Life Cycle Assessment

Fashion DIET

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Learning Objectives

After this lecture you should be able to:

- Explain the relevance of LCA as a tool for environmental management.
- Explain the main characteristics of LCA.
- Demonstrate an understanding of strengths and limitations of LCA by providing examples of environment-related questions that LCA can answer and questions that LCA cannot answer.
- Outline the history of LCA from the 1970s to the present
- Apply LCA for assessing environmental footprints

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Content

1. Introduction
2. Fundamentals
3. Methods
4. Analysis
5. Critical Review
6. Question Bank
7. References / Further Reading

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1. Introduction

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Resource scarcities, environmental pollution and the need for renewable energies have been in the centre of interest for a few decades already

- As early as in the 1970s researchers and decision makers were interested in the resource use and environmental damage implications of particular products and packaging options.
- This has been the starting point for the development of the Life Cycle Assessment (LCA) methodology

Viere (2019)

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The Textile & Fashion Industry

is considered as one of the most polluting industries in the world

1. energy
2. water and harmful chemicals
3. solid waste
4. CO_2 emissions

Resta et al. (2016); Choudhury (2014)

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Structure of the Textile & Fashion Industry

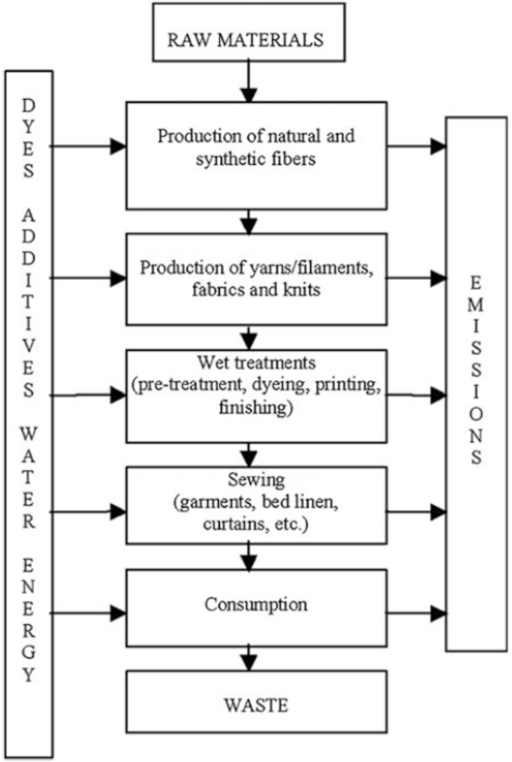

Figure 1: simplified linear textile product chain

The global textile supply chain is complex, involving many different stages and people

- For LCA analyses, environmental data and process inputs and outputs have to be collected.

Choudhury (2014, p.3)

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Structure of the Textile & Fashion Industry

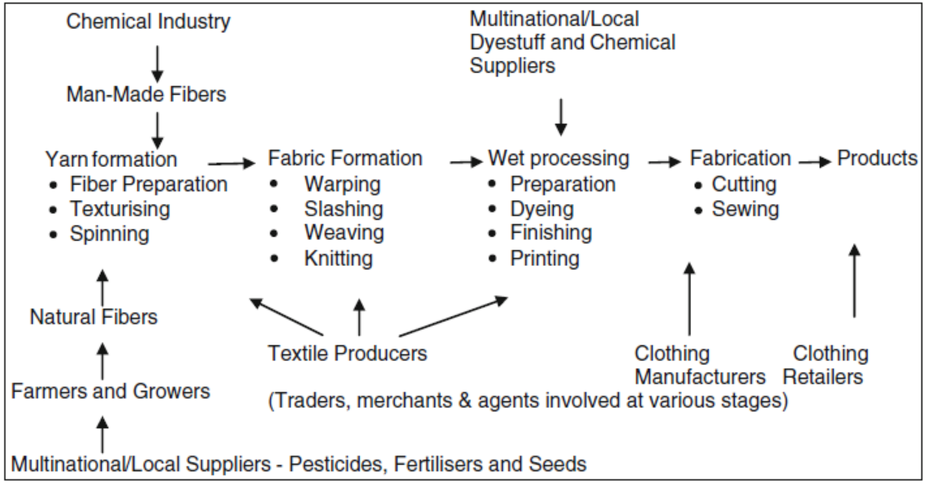

Figure 2: main organizations involved in the textile and clothing supply chain.

The complexities of the supply chain inevitably lead to lack of

- transparency

Choudhury (2014), p.4

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Structure of the Textile & Fashion Industry

Within that structure the following impact can be observed

- Use of toxic chemicals
- Consumption of water
- Consumption of energy
- Generation of waste
- Air emissions
- Transportation
- Packing materials

Choudhury (2014)

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Use of toxic chemicals (PBTs)

around 2000 different chemicals are used in textile processing, especially in textile wet processing, and many of these are known to be harmful to human (and animal) health.

- Persistence
- Bio-accumulation
- Toxicity

Choudhury (2014) , p.5 ff.

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Use of toxic chemicals (PBTs)

Volatile chemicals pose particular problems because they evaporate into the air or are absorbed into foods or through the skin. Some chemicals are carcinogenic or may cause harm to children, even before birth, while others may trigger allergic reactions in some people.

Table 1 List of a few popular but toxic textile chemicals and their fields of application

Name of toxic chemical	Used as/in
Tri-butyl tin oxide (TBTO)	Biocide on hosiery and fabrics
Non-ionic surfactants	Detergents in textile preparation and dyeing
Cationic surfactants	Textile dyeing and finishing
Sodium chloride	Dyeing of cotton textiles
Sodium sulfate	Dyeing of cotton textiles
Copper	Dyeing of cotton and polyamide; in its elemental, non-complexed form, it is toxic
Cyanide	Anti-caking agent in salt

Choudhury (2014), p.7

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Consumption of water

Clean water is both essential to the planet's ecosystems and fundamental to people's well-being. It is a basic human right. Globally, water resources are being degraded by the increasing pressure of human activities.

- Economic and population growth places ever-greater demands on water supplies, reducing the quantity and quality of water
- Clean water is a finite resource which is becoming scarce, and it is used at every step of the wet-processing sequence
- Once charged with chemical additives, the water is expelled as wastewater

Choudhury (2014)

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Consumption of water

The textile and related industries are considered by some to be the second highest consumer and polluter of clean water next to agriculture:

- excessive use of water in washing
- Poor housekeeping measures such as broken or missing valves
- Unattended leaks through pipes and hoses
- Instances when cooling waters are left running even after shutdown of the machinery
- Use of inefficient washing equipment
- Excessively long washing cycles
- Use of fresh water at all points of water use

Choudhury (2014)

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Consumption of energy

The textile industry is a major energy-consuming industry with low efficiency in energy utilization.

- thermal energy dominates in chemical processing, being used mainly for heating water and drying textile materials
- electrical power dominates the energy consumption pattern in spinning and weaving
- The textile industry is one of the largest generators of GHGs (greenhouse gases),

Choudhury (2014)

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Consumption of energy

Energy is one of the main cost factors in the textile industry.

Table 2 Average thermal energy use in dyeing plants of Japan

Thermal energy consumed for	% Share	Required action to reduce heat loss
Heating of product	16.6	
Drying of product	17.2	Avoid over-drying
Heat loss of waste liquor	24.9	Recovery of waste heat
Heat loss from equipment	12.3	Improved insulation
Heat loss with exhaust	9.3	Reduction of exhaust gas
Heat loss from idle equipment	3.7	Stop energy supply during idle time
Heat loss from evaporation	4.7	Use covered equipment
Heat loss with unrecovered condensate	4.1	Optimize recovery of condensate
Heat loss during recovery of condensate	0.6	
Others	6.6	
Total	100	

Choudhury (2014), p.13

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Consumption of energy

There are various possibilities for using renewable energy in the textile industry examples are:

- Installation of wind-powered turbo-ventilators on production plant roofs
- Use of direct solar energy for fiber drying
- Use of solar energy for water heating in the textile industry
- Solar electricity generation

Choudhury (2014)

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Generation of Waste

The textile industry generates all categories of industrial wastes such as liquids, solids, and gases. Industrial solid wastes from textile production include the following:

- Ashes and sludge
- Cardboard boxes, bale wrapping film, or non-recyclable soiled fabric
- Plastic bags containing chemical raw material
- Non-reusable paper cones and tubes
- Waste fabrics, yarns, and fibers from non-recyclable processing
- Unmanaged solid waste is likely to be dumped as landfill.

Choudhury (2014)

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Air Emissions

Burnt fossil fuels contribute to the emissions of carbon dioxide, a primary contributor to the greenhouse effect. Textile manufacture is also responsible for the following emissions:

- Nitrogen oxides and sulfur
- Solvent escaping into the air
- Solvents released from cleaning activities
- Emissions of volatile hydrocarbons which include non-methane hydrocarbons (NMHCs) and oxygenated NMHCs (e.g., alcohols, aldehydes, and organic acids).

Choudhury (2014)

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Air Emissions

Transportation

- Long-distance transport is required to move the finished products from the factories located in low-labor-cost countries to the consumer in a developed country, thus adding to the overall quantity of non-renewable fuel consumed.

Packaging Materials

- For consumer packaging, the packaging used to present products in stores, materials often used are plastic, paper, metal, aluminum, cotton, hemp, and biodegradable materials
- EU Directive 94/62/EC specifies a number of requirements relevant to packaging and packaging waste. It also sets specific recycling targets and maximum levels for heavy metals.

Choudhury (2014)

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Usage of chemicals

- About 2000 different chemicals are used in textile processing, many are harmful
- The chemicals causing particular concern when released into the environment display one or more of the following properties:
  - Persistence (they do not readily break down in the environment)
  - Bio-accumulation (they can accumulate in organisms, and even increase in concentration as they work their way up a food chain)
  - Toxicity

→ PBTs (persistent, bio-accumulative, and toxic substances).

Choudhury (2014)

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2. Fundamentals

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What is LCA?

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Separate Carbon footprinting from LCA

Carbon footprinting

- Carbon footprinting is the central method for assessing the impact of textiles on climate change
- encompasses the entire life cycle of a product or service.

  → T-shirt: from the cultivation of cotton through to the ultimate disposal of the T-shirt.
- Carbon footprinting is a simplified form of product environmental footprint (PEF) Calculation (both based on ISO14040)
- Limitation of Carbon footprinting: only one impact category (climate change) is considered
- PEF or LCA consider other resource, environmental and human health categories, like energy consumption, impacts on habitat and the emission of carcinogens.

Muthu (2015)

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What is LCA?

Life Cycle Assessment (LCA)

LCA is a technique to assess environmental impacts associated with all the stages in the life cycle of a product, from raw material extraction, through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling

- it is comprehensive
- It involves a systematic scientific approach to examine the environmental impacts of the entire life cycle
- it is not simply the quality of the product, nor the amount of waste ending up in a landfill or an incinerator, but the life cycle of the product determines its environmental impact
- it is also a way of measuring whether green improvements have been made or not.

Muthu (2015)

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Historical Background

- Developed first in the 1960s (known as Resource and Environmental Profile Analysis (REPA) or Ecobalances)
- Term LCA became norm in the 1990s; developed in the US & Northern Europe
- First: accounting the physical flows in a product life cycle, then: translation of the inventory results into environmental impact potentials
- At the beginning: no consistency of applied method and scopes
- Most first studies analyzed packaging and were commissioned by companies
- In the 1990s the application of LCA expanded to include other types/products
- In 2011: most practitioners made LCA studies in agriculture (56%); food sectors (62%), other consumer goods (38%) and energy (37%) (Teixeira and Pax 2011)
- 2010s: social dimension taken into consideration
- International Harmonisation and Standardisation: formal standardisation process was initiated by ISO: result ISO 14044 (2006)
- LCA is a young discipline with 50 years of history and less than 30 years of intense development and application

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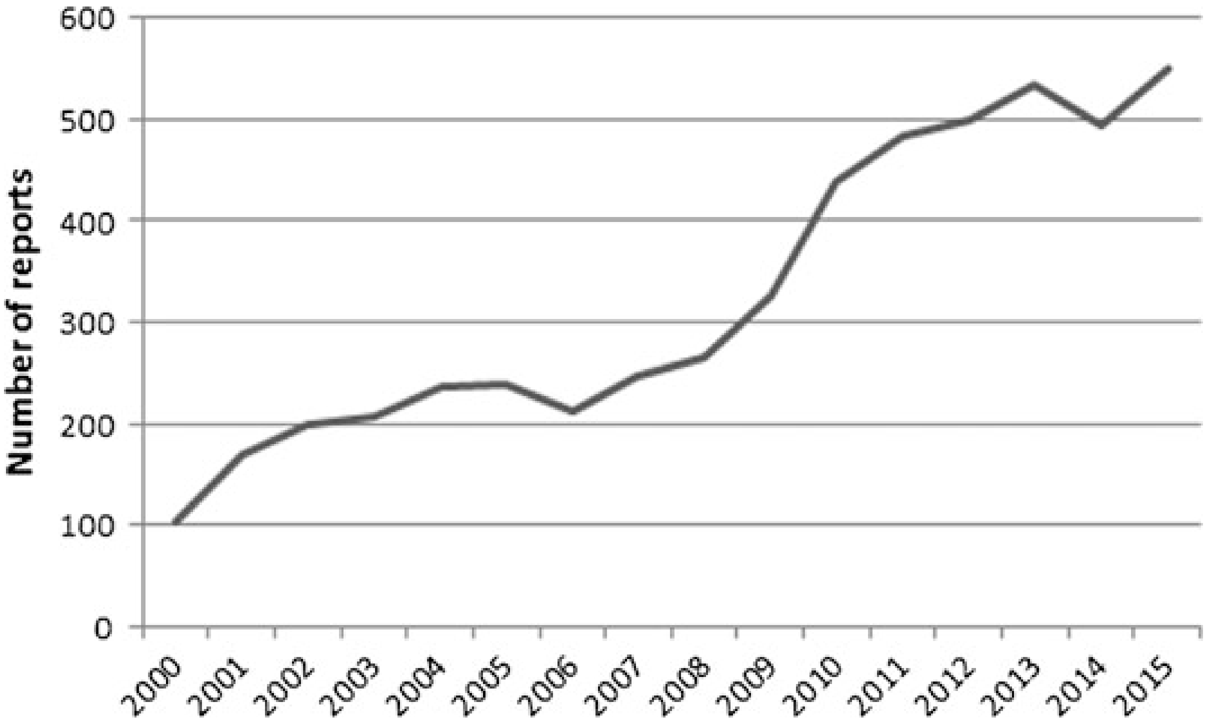
Development in number of published corporate responsibility reports mentioning LCA ("Life cycle analysis" or "life cycle assessment") Hauschild et al., (2018), p.23



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3. Methodological issues

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How does LCA work?

- LCA results answer the question "how much does a product system potentially impact the environment?"
- Part of the answer may be "the impact on climate change is 87 kg of CO2 equivalents".
- The quantitative nature of LCA means that it can be used to compare environmental impacts of different processes and product systems. This can, for example, be used to judge which products or systems are better for the environment or to point to the processes that contribute the most to the overall impact and therefore should receive attention.

Muthu (2015)

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How does LCA work?

- LCA results are calculated by

  (1) mapping all emissions and resource uses and, if possible, the geographical locations of these

  → involves thousands of emissions and resource uses, e.g. "0.187 kg CO_2, 0.897 kg nitrogen to freshwater, 0 .000000859 kg dioxin to air, 1.54 kg bauxite, 0.331 m3 freshwater…".

  (2) use factors derived from mathematical cause/effect models to calculate potential impacts on the environment from these emissions and resource uses.

  → the complexity is reduced by classifying these thousands of flows into a manageable number of environmental issues, typically around fifteen

- Quantifications generally aim for the "best estimate", meaning that average values of parameters involved in the modelling are consistently chosen

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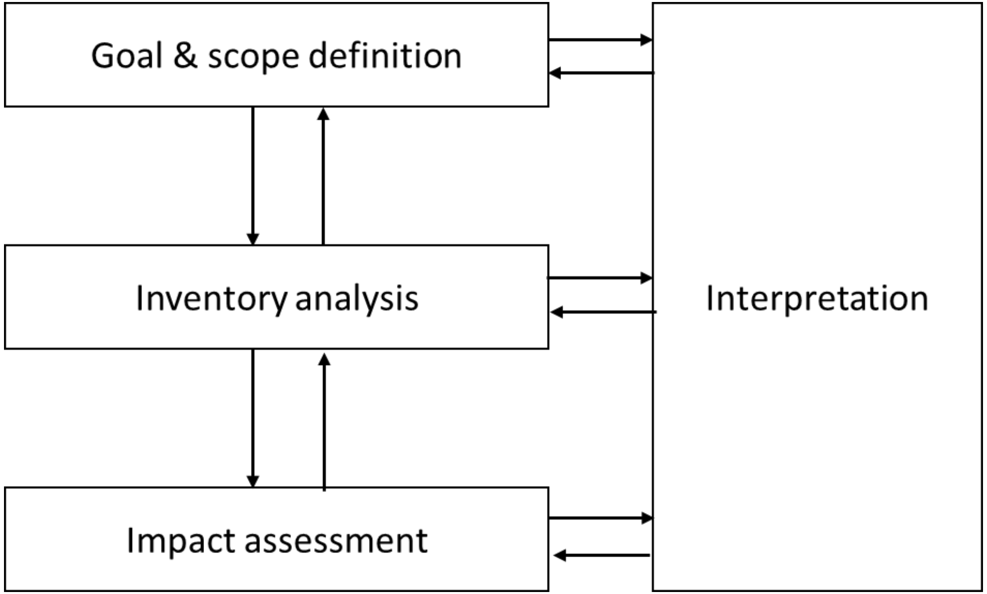
ISO14040 describes LCA as a four-step process



Muthu (2015), p.4

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The goal and scope - which system to assess

- What should be included in the assessment? Different choices:

- attributional approach (e.g. “What is the carbon footprint of this product manufactured at this site?”) or
- consequential approach (e.g. “How does the carbon footprint change if this new product is introduced to the market on this scale?”)
- Decision: allocation of environmental impacts when multifunctional processes are involved.

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Inventory analysis - emission data

- Can be applied at many scales, from individual products to corporations and national industries
- two fundamental methodologies in use for obtaining inventory data: process analysis and inpute/output analysis.
- It is important to obtain high-quality data
- key challenge: make sure that all relevant greenhouse gas emissions are included
- Decide: whether or not the net carbon balance is considered in determining which CO2 emissions should be included

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Impact assessment - choice of method

- Carbon footprint studies typically assume a 100-year time perspective (“GWP100”)
- Alternatives 20-year and 500-year time perspective
- Interpretation: Holistic assessments may require complementary indicators

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4. Analysis

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Conducting LCA studies based on the principles of ISO14040

Zhang et al. (2015). Life cycle assessment of cotton T-shirts in China

- The specific objective of this study is to assess the environmental impacts, to identify the environmental hotspots, and to seek for improvement opportunities during the life cycle of 100 % cotton T-shirt in China.

Life-cycle assessment of continuous pad-dyeing technology for cotton fabrics

- This study aimed at evaluating the life-cycle environmental impacts of the textile-dyeing industry and determining the key processes for mitigating life-cycle environmental impacts efficiently and effectively, which will benefit the application of cleaner production technologies.

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Conducting LCA studies according to the principles of ISO14040

Fidan et al. (2020). Life Cycle Assessment for Neutralization process in Textile Wastewater Treatment Plant

- The aim of this study is to compare the environmental impacts of carbon dioxide and sulfuric acid, which are two alternative chemicals used in the neutralization process of textile facilities, using Life Cycle Assessment (LCA) approach.

Pranav et al. (2020). Case study on sustainability of textile wastewater treatment plant based on lifecycle assessment approach

- The present study is aimed at the estimation of the environmental footprints of a textile effluent treatment plant in India based on Lifecycle analysis (LCA) thinking of gate-to-gate approach with closed-loop recycling.

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5. Critical Review

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Limitations

- LCA has limitations
- The limitations of every study have to be documented in the goal and scope definition (ISO 14040)
- LCA study is resource consuming, mainly due to the large amount of data needed. If data collection is poor, or if not enough data are available, the study will not lead to solid conclusions.
- LCA studies depend on assumptions and scenarios, as LCA assesses the real world in a simplified model.
- It is not easy to communicate the results of an LCA study

Finkbeiner et al. (2014)

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6. Question Bank

What are the major environmental areas of impact caused by the textile and fashion industry?

What are the major processess of the textile and fashion industry? Explain the impact of each step.

What is the difference between carbon footprinting and LCA?

Describe the four steps according to ISO 14040.

What are the reasons for practioners to apply LCA?

Describe limitations of LCA.

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7. References and Further Reading

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