THE LIFE CYCLE INVENTORY & LIFE CYCLE ASSESSMENT OF COTTON FIBER & FABRIC

V2 (REVISED FOR GABI 5)*

A CRITICAL NEED

The textile industry has always been challenged with balancing performance and cost. As resource availability and water scarcity concerns increase, the textile supply chain now has the additional challenge of environmental accountability. From fiber sourcing to end product, stakeholders and consumers alike are demanding methods of measuring and reducing the environmental impact of textile products. Tools such as Life Cycle Inventories and Life Cycle Assessments can aid in environmental decision-making by identifying key impact areas and benchmarking success over time. To better direct research areas, and to better inform decisions along the cotton textile supply chain, the Cotton Foundation undertook the most comprehensive assessment of cotton product life cycles to date—The Life Cycle Inventory & Life Cycle Assessment of Cotton Fiber & Fabric.

LIFE CYCLE TOOLBOX

Key to appreciating the scope and findings of the project is an understanding of the connection between two critical tools in life cycle evaluations:

A Life Cycle Inventory (LCI) is a collection of data sets that quantify energy, water, raw material requirements, air emissions, waterborne effluents, solid wastes and other environmental releases that occur throughout the life cycle of a product, process or activity.

A Life Cycle Assessment (LCA) is an objective process to evaluate the potential environmental burdens associated with the entire life cycle of a specific product, process or activity, and is generally based upon information contained in Life Cycle Inventories.

BENCHMARKING SUCCESS

Prior to the Cotton Life Cycle Inventory & Assessment project, the data sets in the most commonly used LCIs were obsolete; many relying on outdated collections, or even supposition. In 2009, the Cotton Foundation, with support from Cotton Incorporated, the U.S.-based National Cotton Council, and Cotton Council International, undertook an expansive research and data collection project in order to repopulate the most widely used public and proprietary LCIs, such as Ecoinvent and the U.S. Life Cycle Inventory databases. The goals of this ongoing project are to:

1 | Establish agricultural and manufacturing benchmarks that will better guide sustainable research within the cotton industry; and to

2 | Enable cotton supply chain decision-makers to more adequately assess and reduce the environmental impact of their individual cotton production processes.

Data integrity is an essential element of an LCI's utility. As such, The Cotton Foundation engaged an authority in LCA creation, PE International, to oversee the collection of data and modeling. The results and conclusions have undergone an extensive peer review process, and conform to ISO-14040 guidelines.

CRADLE-TO-GRAVE:

A Comprehensive Examination

The Cotton Life Cycle Inventory aims to provide a comprehensive inventory of data relating to cotton production, textile manufacturing, and transportation.

The associated LCA utilizes the LCI data to present a comprehensive cradle-to-grave examination of representative cotton products, specifically knit golf shirts and woven pants, and includes garment creation, consumer product use and maintenance, and product end-of-life.

LCI GLOBAL AVERAGES:

Managing a Detailed View

Primary data for the LCI were collected by Cotton Incorporated through its global network of industry partners and are representative of the years 2005 through 2009. This primary data were supplemented with literature and industry averages. For ease of use and more expeditious incorporation into public and private databases, the cotton LCA project relied on the calculation of global averages for fiber production and textile manufacturing.

1 | Cotton fiber production: The data for fiber production represent a global average of the three largest cotton producing regions (China, India, and the United States) for the years 2005–2009. These regions, combined, accounted for 63% of the world's cotton production in 2010. The data cover raw fiber production from field through to the ginning process (cradle-to-gate) and includes impacts of soil type, climate, seed and chemical inputs, water and fuel use and key dates associated with production, such as planting, fertilizer application, and harvesting. Impacts were calculated for a functional unit of 1,000 kg of cotton fiber.

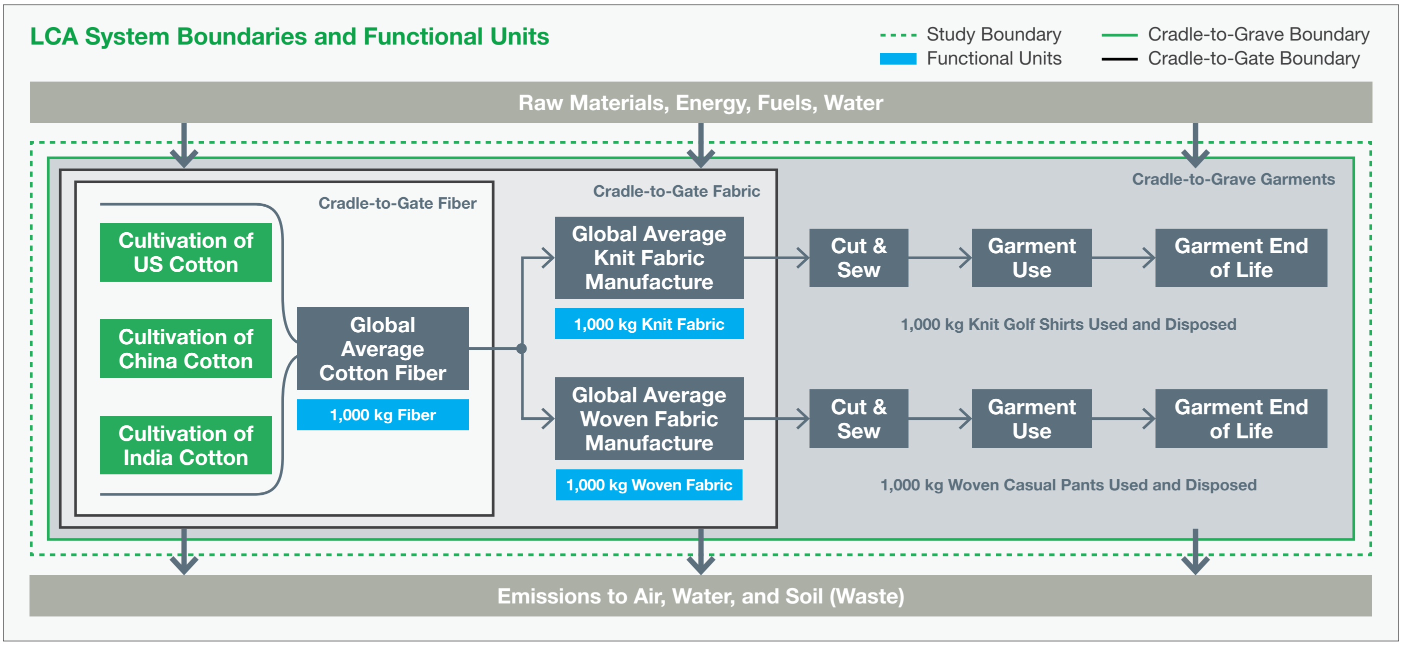
2 | Cotton fabric production: The data for fabric production (knits and wovens) represent global averages of mills in China, India, Turkey, and the Americas; which, accounted for 66% of knits and 51% of wovens processed in 2009. The data collected include bale opening, yarn preparation, spinning, knitting (or weaving), wet preparation, dyeing and finishing. In addition, the data elements included: raw material inputs and outputs; energy inputs by source; dye/chemical input, output and emissions; and solid waste amounts and their disposal (such as whether the waste was recycled, sold, or sent to landfill). The functional unit was 1,000 kg of knit or woven fabric, as appropriate.

3 | Cotton cut-and-sew, consumer use and disposal: Mill data for textile production and for cut-and-sew processes were supplemented with process energy calculations from machinery manufacturers and data available from Cotton Incorporated experts. Background data on ancillary materials, energy and fuels, transportation, and end-of-life were taken from PE International's GaBi databases. Background data on use phase energy and materials were taken from existing government publications, literature values, and PE International GaBi data. Those data were combined with consumer behavior data from the Cotton Incorporated *Lifestyle Monitor*™ survey. The survey pool consisted of 1,000 U.S. citizens between 13 to 70 years of age, and was 60% female and 40% male. The study posed questions about consumers' use and laundering practices for knit shirts and woven pants.

MODELING THE RESULTS:

LCA Boundaries

Cotton is currently found in over two-thirds of all apparel items. To benchmark the environmental impact of every cotton textile product would be an overwhelmingly costly and time-consuming endeavor. To address this and to expedite availability to stakeholders, the cotton LCA examines the life cycles of a knit golf shirt and a pair of woven cotton trousers. The functional weight of 1,000 kg was continued in this facet of the assessment and is equivalent to 2,780 shirts or 1,764 trousers.



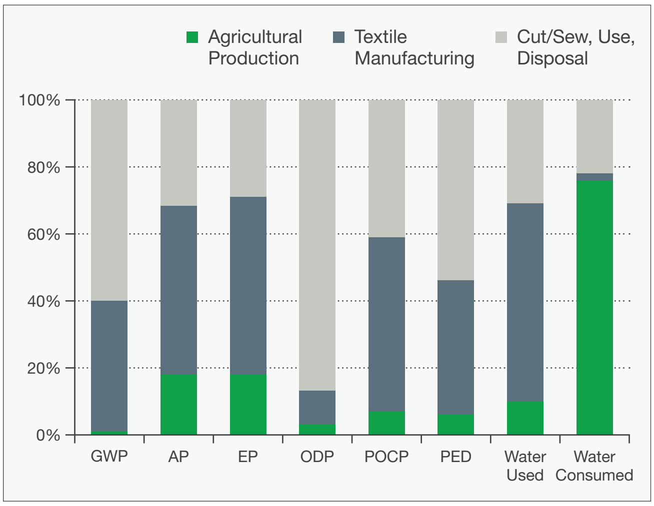
ITEMIZING IMPACT:

Environmental Categories Assessed

An LCA leverages LCI data to determine the potential impact of product life cycles in specific environmental categories, across all life cycle phases. The categories used for the cotton LCA are listed in the table below.

Abbreviation	Technical Term	Example Impact
AP	Acidification Potential	Acid rain
EP	Eutrophication Potential	Water pollution
GWP	Global Warming Potential	Greenhouse gas emitted
ODP	Ozone Depletion Potential	Ozone hole over polar ice caps
POCP	Photochemical Ozone Creation Potential	Smog
PED	Primary Energy Demand	Electricity & fuel needed
WU	Water Used (Gross Volume)	Water used in washing machine
WC	Water Consumed (Net Volume)	Water evaporated in dryer
ETP	Ecotoxicity Potential	Animal health
HTP	Human Toxicity Potential	Human health

The share of each impact across primary life cycle phases for 1,000 kg of knit golf shirts is illustrated in the chart below. Similar results were obtained for 1,000 kg of woven pants.

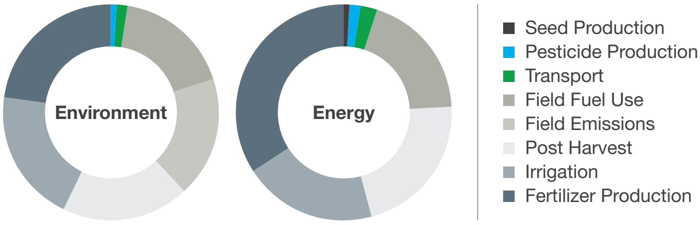


Two additional categories related to toxicity were considered in the study, but are not reported. The UNEP-SETAC USEtox® characterization model was used for both ETP and HTP modeling, but the precision of the current USEtox® characterization factors are less robust than other impact categories. Additional studies are currently underway to assess the accuracy of the USEtox® parameters for agriculture.

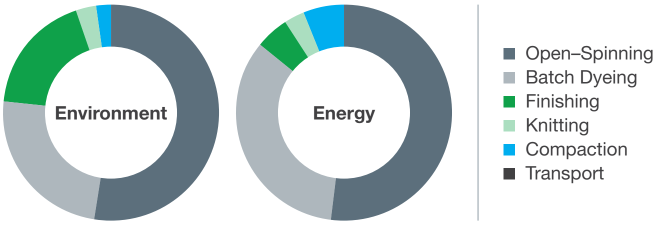
PUTTING IT ALL TOGETHER:

Results and Conclusions

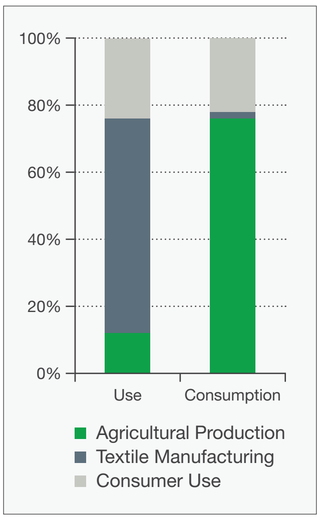
Cotton's Life Cycle Analysis reveals that primary environmental and energy impacts for the cotton Agriculture phase are due to fertilizer production (nitrogen), irrigation, and post harvest (ginning).



In the Textile Manufacturing phase, the cotton LCA of knits indicates that opening through spinning and preparation/ batch dyeing are the two areas where greatest environmental improvements can be made.

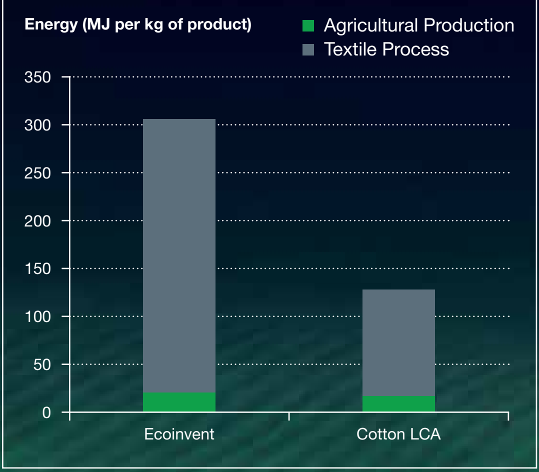


As an environmental indicator for cotton, water metrics vary significantly depending on whether the measure is "Water Used" (the gross volume of water applied) or "Water Consumed" (how much water is retained in the process and not returned to a watershed). The chart below illustrates the disparity in WU and WC for the cotton supply chain. It is important to note that a WC model characterizes irrigation as 100% consumption; though, in fact, a portion of irrigated water is returned to a watershed. Tools such as the infrared thermometer at right aid growers in more efficient use of water. Most WU in the Textile phase is associated with water for power generation; while, in the Agricultural phase irrigation is the majority of water expenditure or withdrawal for both use and consumption.



Agriculture production expenditures from the cotton LCA are in line with those of Ecoinvent, but the discrepancy in textile processing expenditures illustrate the need for keeping data comprehensive and current.

Cotton LCA Updates Existing Data



MOVING COTTON SUSTAINABILITY FORWARD

The research and analysis presented here is merely the first phase of the ongoing Life Cycle Inventory & Life Cycle Assessment of Cotton Fiber & Fabric project. The LCI is being made available to widely-used databases such as Ecoinvent and the U.S. Digital Commons, and will be expanded upon and updated over time. In addition, an interactive environmental assessment tool, slated for completion in early 2012, will enhance environmental decision-making by users of cotton by enabling attributes specific to their products to be evaluated.

The topline results have already helped shape strategic initiatives for the cotton industry including:

1 | Expanding research initiatives in water and nitrogen-use efficiencies;

2 | Working with the LCA community to develop a more accurate model of agricultural toxicity impacts, including the incorporation of textile chemical profiles;

3 | Continuing support of wastewater reduction research in textile manufacturing; and

4 | Educating consumers on sustainable garment care.

* In an effort to keep cotton life cycle assessment current and compatible with widely-used analytic tools, this revision to Cotton's Life Cycle Inventory and Life Cycle Assessment reflects database changes released in the recent GaBi 5 update.

Additional information on The Life Cycle Inventory & Life Cycle Assessment of Cotton Fiber & Fabric can be found in an Executive Summary, available at **http://cottontoday.cottoninc.com**.

The Life Cycle Inventory & Life Cycle Assessment of Cotton Fiber & Fabric is a facet of the VISION 21 Project of The Cotton Foundation, and managed by the Cotton Board, Cotton Incorporated and Cotton Council International.

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