impact.

Also in this study, the results confirm the recommendations on how to reduce the frequency of washing, the use of organic cotton and reduce the use of drying.

6.5. Observation of LCA

There are several factors that have an impact on the environment, they vary depending on the specific study considered. However, it is possible to state that energy consumption is the only element common to all studies, even if some do not indicate it directly. For this reason the Carbon Footprint was used.

As noted earlier, the consumer use phase has a major impact on the environment for the most part except for viscose (low impact impact) and jogging suit (greater impact on production than all uses). Because of the unrepresentative sample used, it is impossible to confirm that synthetic fabrics have a proportionately lower impact during the use phase. While the data appear, on the global, rather coherent for cotton articles.

But even if the results seem very similar for clothing, the environmental impact profile is not always the same: for carpets, for example, the profile of energy and environmental impact is very different: the production phase of materials it involves about 71% of the total energy; and the disposal is equally of high impact, which means that use and recycling have a lower ratio than for example seen before. It is important, however, to underline that the different studies start from different hypotheses concerning the total number of washes and the temperature of washing, drying and ironing, factors that have different consequences on the environmental impact. This is an example to underline how important and decisive the coherence of the data is to improve the analysis.

The production phase is that which, after use, has a greater impact on the environment, although it is important to emphasize, especially for some types of fabrics, that it is difficult to separate the production phase of the fabric from that of the production of the item of clothing.

In general, other phases such as transportation, storage and retailing, if included in the studies, do not decisively affect the previous steps.

Different evaluations, even if they show very different data, show how the end-of-life phase is irrelevant to energy consumption, although it is still possible to improve through incineration.

As shown by the LCA data, the phases of production and use have a strong impact on the environment and most of the indicators refer to them. Improving these aspects means reducing the impact on the environment.

Production

The type of material used for the production of clothing greatly influences the impact of the production process. Natural and synthetic fibers produce different results, the studies evaluated were not exhaustive in applying this distinction also in the life cycle of clothing. Applicable improvements are related to the use of alternative fibers that have lower impacts or, alternatively, to the use of processing methods that reduce environmental impact. Ecological labeling is considered by manufacturers as a method to demonstrate the benefits of the changes made.

The data provided by the studies appear to be quite significant even if they concern only "existing" fabrics (for example cotton, polyester) and not "emerging" fabrics. Furthermore, many reference data are dated or only partially usable, so it is necessary to carry out new and exhaustive searches.

Use

As already mentioned, the use phase has a high environmental impact due to the consumption of water, energy and chemicals used in the washing process to which drying and ironing are added. This, however, depends on consumption habits.

For this, it is necessary to create models that incorporate different management concepts into the life cycle study to avoid errors on the global amount.

Other phasis

Trucks, storage and retailing are neglected in the assessment for their reduced impact, although it would be worth paying more attention to these for further small benefits.

Disposal/End of life

LCA end-of-life data or disposal data received little attention, in many of these studies were limited to modeling typical scenarios, such as landfilling or incineration, although the second option has many advantages in terms of energy saving.

Apparently the hypothesis of tissue recycling has a positive environmental potential, although the relative data are few because of the complex operation of delineation of possible scenarios. However, it is necessary to mention that at the moment the practices used are complex and that different recycling methods are still under development.

In general, the life of the textile product begins with the fibers used to manufacture its fabrics, then moves on to design, production, distribution and sale to end with the use of the consumer / buyer. Once released, the product is disposed of by the user. The final stage of the life cycle of a garment is defined as downcycling, ie landfill: the products are transformed into another (material or product) that has a lower value and quality. What is different is when, once the garment is no longer used, it is given to other subjects who can reuse it by giving it a "second life" in which the cycle starts again from the distribution / use phase.

Upcycling exists when a certain product is transformed into a different product, but of similar or superior value and quality. Transformation is not simply a recycling, but implies a change that passes through creativity.

Cradle-to-Cradle: the *Cradle-to-Cradle* process implies a "*closed-loop*" mode, ie a virtuous circular process that begins with the fiber and ends with it. For such a process to be realized it is necessary that industrial systems adapt to natural ones. The basic idea is that all products, after being used, must return to the industry for their reuse.

Recycle and Reuse

There are several schemes to define the different types of recycling, for example Wang (2010) recognizes four recycling criteria:

1. Primary: recycling of industrial scrap. In textile production, this phase corresponds to the collection of production waste;
2. Secondary: transformation of a product, after use, into raw material. It is necessary to collect, select and recycle in the field of interest after the use phase;
3. Tertiary sector: treatment of plastic waste (in chemical substances, monomers or basic fuels). In the textile sector, we expect collection of production waste in nylon or PET and products no longer usable by consumers;
4. Quaternary: incineration of waste to recover energy. The energy embodied in textile products can be redeemed from the incineration process.

Open-cycle recycling (OLR) is characterized by a process whereby the raw material of the product is used in a second production. Normally, the product that will be created following this operation will not be recycled but disposed of. The OLR minimizes the consumption of virgin materials. This process includes: production of pre-consumer waste; post-consumer textile waste; post-consumer PET bottles.

The yarn quality resulting from the recycling process affects the way in which they are used by the OLR. Normally, if the textile waste is subjected to this process after the use of the customers, they have a lower quality than the production waste, therefore never used. For this reason, the former tend to be unsuitable for use in the clothing industry.

For this reason, recycled fibers are often coupled with virgin fibers. Depending on the quality of the recycled product, the applications may be different: carpets, construction and insulation materials, wiper blades, industrial rags, non-woven fabrics and fibers for the paper industry.

The recycling of materials, which would otherwise be considered waste, allows energy benefits. Recycled PET bottles that are used as clothing fibers bring greater benefits to the environment when compared to virgin PET.

The recycling of different fabrics involves different environmental benefits and, according to the LCA studies, it is necessary to consider with greater precision, and following clear methodologies, the environmental benefits that are found in the union of materials recycled with virgin materials.

Finally, with CLR reference is made to a specific type of recycling in which the recycled material is the same material produced, that is, after being recycled, the product is part of the same production chain. Any system that provides for the reintegration of the fiber into a production chain is called a closed cycle. Below is a sample illustration of the previous example.

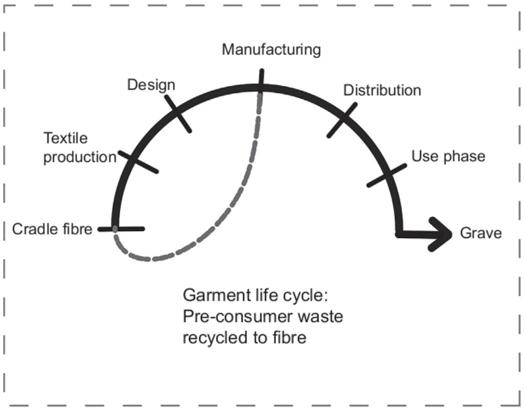

***Figure 2**: Waste pre – consumer by fibers's recycled.*

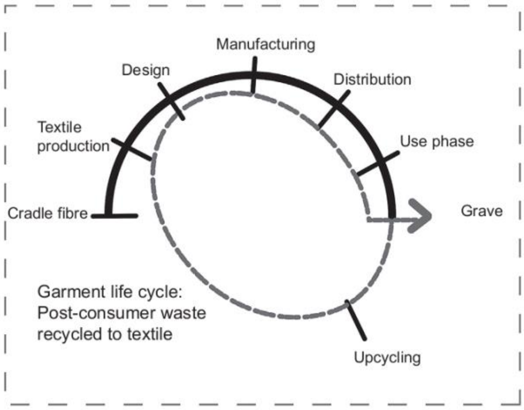

***Figure 3**: Upcycling waste post – cunsumer.*

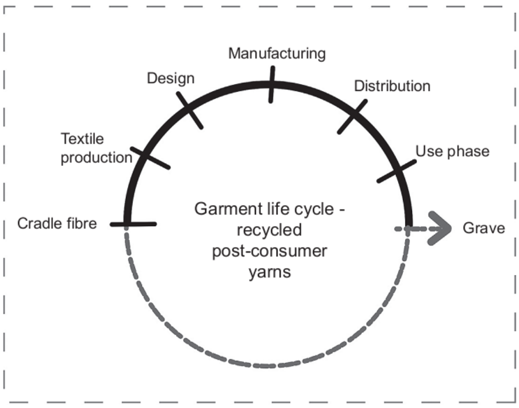

***Figure 4**: Waste post – consumer by fibers's grind*

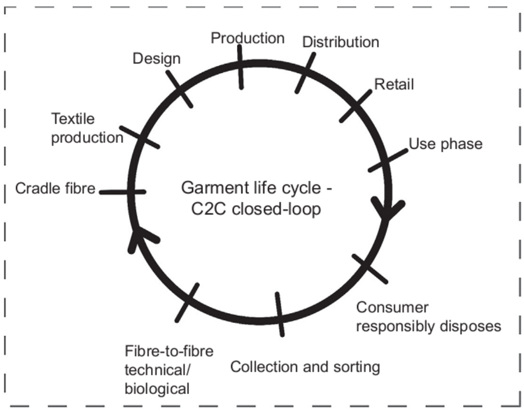

***Figure 5**: Cradle to cradle - Closed loop recycling*

6.6. Conclusions

LCAs provide important data for assessing environmental impacts and implementing good practices to improve the sustainability of textile products.

The existing LCA data refer to the most common and widespread fabrics such as cotton, polyester and viscose, there are still no significant data on the new materials; in some cases LCA may provide dissimilar data due to the use of partial and incorrect indicators.

The fact that several studies hypothesize different behaviors during the use phase makes it difficult to compare data.

The use and production phase of raw materials are those that are distinguished by having a greater environmental impact, but also other phases (such as transport, retail and end of life), which contribute significantly to the impact environmental, should not be neglected to ensure the validity of the LCA.

The level of energy required in the production of natural fibers is lower, but requires more water and high levels of ecotoxicity. While for synthetic fibers there is an opposite situation: less resources, but more energy consumption.

Synthetic garments should be less impactful during the use phase, but this can not be demonstrated due to insufficiently representative data.

Recycling a garment rather than disposing of it can reduce the final impact.

It is possible that in the future the Carbon Footprint will assume a greater importance thanks to campaigns promoted by retailers. The carbon label managed by the Carbon Trust can be a marketing tool.

The methodology used by the LCA studies must be coherent and unified so that the data can be representative, compatible and comparable.

The study of the use phase can result in a large number of errors. It is therefore necessary to adhere to specific studies to eliminate habit hypotheses by replacing them with real consumer life data. This could lead to greater consistency between the studies.

For commonly used fabrics there are LCA data which, however, are sometimes based on outdated information. For emerging and mixed materials, the lack / lack of data is evident, so it is necessary to fill this gap in a coherent way.

The excessive estimates derive from the assumption that a maximum value is used for the washing, drying and ironing energy.

The LCA studies should include data on steps not yet considered in their entirety (transport, sale and storage) so that the general picture can be more detailed.

It is necessary to create a specific model for end-of-life scenarios in order to identify the benefits of recycled products.

The data that could come from the LCA could derive from impacts and social problems, which should therefore be deepened.

The creation of verified patterns of consumer habits can provide useful information to identify ways to change behavior in order to minimize environmental impact.