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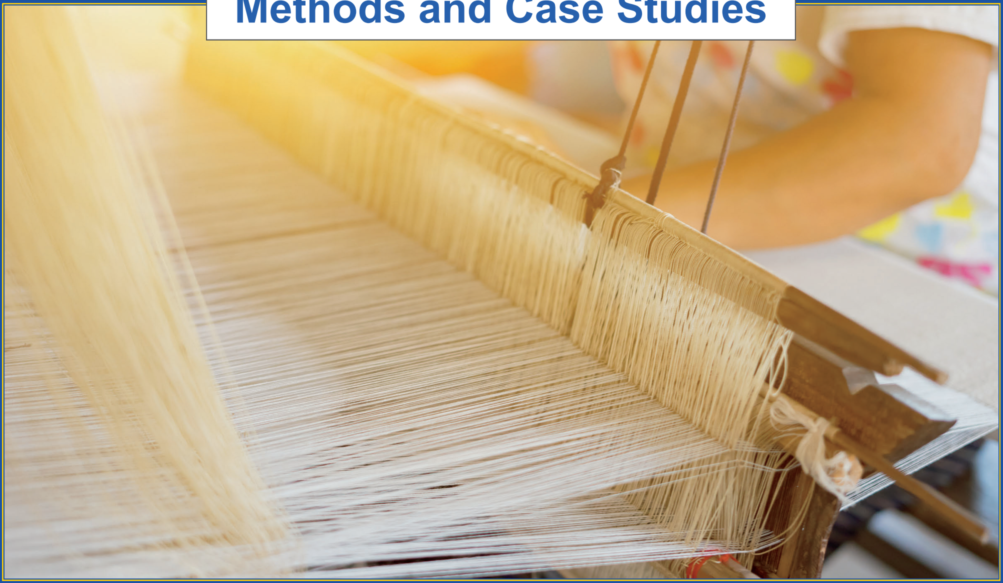
An initiative of the Office of DC (Handlooms)

Carbon Footprint Assessment in the Indian Handloom Sector

Methods and Case Studies



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सत्यमेव जयते

Giriraj Singh

Minister of Textiles
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MESSAGE

I warmly congratulate the Development Commissioner for Handlooms and Indian Institute of Technology Delhi for creating the book, "Carbon Footprint Assessment in the Indian Handloom Sector" that endeavours to promote sustainability in the realm of Indian handlooms.

Our handloom sector is a proud testament to India's rich heritage, supporting millions of livelihoods through sustainable textile production. This book is timely, arriving as India advances boldly toward a cleaner and greener future. It offers simple, step-by-step advice designed to help weavers, community leaders, and policymakers accurately measure and reduce the carbon footprint of handloom products.

The book also features inspiring real-life stories and practical examples from across the country, demonstrating how handloom communities can conserve energy and protect the environment effectively. Moreover, the emphasis on social impact of handloom weaving, particularly in empowering weaver communities and encouraging positive environment practices, resonates deeply with the Government of India's commitment to sustainable development. I am confident that this book will empower weavers to gain well-deserved recognition and fair rewards for their eco-friendly practices, opening doors to new opportunities such as participation in carbon credit programs.

I salute everyone who worked on this important project—including experts from the Indian Institute of Technology Delhi, the Indian Institute of Handloom Technology, the Weavers Service Centres, local weavers, and all other key stakeholders. Your dedication and teamwork have made this book possible. Together, we are building a stronger, greener handloom sector for India’s future.

(Giriraj Singh)

सत्यमेव जयते

Pabitra Margherita

Minister of State for External Affairs and Textiles
Government of India

MESSAGE

It gives me immense pleasure to welcome the publication of the book titled "Carbon Footprint Assessment in the Indian Handloom Sector." Rooted in a long tradition of sustainability, our handloom industry today stands at the crossroads of heritage and innovation, reflecting India's cultural identity while embracing modern and responsible practices.

At a time when the world is focusing on sustainability, this publication provides timely and practical guidance for managing carbon emissions across the sector. By identifying key sources of emissions, it helps the industry take informed action, improve competitiveness and explore new opportunities, including access to carbon markets and wider exports. Through step by step methods, practical tools and real life success stories, it also highlights the vital role of Indian handlooms in promoting sustainable fashion and mindful consumption.

The efforts of the Development Commissioner for Handlooms and Indian Institute of Technology, Delhi in bringing out this important work are truly commendable. I encourage all stakeholders to draw valuable insights from this publication to help build a greener and more resilient future for the handloom industry.

(Pabitra Margherita)

सत्यमेव जयते

Neelam Shami Rao, IAS
Secretary
Ministry of Textiles, Government of India

MESSAGE

The book "Carbon Footprint Assessment in the Indian Handloom Sector" is a timely and commendable contribution to India's ongoing handloom movement in the field of sustainability which plans to blend heritage, innovation and tradition to create a forward-looking, eco-conscious, and economically resilient future for its weavers and stakeholders.

The handloom industry is not only a guardian of India's rich cultural heritage but also a vital contributor to rural economies and sustainable livelihoods. In today's era of growing environmental awareness, providing our sector with robust tools for carbon management is both timely and essential.

This book stands out for its practical approach—offering clear methodologies, actionable templates, and insightful case studies tailored to the unique realities of our handloom clusters. By translating global standards into accessible steps, it empowers weavers, entrepreneurs, and institutions to take meaningful action towards climate and sustainability goals.

Through fostering transparency and data-driven decision-making, this book will help identify emission hotspots, optimize resource use, and unlock new opportunities such as carbon credit monetization for the handloom sector. Most importantly, it places weavers at the heart of India's green transition, ensuring their traditional skills are recognized as an integral part of the climate solution.

I am sure that this book will help in preserving India's rich textile legacy which is rooted in responsible and environment-conscious textile production, from farm to finished products. I encourage all stakeholders to utilize this book to build a more sustainable, competitive, and globally respected handloom sector

(Neelam Shami Rao)

सत्यमेव जयते

Dr. M. Beena, IAS
Development Commissioner (Handlooms)
Ministry of Textiles
Government of India

FOREWORD

I am immensely gratified to present a one-of-a-kind book titled "Carbon Footprint Assessment in the Indian Handloom Sector." This publication marks a significant step forward in our collective journey toward sustainable textile production.

The handloom sector is recognized for its energy efficiency and environmental sustainability. This book provides practical methodologies and real-world case studies to enable all stakeholders—including weavers, educators, and students—to measure and reduce their carbon footprint. The strategies outlined are designed to be accessible and applicable to enterprises of all sizes, ensuring even the smallest operations can implement these sustainable practices.

By using methodologies presented in the book, Handloom groups can adopt new ways to market their products and even get monetized for becoming climate-friendly. This book empowers all weavers & allied workers and projects their important role in weaving the cultural heritage and sustainable environment together.

I offer my heartfelt gratitude to Indian Institute of Technology Delhi team, especially Associate Prof. Bipin Kumar on his efforts to conceptualise the book that encapsulates various aspects of sustainability ingrained in handloom textiles, a beautiful saga that continues even today that plans to steer the future of a better living.

I hope readers will appreciate this effort to inspire more such eco-friendly work and propel India as a leader in sustainable textiles.

(M. Beena)

Preface

India's textile sector is the backbone of the economy, accounting for 2.3% of GDP, 13% of industrial production, and 12% of exports. As the world's sixth-largest textile exporter, it directly employs over 45 million people—making it the second-largest employer after agriculture. The handloom segment preserves India's rich artisanal heritage and empowers millions of rural women. Still, the sector faces major hurdles: intense global competition, fast-changing consumer preferences, and the urgent need for modernization and sustainability.

The Indian handloom sector exemplifies sustainable production. Unlike mechanized manufacturing, it primarily uses renewable human energy, locally sourced natural fibers, and decentralized processes, resulting in significantly lower carbon emissions. Prioritizing and advancing this sector can play a key role in reducing the overall environmental footprint of India's textile industry, which is among the most resource-intensive globally. Given the urgent demands of climate change and sustainability, scrutinizing and minimizing the sector's carbon footprint is more important than ever.

This book, **Carbon Footprint Assessment in the Indian Handloom Sector**, is a practical response to key industry challenges. It aims to provide policymakers, weavers, cluster managers, and industry leaders with a clear framework to measure, understand, and reduce the carbon footprint of textile production. Combining international carbon accounting standards with India's unique context, it offers a step-by-step assessment method supported by real-world case studies from across the country.

To maximize accessibility and practical relevance, the guidelines focus on user-friendliness, actionable steps, and adaptability for all audiences. Special attention is given to low-cost, accessible data collection methods, context-appropriate emission factors, and hands-on tools for measuring carbon footprints at the loom, workshop, or cluster level. By highlighting the inherent advantages of India's handloom sector—its reliance on renewable energy, local materials, and decentralized production—this report underscores not only its heritage strengths but also its untapped climate potential.

Collaboration stands at the heart of this report. These guidelines were primarily shaped by the expertise and practical insights of professionals from the Indian Institute of Technology Delhi, the Indian Institute of Handloom Technology, Weavers Service Centres, grassroots artisan groups, Greenstitch Private Limited, and key government agencies. Additionally, the framework and methodology have benefited from insights drawn from leading international climate and sustainability reports.

India's journey toward a sustainable, low-carbon handloom sector is both a responsibility and an opportunity. As the nation sets ambitious climate goals and faces rising expectations for sustainable textile production, it is crucial to empower every participant—from the largest manufacturers to the smallest weavers—with the knowledge and tools for credible environmental assessment. Transparent, science-based carbon accounting is now essential—not only as a regulatory mandate but also as a gateway to new markets, green investments, and global value chains where sustainability is increasingly rewarded.

This preface is both an invitation and a call to action to everyone associated with the textile sector—including both handloom and powerloom stakeholders—to take part in India's transition to environmentally responsible textile production. By working collectively—grounded in tradition, guided by innovation, informed by scientific rigor, and committed to transparency—we can secure the enduring vitality of our textile legacy while safeguarding our planet for future generations.

Bipin Kumar
Associate Professor
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Author Bio

Dr. Bipin Kumar completed Ph.D. in Textile Engineering from IIT Delhi in 2013. He is currently an Associate Professor in the Department of Textile and Fibre Engineering at IIT Delhi. Previously, he served as a Research Assistant Professor at The Hong Kong Polytechnic University (2016–2017) and was a Fulbright Fellow at UC Davis (2014–2016). His research focuses on smart fibrous materials, advanced fabric structures, e-textiles, recycling, and sustainability.

Dr. Kumar has authored or coauthored 100 peer-reviewed publications, including journal articles, book chapters and conference papers. He holds 9 patents and has authored four books. He has supervised 7 Ph.D. candidates and more than 20 Master's students. Dr. Kumar has made significant contributions to online education, most notably through his widely viewed course "Science and Technology of Weft and Warp Knitting," which has inspired many textile engineers. He has played an active role in several IIT Delhi startups, successfully commercializing products such as Kawach masks, antiviral T-shirts, anti-radiation garments, and monumental indian flags. Currently, he is spearheading the establishment of a Atal Center for Recycling and Sustainability, devoted to high-performance textile waste management and carbon footprint analysis in textile sector.

Awards

- Faculty Start-up Award (FITT/IITDAA, 2021)
- Entrepreneur Faculty Award (IITDAA, 2020)
- IEI Young Engineer Award 2018-19, The Institute of Engineers (India), 2019
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- K. Vasudevan Award, IIT Delhi, 2008, 2009

Membership of Professional Societies

- International Electrotechnical Commission (2019–current)
- Bureau of Indian Standards, India (2019–current)
- AATCC Journal of Research, USA (2019–current)
- Techtextil North America, USA (2015–2016)
- American College of Phlebology (ACP), USA (2014–2015)
- Fiber Society, USA (2016–2017)
- International Compression Club (ICC), Austria (2013–current)
- Expert Panelist (Textile), The Advertising Standard Council of India (2021–current)

Contents

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Handloom Product	Field Data Collection	Data Analysis & Standardization
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Acronyms

CO_2	Carbon Dioxide
CH_4	Methane
N_2O	Nitrous Oxide
GHG	Greenhouse Gas
GWP	Global Warming Potential
CO_2-eq	Carbon Dioxide Equivalent
LCA	Life Cycle Assessment
UNFCCC	United Nations Framework Convention on Climate Change
IPCC	Intergovernmental Panel on Climate Change
US EPA	United States Environmental Protection Agency
ISO	International Organization for Standardization
NHDC	National Handloom Development Corporation
FU	Functional Unit
EF	Emmision Factor
CCTS	Carbon Credit Trading Scheme
CEA	Central Electricity Authority (INDIA)
DEFRA	Department for Environment, Food and Rural Affairs (UK)
IEA	International Energy Agency
EPD	Environmental Product Declaration
CPCB	Central Pollution Control Board (INDIA)

1. Introduction

1.1 Global Warming: An Urgent Call

Global warming refers to the long-term rise in Earth's average temperature, primarily driven by increasing concentrations of greenhouse gases in the atmosphere. Human activities—especially the burning of fossil fuels—have pushed global greenhouse gas (GHG) emissions to new records, despite decades of warnings and international agreements. According to the latest Global Carbon Budget 2024,[1] fossil fuel CO_2 emissions are projected to reach a record 37.4 billion Tonnes in 2024, a 0.8% increase from 2023. Including land-use change emissions such as deforestation, total global CO_2 emissions are estimated at an unprecedented 41.6 billion Tonnes in 2024. Such a result is rapidly worsening climate change: more frequent heatwaves, stronger storms, disruptive rainfall patterns, rising sea levels, and growing threats to food security and biodiversity.

Accelerating Atmospheric CO_2 Concentrations

Atmospheric CO_2 is set to reach an average of about ~425 parts per million (ppm) in 2024, the highest level ever recorded and 2.8–3.6 ppm above last year—marking the steepest annual rise on record.

Persistent Rise Despite Climate Commitments

There is no sign that fossil fuel emissions have peaked globally—emissions continue to grow even as renewables and electric vehicles expand in some regions.

Urgency for Carbon Footprint Assessment

At the current rate of emissions, the planet has a 50% chance of exceeding 1.5°C warming in just six years, making urgent action and robust carbon accounting essential.

India's Climate Goals and Policy Action

India pledges to cut emissions intensity 45% and to achieve 50% non-fossil power by 2030 and targets net zero by 2070 through sustainable, low-carbon initiatives.[2]

1.2 Environmental Impact of the Textile Sector

The textile and fashion industry has a profound and widespread impact on the environment, placing significant demands on natural resources and contributing to ecosystem stress throughout its entire supply chain.[3] From the cultivation of raw materials to fabric dyeing, manufacturing, transportation, everyday use, and eventual disposal, each phase of textile production and consumption affects land, water, and air (Table 1.1). The industry is interconnected with a broad range of environmental challenges, including pollution, waste generation, and the depletion of nonrenewable resources. Processes involved in making textiles often require large amounts of water and energy, while also producing pollutants that can harm aquatic and terrestrial life. Moreover, the industry's practices contribute to the accumulation of waste, both during manufacturing and once products reach the end of their useful life, thereby adding to the pressures on global landfill sites and natural habitats.

Table 1.1 — Environmental impacts of the global textile industry[3]

Indicator	Value/Fact
Clothing waste disposal	1 garbage truckload (textiles) dumped or burned every second
GHG emissions	2–8% of global GHG emissions
Water usage by textiles	86 million Olympic-sized swimming pools of water per year
Global plastic waste from textiles	11% (third largest contributor globally)
Textile sector's microplastic share	9% of ocean microplastic pollution


Textile waste highlights the urgent need for sustainable practices in the industry

1.3 The Need for Carbon Footprint Assessment

A robust carbon footprint (CF) assessment is the first step in understanding how much each process, product, or activity contributes to the climate crisis[4]. In the face of record-breaking emissions and dangerous climate trends, systematic CF assessment is no longer optional—it is the crucial foundation for credible climate action and global competitiveness. For the textile industry, with its complex and resource-intensive supply chain, this journey begins with systematically identifying, accounting, and reporting emissions at every stage, from raw material sourcing to manufacturing, use, and end-of-life disposal (Figure 1.1).

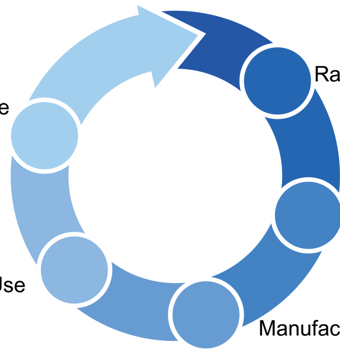


Figure 1.1 — Phases of a product's environmental journey

Key reasons for CF assessment includes:

a) *Identifying Major Emission Sources*
Pinpoints the most significant sources of GHG emissions within production and supply chains, revealing inefficiencies and high-impact areas that need targeted intervention.

b) *Setting Reduction Targets*
Enables organizations and policymakers to set realistic, measurable emission reduction targets in line with science-based and national/international climate goals.

c) *Supporting Climate Disclosures and Action*
Provides standardized data and transparent reporting to support climate-related disclosures, helping businesses meet regulatory requirements and demonstrate progress toward sustainability to stakeholders.

d) *Enhancing Market Competitiveness*
Demonstrates environmental responsibility to global buyers and opens access to markets where sustainable sourcing and low-emission credentials are increasingly required

1.4 Carbon Footprint Assessment in India's Textile Sector

India's textile and apparel industry is a cornerstone of the country's economy and social progress. In the year 2023–24, India's textile and apparel production was valued at about US$ 175.7 billion, and exports reached US$ 35.87 billion.[5] The industry is highly labor-intensive, directly employing more than 45 million people, including many women and workers from rural areas. Its broad reach supports government goals like Make in India, Skill Development, Women's Empowerment, Rural Youth Employment, and inclusive economic growth. The sector:

- Contributes almost 2% to India's GDP
- Makes up 10% of all industrial production
- Accounts for 8.21% of the nation's exports
- Positions India as the sixth largest exporter of textiles worldwide, with a 3.91% share in global trade

Despite these achievements, the textile industry faces major environmental challenges. The sector uses a lot of energy and water, and it produces significant GHG emissions at each stage, from raw materials to finished garments.

CF assessments—which measure the amount of GHG and energy used—are now essential for moving forward. This process helps identify where the most pollution and emissions occur (Figure 1.2)—such as in fabric dyeing or yarn spinning—allowing the industry to set clear targets for reducing its environmental impact and to invest in cleaner, more efficient technologies. By adopting carbon assessments, Indian textile companies can better compete in global markets that increasingly demand sustainable products, strengthen their green brand reputation, and access green financing and incentives provided by the government and international organizations.

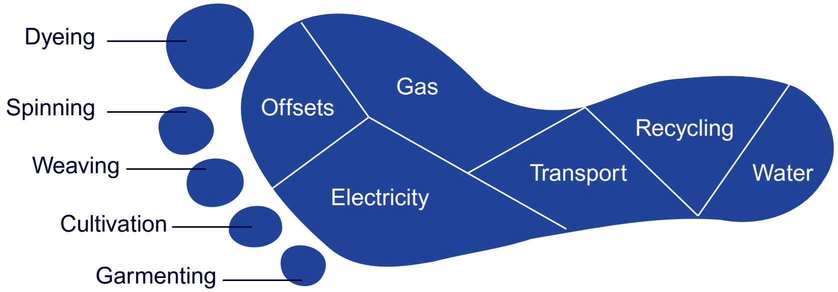


Figure 1.2 — Key sources of CF across the textile supply chain

1.5 Handloom: A Pathway to Low-Carbon and Sustainable Textile Production

India's handloom sector stands out as a model for sustainable textile production, thanks to its minimal reliance on fossil fuels and heavy machinery. Unlike large-scale industrial processes that consume significant amounts of energy and water, handloom weaving depends on the skills of local artisans using simple, manual tools. This not only keeps electricity and fuel usage low but also results in very limited greenhouse gas emissions. According to the 2019–20 Handloom Census,[6] over 35 lakh handloom workers—many of them women in rural communities—depend on this sector for their livelihoods, creating a strong link between environmental stewardship and social equity. By embracing natural fibers, plant-based dyes, and traditional production methods, the handloom sector supports biodegradability, reduces chemical pollution, and embodies the principles of a circular economy.

Systematic CF assessment plays a crucial role in further strengthening the eco-friendly reputation of handloom textiles. Measuring the carbon emissions of handloom products allows producers to demonstrate their low environmental impact, which can help them attract customers, secure green funding, and access new markets that value sustainability. Carbon assessments also help identify the best and most efficient production methods, setting benchmarks for the sector and encouraging wider adoption of sustainable practices.

As a result, the handloom sector is well-positioned not only to support India's climate goals but also to enhance livelihoods and preserve artisanal heritage for future generations.

Summary

Understanding and managing the carbon footprint—the total GHG emissions generated throughout a product's lifecycle—has become crucial for all sectors, including textiles. Conducting systematic CF assessments enables businesses to pinpoint exactly where emissions are highest, implement more sustainable production practices, and set practical goals for reducing their environmental impact. This process isn't just vital for protecting the environment; it also meets the rising global demand for responsible, eco-friendly textile products.

India's textile and apparel sector is a major force in the country's economy, contributing nearly 2% to GDP and supporting over 45 million jobs. However, the rapid expansion of this industry brings environmental challenges, as fabric production uses significant energy and water resources and produces considerable GHG emissions. This makes it urgent for the sector to adopt greener practices.

Within this landscape, handloom weaving stands out as a notably sustainable alternative. Relying on manual labor, local materials, and natural fibers and dyes, handloom operations significantly lower energy use and carbon emissions. These methods not only help safeguard traditional skills and support rural livelihoods but also align with global sustainability standards. Regular CF assessments help both industrial and handloom producers measure their progress, improve their environmental performance, and build trust in domestic and international markets increasingly focused on sustainability and accountability.

2. Understanding Carbon Footprint

2.1 What is Carbon Footprint?

The term ‘carbon footprint’ has gained significant popularity in recent years, becoming central to dialogues on climate change responsibility and mitigation. Its frequent use in media, policymaking, and business underscores its recognized role as a key metric of environmental impact. However, despite its global prominence, there remains substantial ambiguity regarding its exact meaning, measurement scope, and units of expression.[7] Following are definitions adopted by some of the major international institutions:

United Nations Development Programme (UNDP)

A carbon footprint is a measure of the GHG emissions released into the atmosphere by a particular person, organization, product, or activity.

World Health Organization (WHO)

A carbon footprint measures the impact your activities have on the amount of CO_2 produced through the burning of fossil fuels and is expressed as a weight of CO_2 emissions produced in tonnes.

U.S. Environmental Protection Agency (EPA)

The total set of GHG emissions (including CO_2 and other gases) caused directly and indirectly by an individual, organization, event, or product.

Intergovernmental Panel on Climate Change (IPCC)

A measure of the exclusive total amount of emissions of CO_2 that is directly and indirectly caused by an activity or accumulated over the life stages of a product.

Despite variations in definitions, the primary goal remains to identify and assess emissions. A clear understanding of the “carbon footprint” allows for more effective climate action planning and ensures transparent, comparable reporting across sectors and regions.

2.2 Greenhouse Gases and Their Role in Global Climate Agreements

GHGs are atmospheric gases that trap heat and contribute to global warming and climate change. Among these, CO_2 is the most significant, accounting for the largest share of human-caused GHG emissions. CO_2 is primarily released through burning fossil fuels, and it remains in the atmosphere for centuries, making its long-term impact particularly severe. Other important GHGs include CH_4, N_2O, and fluorinated gases such as HFCs, PFCs, SF_6, and NF_3, which are listed in Table 2.1. Human activities—especially energy production, industry, and agriculture—have sharply increased the concentration of all these gases, strengthening the greenhouse effect and causing global temperatures to rise. Reducing the levels of CO_2 and other GHGs is critical for mitigating climate change and ensuring a more stable climate future.

Table 2.1 — Major greenhouse gases

Non-Fluorinated Gases	Fluorinated Gases
Carbon dioxide (CO_2)	Hydrofluorocarbons (HFCs)
Methane (CH_4)	Perfluorocarbons (PFCs)
Nitrous oxide (N_2O)	Sulphur hexafluoride (SF_6)
	Nitrogen trifluoride (NF_3)

To address the growing challenge of climate change, international efforts have been formalized through agreements like the **Kyoto Protocol**[8] and the **Paris Agreement**. The Kyoto Protocol, adopted in 1997 under the **United Nations Framework Convention on Climate Change** (UNFCCC), was the first to set binding targets for developed countries to reduce emissions of key GHGs. All gases under the Protocol are converted into **carbon dioxide equivalents (CO_2-eq)** based on their global warming potentials, providing a common metric for comparison and policy action.

The Paris Agreement (2015) broadened participation, with nearly all nations committing to reduce greenhouse gas emissions through their own Nationally Determined Contributions (NDCs), striving for net-zero emissions by mid-century. Together, these agreements provide the framework for tracking and reducing GHGs and form the cornerstone of global efforts to manage carbon footprints and mitigate climate change.

2.3 Global Warming Potentials and CO_2-eq

Greenhouse gases differ in their impact on global warming due to variations in their ability to absorb energy—known as radiative efficiency—and their atmospheric lifetimes. The Global Warming Potential (GWP) metric allows for comparison by measuring how much heat one tonne of a gas will trap over a set period, relative to one tonne of CO_2, which has a GWP of 1.

Gases with higher GWP values have a greater warming effect per tonne compared to CO_2

By convention, CO_2 has a GWP of 1. CH_4 has a GWP of about 27–30, and N_2O has a GWP of 273 over 100 years, reflecting their higher heat-trapping abilities and longer lifetimes (Table 2.2). Certain fluorinated gases—such as HFCs, PFCs, SF_6, and NF_3—have even higher GWPs, so even small quantities can result in substantial warming. The 100-year GWP metric from the IPCC is widely used in UNFCCC reporting and underpins the multi-gas approach established by the Kyoto Protocol.

Table 2.2 — GWP for major GHGs over 100 years[9]

Greenhouse Gas	GWP (100-year)
Carbon dioxide (CO_2)	1
Methane (CH_4)	27-30
Nitrous oxide (N_2O)	273
Hydrofluorocarbons (HFCs)	124 – 14,800
Perfluorocarbons (PFCs)	7,390 – 12,200
Sulphur hexafluoride (SF_6)	23500
Nitrogen trifluoride (NF_3)	17,000

To compare the climate impacts of various GHG emissions, metrics like GWP convert emissions into a consistent unit — **CO_2 equivalent (CO_2-eq).** To standardize emissions comparisons, each GHG is converted to CO_2-eq using the formula as shown:

$$CO_2\text{-}eq_i = M_i \times E_i$$

Where: M_i = mass of GHG i emitted, E_i = GWP value for gas i (Table 2.2)

2.4 Life Cycle Assessment and Carbon Footprint

Life Cycle Assessment (LCA) and Carbon Footprint (CF) are both valuable tools for evaluating the environmental impact of a product, activity, or company, but they differ in their focus and scope (Table 2.3). LCA is a comprehensive approach that examines all environmental impacts throughout a product's entire life—from raw material extraction to production, use, and disposal. By considering various factors like resource use, pollution, water consumption, and toxicity, LCA helps identify opportunities to improve products or processes and can be integrated with economic and social studies for a full sustainability assessment.

In contrast, the CF focuses specifically on the greenhouse gases emitted during the life cycle of a product, service, or organization. It measures only the impact on climate change (global warming) by tracking gases like CO_2 and CH_4 from the initial stages to end-of-life. In essence, the CF is just one component within the broader LCA framework, covering only the climate aspect, while LCA provides a more complete and detailed picture of all environmental consequences.[10]

Table 2.3 — Comparison of LCA and CF

Feature	CF	LCA
Main focus	GHG emissions (climate impact)	All environmental impacts throughout the life cycle
Measurement scope	Single category (global warming/climate change)	Multiple categories (climate, water, land, toxicity, etc.)
Usefulness	Simple climate indicator; supports climate claims	Comprehensive tool for broad sustainability assessment
Application	Communication, compliance, climate strategy	Product design, regulatory reporting, eco-labeling
ISO Guidelines	ISO 14067, ISO 14064-1	ISO 14040, ISO 14044

2.5 International Guidelines for GHG Accounting and Reporting

Globally recognized organizations have established robust standards for CF and GHG assessment, supporting consistency, transparency, and comparability across sectors and regions. The most widely referenced frameworks ensure organizations can reliably quantify, monitor, and report GHG emissions at the organizational, project, and national levels. Notable international guidelines include:

a) ***The GHG Protocol: A Corporate Accounting and Reporting Standard***

This standard, developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), provides a comprehensive framework for organizations to identify, measure, and report their GHG emissions. It introduces the widely used Scope 1 (direct emissions), Scope 2 (indirect emissions from purchased electricity), and Scope 3 (other indirect emissions) categories. The Protocol ensures consistent, transparent, and credible reporting for corporate and organizational climate action.

b) ***ISO 14064 Series for Greenhouse Gas Accounting***

The ISO 14064 series, published by the International Organization for Standardization (ISO), sets globally recognized requirements and guidelines for the quantification, monitoring, reporting, and verification of GHG emissions and removals at both organizational (ISO 14064-1), project (ISO 14064-2), and validation/verification (ISO 14064-3) levels. This series is widely adopted across industries and supports both voluntary and mandatory reporting programs.

c) ***IPCC Guidelines for National Greenhouse Gas Inventories***

These guidelines provide a detailed, sector-specific methodology to estimate and report national GHG emissions and removals. The most recent version—the 2019 Refinement to the 2006 IPCC Guidelines—ensures national inventories are transparent and comparable under the UNFCCC, the Kyoto Protocol, and the Paris Agreement.

d) ***Publicly Available Specification*** **(*PAS 2050*)**

These guidelines, developed by the British Standards Institution (BSI), establish a standardized approach for evaluating the life cycle GHG emissions of goods and services—commonly known as product carbon footprint. It is widely used for both organizational reporting and calculating the CF of specific products.

e) *United States Environmental Protection Agency (US EPA) GHG Guidelines*

The US EPA's Greenhouse Gas Reporting Program and its extensive inventory guidance offer detailed methodologies for major emitters and organizations to measure and report GHG emissions. The EPA guidance is closely aligned with international standards, including the GHG Protocol and ISO series.

f) *EU Product and Organisation Environmental Footprint (PEF/OEF) Guidelines*

The European Commission's PEF and OEF methodologies offer a harmonized approach to evaluating and communicating the environmental impacts—especially the carbon footprint—of products and organizations within the EU. These guidelines align with the principles of LCA and support regulatory compliance and eco-labeling initiatives.

g) *DEFRA Environmental Reporting Guidelines*

DEFRA guidelines, issued by the UK Department for Environment, Food & Rural Affairs, provide a standardized approach for organizations to measure, manage, and report GHG emissions. Aligned with international standards, these guidelines include updated conversion factors and support both regulatory compliance and voluntary reporting, promoting transparency and consistent communication of environmental impacts.

All these guidelines offer consistent, transparent, and credible frameworks for measuring and reporting emissions across organizations, products, and countries. They facilitate global comparability, regulatory compliance, and climate action through harmonized methodologies. However, despite these international standards, many countries develop and promote their own localized guidelines tailored to their specific national contexts and regulatory requirements.

India's official regulatory framework for GHG accounting is anchored in the Carbon Credit Trading Scheme (CCTS). This system is overseen by the Ministry of Environment, Forest and Climate Change (MoEFCC), the Ministry of Power, and the Bureau of Energy Efficiency (BEE). Accredited verification agencies are responsible for ensuring compliance and reliability, thereby supporting a robust, standardized, and government-mandated approach to GHG accounting at both national and sectoral levels. This framework enables transparent reporting and advances India's climate commitments through effective monitoring and regulation.

Summary

The concept of the carbon footprint is widely used in climate policy, business, and public discourse to quantify GHG emissions caused by individuals, products, or activities, expressed as carbon dioxide equivalents (CO_2-eq). While CO_2 is the most prevalent GHG, other gases like methane (CH_4), nitrous oxide (N_2O), and fluorinated gases also significantly contribute to climate change. International agreements such as the Kyoto Protocol and Paris Agreement establish standardized frameworks for nations to monitor and report GHG emissions, enabling consistent and coordinated global climate action.

Organizations measure and manage emissions using established methodologies like Life Cycle Assessment (LCA), which evaluates all environmental impacts across a product's life span, and carbon footprinting, which focuses specifically on GHG emissions. Prominent international standards—the Greenhouse Gas Protocol, ISO 14064 series, and IPCC Guidelines—provide uniform methods for quantifying, reporting, and reducing emissions. These standards, together with national regulations from agencies like the US EPA, UK DEFRA, and the EU's PEF/OEF initiative, ensure data reliability and comparability across sectors and countries.

In India, greenhouse gas accounting is regulated under the Carbon Credit Trading Scheme (CCTS). This scheme mandates standardized reporting, independent verification, and compliance mechanisms, thereby reinforcing India's national climate commitments and providing a robust framework to monitor and reduce GHG emissions.

3. Methodology

3.1 Background

The ISO 14067 and ISO 14064-1 standards provide structured approaches for measuring GHG emissions, but at different scales. ISO 14067 focuses on quantifying the CF of individual products, evaluating their emissions across the entire life cycle—from raw material extraction to disposal—using a **functional unit** (such as per meter of fabric or per bedsheet). ISO 14064-1, on the other hand, provides guidelines for calculating and reporting total GHG emissions at the organizational level, covering all activities and sources within a company or cooperative, including direct and indirect emissions (Scopes 1, 2, and 3). Both standards emphasize transparent data collection, clear boundary definitions, and standardized reporting in terms of CO_2-eq.

For the handloom sector, the choice of measurement scale should align with assessment goals. Measuring at the product level (such as a sari or bedsheet), following ISO 14067, enables direct comparison between products and supports labeling or eco-certification. Evaluating individual processes like dyeing and weaving using life cycle assessment principles (ISO 14044) helps pinpoint emission hotspots and improve production efficiency. Furthermore, calculating the collective CF at the cluster or cooperative society level—using broader frameworks like ISO 14064-1—captures the overall impact generated by groups of weavers or production units operating together. This aggregated approach not only informs local and regional sustainability programs but also better supports buyer requirements and policy interventions aimed at reducing emissions across the entire value chain.

Figure 3.1 provides a step-by-step summary of the CF assessment process for the handloom sector. It starts with defining the assessment scope, including the product, boundaries, and functional unit. Data is then collected and converted into GHG emissions using standard emission factors. Finally, emissions are aggregated and the results are interpreted to identify major hotspots and guide sustainability improvements.

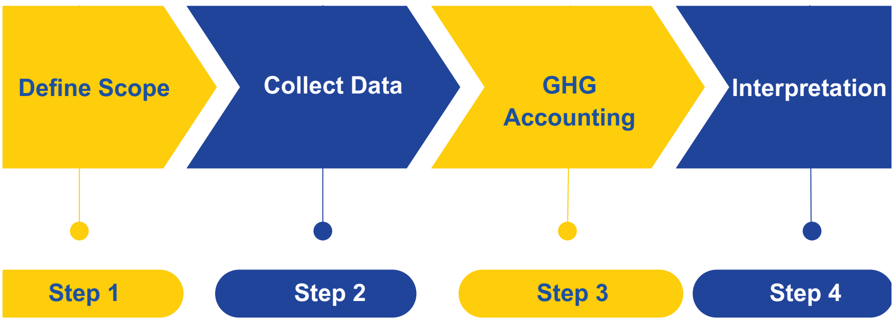


Figure 3.1 — Stages of GHG accounting methodology

3.2 Goal and Scope Definition

Goal

The goal of the CF assessment must be clearly articulated to ensure transparency, relevance, and utility for stakeholders. According to ISO 14044, the goal statement should include:

01. INTENDED APPLICATION

Quantify and communicate GHG emissions from handloom activities to support environmental management, product improvement, and certification needs.

02. REASONS FOR STUDY

Provide reliable data for labeling, sustainability reporting, internal management, and to highlight emission reduction opportunities across the value chain.

03. INTENDED AUDIENCE

Targeted toward producers, cooperatives, sustainability managers, policymakers, certifiers, business buyers, and environmentally conscious consumers.

04. COMPARATIVE ASSERTIONS

If used publicly for product or organizational comparisons, this must be clearly indicated and may require external independent review.

Example (Product Level)

The goal is to assess the CF of one handloom cotton bedsheet manufactured by XYZ Handloom Cooperative, supporting an Environmental Product Declaration (EPD) for use in eco-labeling and comparison with similar textile products.

Example (Organization Level)

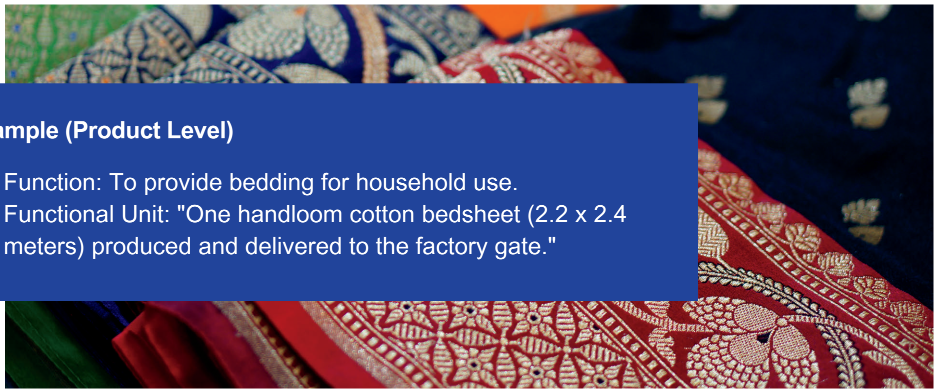
The goal is to quantify and report the total greenhouse gas emissions of XYZ Handloom Cooperative for the fiscal year, to support sustainability reporting, buyer disclosure, and the development of emission reduction strategies.

Scope

The scope of CF study sets clear boundaries to match the goal of the assessment. It defines whether we are measuring a single handloom product, like a bedsheet, or the total emissions from a whole organization, such as a handloom cooperative. The study describes exactly what is being measured, how much, and from which stages—starting from raw material up to packaging for products, or from all organizational activities for the whole cooperative. If more than one product is made, emissions are fairly divided between them. Reliable data sources and quality are specified to ensure accurate and trustworthy results.

3.3 Function and Functional Unit

The **function** in a CF study describes the main purpose or service that the product or organization delivers, acting as the basis for comparison and analysis. The **functional unit** (FU) is a clearly defined, quantifiable reference—such as a product amount, service delivered, or organizational output—against which all environmental data is measured and reported. Selecting an appropriate functional unit ensures consistency, relevance, and comparability of results across different studies or scenarios.



Example (Product Level)

- Function: To provide bedding for household use.
- Functional Unit: "One handloom cotton bedsheet (2.2 x 2.4 meters) produced and delivered to the factory gate."

Example (Organization Level)

- Function: To manufacture handloom textile products.
- Functional Unit: "Total annual production operations of XYZ Handloom Cooperative."

3.4 Defining the System

The system in CF assessment, or LCA, refers to all the processes, activities, and resources involved in creating a product or delivering a service. In the handloom sector, the system could include steps like cotton cultivation, ginning, spinning, weaving, dyeing, finishing, stitching, and packaging. Clearly outlining the system ensures all relevant environmental impacts are considered and reported.

3.5 Boundary Conditions (System Boundaries)

System boundaries define what is included and excluded in the assessment. Setting clear boundary conditions is essential for transparency, relevance, and comparability in CF studies.

Product Perspective

Operational Boundary:

Includes all steps directly involved in the product's creation, such as cotton cultivation, spinning, dyeing, weaving, finishing, and packaging.

Geographical Boundary:

Typically, covers where each process occurs (e.g., local farms, village spinning unit, local dye house).

Common Approach:

Cradle-to-Gate: Most common for product declarations (like EPDs); includes every stage from raw materials (cotton) to the point the completed bedsheet leaves the factory, excluding usage and end-of-life disposal.

Cradle-to-Grave: Can be used if wanting to include use phase and disposal/recycling impacts.

Organization Perspective

Organizational Boundary:

Defines which units are included (e.g., the entire cooperative, all associated home weavers, a cluster of weaving villages).

Operational Boundary:

All processes managed or influenced by the organization.

Scopes (GHG Protocol):

Scope 1: Direct emissions from fuel used in cooperative-owned generators or boilers.

Scope 2: Indirect emissions from purchased electricity powering weaving units or offices.

Scope 3: Other indirect emissions, like transportation of raw materials, staff commuting, outsourced finishing, and upstream cotton cultivation.

3.6 Process Tree

A process tree—also known as a process flow diagram—is a visual map outlining all the steps, inputs, and outputs involved in producing a product or operating an organization. It provides a structured way to represent how materials, energy, and emissions flow through the various activities and processes. This tree helps identify critical points for data collection, clarify system boundaries, and reveal where environmental impacts occur.

Product Level

(Handloom Bedsheet Example)

Organization Level

(Handloom Cooperative Example)

3.7 System Boundary Approaches

Cradle-to-Grave

This approach covers the entire product life cycle—from raw material extraction and production to distribution, use, and final disposal or recycling. (Figure 3.2).

Cradle-to-Gate

This approach evaluates all GHG emissions and resource use—from raw material extraction through each production stage—until the finished product exits the factory.

Gate-to-Gate

Focuses only on a specific segment or process within the overall product life cycle, typically within a single facility or operation—ignoring upstream and downstream activities.

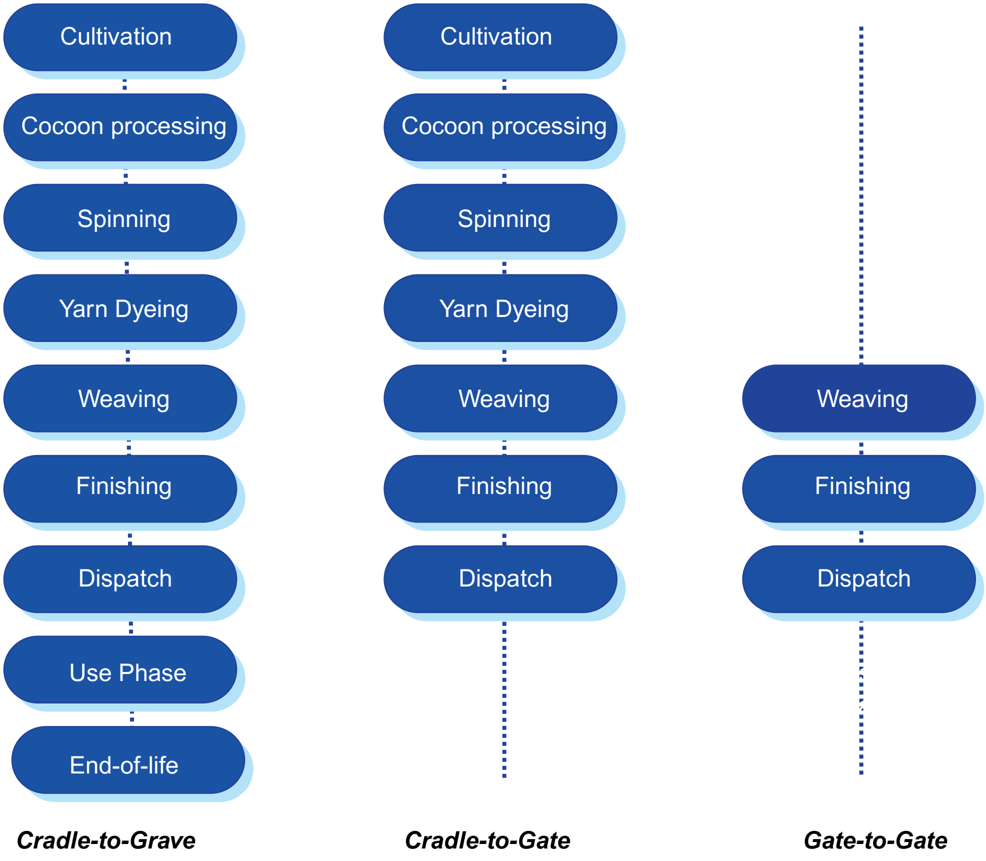


Figure 3.2 — System boundary approaches for a handloom silk sarees

3.8 Identifying Organisational Boundaries

When calculating GHG emissions, it is essential for handloom cooperatives and organizations to clearly define which parts of their operations are included. Handloom organizations can range from small, single-unit societies to large cooperatives managing multiple weaving units spread across different locations.

For instance, if a handloom cooperative society has partial ownership in a shared dyeing facility or operates jointly managed weaving centers with other cooperatives, it must decide how to allocate emissions from these operations. This is typically addressed using one of three recognized approaches (Table 3.1):

Equity Share

The organization accounts for GHG emissions based on its ownership share in each operation or facility. Emissions are reported in proportion to the percentage of equity owned.

Financial Control

The organization accounts for 100% of the emissions from operations over which it has the ability to direct financial and operating policies, regardless of its equity share.

Operational Control

The organization accounts for 100% of the emissions from operations where it has full authority to implement and enforce operating policies, regardless of ownership stake.

Table 3.1 — Examples of organisational boundary approaches for a handloom cooperative

Approach	Example for Handloom Cooperative Society
Equity Share	Reports 40% of emissions from a dyeing unit it owns 40%.
Financial Control	Reports 100% of emissions from a weaving unit whose finances it controls.
Operational Control	Reports 100% of emissions from a spinning unit it manages daily.

3.9 Scope 1, Scope 2, and Scope 3 Emissions

GHG emissions are classified into three categories—Scope 1, Scope 2, and Scope 3—to help organizations systematically measure and manage their CF.

a) *Scope 1: Direct Emissions*
These are emissions from sources that are owned or controlled by the organization. In the handloom sector, Scope 1 includes fuel combustion in on-site generators or boilers, emissions from company-owned vehicles used for raw material transport, and any direct process emissions from dyeing or finishing equipment.

b) *Scope 2: Indirect Energy Emissions*
Scope 2 covers indirect emissions from the generation of purchased electricity, steam, heating, or cooling consumed by the organization. For a handloom cooperative, this typically means accounting for the GHG footprint of electricity used to power looms, lighting, or machinery, even if the power is supplied by an external utility.

c) *Scope 3: Other Indirect Emissions*
These are all other indirect emissions that occur across the value chain. Examples for handloom operations include emissions from the cultivation of cotton, transportation of materials by third-party logistics, the production of purchased dyes and packaging, waste generated in operations, and even employee commuting.

3.10 Data Collection

CF assessment in the handloom sector relies on a structured and transparent approach to data collection. Accurate data enables credible calculation of CF across all life cycle stages—ranging from cotton cultivation and dyeing to weaving and finishing. Wherever possible, primary data should be collected directly from production records, utility bills, fuel receipts, and on-site measurements. When direct data is unavailable, credible secondary sources—such as published emission factors, industry databases, or supplier information—should be utilized.

Clear documentation of data sources, collection frequency, and any estimates or assumptions is essential to ensure both traceability and repeatability of results. More detailed information on data requirements, the specific questions asked at each stage of handloom operations, and the corresponding units of measurement is provided in Chapter 4. This guidance will support users in gathering and organizing the necessary data for a comprehensive and reliable CF assessment for handloom products.

3.11 Data Normalization

Normalization is a key step in CF assessment that ensures data consistency and accuracy by converting activity data into standardized units compatible with emission factors (e.g., kWh, litres, kilograms). This prevents calculation errors and allows GHG emissions to be reported per FU, such as per bedsheet or kilogram of yarn, enabling clear benchmarking.

The following example (Table 3.2) demonstrates typical activity data and the normalization process for assessing the CF of one cotton towel produced by a cooperative operating 150 looms. It illustrates how each data point corresponds to the functional unit (one cotton towel).

Functional Unit

- One cotton towel (e.g., size 70cm x 140cm), produced and ready for dispatch.

Table 3.2 — Example of activity data collection and normalization

Activity	Data Collected (for Cooperative / month)	Normalized Unit	Conversion/ Explanation	Total (per month)	Per Towel (FU)
Electricity	45,000 kWh	kWh	Electricity bills (for 150 looms, dyeing & admin)	45,000 kWh	0.90 kWh per towel (assuming 50,000 towels/month: 45,000/50,000)
Water for Dyeing	240,000 litres	m^3	Water meter/records ; 1 m^3 = 1,000 litres	240 m^3	4.8 litres per towel (240,000/50,000)
Cotton Yarn	6,000 kg	kg	Inventory usage records	6,000 kg	0.12 kg per towel (6,000/50,000)
Dye/Chemicals Used	300 kg dyes; 600 kg chemicals	kg	Purchase/inventory records (dye-house log)	–	0.006 kg dye and 0.012 kg chemicals/towel (by towel count)
Packaging Material	400 kg (cardboard & polywrap combined)	kg	Purchase/inventory records	400 kg	0.008 kg per towel (400/50,000)

3.12 Emission Factors

Emission factors are standardized values used to convert activity data—such as electricity consumed, fuel burned, or water used—into GHG emissions, usually reported as CO_2-eq. These factors are crucial for ensuring carbon footprint calculations are consistent, transparent, and comparable across different assessments. By applying emission factors to each input or process, based on reliable national, international, or sector-specific databases (Table 3.3), organizations can translate raw activity data into meaningful GHG emission estimates. Using standardized emission factors guarantees that all emissions are calculated with recognized methods, enables straightforward comparisons between different energy sources or materials, and supports credible aggregation and reporting of emissions per functional unit—whether at the product or organizational level.

Sources of Emission Factors

- National databases (e.g., India's Central Electricity Authority, CPCB, or equivalent)
- International guidelines (IPCC, DEFRA, IEA)
- Peer-reviewed LCA and sectoral studies

Table 3.3 — Emission factors for common inputs

Activity/Input	Unit	Typical Emission Factor	Source Example
Electricity (Grid, India)	kWh	0.73 kg CO_2e / kWh	CEA (India, 2025)
Diesel	litre	2.653 kg CO_2e / L	IPCC
LPG	kg	2.983 kg CO_2e / kg	IPCC
Water Usage	m^3	0.30 kg CO_2e / m^3 (includes supply/energy)	LCA Databases
Road Transport (Truck)	tonne-km	0.044–0.105 kg CO_2e / tonne-km	DEFRA (UK), National Data
Rail Transport	tonne-km	0.018 kg CO_2e / tonne-km	DEFRA (UK), National Data
Cotton Cultivation	kg	1.8 kg CO_2e / kg	Literature/Sector Studies
Yarn Processing	kg	2.0 kg CO_2e / kg	LCA Studies

EF values can vary based on geography, technology, and data source.

3.13 Carbon Footprint Calculation

Step 1: Assign Emission Factors

For each activity or input (section 3.9)—such as electricity use, diesel, cotton yarn, or water —assign the relevant EF sourced from credible national or international databases (e.g., IPCC, Government of India).

Step 2: Calculate Emissions by Input

Apply the standard formula for each activity:

Emissions (kg CO2-eq) = Activity Data × Emission Factor

Repeat this calculation for every input and process involved in the product's life cycle.

Step 3: Sum Total Emissions

These are all other indirect emissions that occur across the value chain. Examples for handloom operations include emissions from the cultivation of cotton, transportation of materials by third-party logistics, the production of purchased dyes and packaging, waste generated in operations, and even employee commuting.

Example: GHG calculation for 1 Handloom Cotton Towel (Table 3.4)

Functional Unit

- One cotton towel produced and ready for dispatch.

Table 3.4 — Sample data and calculation

Input/Activity	Activity Data per Towel	Emission Factor	Emissions (kg CO_2-eq)
Electricity	0.90 kWh	0.73 kg/kWh	0.657
Diesel	0.02 litre	2.653 kg/litre	0.053
Water for Dyeing	4.8 litres	0.0003 kg/litre	0.0014
Cotton Yarn	0.12 kg	1.8 kg/kg	0.216
Packaging	0.008 kg	1.3 kg/kg	0.0104
Total			0.939

Note: The data in this example are for illustration only and do not reflect actual industry values.

3.14 Interpretation

Once total GHG emissions are calculated (section 3.11), the next crucial step is data interpretation. This process helps translate raw numbers into meaningful insights for decision-making and improvement.

Hotspot Analysis

- Identify which processes or inputs contribute the most to the overall CF.
- For a handloom product, this might reveal that electricity use in weaving or emissions from yarn production are major sources (Example, Table 3.5).

Benchmarking

- Compare the results with similar products, industry averages, or past performance.
- This helps assess if the product or operation is above or below sector norms and highlights areas for progress.

Sensitivity Analysis

- Examine how changes in major data points (e.g., switching to renewable energy, improving efficiency) would affect the total emissions.
- This allows prioritization of actions with the highest potential impact.

Communicating Results

- Share findings with stakeholders—management, buyers, and policymakers.
- Provide context so that non-technical audiences can understand the main sources of emissions and practical improvement options.

Table 3.5 — Hotspot analysis for a cotton towel

Process/Input	Emissions (kg CO_2-eq per towel)	% of Total
Cotton Yarn	0.216	23%
Electricity	0.657	70%
Water for Dyeing	0.0014	<1%
Others	0.0634	7%
Total	0.939	100%

Note: The data in this example are for illustration only and do not reflect actual industry values.

Summary

This chapter presents a clear and flexible methodology for measuring the CF of handloom products and organizations, grounded in international standards such as ISO 14067 (for products) and ISO 14064-1 (for organizations). Recognizing the handloom sector's diversity, the approach allows alignment of system boundaries and measurement scales with specific assessment goals—whether assessing a single product (like a handloom bedsheet, for eco-labeling and product comparisons) or an entire cooperative (supporting group-level sustainability reporting and improvements).

Key elements include precise definition of assessment goals, scope, and functional units, along with clear delineation of organizational and operational boundaries. These boundaries encompass all relevant inputs (materials, energy, water), life cycle stages (from cotton cultivation to packaging), and emissions categories (Scope 1, 2, and 3), ensuring robust and transparent CF calculations for both internal management and external communication.

The recommended four-step process comprises:

Step 1: Defining the goal and scope
Step 2: Collecting standardized data
Step 3: Conducting GHG accounting using credible national and international emission factors
Step 4: Interpreting results for informed decision-making

The framework uses both direct (primary) and indirect (secondary) data, with normalization to guarantee unit compatibility and calculation accuracy. Emissions are calculated for each input using the formula: ***Emissions = Activity Data × Emission Factor***, then aggregated for the product or organization. Interpretation includes hotspot analysis, benchmarking, and sensitivity analysis to evaluate potential improvements.

Overall, this structured methodology supports environmental management, product and process improvement, regulatory compliance, and transparent communication with all stakeholders in the handloom sector.

4. Data Collection

4.1 Background

India's handloom sector is among the world's largest, employing over 3.5 million people—more than 70% of whom are women—and serving as a cornerstone of rural livelihoods, second only to agriculture. Its organizational structure ranges from household-based operations to cooperatives and regional clusters, supporting local economies, community cohesion, and the preservation of cultural heritage. With a diverse portfolio that includes sarees, dress materials, and home furnishings for domestic and export markets, production remains largely unmechanized, relying on human labor and locally sourced materials. This results in significantly lower energy and water consumption compared to mechanized textile manufacturing, especially in clusters situated in traditional weaving regions.

Accurate and systematic data collection is essential for credible CF assessment within this decentralized sector. The diversity in unit size, organizational structure, and production techniques demands customized data collection strategies to reflect variations in raw material sourcing, resource usage, and waste generation. Mapping the architecture of the handloom supply chain—from raw material procurement to finished goods—enables stakeholders to identify emission hotspots and implement targeted mitigation strategies. A comprehensive understanding of these processes not only strengthens carbon accounting but also supports the creation of stage-specific data templates, ensuring emissions from each activity, transfer, and mode of transport are effectively recorded and managed.

4.2 Domains and Data Points

India's handloom sector encompasses a diverse and largely decentralized network of units operating across rural and urban landscapes, each contributing uniquely to carbon emissions through their location, infrastructure, organizational type, size, production processes, and resource usage. The sector's emissions profile is shaped by factors such as dwelling types, energy sources, scale of operations, types of activities (from pre-loom to post-loom processes), raw material procurement, logistics, and waste management. To comprehensively assess and reduce the carbon footprint within this sector, systematic data collection must target specific points across each of these domains, ensuring that both direct and indirect emissions from every aspect of handloom operations are accounted for (Table 4.1).

Table 4.1 — Key areas and data collection points in handloom for CF assessment

Area	Data Collection Points	Example
Location & Infrastructure	Site type; basic utilities	Rural village
Unit/Entity Type	Household/non-household; production scale	Cooperative unit
Types of Activities	Main work/process types	Loom weaving
Process Stages & Activities	Process steps; loom types	Dyeing process
Raw Material Sourcing	Material type, source, quantity	Cotton yarn usage
Energy & Fuel Use	Type and amount of energy/fuel	Wood usage
Water Use	Water source and quantity	Borewell water
Transport & Logistics	Product quantity; Distance travelled	120 km by truck
Waste Generation / Management	Waste types, quantity, and disposal	Effluent discharge
Workforce & Operational Scale	Number of units; workforce; management type	20 Looms

4.3 Process Data Collection Templates

To ensure a systematic and comprehensive CF assessment in the handloom sector, it is vital to use standardized data collection templates tailored to each key production or process stage. These templates function as practical tools to capture consistent, detailed, and process-specific information on resource use, energy consumption, emissions, and outputs.

For each process—such as weaving, dyeing, spinning, finishing, or packaging—the templates should specify essential input and output parameters, including material types and quantities, energy sources and usage, water consumption, chemicals or dyes applied, waste generated, and relevant operational details (e.g., number of looms, batch size, shift patterns).

Applying these standardized templates consistently improves data accuracy, facilitates identification of environmental hotspots, and enables benchmarking and comparative analysis across products, processes, and organizational units over time.


Dyeing


Winding


Weaving


Warping

Degumming (Silk Yarn)

Question	Units/Details
What quantity of silk yarn is processed per batch?	kg
What chemicals (type and quantity) are used for degumming?	Type, kg/litres
What is the volume of water used in degumming?	litres
What is the temperature and duration of degumming?	°C, hours/minutes
What type and quantity of fuel/energy is used for heating?	Type, litres/kg/m^3
How much electricity is consumed?	kWh
What is the volume & composition of wastewater generated?	litres, COD/BOD/pH

Hot and Cold Wash Process

Question	Units/Details
What is the volume of water used for washing?	litres
What chemicals or detergents are added (type and quantity)?	Type, kg/litres
What is the temperature and duration of washing?	°C, hours/minutes
What type and quantity of fuel/energy is used for heating?	Type, litres/kg/m^3
How much electricity is consumed?	kWh
What is the volume and chemical composition of wastewater generated?	litres, COD/BOD/pH

Note: *These templates present core questions and data points for CF assessment in handloom operations. For more detailed or specialized emission analysis, additional or process-specific questions may be required.*

Warping Process

Question	Units/Details
What is the electricity consumption for warping?	kWh
Are any chemicals or lubricants used?	Type, kg/litres
What is the volume of waste generated?	kg

Packaging

Question	Units/Details
What type and quantity of packaging materials are used?	Type, kg
What is the batch size for packaging/dispatch?	kg

Weaving Process

Question	Units/Details
What is the total quantity of yarn used (warp, weft, zari)?	kg
What is the electricity consumption for weaving?	kWh
Are any chemicals or lubricants used during weaving?	Type, kg/litres
What is the volume of waste generated (yarn waste, trimmings, etc.)?	kg

Note: *These templates present core questions and data points for CF assessment in handloom operations. For more detailed or specialized emission analysis, additional or process-specific questions may be required.*

Dyeing

Question	Units/Details
What type and quantity of dyes are used (natural/synthetic)?	Type, kg
What chemicals or auxiliaries are added (type and quantity)?	Type, kg/liters
What is the volume of water used for dyeing and rinsing?	litres
What is the temperature and duration of dyeing?	°C, hours/minutes
What type and quantity of fuel/energy is used for heating?	Type, litres/kg/m^3
How much electricity is consumed?	kWh
What is the volume and composition of wastewater generated?	litres, COD/BOD/pH
What is the quantity of solid waste (e.g., leftover dyes, sludge) generated?	kg

Ironing

Question	Units/Details
Type of ironing/pressing equipment used	Manual, steam, electrical
Quantity of items ironed/pressed per batch	Pieces/batch
Duration and temperature of ironing/pressing per batch	Hours/minutes, °C
Type and quantity of energy used (electricity, steam/LPG)	kWh, kg, litres
Total water use (if steam) and solid waste generated	litres, kg/type

Note: *These templates present core questions and data points for CF assessment in handloom operations. For more detailed or specialized emission analysis, additional or process-specific questions may be required.*

4.4 Product Footprint Data Collection Flow

The product footprint data collection flow systematically captures resource use, energy inputs, and emissions at each stage of a handloom product's life cycle—from raw material sourcing and pre-processing to weaving, finishing, packaging, and distribution.

Step 1 - Define Product & Goal

- State the functional unit (e.g., "1 saree")
- Set system boundaries (cradle-to-gate, gate-to-gate, cradle-to-grave)

Step 2- Map Life Cycle Stages

- Raw material extraction/procurement
- Pre-processing (spinning, dyeing, etc.)
- Weaving (manufacturing)
- Post-processing (washing, finishing, packaging)
- Distribution/transport
- Use phase (if relevant)
- End-of-life disposal or recycling

Step 3- Detail Activities at Each Stage

- List all activities/processes per stage
- Identify input and output flows (materials, energy, waste)

Step 4- Data Collection Points

- Primary data: Direct measurements or records (energy, material input)
- Secondary data: Database emission factors for upstream/downstream stages

Step 5- Gather Activity Data

- Quantities of each input/output per process/stage
- Transport distances and mode for each material/product transfer
- Waste generated and treatment type

Step 6 - Apply Emission Factors

- Assign relevant emission factors to each activity data

S***tep 7*** - **Calculate Total Product Carbon Footprint**

- Multiply activity data (per FU) by their emission factors at each stage
- Sum all stage-wise emissions for total product footprint

4.5 Process Level Data Collection Flow

Detailed process-level data collection is crucial for the handloom sector, where emissions per unit are often lower but highly variable, enabling precise mitigation and improvement strategies. The process-level data collection flow focuses on systematically tracking resource inputs, energy use, material consumption, and waste outputs for each discrete production process or operation, enabling pinpointing of emission sources and supporting targeted efficiency and emission reduction strategies (e.g., data collection for the dyeing process in a handloom unit).

Step 1 - Identify All Processes within the System Boundary

For a handloom unit, this often includes processes such as:

- Yarn dyeing
- Loom operations (weaving)
- Preparatory steps (e.g., sizing, warping)
- Finishing processes
- Packaging

Step 2 - List Inputs and Outputs for Each Process

- Energy types and consumption (electricity, biomass, fossil fuels)
- Material use (dyes, auxiliaries, packaging)
- Waste streams (effluents, scraps)

Step 3 - Determine Measurement Points

- Metered energy use, bills, supplier records, direct observations
- Track procurement or stock records
- Quantify waste via weigh scales, effluent monitoring equipment, or regular visual surveys

Step 4 - ***Collect Quantitative Data***

- Record quantities and frequencies
- Distinguish between sourced and onsite operations

Step 5 - Assign Process-Specific Emission Factors

Use localized or average emission factors as available. These may be sourced from:

- National GHG inventory guidelines
- IPCC reports
- Scientific literature

Step 6 - Compute Emissions per Process

Process Carbon Footprint = Activity Data × Emission Factor

4.6 Organization Level Data Collection Flow

Collecting organization-wide data enables handloom enterprises to meet compliance requirements, attract sustainability-conscious buyers, and prioritize improvements across their value chain. This involves systematically gathering and aggregating data on all emissions sources and resource consumption activities under the control of a handloom entity—whether a cooperative society, producer company, or master weaver setup. This includes capturing energy and water usage, procurement of raw materials, waste generation, employee commuting, transportation of goods, and any centralized services or production auxiliaries. By collecting and standardizing information across different departments, production facilities, or operational units, organizations can calculate their total CF, identify emission hotspots, and inform decisions for both compliance and improvement.

Step 1 - Define Reporting Scope and Organizational Boundaries

- Decide which sites (production centers, administrative offices) and entities (departments, subsidiaries) are included, based on operational or financial control.

Step 2 - Map Organizational Activities

- Energy: Electricity use for lighting, heating, loom operation; direct diesel/LPG
- Logistics: Material and product transport (company or hired vehicles)
- Procurement: Yarn, dyes, packaging, machinery
- Other: Employee commuting, water use, waste management

Step 3 - Identify Data Sources

- Collect data from: utility bills, purchase records, travel logs, payroll (for commuting), waste invoices

Step 4 - Develop Data Collection Templates

- Design standardized spreadsheets or software forms, organized by facility or department

Step 5 - Aggregate Collected Data

- Combine each department’s summaries for a full organization-wide dataset

Step 6 - Apply Appropriate Emission Factors

- Use grid region emission factors for electricity, supplier life-cycle data for purchased goods, and government/sector values for fuel types.

Step 7 - Calculate Organization-Wide Carbon Footprint

- Sum all calculated emissions by scope (Scope 1, 2, and 3 as relevant)

Summary

This chapter presents a robust framework for capturing carbon footprint data tailored to the complexities of India's decentralized handloom sector. It highlights the necessity of accurate, process-specific, and organization-wide data collection, accounting for the sector's varied unit types, diverse activities, and resource use patterns. By offering structured templates for each key production step—from raw material sourcing and dyeing to weaving, finishing, and packaging—the chapter ensures critical data points are systematically recorded. These templates are designed not only to facilitate comprehensive data gathering at the product, process, and organizational levels but also to enable meaningful aggregation, benchmarking, and comparative analysis across the sector.

Additionally, the chapter details a clear, stepwise approach to data collection at all operational levels, empowering both small household units and large cooperatives to track and manage their emissions and resource consumption rigorously. By emphasizing standard protocols and actionable formats, it provides the foundation for credible carbon accounting and supports the sector's transition toward greater sustainability.

The subsequent section features practical case studies that demonstrate how these data collection steps are applied in real-world handloom scenarios, offering readers deeper insight into effective CF assessment in practice.

Annex A

Carbon Footprint of Handloom Cotton Bedsheet

1. Background

The Kannur cluster in Kerala is celebrated for its exquisite handloom cotton products, particularly cotton bedsheets that symbolize comfort and tradition. Known for their superior softness, durability, and breathability, these bedsheets are crafted using age-old weaving techniques unique to the region. Weavers incorporate vibrant patterns and intricate designs, reflecting Kerala's rich cultural heritage. The cotton used is naturally absorbent and ideal for warm climates, making Kannur's bedsheets highly sought after for personal and household use. This blend of quality cotton and skilled craftsmanship positions the Kannur cluster as a prominent hub for premium handloom cotton bedsheets.

2. Goal and Scope

This study aims to help handloom weavers, cooperatives, government agencies, and textile stakeholders understand how to measure the CF of handloom processes in cotton bedsheet production. It provides a clear methodology to calculate emissions from traditional handloom manufacturing, supporting informed efforts to reduce environmental impact.

For this CF assessment, the study adopts a **gate-to-gate** system boundary, starting from the point at which cotton yarn is supplied by the National Handloom Development Corporation (NHDC) to the cooperative society at Kannur. The assessment includes all activities, including the transport of yarn from the supplier, receipt and storage at the cooperative, preprocessing, dyeing, weaving, post-weaving treatments, cutting, stitching, quality control, packaging, and internal transportation. It also covers waste management and utility usage (electricity, fuel, water) throughout these processes.

3. Boundary Conditions

System Start
The assessment begins with the arrival of ready-to-use cotton yarn at the cooperative society from NHDC.

System End
The system boundary ends at the completion of bedsheet packaging, before distribution to retailers or consumers.

Included Processes

This CF assessment encompasses all key operational processes directly controlled and executed by the handloom cooperative society related to the production of the cotton bedsheet.

- ***Transport and Procurement of Cotton Yarn***: Transporting yarn from the supplier (e.g., NHDC) to the cooperative.
- ***Receiving and Handling Ready-to-Use Cotton Yarn*** - Inspection, storage, and preparation of yarn for weaving.
- ***Weaving*** - Handloom operations converting cotton yarn into fabric using traditional methods.
- ***Wet Processing*** - This include processes, degumming, washing, dyeing and finishing, as relevant to the bedsheet production.
- ***Cutting, Stitching and Packaging*** - Tailoring the woven fabric into bedsheet form, including hemming and quality control.
- ***Onsite Utilities and Support*** - Energy and water consumption within the cooperative facility, including lighting, machinery operation, and waste management related to production.

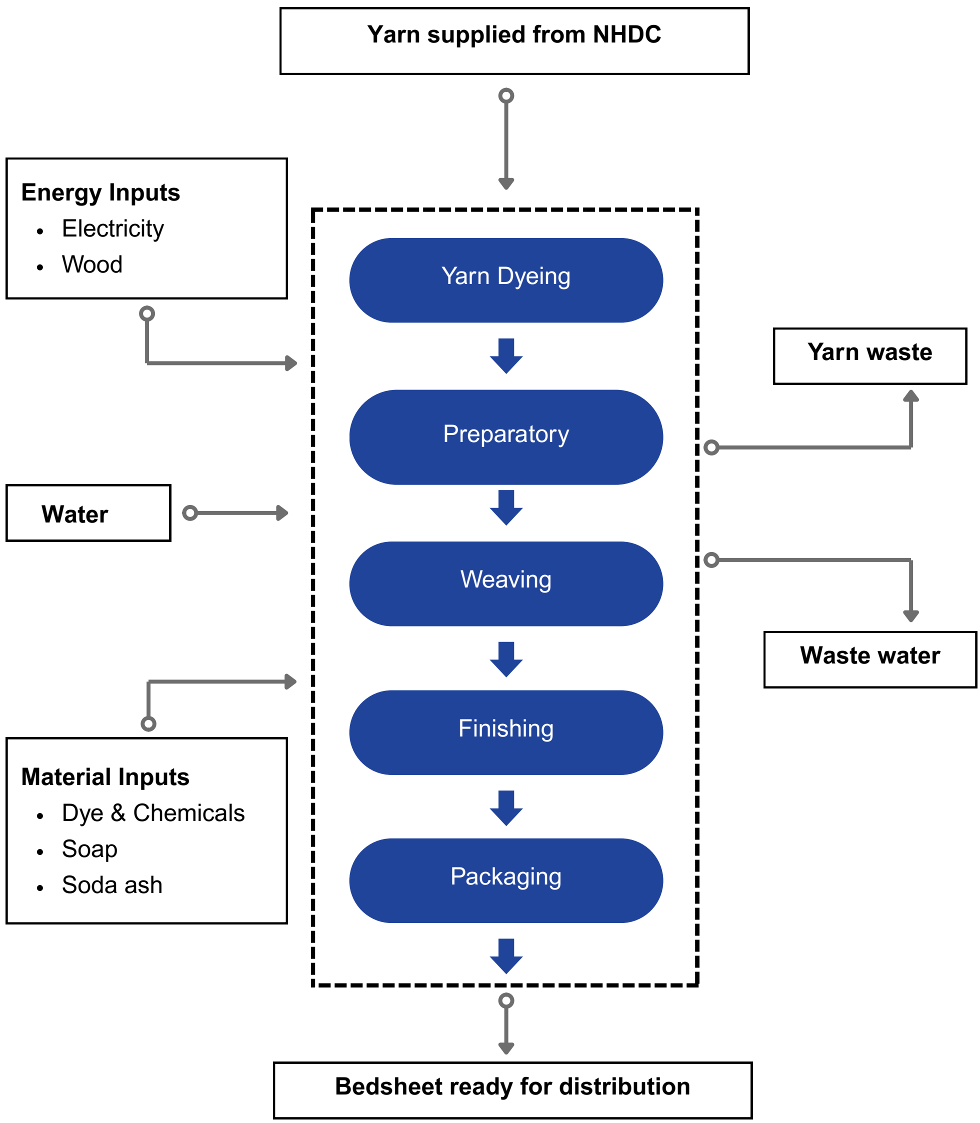
Excluded Upstream and Downstream Processes

The assessment excludes upstream processes like cotton cultivation, ginning, fiber cleaning, and yarn manufacturing, along with related inputs and transport. It also omits downstream activities such as product distribution, consumer use, and end-of-life disposal or recycling.

4. Functional Unit

One finished handloom cotton bedsheet, weighing 565 gm, with dimensions of 60 inches by 90 inches (approximately 152cm × 229cm), ready for packaging and distribution.

5. Process Tree and Material Flow



6. Inventory Dataset (per FU)

At each step of producing the handloom cotton bedsheet, data on inputs (electricity, water, chemicals, materials) and outputs (waste, finished product) were systematically collected and tracked through direct measurements, records, and operator interviews (Table A1). For shared resources, figures were proportionally attributed to each bedsheet. All data were then normalized to reflect the resource use and emissions for one standard bedsheet (565g, 60in × 90in), ensuring consistency and comparability across the entire production process.

7. Emission Factor

For this assessment, emission factors were sourced from internationally recognized and robust databases—including EPA, Ecoinvent v3.11, GaBi, and CEA—to ensure accuracy, consistency, and transparency in CF calculations for all process inputs and outputs (Table A2). These sources were selected for their credibility and relevance to textile sector activities, enabling reliable quantification of GHG emissions throughout each stage of the handloom bedsheet production process.

8. Carbon Footprint Calculation

The CF calculation presented in the Table A3 involves converting all activity values for each process input or output into standardized units compatible with the corresponding EF. Each activity value is then multiplied by its respective EF, resulting in total GHG emissions expressed as kilograms of kg CO_2-eq. The results further break down the contribution of each input or process step as a percentage of the overall CF, providing valuable insight into the most significant emission sources in the production of the handloom cotton bedsheet.

Table A1 — Inventory Dataset (per FU)

Activity	Activity Data (per FU)	Unit
Wastewater treatment	107.5	Litre
Transport (truck)	250	km
Yarn Waste	0.012	kg
Dye	0.008	kg
Caustic Soda	0.016	kg
Sodium hydrosulphite	0.016	kg
Water	108.7	Litre
Electricity	0.38	kWh
Wood	0.36	kg
Wastewater disposed	107	Litre
Soap	0.001	Litre
Wetting Oil	0.001	Litre
Soda ash	0.006	kg

Table A2 — EF values used for CF calculation

Activity	EF	Unit	Source of EF
Wastewater Treatment	0.947	kg CO_2-eq/m3	Ecoinvent v3.11
Transport (truck)	0.160	kg CO_2-eq/metric ton*km	Ecoinvent v3.11
Yarn Waste	0.990	kg CO_2-eq/kg	Ecoinvent v3.11
Dye	2.540	kg CO_2-eq/kg	GaBi
Caustic Soda	1.350	kg CO_2-eq/kg	Ecoinvent v3.11
Sodium Hydrosulphite	2.290	kg CO_2-eq/kg	Ecoinvent v3.11
Water	0.001	kg CO_2-eq/kg	Ecoinvent v3.11
Electricity	0.730	kg CO_2-eq/kWh	CEA
Wood	1,640	kg CO_2-eq/Short ton (907 kg)	EPA
Wastewater disposed	0.038	kg CO_2-eq/kg	Ecoinvent v3.11
Soap	4.624	kg CO_2-eq/kg	Ecoinvent v3.11
Wetting Oil	2.885	kg CO_2-eq/kg	Ecoinvent v3.11
Soda ash	0.45	kg CO_2-eq/kg	Ecoinvent v3.11

Table A3 — CF calculation for a cotton bedsheet (per FU)

Activity	Emmision (kg CO_2-eq)
Yarn Waste	0.012
Dye	0.020
Caustic Soda	0.021
Sodium Hydrosulphite	0.036
Water	0.143
Electricity	0.273
Wood	0.643
Transport (truck)	0.024
Soap	0.004
Wetting Oil	0.003
Soda ash	0.003
Wastewater disposed	0.0040
Wastewater treatment	0.102
Total	**1.285**

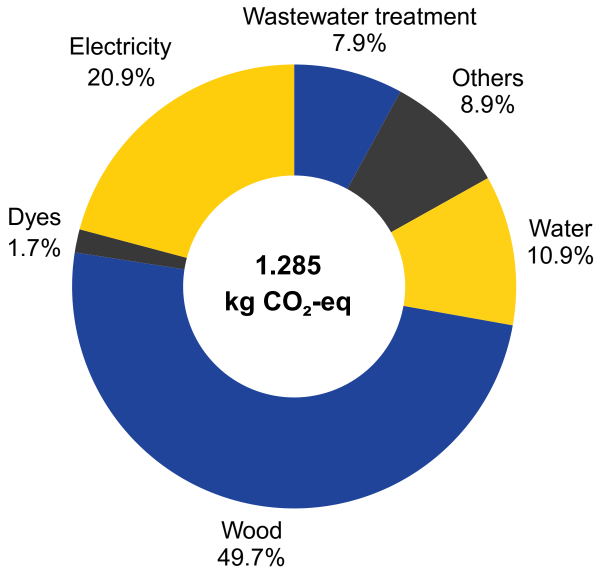


Figure A1 — CF breakdown by process input (%)

9. Interpretation

The CF assessment indicates that wood—used predominantly as a heating fuel—accounts for almost half (49.7%) of the total GHG emissions generated per handloom cotton bedsheet. Electricity (20.9%) and water usage (10.9%) also make substantial contributions to the overall CF. By comparison, chemicals (including dyes at 1.7%) and wastewater treatment (7.8%), along with other minor sources (8.9%), have a relatively smaller impact. To achieve the most significant reductions in the bedsheet's CF, interventions should prioritize increasing energy efficiency—especially in fuel and electricity use—and optimizing water consumption during production.

When comparing total emissions, the handloom process for a cotton bedsheet (1.30 kg CO_2-eq per 565 g bedsheet) is markedly less carbon intensive than the equivalent powerloom process (5.08 kg CO_2-eq per 565 g output, based on Ecoinvent v3.11 data, including both weaving and dyeing operations). The powerloom process, characterized by higher electricity consumption and mechanization, results in nearly four times the emissions of the traditional handloom route. This substantial difference emphasizes the sustainability advantage of handloom production methods, which have a much lower environmental footprint.

Further improvements in fuel efficiency and water use within handloom operations can enhance this advantage, making handloom bedsheets even more attractive from a climate and ecological perspective.

10. Recommendations

To effectively reduce the CF of handloom bedsheet production, the main focus should be on improving energy efficiency at every stage of the process. Using cleaner fuels or switching to renewable energy sources like solar or biogas can significantly lower emissions from heating and electricity use. Alongside energy, managing water wisely by conserving and recycling it wherever possible will help reduce the environmental impact. Additionally, exploring the use of alternative materials that cause less pollution, and cutting down waste through better process management and recycling, are important steps toward a greener production.

It's important to note that this study is based on data collected from a single local handloom cooperative. Because of this, the results may not represent the entire handloom or weaving industry, as different regions and producers may use varying technologies, materials, or methods that affect their emissions. The scale of operations and local practices can also cause differences in the carbon footprint from one producer to another.

Another key point is that there are uncertainties in both the data gathered and the emission factors used to calculate the carbon footprint. These uncertainties mean that variations in emission factors can have a meaningful effect on the final results. To understand how much the carbon footprint might change based on different assumptions or data, it is useful to carry out sensitivity analyses. This helps confirm which factors have the most influence and improves confidence in the findings.

Overall, the results of this research should be seen as indicative of the specific local context studied. For a broader understanding of the entire sector, more comprehensive assessments covering multiple locations and producers are needed. These wider studies can help inform policies, sustainability strategies, and improvements at an industry level.

Annex B

Carbon Footprint of Balaramapuram Saree

1. Background

This study examines the carbon footprint (CF) of Balaramapuram sarees, renowned for their rich heritage, intricate craftsmanship, and lasting quality.[11] Originating from the Balaramapuram cluster near Thiruvananthapuram, Kerala's capital, these handloom sarees are celebrated for their cream-and-gold Kerala weave, locally known as "kasavu." The kasavu sarees are distinguished by the golden zari borders and age-old weaving traditions, making them a symbol of elegance for both everyday and festive occasions.

The cluster's weaving practices are rooted in Kerala's oldest handloom heritage, blending innovative dyeing techniques and ayurvedic treatments that use natural herbs and plant extracts. In recognition of their authenticity and unique methods, Balaramapuram weaves received Geographical Indication (GI) status in 2010. Today, these sarees represent a harmonious blend of cultural tradition, skilled artistry, and holistic well-being, making them highly valued throughout India and beyond.

2. Goal and Scope

This study aims to assist handloom weavers, cooperatives, government agencies, and textile stakeholders in understanding how to measure the CF of handloom processes involved in Balaramapuram saree production.

For this CF assessment, a gate-to-gate system boundary is adopted, beginning with the procurement of warp and weft yarn from the NHDC to the handloom society in Balaramapuram. The assessment covers all activities, including yarn transport from local suppliers, receipt and storage at the cooperative, preprocessing, weaving, post-weaving treatments, quality control, packaging, and internal transportation. It also includes waste management and the use of utilities such as electricity, fuel, and water throughout these processes.

3. Boundary Conditions

System Start
The assessment begins with the procurement of ready-to-use cotton and zari yarn by the cooperative society from NHDC.

System End
The system boundary concludes with the completion of Balaramapuram saree packaging, prior to distribution to retailers or consumers.

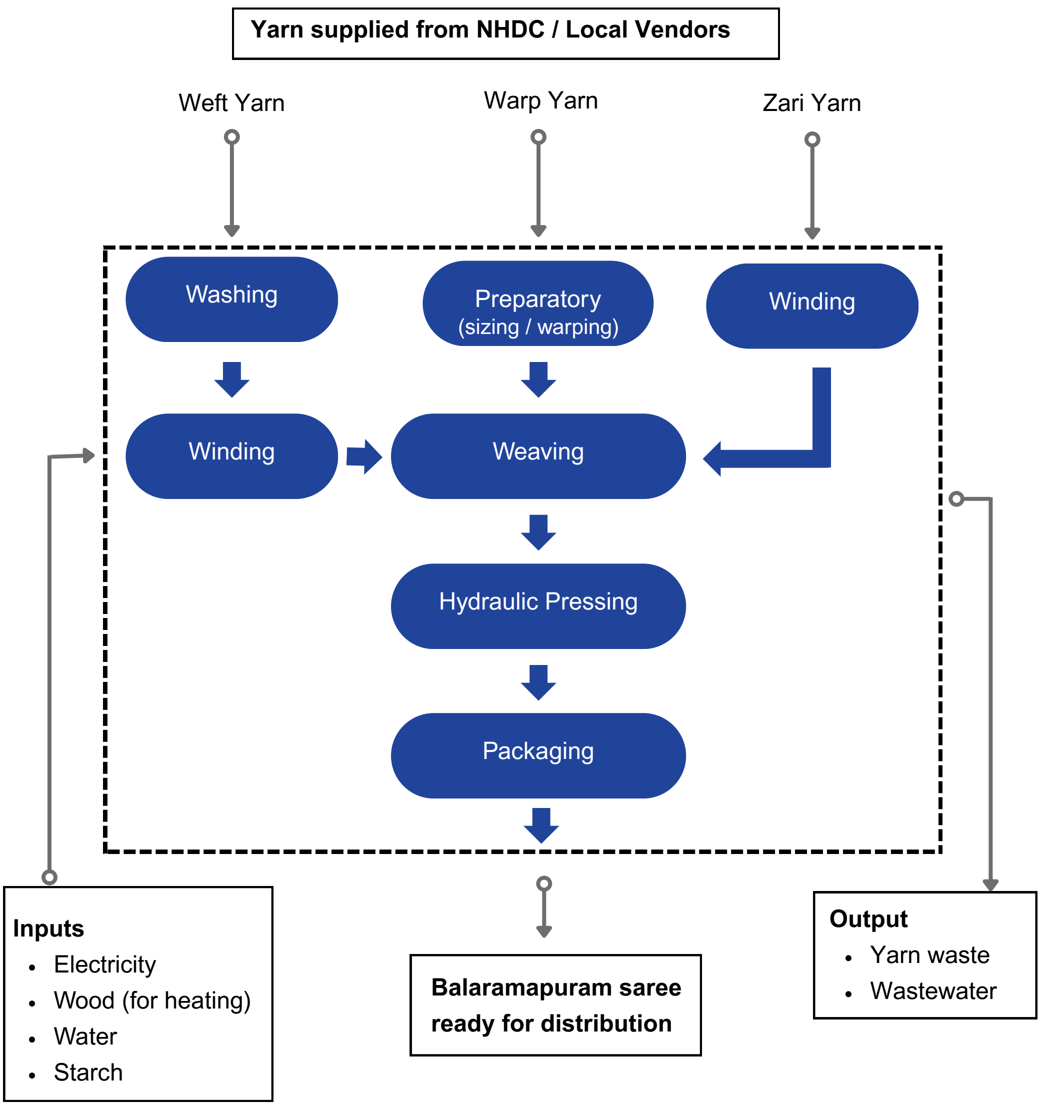
Excluded Upstream and Downstream Processes

The assessment excludes upstream activities such as cotton cultivation, zari yarn production, ginning, fiber cleaning, yarn manufacturing, and associated inputs and transportation. It also omits downstream processes, including product distribution, consumer use, and end-of-life disposal or recycling.

4. Functional Unit

One finished handloom Balaramapuram saree, weighing 800 gm, with dimensions of 55 inches in width and 6.5 meters in length, ready for packaging and distribution.

5. Process Tree and Material Flow



6. Inventory Dataset

Table B1 — Inventory Dataset (per FU)

Activity	Activity Data (per FU)	Unit
Transport (scooter, for yarn sourcing)	10	km
Yarn Waste	0.015	kg
Water	4	Litre
Electricity	1.28	kWh
Wood	0.5	kg
Starch	0.25	kg
Packaging	0.015	kg

7. Carbon Footprint Calculation

Table B2 — CF calculation for a Balaramapuram saree (per FU)

Activity	Emmision (kg CO_2-eq)
Transport (scooter, for yarn sourcing)	0.05
Yarn Waste	0.014
Water	0.005
Electricity	0.93
Wood	0.904
Starch	0.36
Packaging	0.06
Total	**2.33**

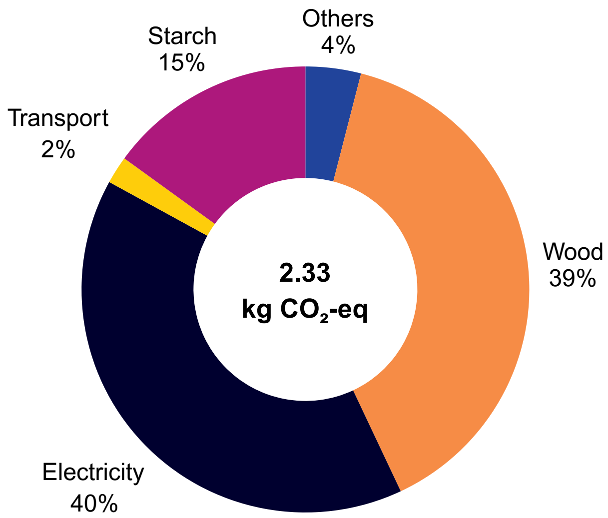


Figure B1 — CF breakdown by process input (%)

8. Interpretation

Based on the collected data, the main contributors to the CF of the Balaramapuram saree are electricity (40%) and wood (38.8%), followed by starch (15.3%), transport (2.23%); packaging (2.75%), yarn waste (0.62%) and water (0.23%) contribute minimally.

This breakdown highlights that electricity and wood used for process energy are the dominant emission sources. Starch also have notable impacts, while other inputs are comparatively minor. Therefore, the most effective strategies for reducing the saree's CF include improving energy efficiency, shifting to renewable or cleaner fuels and reducing starch consumption. Focusing on these areas can help Balaramapuram saree producers significantly lower emissions and advance sustainable handloom saree manufacturing.

9. Recommendations

This assessment is based on data collected from a specific local cooperative in Balaramapuram and may not fully capture the diversity of handloom saree production processes or weaving units across the region. Significant differences in technology, resource availability, scale of operation, and regional practices can affect results in other clusters or among different producers.

Additionally, uncertainties in data quality and emission factors may introduce variability into the findings. Conducting sensitivity analysis is advised to assess how key parameters—such as energy consumption, raw material choices, or emission factors—impact the overall CF results.

Therefore, these findings should be viewed as indicative of the local context of Balaramapuram. For broader or sector-wide conclusions, more comprehensive studies including multiple units or clusters are recommended to reflect the full range of handloom saree production practices.

Annex C

Carbon Footprint of Tangail Saree

1. Background

This study focuses on the CF of Tangail sarees, now mainly produced in West Bengal's Fulia cluster. Skilled artisans from Nadia and Purba Bardhaman districts have preserved and adapted the traditional weaving techniques, creating sarees known for their fine texture and intricate patterns. Recognized as symbols of Bengali cultural heritage and craftsmanship, Tangail sarees are cherished for both everyday wear and special occasions. They play a vital role in the region's social fabric and economy, supporting artisan livelihoods and sustaining a rich weaving tradition.

In January 2024, the Indian government, through the Department for Promotion of Industry and Internal Trade (DPIIT), officially granted the Tangail Saree of Bengal a Geographical Indication (GI) tag. The GI status helps protect the saree's authenticity and supports the livelihoods of Bengali weaving communities, ensuring the preservation of this valuable artisanal legacy.

2. Goal and Scope

This study aims to support handloom weavers, cooperatives, government agencies, and textile stakeholders in accurately measuring the CF of the handloom processes involved in Tangail saree production. The assessment adopts a gate-to-gate system boundary, encompassing all stages from the procurement of warp and weft yarn—sourced from NHDC or local vendors—to the handloom society in Fulia, West Bengal. It includes yarn transport, storage at cooperatives, preprocessing, weaving, post-weaving treatments, packaging, internal transportation, waste management, and the use of utilities such as electricity, fuel, and water throughout these processes.

3. Boundary Conditions

System Start

This assessment begins with the procurement of ready-to-use cotton and zari yarn by the cooperative society from NHDC.

System End

The system boundary concludes upon the completion of Tangail saree packaging, just before distribution to retailers or consumers.

Excluded Upstream and Downstream Processes

The assessment excludes upstream activities such as cotton cultivation, zari yarn production, ginning, fiber cleaning, yarn manufacturing, and their related inputs and transportation. It also omits downstream processes, including product distribution, consumer use, and end-of-life disposal or recycling. This focus ensures the study is limited to the gate-to-gate production stages within the cooperative's operations.





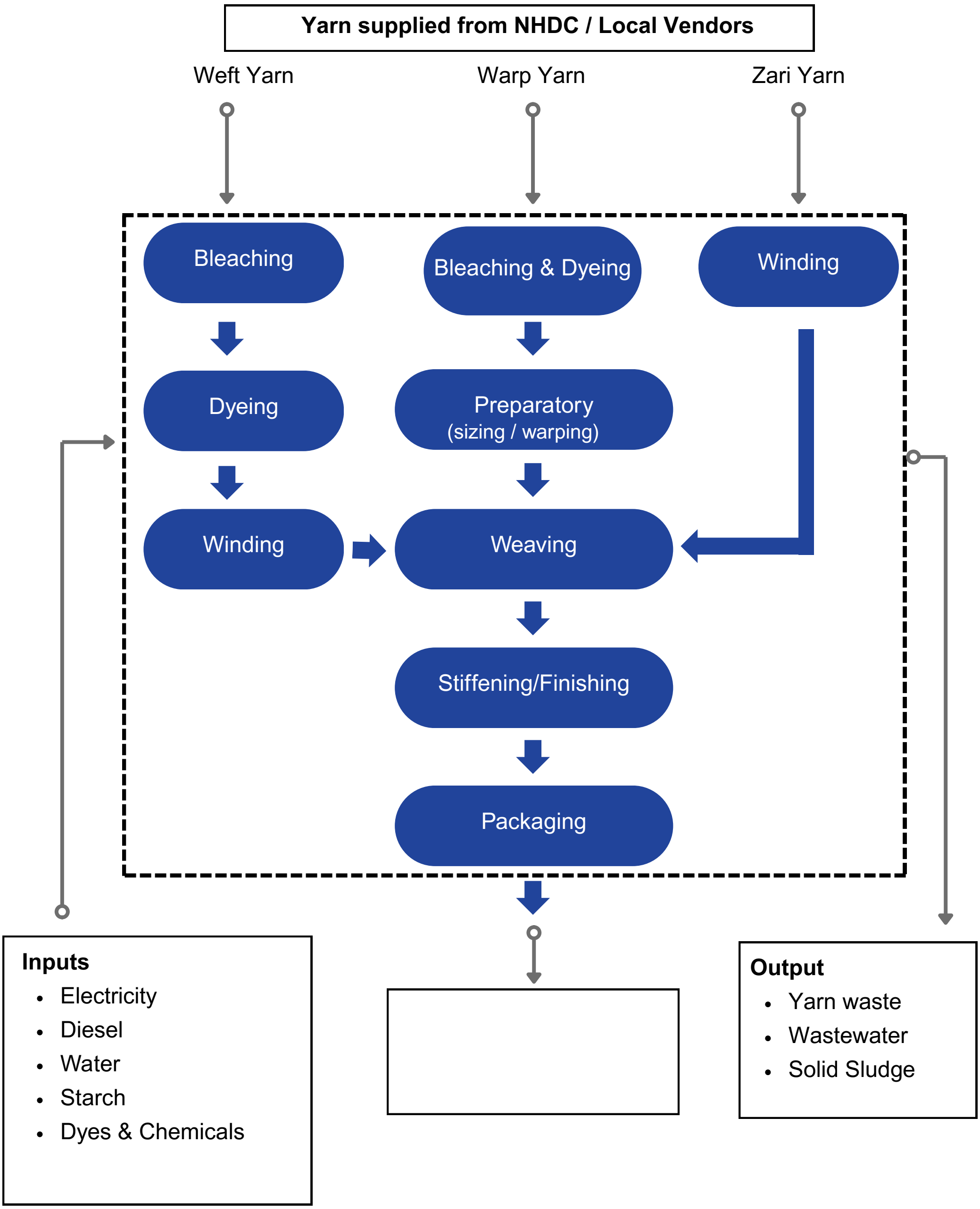

4. Functional Unit

One finished handloom Tangail saree, weighing 470 gm, with dimensions of 47 inches in width and 5.5 meters in length, ready for packaging and distribution.





5. Process Tree and Material Flow



6. Inventory Dataset

Table C1 — Inventory Dataset (per FU)

Activity	Activity Data (per FU)	Unit
Transport (truck)	100	km
Sizing Chemical ($CaOCl_2$)	0.032	kg
Water	2.25	Litre
Waste water	2.24	Litre
Dye	0.006	kg
Caustic Soda	0.008	kg
Sodium Hydrosulphite	0.008	kg
Fuel (Diesel)	0.08	Litre
Electricity	1.23	kWh
Solid Waste (sludge)	0.008	kg
Starch	0.05	kg
Lime	0.002	kg
Yarn Waste	0.0207	kg

7. Carbon Footprint Calculation

Table C2 — CF calculation for a Tangail saree (per FU)

Activity	Emmision (kg CO_2-eq)
Transport (truck)	0.015
Sizing Chemical ($CaOCl_2$)	0.077
Water	0.003
Waste Water	0.084
Dye	0.016
Caustic Soda	0.011
Sodium Hydrosulphite	0.018
Diesel	0.079
Electricity	0.894
Solid Waste (sludge)	0.003
Starch	0.071
Lime	0.003
Yarn Waste	0.021
Total	**1.294**

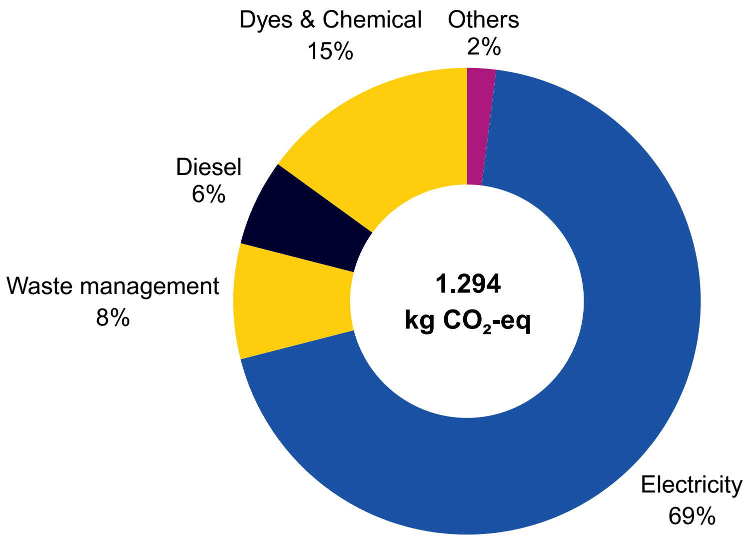


Figure C1 — CF breakdown by process Input (%)

8. Interpretation

The CF analysis reveals that electricity consumption is by far the dominant source of greenhouse gas emissions, accounting for 69% of the total process emissions. Chemical inputs—including dyes and auxiliaries—contribute 15%, making them the second largest category, while waste management (8%) and diesel fuel use (6%) also play significant roles. Remaining contributions are from water use, and other minor sources, together comprising a small fraction of the overall impact.

Given this distribution, the most effective strategies for reducing CF include transitioning to renewable or low-carbon electricity sources, and implementing energy efficiency measures throughout the production process. Reducing the use or substituting high-impact chemicals with eco-friendly alternatives could further decrease emissions associated with dyes and auxiliaries. Additionally, optimizing waste management and recycling—particularly for solid waste and sludge—and replacing diesel with cleaner fuels would help minimize emissions across multiple process stages. Such targeted interventions would address the main emission hotspots identified in the assessment, promoting more sustainable handloom production.

10. Recommendations

This assessment is based on data collected from a specific cooperative society within the Fulia cluster and may not fully represent the diversity of Tangail saree production across different regions or weaving units. Variations in technology, resource availability, scale of operations, and local practices can lead to differences in CF outcomes among producers.

Moreover, uncertainties related to data quality, emission factors, and assumptions used in the analysis may influence the accuracy of the results. Conducting sensitivity analyzes to evaluate the impact of key variables—such as energy consumption, raw material sourcing, and emission coefficients—is recommended to better understand their effect on overall emissions.

Therefore, these findings should be interpreted as indicative of the local context within the Fulia cooperative cluster. For more generalizable conclusions, further studies involving multiple weaving units or clusters, incorporating broader geographical and operational variations, are suggested. Such comprehensive research would enhance the understanding of the CF of Tangail saree production across the sector and support more effective mitigation strategies.

Annex D

Carbon Footprint of Handloom Floor Mat

1. Background

This study focuses on the CF of handloom floor mats produced in Panipat, Haryana—widely recognized as India's "Carpet City." Panipat has a storied legacy in textile weaving, with its artisans mastering centuries-old techniques to craft floor mats and carpets of exceptional durability, comfort, and vibrant design. The region is particularly known for its use of recycled cotton, wool, and other eco-friendly materials, making Panipat floor mats both sustainable and environmentally responsible. These products skillfully blend traditional patterns with contemporary styles, catering to both domestic and global markets. The ethical and artisanal nature of Panipat's handloom sector not only preserves vital local livelihoods but also exemplifies India's rich heritage of sustainable textile craftsmanship. By assessing the CF of these floor mats, the study aims to highlight their environmental profile alongside their cultural and economic importance.

2. Goal and Scope

The objective of this study is to assess and quantify the CF of a typical handloom cotton floor mat produced in Panipat. The findings will help local weavers, producers, exporters, and policymakers better understand the carbon impact of their processes and identify opportunities for sustainability improvements. The process from the arrival of cotton yarn at the weaving unit through weaving, finishing, and packaging until the finished mat is ready for distribution. The study quantifies GHG emissions generated during production steps, excluding use and disposal.

3. Boundary Conditions

System Boundary

This assessment uses a gate-to-gate approach, focusing exclusively on the stages from the entry of yarn to the exit of the finished, packaged floor mat.

Included Processes

- Transportation of yarn to the Panipat weaving unit
- Yarn preparation, dyeing, and drying
- Handloom weaving
- Cutting, finishing, and inspection
- Final packaging for distribution

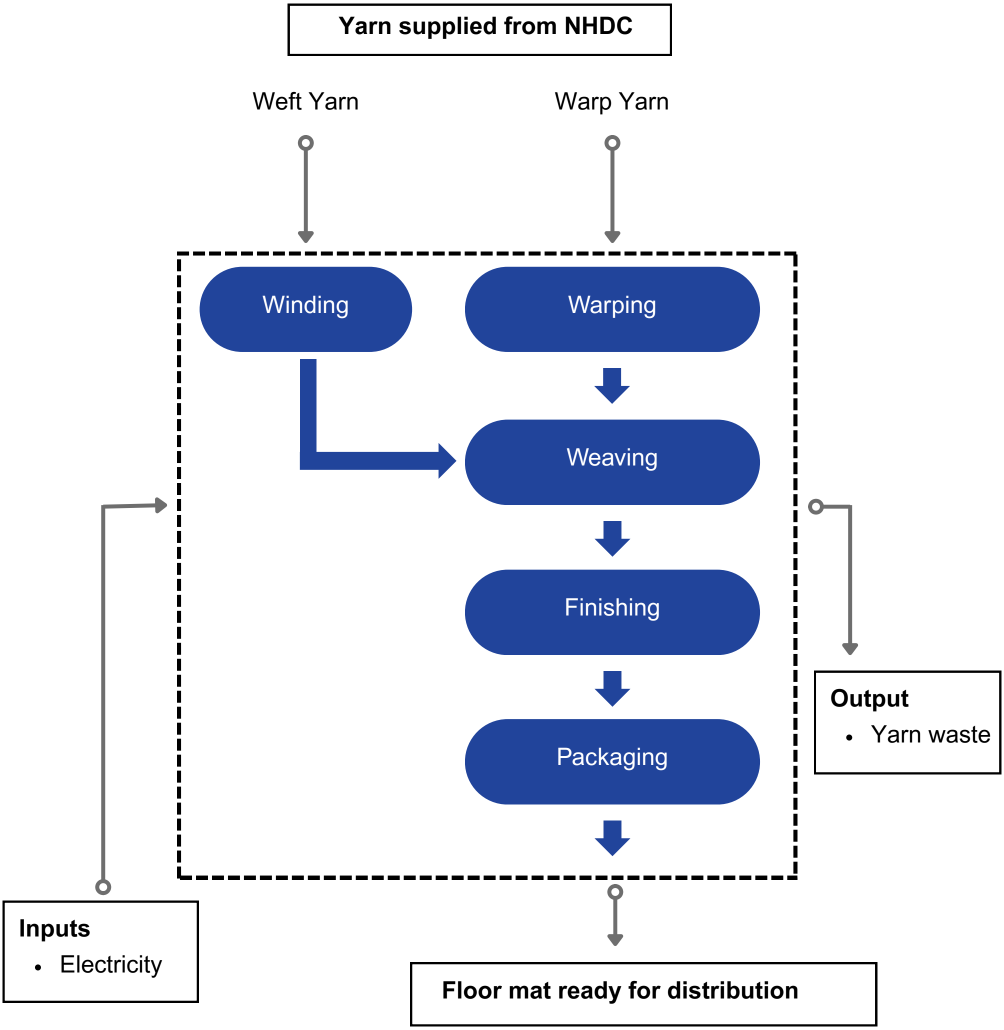
Excluded Upstream and Downstream Processes

The excluded upstream processes are cotton cultivation, spinning of raw fibers, yarn manufacturing, dye production, and water or energy generation related to external activities. Downstream processes not considered include product distribution to retailers, consumer use (such as cleaning and maintenance), and end-of-life disposal or recycling.

4. Functional Unit

One finished handloom cotton floor mat, measuring 60 × 90 cm, made with 4/6 warp and 2/4 9-ply weft, weighing 900 grams, ready for packaging and distribution.

5. Process Tree and Material Flow



6. Inventory Dataset

Table D1 — Inventory Dataset (per FU)

Activity	Activity Data (per FU)	Unit
Transport (truck)	220	km
Yarn Waste	0.031	kg
Electricity	0.131	kWh

7. Carbon Footprint Calculation

Table D2 — CF calculation for a floor mat (per FU)

Activity	Emmision (kg CO_2-eq)
Transport (truck)	0.033
Yarn Waste	0.031
Electricity	0.095
Total	**0.159**

Disclaimer: The results are based on data from a single unit. Further detailed studies and sensitivity analyses are required to draw conclusions for the entire sector.

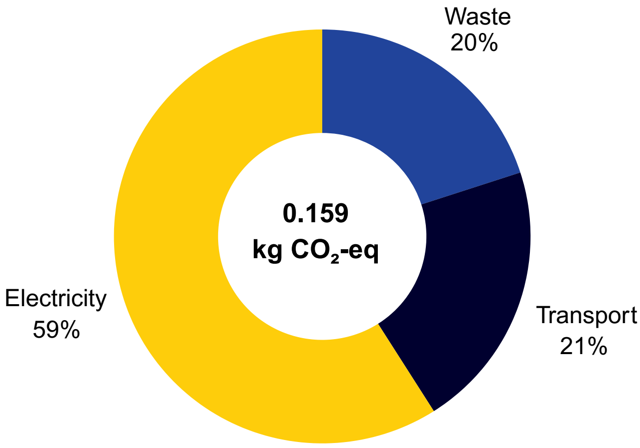


Figure D1 — CF breakdown by process input (%)

8. Interpretation

When compared to many other handloom products, the CF of carpet making is notably low, with a total of just 0.159 kg CO_2-eq per mat. This reflects efficient resource use and streamlined processes within the Panipat handloom sector.

The CF assessment for the floor mat shows that electricity use is the largest source of greenhouse gas emissions (59.75%), followed by transport (20.6%) and yarn waste (19.6%). Prioritizing energy efficiency and considering cleaner power sources will provide the greatest potential for emission reduction, while transport optimization and waste minimization offer additional improvements.

Disclaimer: Variability and uncertainties in input data, emission factors, and resource use measurements mean that the findings are indicative rather than definitive; further sensitivity analyses and broader studies are needed for comprehensive sector-wide conclusions.

Annex E

Carbon Footprint of Handloom Ikat Saree

1. Background

Ikat sarees from Odisha are a treasured part of India's textile legacy, renowned for their vibrant colors, complex patterns, and the meticulous tie-and-dye (bandha) technique. Primarily produced in regions such as Sambalpur, Bargarh, and Nuapatna, these handloom sarees showcase centuries-old weaving and dyeing skills passed down through generations. The unique process involves tying portions of the yarn and repeatedly dyeing them to create striking, multi-colored, and geometric designs that are featured in both the warp and weft—a technique locally known as "bandha." Once woven, the designs appear identical on both sides of the fabric, underscoring the high level of craftsmanship involved. Odisha's Ikat is celebrated not just for its artistry, but also for its cultural depth; the motifs and colors often symbolize local traditions, myths, and social identity

2. Goal and Scope

The objective of this study is to quantify the CF of an Ikat saree by evaluating emissions generated during key production stages—yarn preparation, dyeing, and weaving—within the handloom unit, enabling targeted sustainability improvements. The insights from this study will benefit weavers, policymakers, and sustainable fashion brands by promoting eco-friendly practices and enhancing the market value of traditional handloom products.

3. Boundary Conditions

System Boundary
This assessment uses a gate-to-gate approach, focusing exclusively on the stages from the entry of yarn to the exit of the finished, packaged ikat saree.

Included Processes

- Transportation of undyed cotton yarn from NHDC to weaving unit
- Yarn preparation, dyeing, tieing, drying and untieing
- Handloom weaving
- Cutting, finishing, and inspection
- Final packaging for distribution

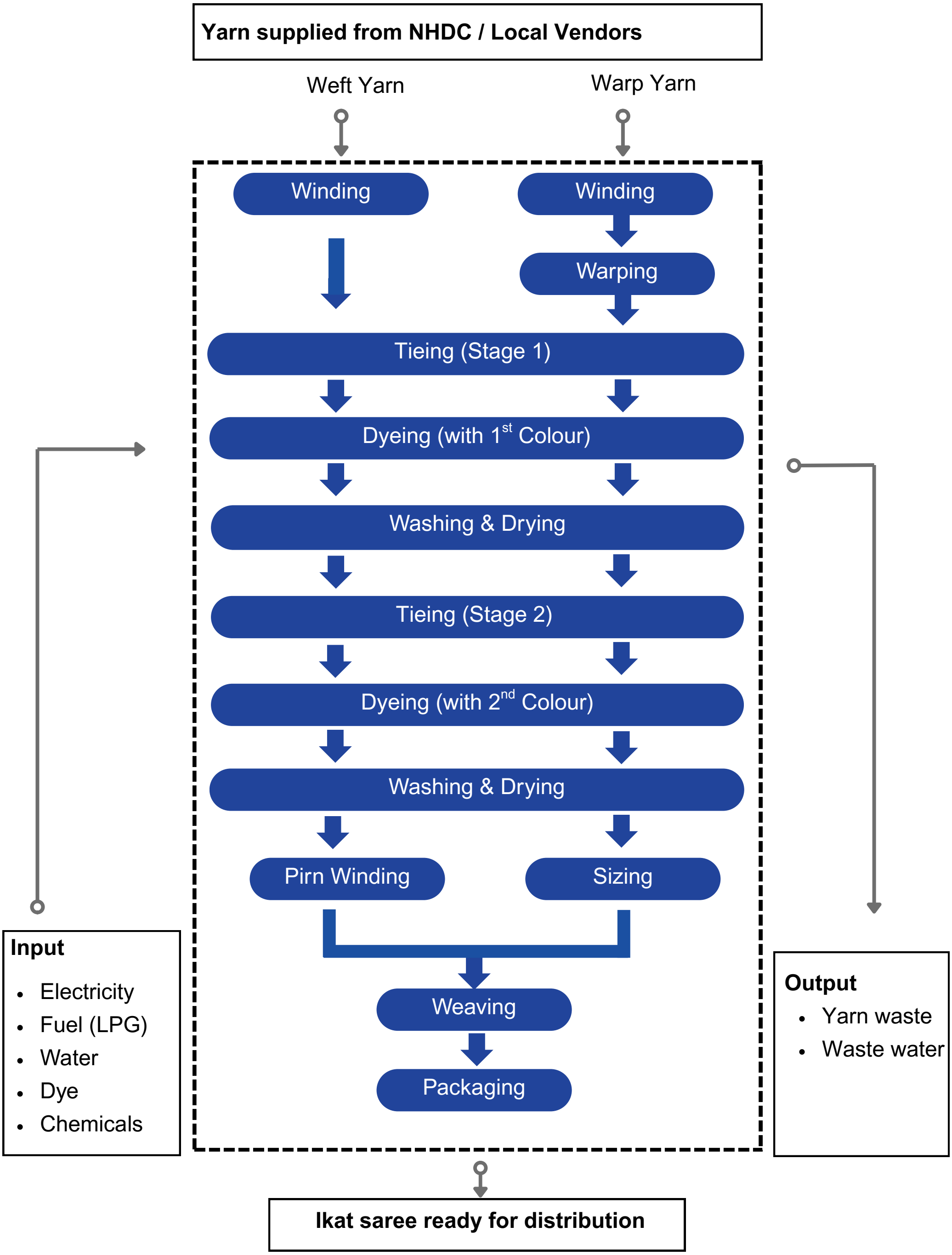
Excluded Upstream and Downstream Processes

The excluded upstream processes are cotton cultivation, spinning of raw fibers, yarn manufacturing, dye production, and water or energy generation related to external activities. Downstream processes not considered include product distribution to retailers, consumer use (such as cleaning and maintenance), and end-of-life disposal or recycling.

4. Functional Unit

One finished handloom Ikat saree, weighing 430 gm, with dimensions of 47 inches in width and 5.5 meters in length, ready for packaging and distribution.

5. Process Tree and Material Flow



6. Inventory Dataset

Table E1 — Inventory Dataset (per FU)

Activity	Activity Data (per FU)	Unit
Transport (via Scooter)	10	km
Water	33.5	Litre
Waste water	31	Litre
Dye	0.036	kg
Sodium Hydrosulphite	0.087	kg
Caustic Soda	0.087	kg
LPG	0.014	kg
Electricity	2.5	kWh
Starch	0.05	kg
Yarn Waste	0.050	kg

7. Carbon Footprint Calculation

Table E2 — CF calculation for a Ikat saree (per FU)

Activity	Emmision (kg CO_2-eq)
Transport (via scooter)	0.027
Water	0.044
Waste Water	0.001
Dye	0.092
Sodium Hydrosulphite	0.200
Caustic Soda	0.118
LPG	0.017
Electricity	1.818
Starch	0.065
Yarn Waste	0.050
Total	**2.430**

Disclaimer: The results are based on data from a single unit. Further detailed studies and sensitivity analyses are required to draw conclusions for the entire sector.

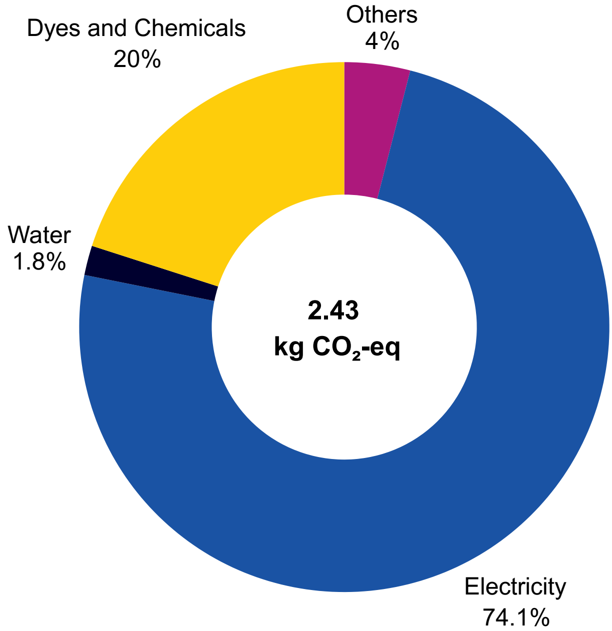


Figure E1 — CF breakdown by process input (%)

8. Interpretation

The CF assessment of an Ikat saree shows that electricity use is the most significant emission source, accounting for 74.1% of total emissions (1.818 kg CO_2-eq out of 2.43 kg CO_2-eq). Dyes and chemical inputs represent the next largest contribution at 20%, while 'Others'—including activities such as wastewater management, yarn waste disposal, and LPG fuel use—comprise 4%. Water use contributes an additional 1.8% to the overall CF.

Given this distribution, improving energy efficiency and increasing the use of renewable electricity within the production process offer the greatest potential for emission reduction. Further gains can be achieved by optimizing the use and handling of dyes and chemicals. Although water use and minor waste streams make relatively small contributions, continual improvements in these areas will also support overall sustainability.

Annex F

Carbon Footprint of Handloom Ashawali Saree

1. Background

Ashawali silk sarees, originating from Ahmedabad in Gujarat, are among India's most celebrated handloom textiles, renowned for their intricate brocade work, rich patterns, and vibrant use of gold zari. Tracing their legacy back over six centuries, Ashawali sarees showcase a unique weaving tradition that blends dense patterning, metallic threads, and finely detailed motifs of birds, flowers, and peacocks. The heart of the Ashawali technique lies in its elaborate hand-weaving process—often taking 15 to 20 days per saree—executed on jacquard pit looms by highly skilled artisans. Each saree features ornate borders and finely enameled pallus, sometimes repurposed from vintage textiles through upcycling. Traditionally supported by royal patronage, Ashawali weaving integrates cultural heritage with sustainability. Today, these sarees remain a testament to Gujarat's artistry, embodying centuries of craftsmanship and continuing to command admiration in both Indian and international markets.

2. Goal and Scope

The objective of this study is to quantify the CF of an Ashawali silk saree by evaluating the GHG emissions associated with its production, aiming to promote environmentally responsible practices and enhance the sustainability of traditional handloom weaving.

The study adopts a gate-to-gate approach, focusing on key stages within the handloom unit—silk yarn preparation, dyeing, brocade weaving, and finishing. It identifies major emission sources and assesses energy, water, and chemical usage. The findings are intended to benefit weavers, policymakers, and eco-conscious consumers by supporting sustainable production and increasing the saree's market value through greater environmental transparency.

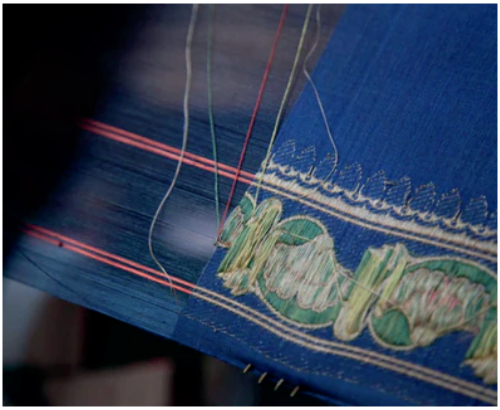
3. Boundary Conditions

System Boundary
This assessment uses a gate-to-gate approach, focusing exclusively on the stages from the entry of yarn to the exit of the finished, packaged Ashawali saree.

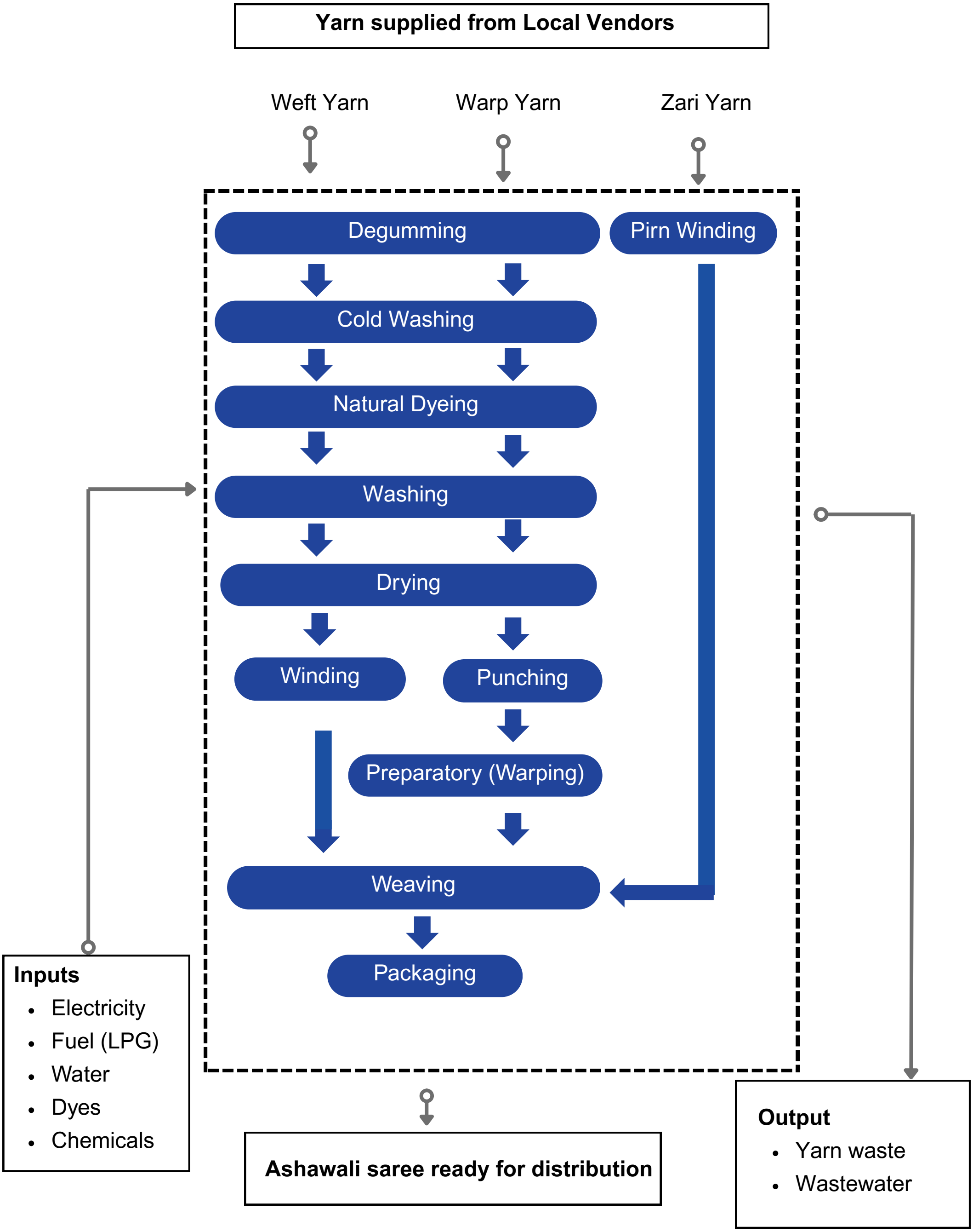
Excluded Upstream and Downstream Processes
The excluded upstream processes are zari yarn production, silk cultivation, spinning of raw fibers, yarn manufacturing, dye production, and water or energy generation related to external activities. Downstream processes not considered include product distribution to retailers, consumer use (such as cleaning and maintenance), and end-of-life disposal.

4. Functional Unit

One finished handloom Ashawali silk saree, weighing 620 gm, with dimensions of 47-48 inches in width and 6.5 meters in length, ready for packaging and distribution.



5. Process Tree and Material Flow



6. Inventory Dataset (per FU)

Table F1 — Inventory Dataset (per FU)

Activity	Activity Data (per FU)	Unit
Transport (via truck)	1700	km
Water	167.78	Litre
Waste Water	136	Litre
Dye (Pomegranate)	0.467	kg
Dye (Merigold flower)	0.208	kg
Auxiliary 1 (Lime)	0.001	kg
Auxiliary 2 (Alum)	0.064	kg
Auxiliary 3 (Soda Ash)	0.221	kg
Auxiliary 4 (Softener)	0.001	kg
Fuel (LPG)	0.807	kg
Electricity	16	kWh
Yarn Waste	0.03	kg
Packaging (PP)	0.01	kg

7. Carbon Footprint Calculation

Table F2 — CF calculation for an Ashawali saree (per FU)

Activity	Emmision (kg CO_2-eq)
Transport	0.177
Water	0.221
Waste water	0.005
Dye (Pomegranate)	0.248
Dye (Merigold flower)	0.247
Auxiliary 1 (Lime)	0.001
Auxiliary 2 (Alum)	0.048
Auxiliary 3 (Soda Ash)	0.102
Auxiliary 4 (Softener)	0.002
Fuel (LPG)	0.944
Electricity	11.632
Yarn Waste	0.030
Packaging (PP)	0.008
Total	13.656

Disclaimer: The results are based on data from a single unit. Further detailed studies and sensitivity analyses are required to draw conclusions for the entire sector.

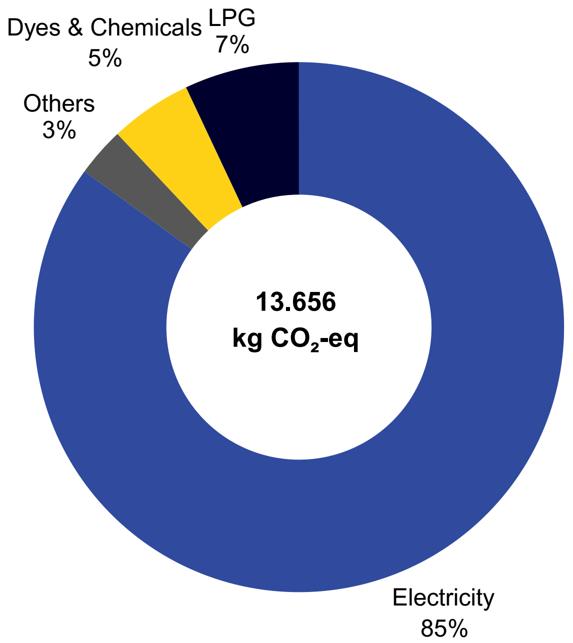


Figure F1 — CF breakdown by process input (%)

8. Interpretation

The CF analysis for the Ashawali saree highlights that electricity consumption is the overwhelmingly dominant source of greenhouse gas emissions, accounting for 85% of the total process input. This strong reliance on electricity reflects the energy-intensive nature of brocade weaving and related operations within the handloom unit. Other notable contributors include LPG (7%), dyes and chemicals (5%), and a smaller share from other sources (3%).

Given this distribution, efforts to reduce the overall carbon footprint should prioritize improving energy efficiency and transitioning to renewable electricity sources wherever possible. Additionally, optimizing the use of LPG and minimizing the environmental impact of dyes and chemicals through process improvements or eco-friendly alternatives can further reduce emissions.

Annex G

Carbon Footprint of Dharmavaram Saree

1. Background

Dharmavaram silk sarees from Andhra Pradesh are a cherished part of India’s textile heritage, known for their vibrant colors, broad gold zari borders, and intricate weaving. The Dharmavaram cluster is a leading handloom center, producing luxurious silk sarees highly valued in traditional ceremonies like weddings and festivals, as well as in domestic and international markets.

The weaving process is detailed and labor-intensive, where skilled artisans use traditional pit looms to craft distinctive textures and elaborate zari patterns. The broad borders and pallus often showcase motifs inspired by temple architecture, flora, and mythology, woven with real gold and silver threads alongside fine silk yarn. Combining hand-dyeing with precise weaving techniques, these sarees are prized for their durability, rich texture, and elegant sheen, reflecting generations of craftsmanship and cultural legacy.

2. Goal and Scope

The objective of this study is to measure the carbon emissions generated during the production of a Dharmavaram silk saree, focusing on understanding the environmental impact of traditional handloom processes and paving the way toward low-impact, sustainable alternatives. The assessment adopts a gate-to-gate approach, covering major stages within the production unit such as silk yarn sourcing, dyeing, zari work, and handloom weaving. It accounts for energy, water, and material usage at each stage. The results aim to benefit weavers, designers, and policymakers by supporting eco-certification, promoting greener production methods, and enhancing the saree’s appeal in sustainable fashion markets.

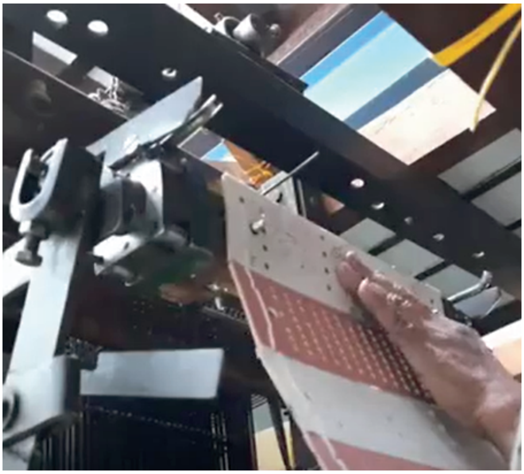
3. Boundary Conditions

System Boundary
This assessment uses a gate-to-gate approach, focusing exclusively on the stages from the entry of yarn to the exit of the finished, packaged Dharmavaram silk saree.

Included Processes
- Transportation of undyed mulberry silk yarn
- Yarn preparation, dyeing, and drying
- Handloom weaving (manual or minimal electricity use)
- Cutting, finishing, and inspection
- Final packaging for distribution

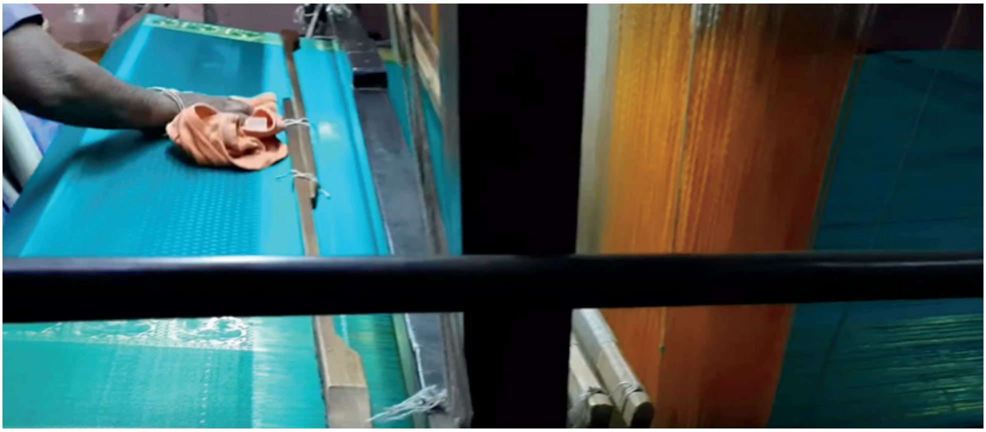
Excluded Upstream and Downstream Processes

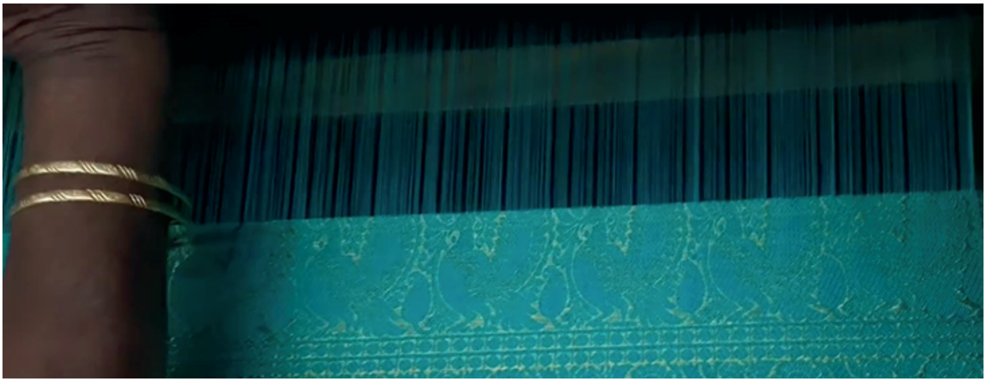
The excluded upstream processes are silk cultivation, spinning of raw fibers, zari yarn production, yarn manufacturing, dye production, and water or energy generation related to external activities. Downstream processes not considered include product distribution to retailers, consumer use (such as cleaning and maintenance), and end-of-life disposal or recycling.



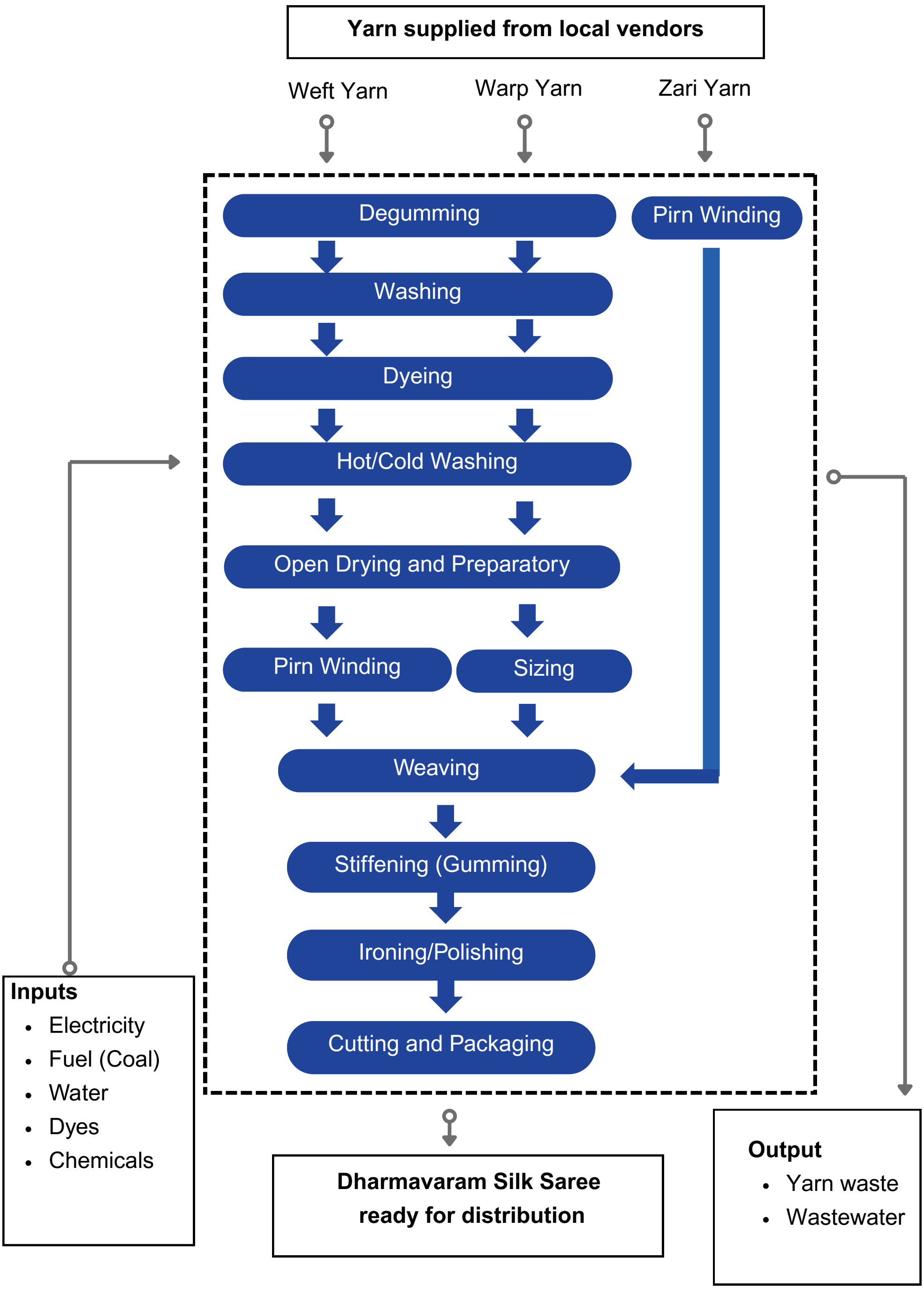
4. Functional Unit

One finished handloom Dharmavaram saree, weighing 650 gm, with dimensions of 47-48 inches in width and 5.5 meters in length, ready for packaging and distribution.





5. Process Tree and Material Flow



6. Inventory Dataset

Table G1 — Inventory Dataset (per FU)

Activity	Activity Data (per FU)	Unit
Transport (via scooter)	14.000	km
Water	91.250	Litre
Waste Water	85.800	Litre
Dye	0.018	kg
Auxiliary 1 (Acetic Acid)	0.042	kg
Auxiliary 2 (Soda Ash)	0.009	kg
Fuel (LPG)	0.186	kg
Electricity	9.000	kWh
Yarn Waste	0.006	kg
Packaging (PP)	0.018	kg

Disclaimer: The results are based on data from a single unit. Further detailed studies and sensitivity analyses are required to draw conclusions for the entire sector.

7. Carbon Footprint Calculation

Table G2 — CF calculation for a Dharmavaram saree (per FU)

Activity	Emmision (kg CO_2-eq)
Transport	0.051
Water	0.120
Waste Water	0.003
Dye (Acid)	0.040
Auxiliary 1 (Acetic Acid)	0.109
Auxiliary 2 (Soda Ash)	0.041
Fuel (LPG)	0.217
Electricity	6.543
Yarn Waste	0.006
Packaging (PP)	0.014
Total	7.147

Disclaimer: The results are based on data from a single unit. Further detailed studies and sensitivity analyses are required to draw conclusions for the entire sector.

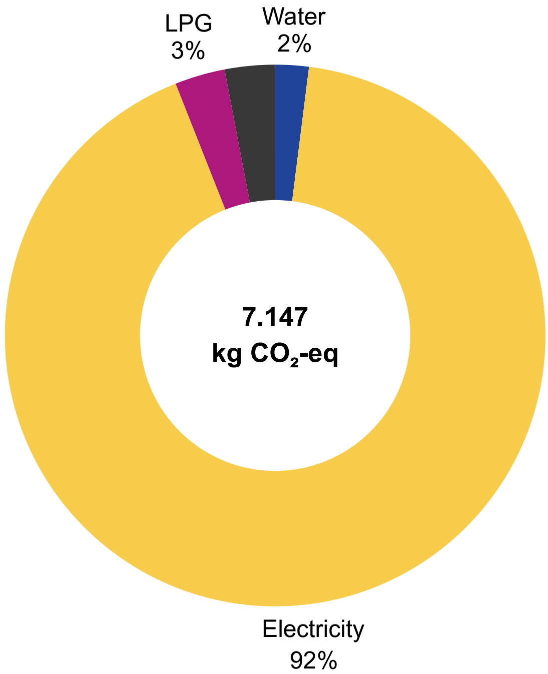


Figure G1 — CF breakdown by process input (%)

8. Interpretation

The CF analysis of Dharmavaram saree manufacturing reveals that electricity usage is by far the dominant source of GHG emissions, making up 92% of total inputs. This underscores the highly energy-intensive nature of the process, with electricity powering most of the production activities. LPG and water contribute much smaller shares, at 3% and 2% respectively, while other factors such as packaging, dyes and chemicals, wastewater, and yarn waste together account for the remaining 3%.

This breakdown highlights that the environmental impact of Dharmavaram saree production is primarily driven by electricity consumption. As a result, the most effective strategies for emissions reduction involve improving energy efficiency and transitioning to renewable electricity sources within the manufacturing process. Efforts to optimize water use and minimize reliance on LPG can also contribute, but their overall impact will be modest compared to electricity-related measures.

Annex H

Carbon Footprint of Handloom Banarasi Silk Saree

1. Background

Banarasi silk sarees from Varanasi are a distinguished icon of India's textile heritage, renowned for their luxurious silk fabric, intricate zari brocade work, and timeless elegance. Varanasi, one of India's oldest and most revered weaving centers, has preserved traditional handloom techniques for over five centuries. Skilled artisans use fine silk threads combined with real gold and silver zari to create elaborate floral and Mughal-inspired motifs through a labor-intensive hand-weaving process. Crafting a single Banarasi saree can take anywhere from 15 days to several months, depending on the complexity of the design. This meticulous process involves multiple stages, including yarn preparation, brocade weaving on jacquard looms, dyeing, and finishing. Banarasi sarees continue to enjoy immense popularity both within India and internationally, symbolizing cultural richness and artisanal mastery that have been perfected over generations.

2. Goal and Scope

The objective of this study is to quantify the CF of a Banarasi silk saree by assessing the environmental impact of its production processes, with the aim of promoting sustainable handloom practices and enhancing the eco-profile of this heritage textile. The study will follow a gate-to-gate approach, covering key stages such as silk yarn procurement, dyeing, zari preparation, jacquard weaving, and finishing within the weaving unit. It will evaluate resource consumption—energy, water, and materials—to identify major emission hotspots. The findings will aid weavers, policymakers, and eco-conscious brands in adopting greener technologies and positioning Banarasi sarees in the global sustainable fashion market.

3. Boundary Conditions

System Boundary

This assessment uses a gate-to-gate approach, focusing exclusively on the stages from the entry of yarn (to a weaving unit) to the exit of the finished, packaged banarasi silk saree.

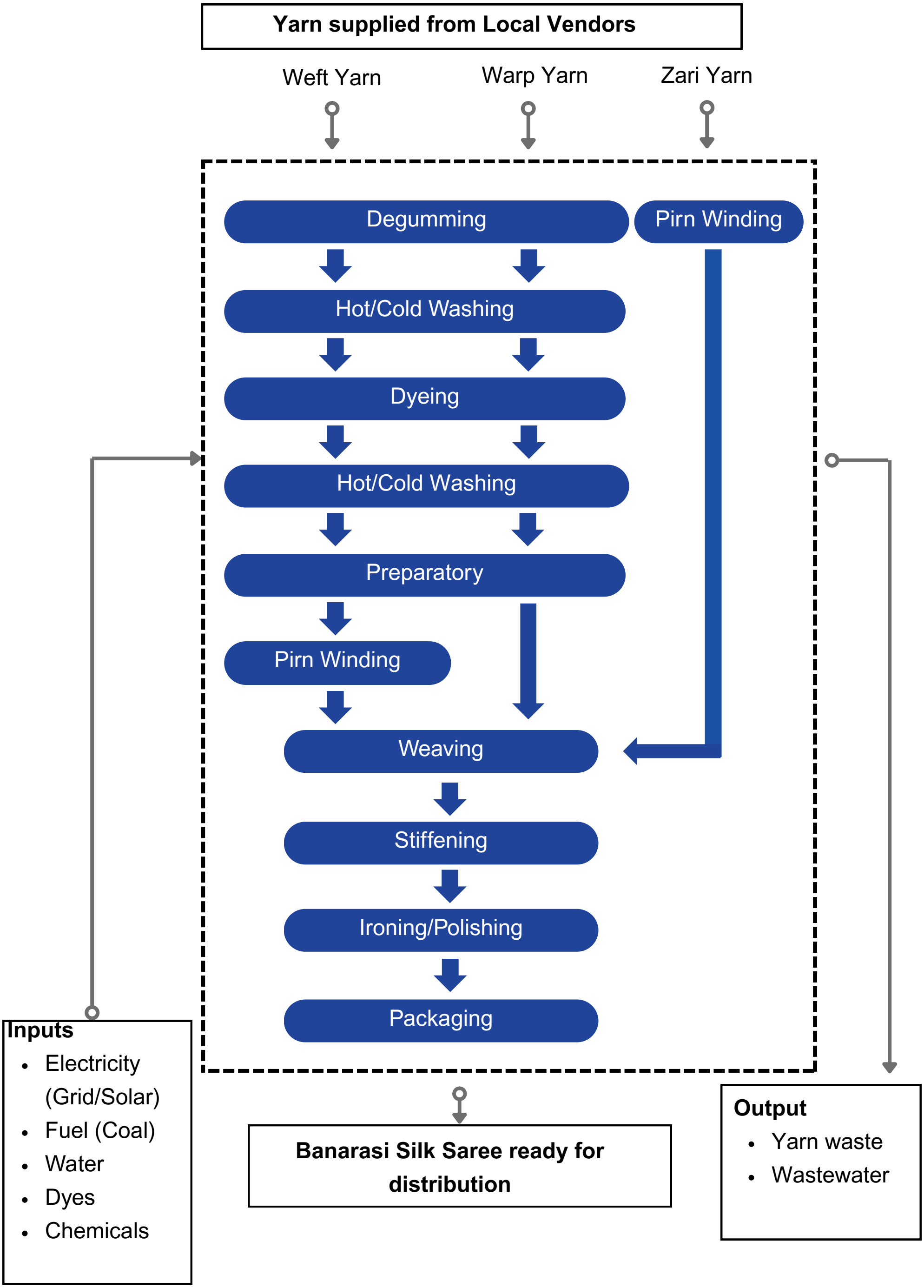
Excluded Upstream and Downstream Processes

The excluded upstream processes are zari yarn production, silk cultivation, spinning of raw fibers, yarn manufacturing, dye production, and water or energy generation related to external activities. Downstream processes not considered include product distribution to retailers, consumer use (such as cleaning and maintenance), and end-of-life disposal or recycling.

4. Functional Unit

One finished handloom banarasi silk saree, weighing 850 gm, with dimensions of 47-48 inches in width and 6.5 meters in length, ready for packaging and distribution.

5. Process Tree and Material Flow



6. Inventory Dataset (per FU)

Table H1 — Inventory Dataset (per FU)

Activity	Activity Data (per FU)	Unit
Transport (via truck)	1420	km
Water	140.167	Litre
Waste Water	136.000	Litre
Dyes (Acid)	0.013	kg
Auxiliary 1 (Acetic Acid)	0.060	kg
Auxiliary 2 (Soap)	0.540	Litre
Fuel (Coal)	1.818	kg
Electricity (Grid)	20.455	kWh
Electricity (Solar)	0.800	kWh
Yarn Waste	0.019	kg
Packaging (PP)	0.040	kg

7. Carbon Footprint Calculation

Table E2 — CF calculation for a Banarasi silk saree (per FU)

Activity	Emmision (kg CO_2-eq)
Transport	0.210
Water	0.185
Waste Water	0.005
Dye	0.028
Auxiliary 1 (Acetic Acid)	0.165
Auxiliary 2 (Soap)	1.319
Fuel (Coal)	0.625
Electricity (Grid)	14.870
Electricity (Solar)	0.033
Yarn Waste	0.018
Total	17.497

Disclaimer: The results are based on data from a single unit. Further detailed studies and sensitivity analyses are required to draw conclusions for the entire sector.

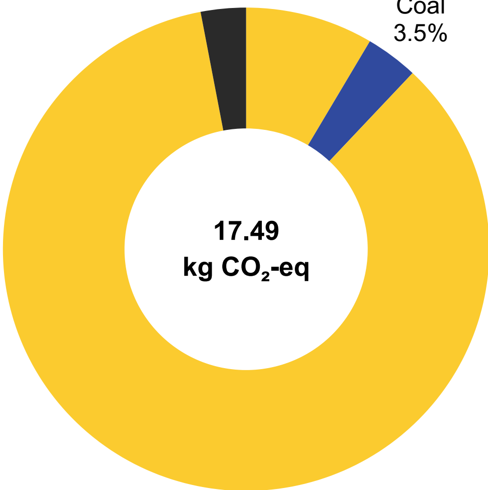


Figure H1 — CF breakdown by process input (%)

8. Interpretation

The CF analysis for Banarasi silk saree manufacturing reveals that electricity consumption is overwhelmingly the primary contributor, accounting for 85% of total emissions. This highlights how energy-intensive the weaving and related processes are, with grid electricity powering most activities within the production chain. Chemicals—including dyes and finishing agents—make up the next largest share at 8.5%, emphasizing the environmental impact of wet processing steps. Other contributors include coal (3.5%) and miscellaneous sources (3%), which together form a minor fraction but still add to the overall impact.

To meaningfully reduce the CF of Banarasi saree production, strategies should focus on improving energy efficiency, transitioning to renewable electricity sources, and adopting cleaner production practices. Particular attention should be given to optimizing or substituting chemical use in dyeing and finishing, as well as exploring cleaner fuel options. Overall, addressing electricity use and process chemistry presents the best opportunities for lowering emissions and enhancing sustainability in Banarasi silk saree manufacturing.

Annex I

Carbon Footprint of Silk Dyeing (Sualkuchi)

1. Background

The silk dyeing process in Sualkuchi, Assam, is an essential part of India's rich textile heritage, celebrated for its vibrant colors, traditional techniques, and the use of natural and azo-free dyes. Known as the "Manchester of Assam," Sualkuchi is a famed handloom center where skilled artisans meticulously dye and weave exquisite silk fabrics that beautifully blend local traditions with global fashion demands.

The dyeing process involves soaking the silk yarns or fabrics in natural dye baths made from plant extracts, flowers, and minerals, ensuring eco-friendly and skin-safe colors. Artisans carefully control the temperature and duration of dyeing to achieve the desired shades and colorfastness. Following this, the dyed yarns are dried and skillfully woven into intricate patterns, producing the signature lustrous and colorful silk textiles of the region.

2. Goal and Scope

The objective of this study is to comprehensively quantify the CF of the silk dyeing process in Sualkuchi, aiming to evaluate its environmental impacts and uncover practical strategies to reduce emissions without compromising traditional dyeing methods. The study will conduct a detailed gate-to-gate assessment focused specifically on the dyeing stage, examining all relevant resource inputs—including water, energy sources, dye chemicals, and heating techniques—as well as waste generation and management tied to local practices. By quantifying emissions and resource use specifically at the dyeing stage, it can reveal how this process contributes to the overall environmental footprint of silk product development. This understanding enables stakeholders to target improvements that reduce carbon emissions and resource consumption across the supply chain

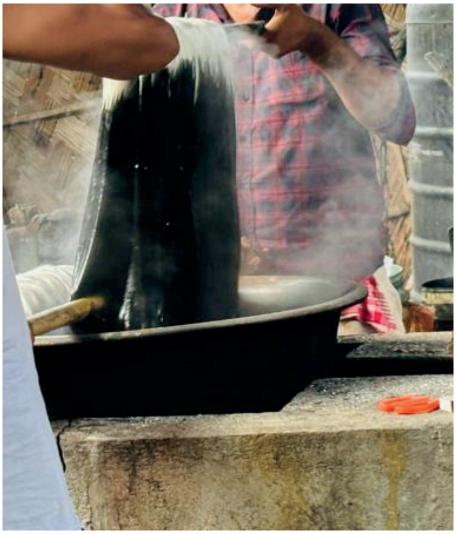
3. Boundary Conditions

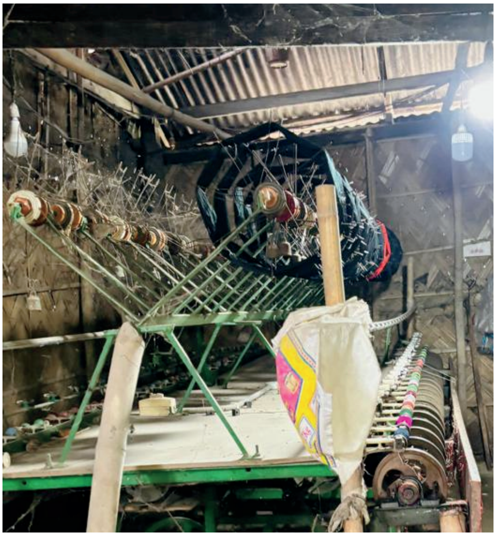
System Boundary
This assessment uses a gate-to-gate approach, focusing exclusively on the stages from the entry of yarn to the exit of the packaged dyed silk yarn.

Included Processes
- Transportation of undyed silk yarn
- Yarn preparation, dyeing, and drying
- Final packaging for distribution

Excluded Upstream and Downstream Processes

Excluded from this study are upstream processes like silk cultivation, spinning, yarn manufacturing, and off-site water or energy generation. Downstream steps such as fabric manufacturing, product finishing, distribution, consumer use, and end-of-life disposal or recycling are also not considered

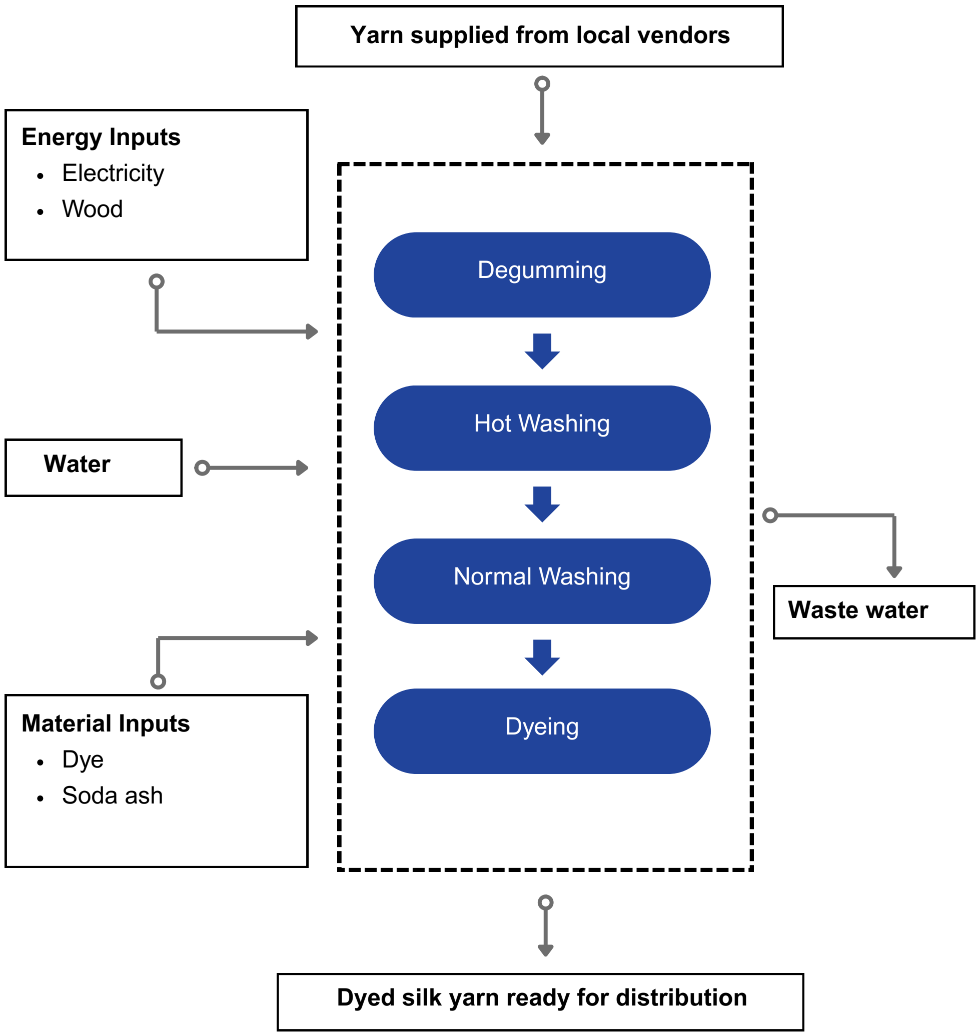




4. Functional Unit

1 kg of silk yarn for warp (dark shade), ready for packaging and distribution.

5. Process Tree and Material Flow



6. Inventory Dataset

Table I1 — Inventory Dataset (per FU)

Activity	Activity Data (per FU)	Unit
Electricity	1.30	kWh
Water	79.2	Litre
Waste Water	71.7	Litre
Transport (via scooter)	10	km
Soda Ash	0.050	kg
Wood	5.000	kg
Dye (Direct)	0.030	kg

Disclaimer: The activity data are specific to the local unit studied and may differ from those of other silk dyeing process units due to variations in technology, process scale, and regional practices.

7. Carbon Footprint Calculation

Table I2 — CF calculation for a kg of silk yarn for dyeing process (per FU)

Activity	Emmision (kg CO_2-eq)
Electricity	0.945
Water	0.104
Waste Water	0.0027
Transport	0.124
Soda Ash	0.023
Wood	9.040
Dye (Direct)	0.067
Total	10.31

Disclaimer: The results are based on data from a single unit. Further detailed studies and sensitivity analyses are required to draw conclusions for the entire sector.

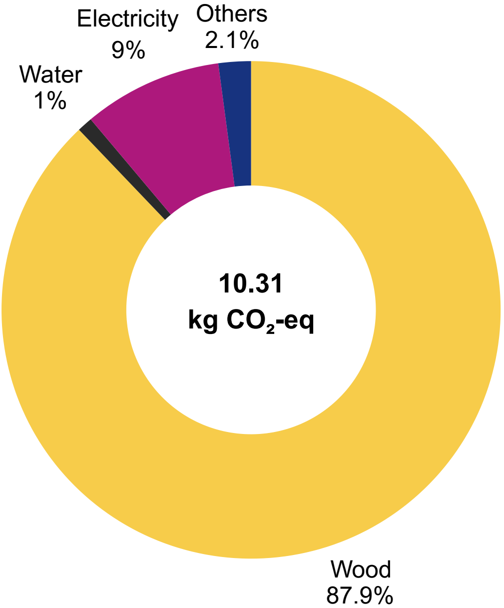


Figure I1 — CF breakdown by process input (%)

8. Interpretation

Based on the CF chart for the yarn silk dyeing process, wood usage accounts for the largest share of emissions (87.9%), followed by electricity (9%), with minor contributions from others (2%) and water (1%). This pattern indicates that traditional fuel sources like wood are the main contributors to the CF in silk dyeing, particularly when used for heating dye baths or other thermal processes. Electricity use, while significant, is secondary but still considerable.

These results highlight that:

- Reducing reliance on wood or switching to cleaner, more efficient fuels (or renewable energy sources) could dramatically lower emissions.
- Improving energy efficiency—both in thermal processes (to reduce wood use) and electrical systems—can further cut the CF.
- While water and miscellaneous inputs contribute less overall, optimizing water use and process controls can still provide incremental environmental benefits.

Annex J

Carbon Footprint of Tussar Silk Dress Material

1. Background

Tussar silk, also known as Kosa silk, is a prized variety of wild silk originating mainly from the tribal regions of Jharkhand, Chhattisgarh, Odisha, and West Bengal. Distinct from mulberry silk, it is produced by silkworms that feed on forest trees such as Asan and Arjun, resulting in a fabric renowned for its natural golden sheen, rich texture, and slightly coarse feel. Tussar silk holds deep cultural significance and supports traditional livelihoods, particularly among tribal communities involved in forest-based sericulture and handloom weaving.

The production process begins with the collection of single-shelled, oval-shaped cocoons from the wild. These cocoons are boiled, which softens them and makes it easier to extract the fine silk threads. Once the silk fibers are extracted, skilled artisans weave them into fabric using traditional handlooms. This meticulous, labor-intensive process often features intricate designs and patterns, reflecting the artistry and heritage of the weavers.

2. Goal and Scope

The objective of this study is to assess the CF of natural Tussar silk dress material by measuring CF generated during its production after yarn procurement. The scope begins from yarn degumming and extends through key production stages, including handloom weaving, finishing, and final packaging. The study focuses on evaluating energy consumption, water usage, biomass dependence, and emissions during each stage. By concentrating on these post-yarn processes, the study aims to identify key emission hotspots and provide targeted insights.

3. Boundary Conditions

System Boundary

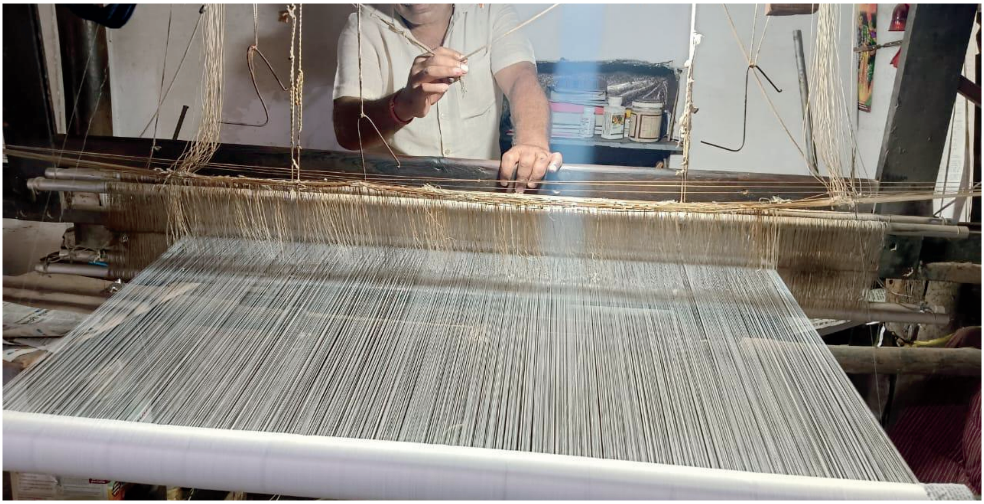
This assessment uses a gate-to-gate approach, focusing exclusively on the stages from the entry of yarn to the exit of the finished, packaged natural Tussar silk dress material.

Included Processes

- Transportation of undyed silk yarn
- Yarn preparation
- Handloom weaving
- Cutting, finishing, and inspection
- Final packaging for distribution

Excluded Upstream and Downstream Processes

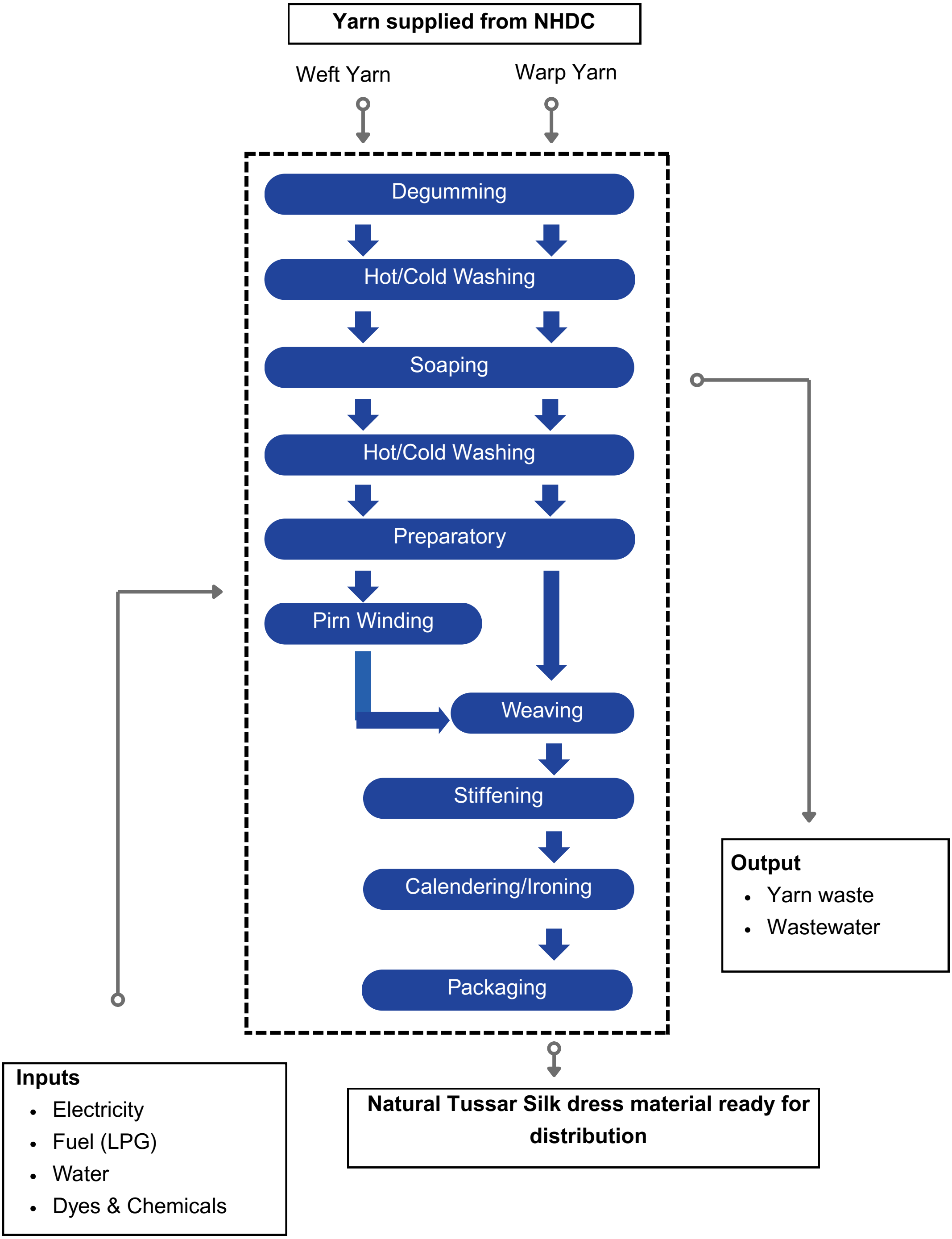
The excluded upstream processes are silk cultivation, spinning of raw fibers, yarn manufacturing, dye production, and water or energy generation related to external activities. Downstream processes not considered include product distribution to retailers, consumer use (such as cleaning and maintenance), and end-of-life disposal or recycling.



4. Functional Unit

One finished handloom natural Tussar Silk dress material, weighing 100 gm, with dimensions of 40 inches in width and meters in length, ready for packaging and distribution.

5. Process Tree and Material Flow



6. Inventory Dataset (per FU)

Table J1 — Inventory Dataset (per FU)

Activity	Activity Data (per FU)	Unit
Electricity	0.459	kWh
Water	16.000	Litre
Waste water	16.000	Litre
Transport (international)	9600	km
Auxiliary 1 (Soap)	0.026	kg
Fuel (LPG)	0.033	kg
Transport (domestic)	8.000	km
Yarn Waste	0.012	kg
Starch	0.015	kg

Disclaimer: The activity data are specific to the local handloom unit studied and may differ from those of other Tussar Silk dress material production units due to variations in technology, process scale, and regional practices.

7. Carbon Footprint Calculation

Table J2 — CF calculation for a natural Tussar silk dress material (per FU)

Activity	Emmision (kg CO_2-eq)
Electricity	0.334
Water	0.021
Waste Water	0.0006
Transport (international via ship)	0.021
Auxiliary 1 (Soap)	0.063
Fuel (LPG)	0.038
Transport (domestic via scooter)	0.01
Yarn Waste	0.012
Starch	0.021
Total	0.522

Disclaimer: The results are based on data from a single unit. Further detailed studies and sensitivity analyses are required to draw conclusions for the entire sector.

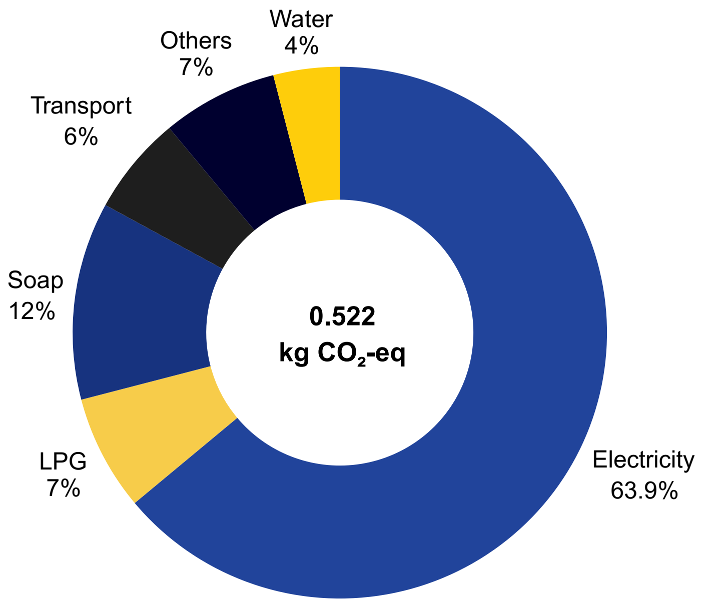


Figure J1 — CF breakdown by process input (%)

8. Interpretation

The CF chart for natural Tussar silk dress material highlights electricity consumption (63.9%) as the dominant source of emissions, followed by soap (12%), LPG (7%), transport (6%), water (4%) and others including yarn waste (2%), starch (4%), and waste water(<1%). This distribution indicates that energy-intensive processes are the leading contributors to emissions, especially those relying on grid electricity. While some effort may be made to use alternatives such as LPG, the overwhelming reliance on electricity underscores the need for energy efficiency and a shift towards renewable power.

The significant share from soap and LPG also suggests that improvements in chemical selection and fuel use, as well as greater resource efficiency in washing and processing, could further reduce the overall CF.

Annex K

Carbon Footprint of Kullu Shawl

1. Background

Kullu shawls, named after the capital town of Himachal Pradesh, have evolved from plain indigenous styles to intricate patterned designs influenced by Bushahr weavers in the 1940s. Today, both men and women weave these shawls on handlooms, with production involving pre-weave activities and the use of vegetable or chemical-dyed yarns. Master weavers procure raw materials and coordinate the work of around 20,000 local artisans, most of whom are part of cooperatives.

These shawls are celebrated for their elegant geometric and floral patterns—sometimes in up to eight colors—using traditional bright shades as well as contemporary pastels. High-quality yarns, such as yak's wool, sheep wool, Angora, and Pashmina, are spun using spinning wheels and then woven on handlooms. Supported by strong cooperative societies and marketed through various outlets, Kullu shawl weaving sustains thousands of artisans and stands as a testament to both traditional craftsmanship and sustainable agricultural practices in Himachal Pradesh.

2. Goal and Scope

The objective of this study is to assess the CF of a Kullu shawl by measuring CF emissions generated during its production within the handloom unit. The scope of this study begins from the point of receiving processed and dyed wool yarn at the handloom unit and extends through all subsequent production stages, including warping, handloom weaving, finishing, and final packaging of the Kullu shawl. It focuses on evaluating energy consumption (e.g., for heating dye baths and drying), water usage, chemical inputs, and direct process emissions during each stage. By concentrating on in-unit activities, the study aims to identify emission hotspots specific to wool-based handloom processes and provide targeted insights for improving sustainability.

3. Boundary Conditions

System Boundary
This assessment uses a gate-to-gate approach, focusing exclusively on the stages from the entry of yarn to the exit of the finished, packaged Kullu Shawl.

Included Processes
The Kullu shawl's footprint covers key steps: transporting dyed yarn, yarn preparation, handloom weaving, finishing, and packaging.

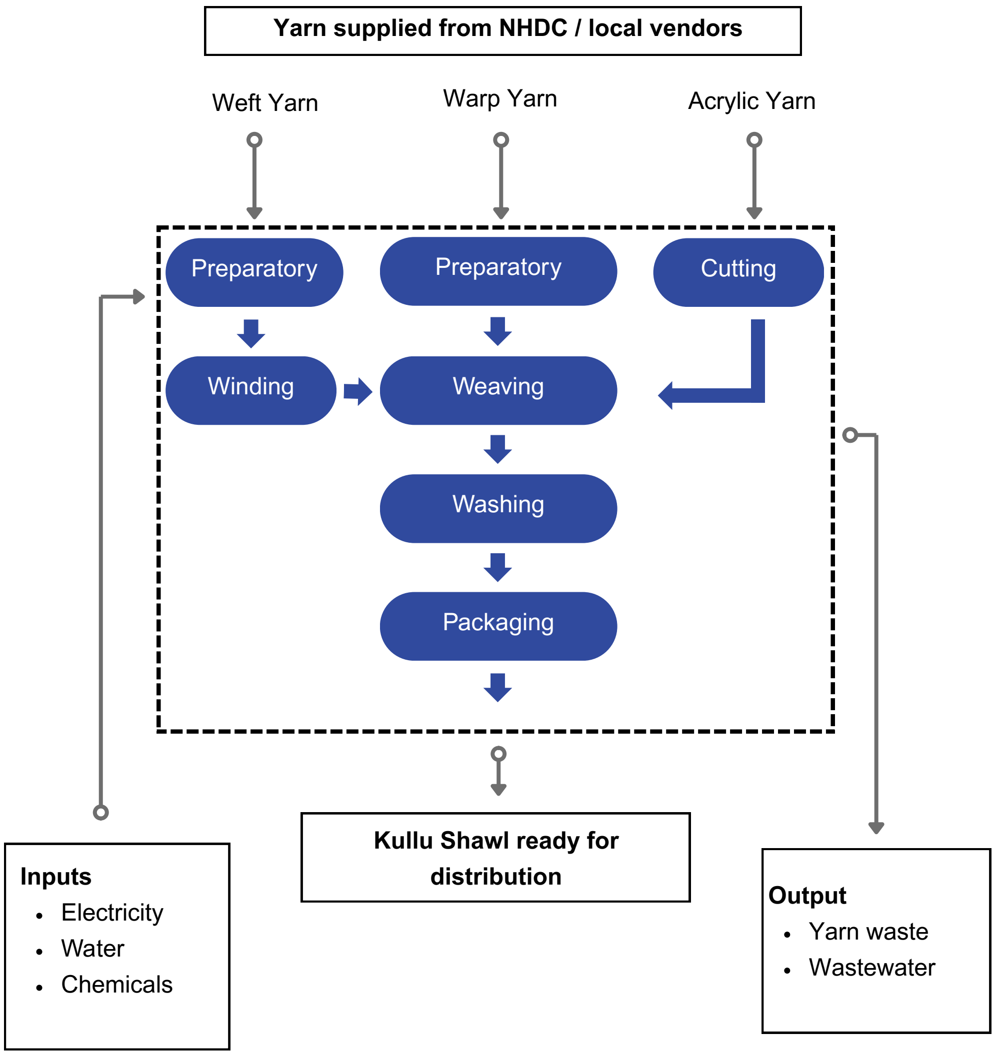
Excluded Upstream and Downstream Processes

Excluded upstream processes are wool production, yarn manufacturing, spinning of raw fibers, and water or energy generation associated with external activities. Downstream processes not considered include product distribution to retailers, consumer use (such as cleaning and maintenance), and end-of-life disposal or recycling.

4. Functional Unit

One finished handloom Kullu Shawl, weighing 375 gm, with dimensions of 40 inches in width and 80 inches in length, ready for packaging and distribution.

5. Process Tree and Material Flow



6. Inventory Dataset (per FU)

Table K1 — Inventory Dataset (per FU)

Activity	Activity Data (per FU)	Unit
Transport (truck)	80.00	km
Water	7.00	Litre
Waste Water	6.80	Litre
Auxiliary 1 (Soap)	0.01	kg
Electricity (Solar)	3.50	kWh
Electricity (Grid)	0.031	kWh
Yarn Waste	0.024	kg
Auxiliary 2 (Softener)	0.04	Litre

Disclaimer: The activity data are specific to the local handloom cooperative studied and may differ from those of other Kullu Shawl production units due to variations in technology, process scale, and regional practices.

7. Carbon Footprint Calculation

Table K2 — CF calculation for a Kullu shawl (per FU)

Activity	Emmision (kg CO_2-eq)
Transport (truck)	0.005
Water	0.009
Waste water	0.000
Packaging (PP)	0.014
Auxiliary 1 (Soap)	0.024
Electricity (Solar)	0.165
Electricity (Grid)	0.022
Yarn Waste	0.024
Auxiliary 2 (Softener)	0.128
Total	0.392

Disclaimer: The results are based on data from a single unit. Further detailed studies and sensitivity analyses are required to draw conclusions for the entire sector.

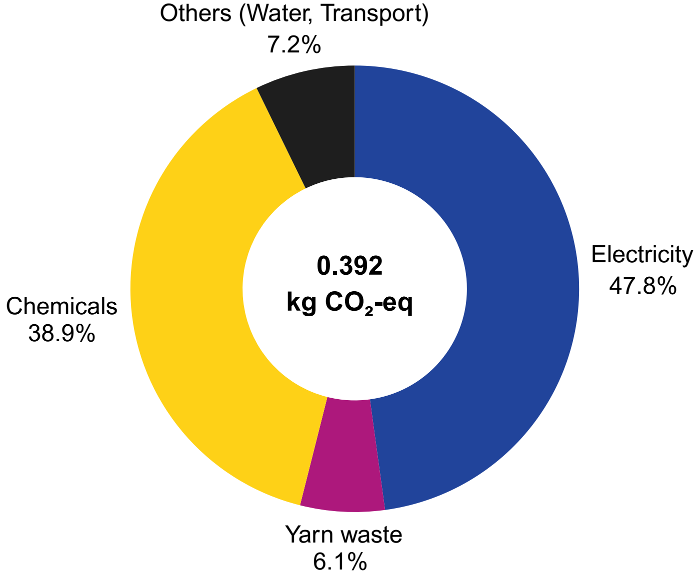


Figure K1 — CF breakdown by process input (%)

8. Interpretation

The CF chart for the Kullu shawl highlights electricity consumption (47.8%) and chemical inputs (38.9%) as the primary sources of emissions, followed by yarn waste (6.1%) and others (7.2%), such as transport, wastewater, and water. This distribution points to significant impacts from energy-intensive operations—especially processes like calendaring—and the use of various chemicals. While some solar energy is integrated, the high electricity demand remains a substantial contributor to emissions.

The notable role of chemicals and the minor share from logistics and waste management underscore opportunities for improvement in process optimization, chemical selection, and resource efficiency to further reduce the overall CF.

List of Emission Factor

Activity	EF	Unit	Source of EF
Transport (truck)	0.16	kg CO_2-eq/metric ton*km	Ecoinvent v3.11
Yarn Waste	0.99	kg CO_2-eq/kg	Ecoinvent v3.11
Caustic Soda	1.35	kg CO_2-eq/kg	Ecoinvent v3.11
Sodium Hydrosulphite	2.30	kg CO_2-eq/kg	Ecoinvent v3.11
Water (via Tap)	0.0013	kg CO_2-eq/kg	Ecoinvent v3.11
Electricity (Grid)	0.73	kg CO_2-eq/kWh	CEA
Wood	1,640.00	kg CO_2-eq/Short ton (907 kg)	EPA
Electricity (Solar)	0.05	kg CO_2-eq/kWh	Ecoinvent v3.11
Soap	3.90	kg CO_2-eq/kg	Ecoinvent v3.11
Yarn (Spinning)	7.63	kg CO_2-eq/kg	Ecoinvent v3.11
Soda Ash	0.45	kg CO_2-eq/kg	Ecoinvent v3.11
Wastewater Disposed	0.04	kg CO_2-eq/kg	Ecoinvent v3.11
Wastewater Treatment (Textile)	0.92	kg CO_2-eq/m3	Ecoinvent v3.11
Nonwoven (PP)	4.31	kg CO_2-eq/kg	Ecoinvent v3.11
Dyeing (cotton)	3.50	kg CO_2-eq/m3	Ecoinvent v3.11
Transport (Scooter)	0.061	person.km	Ecoinvent v3.11
LPG	1.17	kg CO_2-eq/kg	Ecoinvent v3.11
Coal	0.344	kg CO_2-eq/kg	Ecoinvent v3.11

Disclaimer: EF values are subject to variability due to differences in geographic location, technological processes, and the data sources

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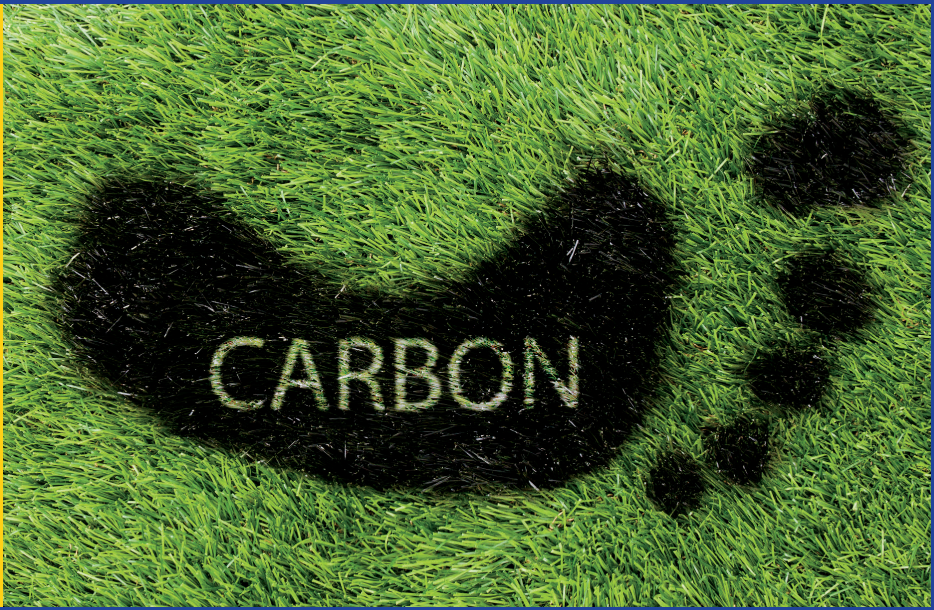
Handloom weaving is a beacon of low-carbon craftsmanship—each handloom textile leaves a remarkably smaller environmental footprint compared to industrial alternatives. By choosing handloom, we honor tradition, cut carbon emissions, and embrace a truly sustainable path for people and the planet.

To truly make textiles more sustainable, we need to measure the carbon footprint at every step of production.

Measuring is the first step to fixing problems. If we don't track the numbers—from raw materials to finished fabrics—we can't know what needs to change or if progress is real. By counting every bit of carbon used, we can see where to improve, use resources wisely, and show real results.



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