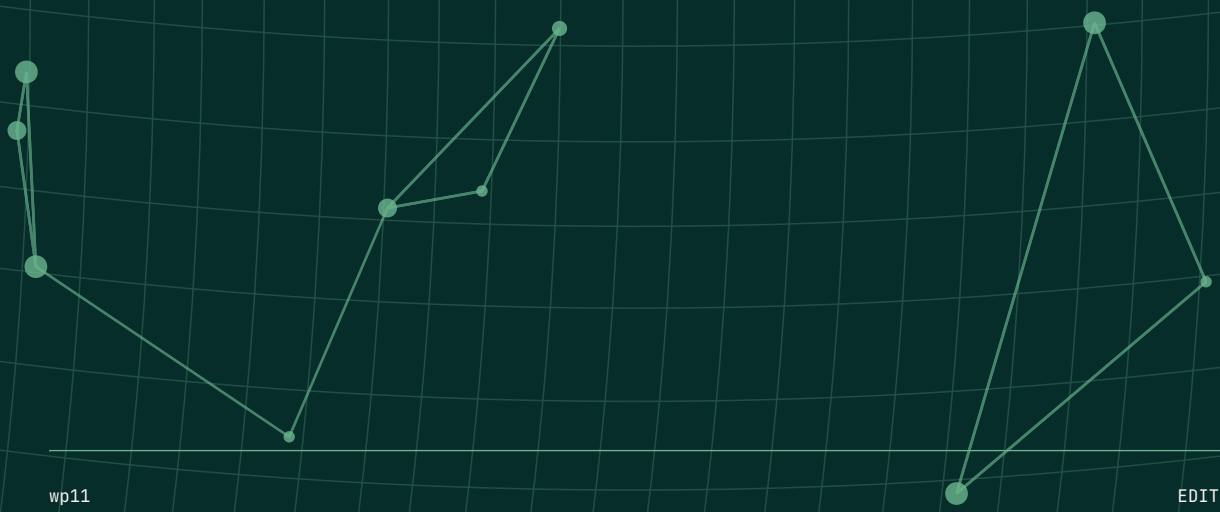
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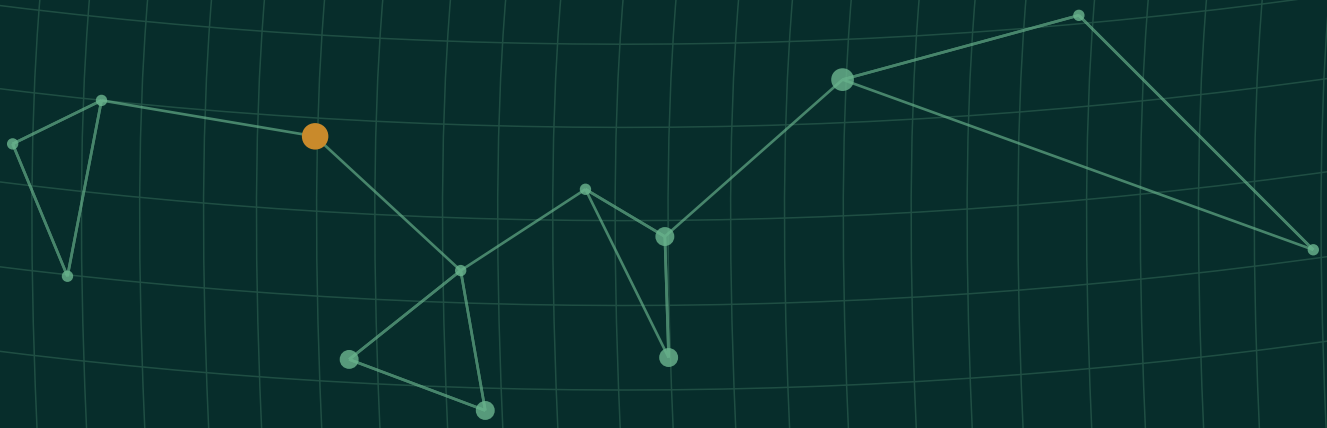
Closing the Loop

Circular textiles: pre-consumer waste, recycling routes and producer responsibility



wp11
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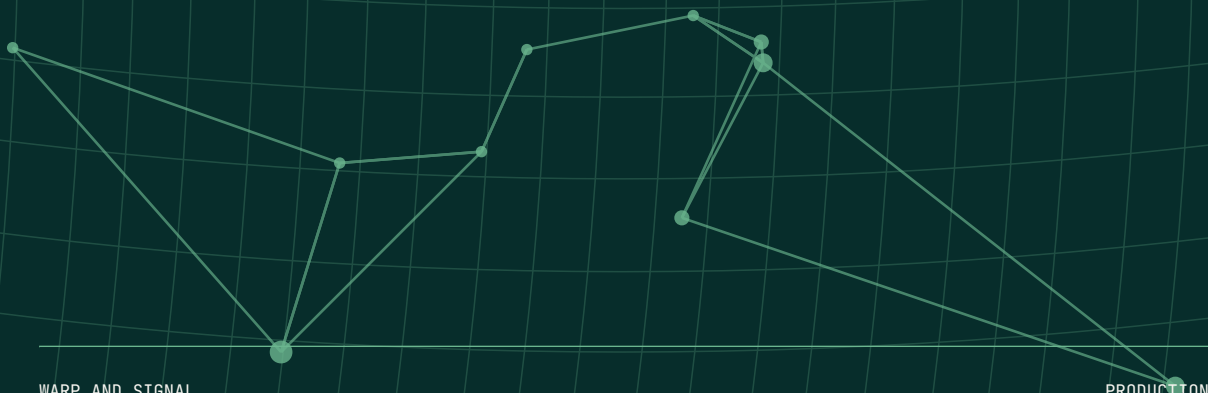
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HONG KONG SAR



THE GFT THESIS

Value is made where it is measured.

GFT engineers sustainable factories that capture their own data from the first shift, so raw-material economies can keep the value they grow.



Read the evidence before acting on the recommendation.

ISSUER	Green Future Tech Limited, Hong Kong SAR
DOCUMENT	wp11 / Closing the Loop
EDITION DATE	2026-10-30
AUDIENCE	Industrial sponsors and plant directors of greenfield cotton-to-garment ventures in Cameroon and the CFA-franc zone, Production engineers, cutting-room managers and quality leads designing shop-floor waste segregation and mass-balance logs, Spinning, knitting and textile-recycling operators evaluating mechanical tearing and chemical dissolving-pulp investments, Trade, environment and industrial policymakers across CEMAC, AfCFTA and the European Union, Development-finance institutions and sustainability auditors verifying Global Recycled Standard, ISO 59014 and Extended Producer Responsibility compliance
STATUS	Research edition. Generated locally. Publication and operating-performance acceptance are separate decisions.
PROGRAMME	GFT's Cameroon textile programme: feasibility, performance-management system design and digital strategy. Prepared 31 January 2024; source-refresh annotations retained in 2026.

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Build the factory and its evidence as one system.

Global fibre production reached a record 124 million tonnes in 2023, yet 73 percent of clothing material is landfilled or incinerated at end of life and less than 1 percent is recycled into new clothing, destroying more than US$500 billion in value annually. Cameroon experiences the sharpest form of this linear asymmetry: it harvests 314,455 to 340,000 tonnes of seed cotton a year through more than 220,000 SODECOTON producers, exports about 95 percent of its lint raw, and absorbs a rising tide of imported second-hand garments and synthetic contraband that overwhelms municipal waste systems. This white paper argues that circularity for a greenfield cotton-to-garment maker begins on the factory cutting-room floor, not at the municipal dump. In a cut-make-trim plant sized at an illustrative 3.0 million garments a year, marker geometry and sewing defects consume 15 to 22 percent of purchased fabric, generating 135 to 210 tonnes of pure, unsoiled cotton clips annually. By segregating clips by shade and batch at the cutting table, recording per-lay mass balance in GFT's Performance-Management System from Shift 1, preventing rework and deadstock through computer-vision inspection and machine-learning demand forecasting, and looping baled clips into regional open-end spinning poles such as Camtext SA, a greenfield maker turns waste into margin while meeting European Union Ecodesign and Extended Producer Responsibility rules. [R01] [R04]

01 Global fibre output reached 124 million tonnes in 2023 and is projected to hit 160 million tonnes by 2030, yet 73 percent of clothing materials are landfilled or burned and less than 1 percent enter closed-loop clothing-to-clothing recycling, losing over US$500 billion a year. [S01] [S02] [S08] [S09]

02 Cameroon harvests 314,455 tonnes (2023) to 340,000 tonnes (2024) of seed cotton and projects over 350,000 tonnes in 2025 across 220,000+ SODECOTON farmers, but exports 95 percent of its lint raw against a 50 percent local-processing target by 2030. [R01] [R02] [R03] [R06] [R07]

03 Upstream ginning of Cameroon's harvest yields roughly 54 percent cottonseed alongside 9,000 to 15,000 tonnes of short-staple linters/motes and 500,000+ tonnes of woody cotton stalks, while spinning 12,000 tonnes of lint at Camtext SA scale generates 960 to 2,160 tonnes of virgin-purity card and comber waste. [R01] [R03] [R09] [R10] [S16] [S17] [S37]

04 Because raw fabric accounts for 50 to 60 percent of total garment cost and cutting-room marker loss plus defects consume 15 to 22 percent of input yardage, saving 2 percent of fabric consumption raises operating profit margin by 1 percentage point, while a 3.0 million garment a year CMT plant generates 135 to 210 tonnes of recoverable cotton clips annually. [S32] [S33] [R29]

05 Segregating 100 percent cotton cutting clips by shade at the cutting table preserves 3.0 to 4.5 times the value of mixed floor sweepings, while machine-learning classifiers on Near-Infrared (900 to 1,700 nm) spectra achieve 91.7 percent composition accuracy and 92.6 percent binary elastane detection for external bales. [S10] [S24] [S25] [S26] [S27]

06 Mechanical tearing is the most capital- and energy-efficient recycling route for African industrial clusters (proven across 326,300 tonnes of post-industrial waste in Egypt, Morocco and Tunisia), producing commercial rotor yarns when blended at 20 to 35 percent with virgin SODECOTON lint and routing short card droppings into non-woven building insulation. [S20] [S24] [S25] [S28]

07 Chemical cellulosic regeneration overcomes mechanical staple shortening by using acid, alkaline or deep eutectic solvent pre-treatments to tune waste-cotton degree of polymerisation from 2,409 down to 500-700, achieving 98.80 percent alpha-cellulose purity and 88.01 percent pulp yield for viscose and Lyocell wet-spinning. [S34] [S35] [S36]

08 European Union exports of used textiles nearly tripled from 550,000 tonnes in 2000 to 1.7 million tonnes in 2019 and 1.44 million tonnes in 2025, transferring unrecyclable synthetic waste to African ports without sharing Extended Producer Responsibility funds while eroding domestic incumbents such as CICAM (down from 85 percent to 5 percent market share). [R11] [R12] [S11] [S13] [S29] [S30] [S31]

09 The revised EU Waste Framework Directive (in force 16 October 2025 after mandatory separate collection on 1 January 2025), France's Refashion 2026 eco-modulation scale, and ESPR Regulation (EU) 2024/1781 banning unsold apparel destruction turn durability lab testing, GRS v4 recycled content and mono-material cotton design into direct financial and compliance imperatives. [S03] [S04] [S05] [S06] [S12] [S14] [S22] [S23] [S28]

10 Deploying computer-vision defect detection (>90 percent accuracy versus 60 to 70 percent manual) and machine-learning demand forecasting (errors cut 20 to 50 percent, inventory costs down 35 to 40 percent) atop GFT's shop-floor Performance-Management System eliminates defect rework and deadstock overproduction while maintaining an auditable ISO 59020 and GRS v4 mass-balance ledger. [R27] [R28] [R29] [S21] [S28] [S39] [S40]

01

THE LINEAR TRAP AND THE PRE-CONSUMER ADVANTAGE / PROBLEM AND POSITION

Circularity in cotton economies begins on the cutting-room floor, not at the municipal dump

A cotton economy gains its most recoverable textile feedstock before a garment reaches a consumer. The practical starting point is an identified, weighed and segregated factory offcut, not an anonymous bale of mixed municipal clothing.

CHAPTER 01
DECISION TEST

A cotton economy gains its most recoverable textile feedstock before a garment reaches a consumer. The practical starting point is an identified, weighed and segregated factory offcut, not an anonymous bale of mixed municipal clothing.

Circular textiles should start where material identity is still intact. For a greenfield cotton garment operation, that point is the cutting table. Its offcuts can retain a supplier batch, fibre specification, colour family and weighed origin. Mixed municipal clothing normally arrives without that assurance and carries additional wear, blends, trims and soil. The first circular investment should therefore be a production discipline: prevent avoidable loss, separate unavoidable offcuts when they arise, reconcile their mass and transfer them to a specified recovery route. Municipal collection remains necessary for public sanitation and later-stage recovery, but it is the wrong foundation for a new cotton factory's first fibre-to-fibre loop.

This position does not claim that every factory offcut is recyclable, that sorting costs nothing, or that a bale leaving a factory has already become new yarn. Those outcomes require an accepted specification, a capable receiver and evidence of what happened after transfer. Nor does the chapter present an installed GFT factory or a measured GFT recycling result. It sets out a design position for GFT's Cameroon textile programme, connects that position to opened evidence, and makes the remaining operating tests explicit.

1.1

Global fibre output reached 124 million tonnes in 2023 while closed-loop recycling stayed below 1 percent

The global evidence shows a widening material-throughput problem, not a single recycling rate that can be applied to every product and place. Textile Exchange's reported global fibre production rose from 116 million tonnes in 2022 to 124 million tonnes in 2023. Its continuation scenario reaches 160 million tonnes in 2030 if current trends persist. The same account places pre-consumer and post-consumer recycled textiles below 1 percent of the global fibre market. That last measure concerns fibre supply, which is different from the share of discarded clothing recycled after use. [S02]

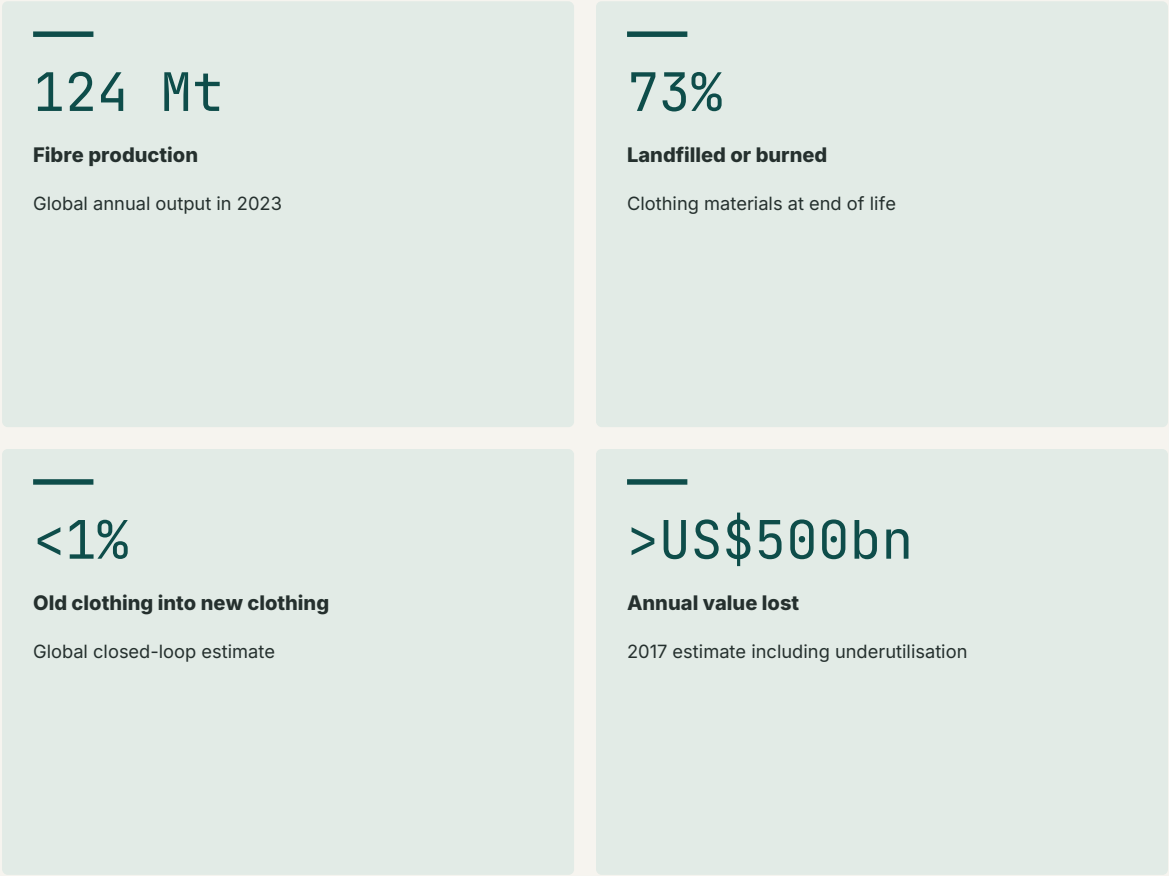
The Ellen MacArthur Foundation gives the complementary end-of-life view: 73 percent of materials used to produce clothing are landfilled or burned after use, while less than 1 percent of old clothing becomes new clothing. These are global system estimates associated with an earlier analytical baseline, not measurements of Cameroon's present waste stream. Their value here is directional. A system can expand fibre supply while still losing most clothing material at the end of use. [S09]

The economic loss is also dated but material. The Foundation's 2017 report estimated that clothing underutilisation and lack of recycling destroyed more than US$500 billion of value each year. This figure combines underuse and recycling failure. It should not be relabelled as the recoverable value of textile waste alone, converted into a current Cameroon opportunity, or added to a material mass balance. [S08]

Exhibit 1, p. 17 keeps these measures visible without forcing them into one artificial flow.

EXHIBIT 01 / REPORTED GLOBAL MEASURES, WITH SOURCE DATES RETAINED

Global circularity indicators describe different boundaries and cannot be added as one flow



SOURCED [S02] [S08] [S09] Annual fibre production is a supply measure. Landfill or burning and clothing-to-clothing recycling are end-of-life measures. The value-loss estimate also includes clothing underutilisation. No tonnage conversion or common denominator is inferred.

1.2 A MASS BALANCE NEEDS ONE DENOMINATOR AND ONE PERIOD

The first engineering lesson is negative: do not draw 124 million tonnes of annual fibre entering a Sankey diagram and then assign 73 percent of that tonnage to landfill. The fibre figure covers apparel, home textiles, footwear and other applications in a production year. The end-of-life percentages concern clothing material, which can have been produced in earlier years and can remain in use for different durations. Combining them would confuse a flow of new supply with the fate of a different stock of used products. [S02] [S09]

That distinction matters for industrial decisions. Annual fibre production informs the scale of material demand. End-of-life shares inform the need for collection, sorting and recovery. A recycling investment instead needs a local, measured feedstock balance: what mass becomes available, at which sites, in which composition, over what period, and with which existing destination. None of the global figures answers that local question.

The word recycling also conceals different outcomes. Reuse extends a garment's life without returning it to fibre. Mechanical or chemical recycling produces a secondary material. Cascading into insulation, wiping cloths or stuffing may retain utility without returning the material to apparel. Landfill and incineration are not recycling. A factory claim should name the actual destination and the evidence available, rather than treating every diversion from disposal as clothing-to-clothing recovery. The Foundation's report distinguishes clothing-to-clothing recycling from lower-value cascading and warns that cascaded products can themselves become final waste. [S08]

1.3 THE POLICY CONCLUSION IS TO INTERVENE BEFORE MATERIAL BECOMES ANONYMOUS

Global averages cannot tell a plant manager which bin to place beside a cutting table. They do show why an intervention limited to collection after disposal is too late for much of the material value. Once fibre origin, shade, finish and physical condition have become uncertain, more handling and testing are needed before a recycler can decide whether the input is acceptable.

The appropriate response is not to abandon post-consumer systems. It is to separate the tasks. Municipal systems need safe collection and socially responsible treatment. A new manufacturer has a narrower and more controllable opportunity: keep its own production residues identified from the moment they arise. That opportunity is immediate, local and auditable. It also creates operating evidence before a company makes a broader public claim about circularity.

1.4

Cameroon exports 95 percent of its cotton lint raw while absorbing unrecyclable imported apparel waste

Cameroon's inherited sector register records about 95 percent of cotton fibre exported raw and about 5 percent processed locally. The original publication date is not recorded, and this chapter has not independently refreshed that split. It is a sector baseline rather than a current factory measurement. The national industrialisation target cited in the same register is 50 percent local processing by 2030. [R06] [R07]

The contrast is stark because Cameroon has an organised agricultural supply base. The register records seed-cotton output of 330,000 tonnes in 2022, 314,455 tonnes in 2023 and about 340,000 tonnes in 2024. A separate 2025 projection above 350,000 tonnes is a projection, not realised production. SODECOTON's profile records more than 220,000 supported producers, nine ginning plants and two oil mills. These figures establish the relevance of cotton to northern production and rural livelihoods, not the availability of garment-grade recycled feedstock. [R01] [R02] [R03]

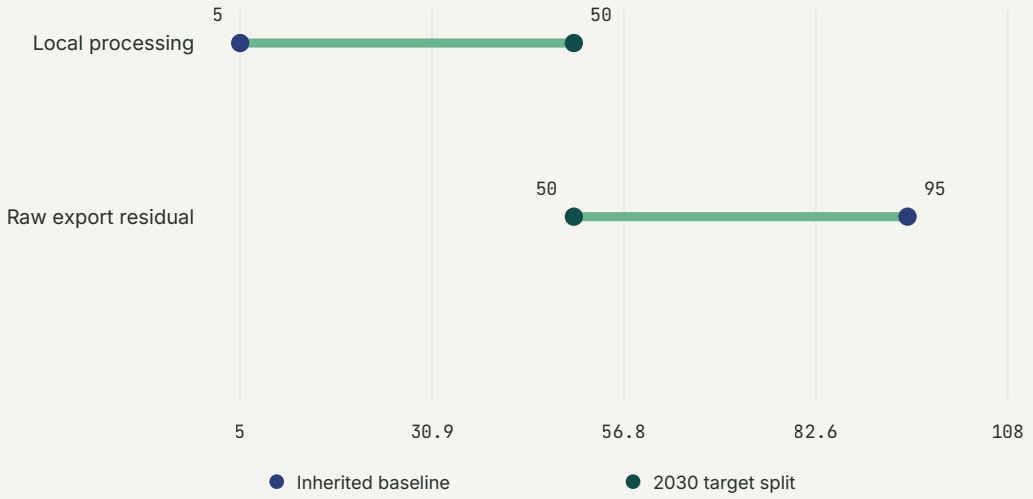
At the same time, domestic garment supply faces strong import pressure. The inherited register records CICAM's market share falling from about 85 percent three decades ago to about 5 percent in the register's present-day account. This is a sourced account of one named incumbent, not a measure of every clothing import or a GFT competitive result. It does not by itself establish the fibre composition or disposal rate of imported garments. [R11]

The defensible inference is structural rather than arithmetical. A country can export relatively well-identified virgin fibre while its clothing market receives products whose production history and eventual disposal pathway are much harder to control. Building domestic garment capacity addresses the first asymmetry only if it retains more material value locally. It addresses the second only if the new operation avoids adding its own anonymous waste to the municipal burden.

Exhibit 2, p. 19 expresses the national processing ambition as a change in share, not as a production forecast.

EXHIBIT 02 / PERCENT OF COTTON FIBRE IN THE STATED BOUNDARY

The national processing target implies a 45 percentage point shift in a simplified fibre split



DERIVED [R06] [R07] Inherited baseline: local processing 5% and raw export 95%. Target: local processing 50% by 2030. The target-side raw-export residual is derived as 100 - 50 = 50%, assuming a simplified two-category split. The change in local-processing share is 50 - 5 = 45 percentage points. This is not a forecast of volumes or plant capacity.

1.5 THE PROCESSING TARGET IS A MATERIAL CHALLENGE BEFORE IT IS A RECYCLING TARGET

Moving from the inherited local-processing share to the national target would require a 45 percentage point increase within the simplified boundary shown above. That arithmetic says nothing about how much additional spinning, fabric formation or garment capacity will actually be commissioned. Seed cotton is not lint, lint is not fabric, and fabric is not an accepted garment. Each conversion has its own yield, quality and timing. A serious programme must preserve those distinctions rather than applying one national percentage to every stage. [R01] [R06] [R07]

Circularity supports the processing objective in two ways. First, reducing avoidable factory loss means that more purchased fabric becomes saleable product. Second, recovering unavoidable clean residues can supply another process instead of requiring disposal. Neither mechanism substitutes for the primary investment in competitive production. A recycling line fed by an underused or quality-unstable garment plant would inherit that instability.

The announced SODECOTON and CICAM industrial pole and the Camtext SA project belong to this wider processing context. The register describes the former as an announced merger targeted by 2030. It describes Camtext SA as a planned integrated project with 12,000 tonnes a year of processing and optimal capacity around 2033. These are announcements and design parameters, not evidence of current output or of an existing waste-return partnership with GFT. [R08] [R09] [R10]

1.6 MUNICIPAL WASTE IS A PUBLIC OBLIGATION, NOT THE FACTORY'S EASIEST INPUT

Imported second-hand clothing and unsold garments can create real municipal costs, but the opening chapter should not claim a Cameroon-specific unsellable fraction without a local study. The safer industrial statement is that mixed post-consumer textiles require identification and condition assessment before a high-value recycling route can be selected. Research on post-consumer sorting identifies incomplete composition information, blends and elastane as barriers to accurate separation and higher-value recovery. [S26]

A greenfield producer should support responsible municipal outcomes through product design, durability, disclosure and any applicable producer-responsibility duties. Those duties differ by market and need legal confirmation. They are not a reason to make a new plant dependent on an uncharacterised municipal stream. The plant's first circular contract should instead concern material whose generation it can observe directly.

1.7

Pre-consumer factory waste provides the lowest-entropy feedstock for fibre-to-fibre recovery

Low entropy is useful shorthand here only if it is translated into operating facts. A clean cutting clip has not been worn, washed, soiled by a consumer or mixed with household refuse. Its fabric roll can carry a supplier and batch identity. Its composition and finish can be known from the purchase specification. Its shade can be inherited from the lay. Its size and freedom from zips, buttons and other hardware can be controlled by where it is collected. None of these attributes guarantees acceptance by a recycler, but together they reduce uncertainty before recovery begins.

Post-consumer material begins from a different evidential position. The University of Groningen study explains that fibre-composition information is often incomplete or unclear, that different fibres need different recycling processes, and that mixed streams can consequently move towards low-value incineration. It also reports that undetected elastane can disrupt shredding, filtering and output quality. These are reasons to identify and separate material, not proof that every post-consumer garment is unusable. [S26]

Pre-consumer waste is not one homogeneous substance. Spinning residues, greige selvedges, dyed cutting clips, sewing-thread trim, rejected panels and unsold garments differ in construction, finish and prior processing. Reusable roll ends should remain fabric rather than being shredded prematurely. A rejected garment may require

trim removal. Mixed overlock waste may carry a different polymer from the body cloth. The correct classification begins with the actual production event and the intended receiver's specification, not with a generic claim that factory waste is pure cotton.

UNIDO's Morocco business case makes this distinction commercially relevant. Its cited waste-mapping study estimated more than 83,000 tonnes of textile waste a year, with 42 percent comprising cotton-rich blends and 14 percent comprising 100 percent cotton fibres. Both categories were treated as high value in that study, but they are not interchangeable feedstocks. A cotton-rich blend still requires a route designed for its other fibre fraction. [S24]

The wider North African assessment shows why aggregation matters without making the tonnage uniform. The cited country estimates sum to 326,300 tonnes a year: 212,000 tonnes in Egypt, 83,200 tonnes in Morocco and 31,100 tonnes in Tunisia. The underlying SwitchMed study years differ. This total is an estimate of post-industrial waste generation, not a measured pool of clean cotton available for one recycler. [S25]

1.8 POINT-OF-GENERATION SEPARATION AVOIDS PAYING TO RECONSTRUCT IDENTITY

The Morocco pilot initially encountered garment companies without waste-management practices, so EVLOX segregated material after collection in central storage. UNIDO reports that post-collection segregation carried high costs and that transport could account for 30 to 40 percent of total textile-waste recycling cost in that pilot. The same project gathered and sorted approximately 160 tonnes over four months. Those observations do not set a Cameroon cost ratio, but they demonstrate the operational penalty of postponing separation. [S24]

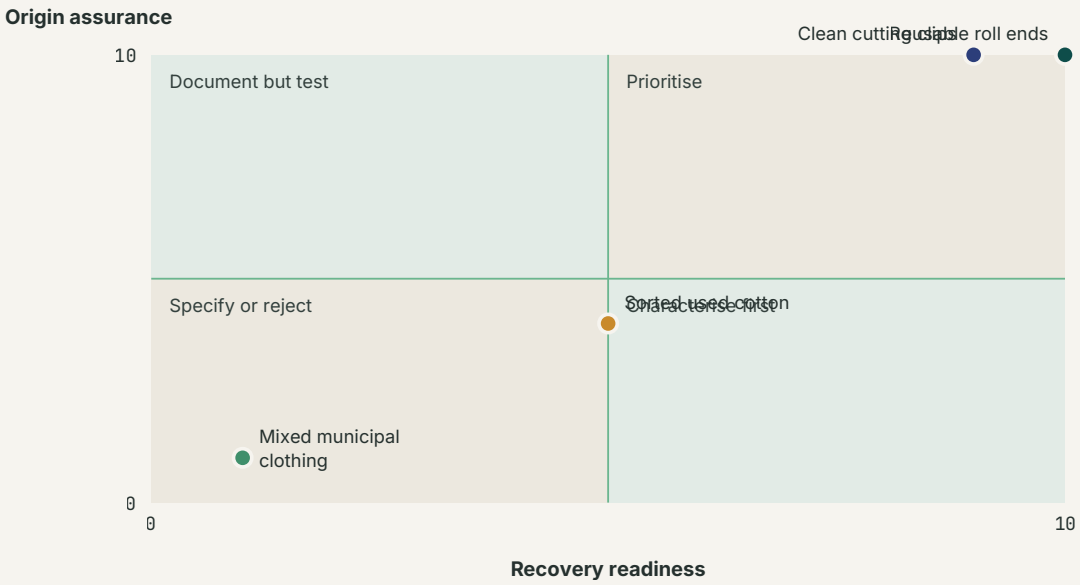
A known roll identity is therefore an asset worth preserving. If white, dark and blended clips are swept into one sack, a later operator must rediscover what the factory already knew. The later process may need manual picking, instrumental testing, additional containers and rejected material handling. Some information, such as the exact lay of origin, may be impossible to reconstruct. Separation at source is not merely cleaner housekeeping. It prevents the destruction of production information.

Reverse Resources describes the resulting supply-chain bottleneck as a shortage of clean, traceable and scalable waste. Its interview states that recycling technologies handling 12,000 tonnes and moving towards more than 200,000 tonnes a year increase the need for reliable feedstock. These figures describe a practitioner's view of technology scale, not a required size for a Cameroon plant. The relevant lesson is that a recycler needs dependable input specifications and delivery records, not just an annual waste headline. [S10]

Exhibit 3, p. 22 summarises the chapter's qualitative comparison. Its scores are a decision aid, not measured performance.

EXHIBIT 03 / ILLUSTRATIVE GFT ASSESSMENT, 0 LOW TO 10 HIGH

Known factory residues need less reconstruction than mixed municipal clothing



ILLUSTRATIVE [S10] [S24] [S26] Illustrative positions informed by the cited sorting and pilot evidence. Origin assurance considers batch identity, prior use and traceability. Recovery readiness considers composition knowledge, wear and soil, trims, shade consistency, and expected sorting burden. Scores are not laboratory measurements, prices or acceptance guarantees.

1.9 INSTRUMENTAL SORTING IS A BACKSTOP, NOT A REASON TO MIX KNOWN CLIPS

Near-infrared spectroscopy can help when origin records are absent or need independent checking. In the Groningen proof of concept, 181 certified-supplier samples were measured in the 900 to 1,700 nanometre band. The best composition classifier achieved 91.7 percent accuracy. The separate elastane model reported 92.6 percent overall accuracy, but only 83.3 percent for elastane-present samples. That last result is important because a missed contaminant can be more consequential than an overcautious rejection. [S26]

The study itself calls for further validation on real-world samples with wear, detergents, moisture and incomplete labels. It would therefore be wrong to transfer its laboratory accuracy directly to a conveyor receiving Cameroon municipal clothing. It would be equally wrong to install instrumental sorting and then relax source segregation. A known cutting clip should not be made anonymous simply because a later sensor might reconstruct part of its identity. [S26]

The practical hierarchy is clear. Preserve documented identity first. Check conformance at receipt and before baling. Use instrumental classification for uncertain external material, supplier audits and exceptions. Keep a rejection and quarantine route for material that fails the receiver's requirements. The matrix above cannot establish those requirements; an actual recycling partner must state them for its process.

1.10

Greenfield layout can avoid the retrofit penalty, though segregation is never free

A greenfield design can place material routes, containers and weighing points into the original operating layout. This avoids some later disruption to occupied production space and allows the collection routine to be designed alongside the cutting method. It does not make segregation free. Containers, identification, floor space, weighing, handling, training, supervision, baling and rejected-load management all require resources. The correct claim is a potentially avoided retrofit premium, not zero circularity cost.

The design unit should be the lay or another documented production batch. Before cutting, the team knows which fabric is being issued and which product components will be generated. The collection arrangement should preserve that connection. Pure cotton clips from one shade family should not meet synthetic-rich trim, food waste, packaging or floor sweepings. Reusable remnants need a separate location because their highest-value route may be direct fabric reuse rather than fibre recovery.

Container colour can assist recognition, but colour alone is not a record. Each container needs a durable identity linked to the source batch, material class, shade or other receiver-relevant attribute, tare condition and responsible role. The label must survive the physical transfer from table to store to bale. Where several source containers are consolidated, the record should retain their contributions. Otherwise the factory has preserved physical cleanliness while losing traceable origin.

> **GFT NOTE**
>
> Design the cutting room around four material decisions rather than around a single waste bin: return reusable fabric to stock, hold clean identified clips for the intended recycler, quarantine uncertain or contaminated material, and record disposal only for residues with no accepted recovery route. Give each decision a physical location and a responsible production role. Pilot the handling time and container requirement before claiming a capital or labour premium of zero.

UNIDO's decision to train garment makers in in-factory segregation after experiencing central sorting costs supports this design sequence. It does not prove that one prescribed bin layout will fit every factory. A greenfield team should map actual movement, test whether containers obstruct safe work, and measure any additional touches. If the proposed system slows cutting or encourages unsafe manual handling, the layout must change. [S24]

1.11 SEGREGATION BEGINS IN PRODUCT AND PURCHASING SPECIFICATIONS

The easiest contamination to manage is the contamination never introduced. Product specifications should identify body fabric, sewing thread, labels, interlinings, prints and trims. Purchasing documents should preserve fibre composition, supplier batch and finish information. Where a product deliberately uses polycotton or elastane for a functional reason, its offcuts need their own declared stream and recovery decision. Mono-material cotton is a design choice for suitable products, not a universal substitute for performance requirements.

Supplier agreements should also distinguish fabric that can be returned, remnants that can be reused and clips intended for recycling. A receiver may require particular shade groups, dimensions, moisture conditions, bale densities or documentation. Until those terms are known, a factory can build good records but cannot honestly call the output certified feedstock. Early engagement with the intended recycler converts an internal housekeeping exercise into a testable supply specification.

This is why the first circular team includes production, quality, procurement and logistics. Production understands where residues arise. Quality understands defects and acceptance. Procurement holds composition and supplier evidence. Logistics understands consolidation, storage and dispatch. A sustainability report assembled later cannot recreate missing observations if those functions never captured them.

1.12

Measurement from the first shift turns circularity into a mass-balance ledger

GFT's Cameroon textile programme joins feasibility, performance-management system design and digital strategy around the same production logic. For circularity, that means the sustainability commitment must become a measured material event. A factory should know what fabric entered a defined operation, what accepted product left it, which residues were generated, which material returned to stock, and which transfers remain unresolved. The record is useful even before enterprise software is selected because its first purpose is physical control.

The public description of ISO 59020:2024 supports measurement within defined economic systems and consistent collection and calculation. This chapter uses that principle to insist on a boundary, denominator and unit for every circularity indicator. It does not claim that the public description prescribes a particular cutting-room dashboard, and it does not rely on access to the full paid standard. [S40]

Textile Exchange's Content Claim Standard 3.1 supplies a more specific chain-of-custody discipline. It requires ongoing volume reconciliation by lot or batch, documented equations, expected waste factors, and consideration of inventory, waste and rejected products. It also requires claimed material to be identified and segregated, with composition calculations when blending occurs. A small factory ledger can prepare these observations without asserting that it has achieved certification. The applicable scheme edition and an accredited auditor must govern any later claim. [S0101]

Exhibit 4, p. 25 shows the proposed relationship between physical work and management decisions.

EXHIBIT 04 / PROPOSED GFT CONTROL ARCHITECTURE

The cutting-floor stack joins material identity to a recovery decision



ILLUSTRATIVE [S40] [S0101] Illustrative architecture for a greenfield operation, informed by defined-boundary measurement and chain-of-custody principles. It is not an installed GFT system, a certification result or proof that a recycler accepted the material.

1.13 THE MINIMUM EQUATION MUST PRESERVE UNRESOLVED MATERIAL

At its simplest, a period balance starts with opening stock plus measured receipts. It then accounts for accepted output, reusable returns, each classified residue, closing stock and a signed unresolved difference. The equation must use a consistent material basis. Packaging, cores and internal transfers should not inflate fabric consumption or waste generation. A transfer from the cutting table to a central store changes custody inside the plant; it does not create a second tonne of waste.

The unresolved difference is not an embarrassment to erase. It may reveal timing differences, tare errors, unrecorded stock, scale problems or genuine loss. Its cause should be investigated rather than assumed. Textile Exchange's cited standard requires waste-factor deviations to be investigated within its certification context; it does not authorise a factory to hide an unexplained balance inside a generic waste percentage. [S0101]

A mass balance also needs a meaningful denominator. Waste per accepted garment helps commercial review but changes with garment weight and product mix. Residue as a share of fabric issued helps assess material conversion but depends on stock timing. Clean clips as a share of all residues describes classification, not successful recycling. Recycled content in a later yarn is a different measure again. Publishing one percentage without naming its numerator and denominator invites false comparison.

WORKED EXAMPLE: A CLOSED BALANCE STILL DOES NOT PROVE RECYCLING

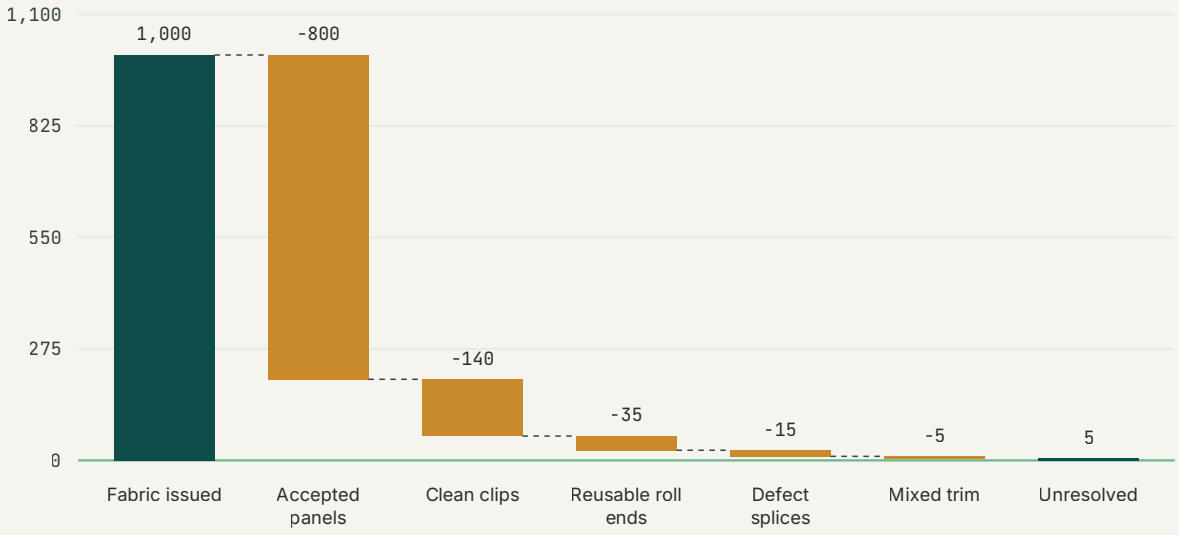
Assume an illustrative cutting period with 1,000 kg of net fabric issued. Constructed observations are 800 kg of accepted panels, 140 kg of clean identified cotton clips, 35 kg of reusable roll ends, 15 kg of defect splices, 5 kg of mixed trim and 5 kg of unresolved difference. The arithmetic is 800 + 140 + 35 + 15 + 5 + 5 = 1,000 kg. These are assumed inputs used to demonstrate the accounting method, not GFT operating data.

In this illustrative case, clean identified clips equal 140 / 1,000 × 100 = 14 percent of fabric issued. Reusable roll ends remain stock rather than waste. The 5 kg unresolved difference equals 0.5 percent of the same issued mass and remains open for review. The calculation establishes neither a recycling yield nor a certification threshold. The clean clips count as recovered only when a defined receiver accepts and processes them under the required evidence.

Exhibit 5, p. 26 retains every constructed destination, including the unresolved balance.

EXHIBIT 05 / KG, ILLUSTRATIVE CUTTING PERIOD

A complete cutting balance separates reusable stock, classified residues and unresolved mass



ILLUSTRATIVE Constructed inputs only: 1,000 kg issued = 800 accepted panels + 140 clean clips + 35 reusable roll ends + 15 defect splices + 5 mixed trim + 5 unresolved. Clean clips / issued fabric = 140 / 1,000 = 14%. Unresolved share = 5 / 1,000 = 0.5%. This demonstrates arithmetic, not observed factory performance or recycling.

1.14 CUSTODY ENDS AT AN EVIDENCED TRANSFORMATION, NOT AT THE FACTORY GATE

A bale dispatched to a broker is not necessarily a bale recycled. The ledger should therefore distinguish internal classification, outbound transfer, receiver acceptance and verified transformation. Each stage answers a different question. What did the factory generate? What did it send? What did the receiver accept? What output did the receiver actually produce, with which losses and destinations?

This distinction protects the factory from overstating its result. It also improves procurement. If a receiver repeatedly rejects a shade or construction, the plant can change its product or sorting specification. If accepted mass differs systematically from dispatched mass, the teams can investigate moisture, packaging, weighing or handling. If no final transformation evidence is available, the report should say so rather than substituting an assumed recycling rate.

The first-shift ledger is consequently both an operating tool and a limit on language. It allows the plant to report measured generation and transfer accurately while leaving later outcomes open until evidence arrives. That is more useful than a polished circularity percentage built from assumptions.

1.15

Circular operations reinforce capacity utilisation and first-pass yield rather than competing with them

Circularity should not become a parallel project that consumes production attention while the main line underperforms. Its first duty is to improve material conversion and prevent avoidable loss. Better use of fabric, fewer defective panels and less unsold output all reduce the residue requiring recovery. Recovery then addresses the unavoidable remainder. This order keeps waste prevention ahead of waste management.

The need for operating discipline is visible in the inherited account of CICAM. July 2023 capacity-utilisation figures were 33.7 percent at Garoua, 48.9 percent at CICAM 1 and 10.83 percent at CICAM 2, with underutilisation estimated to have cost about XAF 2 billion in 2020. These figures concern named incumbent plants at stated dates. They do not predict a greenfield venture's utilisation, and they do not prove that recycling would improve it. [R12]

The connection is more direct at the process level. A defective panel consumes fabric and may also consume sewing labour, thread, trims and machine time before rejection. Producing garments for which there is no buyer consumes the same resources and adds storage. Recycling the resulting material may recover some value, but it cannot erase all the processing already performed. Prevention protects more of the original investment.

Computer vision can assist one part of that prevention task. The inherited evidence register summarises manual fabric inspection at 60 to 70 percent accuracy and computer vision above 90 percent across more than 40 defect types, with line-scan inspection up to 60 metres a minute. These are literature benchmarks rather than guaranteed local performance. A factory still needs acceptance tests on its fabrics, lighting, defect classes and line conditions. [R29]

Demand forecasting addresses a different source of waste. McKinsey's reported fashion-sector estimates include forecast errors reduced by 20 to 50 percent and inventory costs reduced by 35 to 40 percent when artificial intelligence is deployed at

scale. These are not cold-start promises for a new Cameroon factory. Useful forecasting requires relevant order history, product definitions and review by people who understand the market. [R27]

The correct operating sequence is therefore straightforward. Inspect incoming material before committing it to a lay. Measure first-pass quality where work occurs. Produce against a documented demand plan. Investigate the causes of residue before investing in ways to process more of it. Then contract a recovery route for clean, unavoidable offcuts. Digital tools support that sequence; they do not replace the underlying supervision or make all rework and deadstock disappear.

This also clarifies the place of circularity in daily management. The cutting-room lead should care about clean clips because they reveal conversion performance as well as recovery potential. The quality lead should care because contamination and defects change the available route. The plant manager should care because purchased fabric, accepted output and unsold stock affect cash. Circularity becomes useful when these are different views of the same production record, not competing reporting systems.

1.16

GFT's thesis links domestic value retention with verifiable producer responsibility

GFT's position is a dual commitment: retain more value from Cameroon cotton through local transformation, and account honestly for the residues created by that transformation. The national raw-export baseline and local-processing target establish the strategic direction, not the performance of any single venture. [R06] [R07] The cutting floor supplies a practical starting point because the producer can observe and control material there before it enters a more uncertain downstream system.

Producer responsibility then has two levels. Operationally, the manufacturer must know what it generated, prevent what it could, preserve usable material and select a responsible destination. In markets where formal Extended Producer Responsibility rules apply, the legal obligations, covered entities, reporting boundaries and fees need separate confirmation. An internal mass balance may help assemble evidence, but it does not by itself establish legal compliance.

Market access reinforces the need for this discipline without changing the chapter's starting point. The shared register records Cameroon's AGOA eligibility as terminated from 1 January 2020 and continuing ineligibility through 2025. That supports the programme's emphasis on domestic and regional demand rather than a presumed United States preference. It does not remove the value of building product and custody records that can respond to other buyers' requirements. [R18]

The following chapters examine the work in greater detail: upstream co-products, cutting loss, sorting, mechanical and chemical routes, blends, imported clothing burdens, producer responsibility, unsold stock, verification, factory logs, regional partnerships and phased investment. Their shared premise is that technology choice comes after material characterisation. A factory should not buy a recycling process and then search for a feedstock story to justify it.

Several tests remain decisive. The intended receiver must confirm composition, shade, finish and contamination limits. The plant must measure actual generation by stream and product mix. Handling trials must establish labour, space and safe movement. Logistics must show that consolidation and transport preserve value. Commercial terms must state who owns the residue and who bears rejection cost. Chain-of-custody and certification claims require the applicable standards and independent assessment. Environmental benefit requires a comparison with the displaced alternative, not an assumption that every recovery route is preferable.

None of the illustrative factory figures in this chapter is a production forecast, an investment return or an achieved GFT result. Nothing here constitutes investment, legal or tax advice. The chapter's narrower conclusion is actionable: begin with known material, preserve its identity, measure its movement and make each recovery claim stop at the limit of the evidence.

Circularity begins when a factory can name, weigh and route the material it once called waste.

CHAPTER SOURCE NOTES

S02 United States Fashion Industry Association (citing Textile Exchange). 2024-09-27.

S09 Ellen MacArthur Foundation. 2021-06-22.

S08 Ellen MacArthur Foundation. 2017-11-28.

R06 Cameroon Trade Hub. Publication date unrecorded; inherited source-text check.

R07 Ecofin Agency. Publication date unrecorded; inherited source-text check.

R01 Business in Cameroon. Publication date unrecorded; inherited source-text check.

R02 Fibre2Fashion; Business in Cameroon. Publication date unrecorded; inherited source-text check.

R03 SODECOTON. Publication date unrecorded; inherited source-text check.

R11 Business in Cameroon; MMI News. Publication date unrecorded; inherited source-text check.

R08 Business in Cameroon. Publication date unrecorded; inherited source-text check.

R09 Ecofin Agency. Publication date unrecorded; inherited source-text check.

R10 Ecofin Agency. Publication date unrecorded; inherited source-text check.

S26 University of Groningen. 2026-04-22.

S24 United Nations Industrial Development Organization (UNIDO). 2023-11.

S25 Closed Loop Fashion and Reverse Resources. 2022-11-30.

S10 Fashion for Good and Reverse Resources. 2025-08-12.

S40 International Organization for Standardization (ISO). 2024-05.

S0101 Textile Exchange. 2022-06-09.

R12 Business in Cameroon. Publication date unrecorded; inherited source-text check.

R29 MDPI; industry inspection literature. Publication date unrecorded; inherited source-text check.

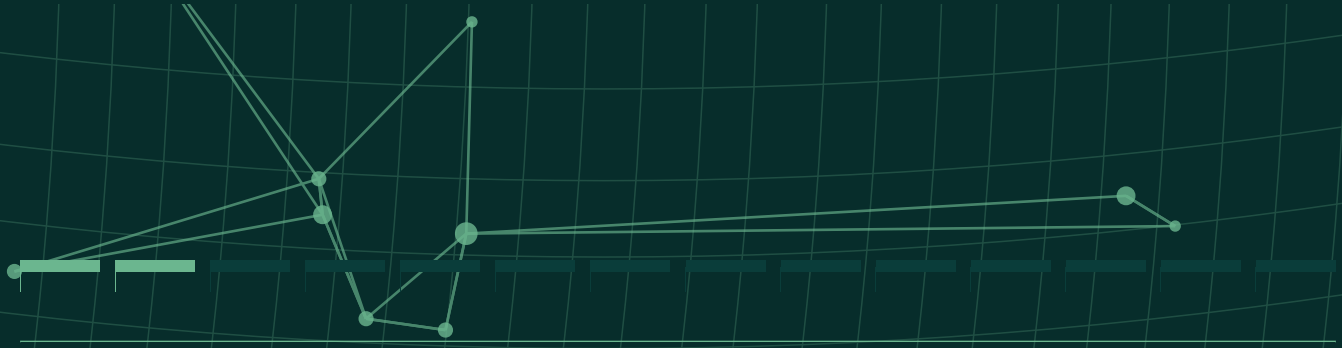
R27 McKinsey, The State of Fashion 2025. Publication date unrecorded; inherited source-text check.

R18 Congressional Research Service IF10149; AGOA (Wikipedia). Publication date unrecorded; inherited source-text check.

02

Ginning and spinning co-products hold the first uncaptured value pool in the cotton belt

Before cloth is woven, seed cotton and lint have already generated cottonseed, linters, motes, stalks and comber noils. Their value depends on measured recovery, not on the harvest total alone.



CHAPTER 02
DECISION TEST

Before cloth is woven, seed cotton and lint have already generated cottonseed, linters, motes, stalks and comber noils. Their value depends on measured recovery, not on the harvest total alone.

The first uncaptured value pool in the cotton belt is not a single reservoir of waste. It is a set of distinct material streams created at the gin, the oil mill, the field and the spinning frame. Cottonseed is usually the largest by mass, but linters, comber noils and clean yarn waste can carry greater value per tonne when their purity is preserved. The investment case therefore begins with separate weigh-bridge records and quality tests, not with a circularity label. Applying UNCTAD's rough ginning split to Cameroon's approximate 2024 harvest of 340,000 tonnes of seed cotton gives a screening estimate of 187,000 tonnes of cottonseed, 136,000 tonnes of lint and 17,000 tonnes still to be allocated through plant measurement. These are derived quantities, not observed SODECOTON outputs or a forecast of saleable co-products. [R01] [S17]

This distinction changes the development question. The useful question is not how much residue the national harvest could contain in theory. It is which legal owner controls each stream, at what moisture and contamination level, in which months, and within what transport radius of a buyer. A gin can measure seed and motes. An oil mill can measure delinting and crushing yields. A spinning mill can measure stage-specific waste. Field stalks require a separate farm collection balance. Combining these boundaries into one national tonnage would overstate the supply available to any plant.

2.1

Seed-cotton ginning yields roughly 55 percent cottonseed and 40 percent lint, with the balance requiring measurement

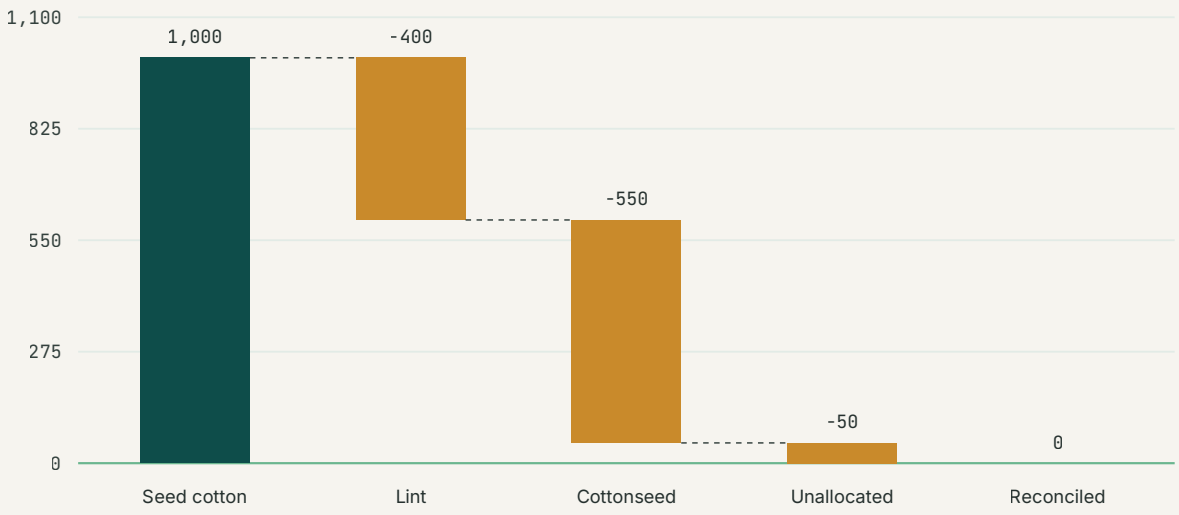
Cameroon's inherited production register records 330,000 tonnes of seed cotton in 2022, 314,455 tonnes in 2023 and about 340,000 tonnes in 2024. A separate entry records a projection above 350,000 tonnes for 2025, while the wider CFA-zone crop is recorded at 2.3 million tonnes in 2024/25. The projection is not realised output, and the regional figure is not a Cameroon denominator. [R01] [R02] [R05] SODECOTON's inherited company profile records more than 220,000 producers, nine ginning plants and two oil mills in northern Cameroon. That network offers points at which material can be weighed, but the register does not provide gin-by-gin recovery data. [R03]

UNCTAD gives a deliberately simple rule of thumb: ginning seed cotton yields roughly 55 percent cottonseed and 40 percent lint. [S17] The remaining approximate 5 percent is not identified in that sentence. It must not automatically be labelled motes, hulls or usable short fibre. Hulls belong to the later seed-processing balance, while linters remain attached to the seed after ginning. ICAC's process description makes this sequence clear: mechanical delinting removes residual fibres, dehulling separates the hulls, and oil extraction leaves a protein meal. [S0204]

The screening calculation in **Exhibit 6**, p. 32 preserves that uncertainty. It assigns only the two sourced fractions and leaves an explicit unallocated balance.

EXHIBIT 06 / TONNES OF SEED COTTON AND GINNING OUTPUTS

A 1,000 tonne screening balance leaves 50 tonnes unallocated for plant measurement



DERIVED [S17] Derived from UNCTAD's rough rule of 40 percent lint and 55 percent cottonseed. Calculation: 1,000 × 0.40 = 400; 1,000 × 0.55 = 550; unallocated balance = 1,000 - 400 - 550 = 50. The unallocated amount is not a measured residue specification.

The exhibit is a bookkeeping template, not a claim that every gin achieves the same outturn. Harvest method, foreign matter, drying, cleaning settings and the treatment of good fibre removed with trash all affect a closed balance. ICAC reports 1.4 to 1.5 pounds of seed per pound of fibre as a separate general relationship, which is close to, but not identical with, the UNCTAD rule. [S0204] A plant should therefore use the international figures to design its ledger and then replace them with weighed lots.

A usable gin record starts with incoming seed-cotton mass and moisture, lint bales pressed, cottonseed dispatched, motes and other residues collected, and unmeasured stock change. Each output needs a destination and a timestamp. The difference between inputs and outputs is an exception to investigate, not a residual to hide inside a waste percentage. Moisture correction matters because a wet tonne purchased and a dry tonne sold are not interchangeable.

GFT NOTE

GFT recommends a gin-by-gin mass-balance pilot before any national co-product volume is quoted to investors. Record at least one complete procurement season, reconcile seed cotton to lint, seed and named residues, and retain the moisture basis. Only then should a plant coefficient replace the screening rule used here.

2.2

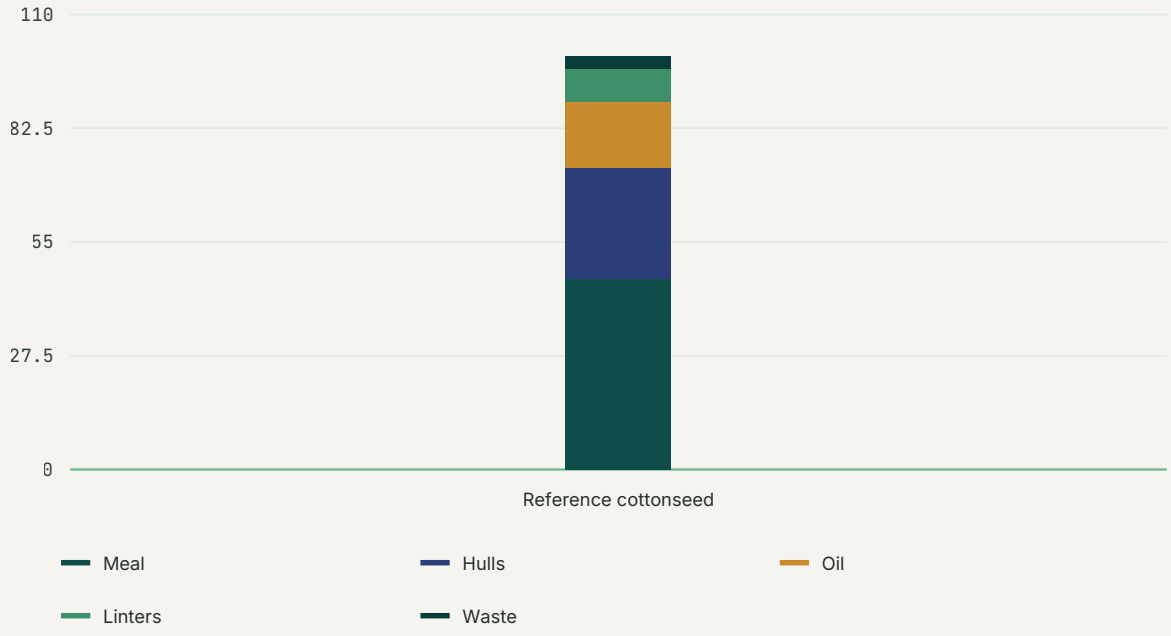
Cottonseed crushing separates oil, meal, hulls and linters rather than producing one generic cake

Cottonseed is already an industrial input, not an unavoidable disposal cost. ICAC identifies four products from scientific seed processing: linters, hulls, vegetable oil and protein meal. [S0204] Whole fuzzy cottonseed contains about 18 to 20 percent oil and 20 to 22 percent protein in the source's typical composition, but those figures are compositional properties, not guaranteed commercial recovery rates. [S0204] Expeller or solvent extraction, delinting, dehulling, seed variety, moisture and the share retained for planting or whole-seed feed all change the saleable outputs.

ITC provides a complementary generic composition for ginned cottonseed: about 46 percent meal, 27 percent hull, 16 percent oil, 8 percent linter and 3 percent waste. [S0201] **Exhibit 7**, p. 33 shows that the oil fraction is only one part of the seed's potential value. The two ICAC and ITC profiles should not be averaged. They answer slightly different questions and use generic reference material rather than Cameroonian mill measurements.

EXHIBIT 07 / PERCENT OF GINNED COTTONSEED BY MASS

Meal and hulls dominate a generic cottonseed composition before mill-specific recovery is measured



SOURCED [S0201] Generic composition reported by ITC from ICAC reference material: 46 percent meal, 27 percent hull, 16 percent oil, 8 percent linter and 3 percent waste, summing to 100 percent. This is not a SODECOTON yield or an oil-mill recovery forecast.

For illustration only, applying that reference composition to the derived 187,000 tonne national cottonseed quantity would represent 86,020 tonnes of meal, 50,490 tonnes of hulls, 29,920 tonnes of oil, 14,960 tonnes of linters and 5,610 tonnes of waste.

The calculation is simply the seed estimate multiplied by each ITC share. It is not a production plan: it assumes every derived tonne exists, reaches processing and follows the generic composition. [R01] [S17] [S0201]

The two oil mills in SODECOTON's inherited profile provide an institutional starting point for measuring real recovery, but they do not evidence spare capacity, current technology or uncontracted seed supply. [R03] UNCTAD's African analysis found that only 75 percent of cottonseed was crushed for oil and meal, leaving 25 percent unused at the time of that assessment. It valued the unused seed at about US$237 million, mostly in West Africa. [S17] Those continental observations demonstrate a value gap; they do not establish the same gap in Cameroon today.

Oil and meal also serve different markets. UNCTAD describes cottonseed oil as the most valuable cotton by-product in price-to-weight terms and identifies edible oil and animal feed as viable African by-products. [S17] Its completed Eastern and Southern Africa programme examined meal that could feed poultry and other non-ruminants, alongside fuel briquettes and absorbent cotton. [S18] The commercial implication is to test each output against its own specification. Crude oil, refined edible oil, ruminant feed and detoxified meal are not interchangeable products.

A mill ledger should therefore split incoming fuzzy seed into planting seed, whole-seed feed, mechanically delinted seed and any acid-delinted seed before calculating crusher yield. It should then weigh linters, hulls, oil, meal and final losses by lot. The WTO, ITC and UNCTAD joint initiative identifies limited extraction technology, seed stocking finance, storage and specialist skills as constraints in participating least-developed countries. [S16] These are due-diligence questions for Cameroon, not defects that can be presumed at named local mills.

2.3

Mechanically recovered linters suit absorbent cotton and dissolving pulp, but their denominator is seed

Linters are the short fibres that remain attached to cottonseed after the spinnable lint has been ginned. They are not an additional fraction to add to the cottonseed total: they are contained within it. ICAC distinguishes mechanical delinting, which recovers the fibres, from acid delinting used for planting seed, which destroys the fuzz. [S0202] This process choice determines whether a potential cellulose stream becomes a baleable co-product or disappears during seed preparation.

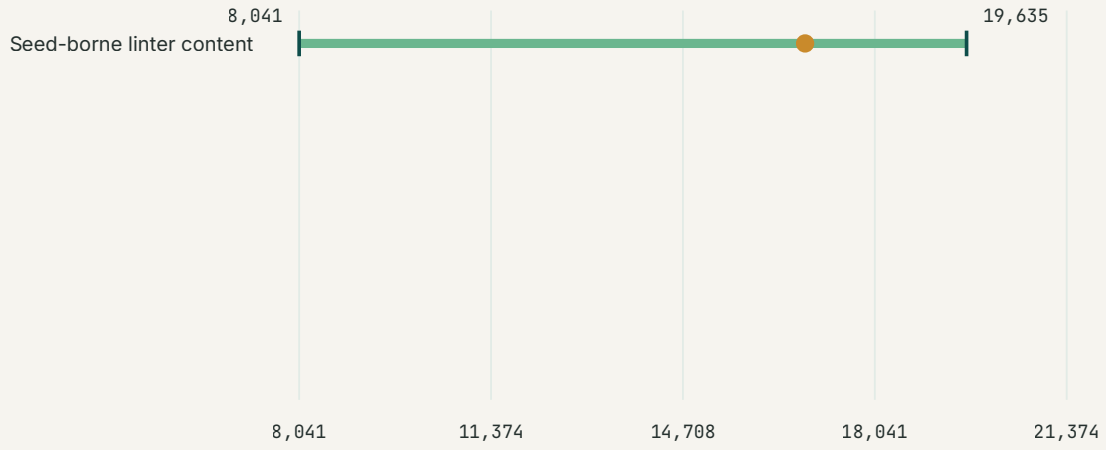
The typical yield reported by ICAC is around 9 percent of seed weight, not 9 percent of seed cotton. Its cited species study reports about 10.5 percent for Gossypium hirsutum, 4.3 to 5.9 percent for the named Indian native species, and naked seed for Gossypium barbadense. [S0202] The variation prevents a single linter coefficient from being treated as an agronomic constant. A Cameroon assessment must establish variety, delinting route and actual recovery at each oil mill.

Exhibit 8, p. 35 applies the reported lower, typical and upper yields to the derived 187,000 tonnes of cottonseed from the approximate 2024 harvest. The result is a theoretical content range of 8,041 to 19,635 tonnes a year, with 16,830 tonnes at the

typical 9 percent yield. It assumes that the rough ginning split holds and that all seed contains the relevant linter fraction. It does not assume that all seed is mechanically delinted, so it is not a recoverable supply forecast. [R01] [S17] [S0202]

EXHIBIT 08 / TONNES A YEAR OF SEED-BORNE LINTERS, THEORETICAL

Theoretical linter content is sensitive to species and must not be read as recoverable supply



DERIVED [R01] [S17] [S0202] Derived screening range, not a statistical interval. Approximate 2024 seed cotton 340,000 t x 55 percent = 187,000 t seed. Bounds: 187,000 × 4.3 percent = 8,041 t and 187,000 × 10.5 percent = 19,635 t. Midpoint uses the typical 9 percent yield: 16,830 t. Species and process context comes from ICAC.

This range corrects two common errors. First, multiplying a linter yield by seed cotton rather than cottonseed inflates the denominator. Second, treating theoretical content as collected supply ignores the share of seed used for planting, fed whole or acid delinted. UNCTAD's four-country surveys found that limited quantities of linters and hulls could rule out commercial-scale ventures, even before product economics were considered. [S37]

Gin motes require their own ledger. They arise during ginning and can contain recoverable fibre mixed with plant material, whereas linters are removed from the seed later. UNCTAD identifies short-staple fibres disposed of by ginners and spinners as candidate feedstocks for value addition, but it does not provide a Cameroon mote yield. [S37] The correct planning action is to sample and clean named lots, measuring recovered fibre, residual trash and moisture. A generic cellulose price cannot be applied to an uncharacterised mote stream.

The end markets also have different gates. ICAC describes comber noil and linters as feedstocks for absorbent cotton, speciality paper, nonwovens and regenerated cellulose. [S0202] A peer-reviewed dissolving-pulp review identifies cotton linters as a common raw material because of cellulose content above 86 percent. [S0205] That chemical suitability does not remove the need for reactivity, ash, foreign-matter and moisture specifications, nor does it prove that a local pulp reactor is the right investment.

Absorbent cotton offers a more modest reference scale, but still not an automatic business case. UNCTAD's Ugandan investment profile proposes a 260 tonne a year facility using short-staple cotton and gin waste, with a stated lint-to-cotton-wool conversion of 100:86. [S0207] This is a proposed project profile for Uganda, not a verified Cameroon plant or a universal minimum efficient scale. It nevertheless shows why feedstock quality and market qualification matter more than a large national residue estimate.

WORKED EXAMPLE: DELINTING COVERAGE DETERMINES RECOVERED LINTERS

Take an illustrative gin cluster receiving 100,000 tonnes of seed cotton. Using UNCTAD's rough 55 percent seed share gives 55,000 tonnes of cottonseed. [S17] Assume, solely for this example, that 60 percent of that seed is mechanically delinted and that ICAC's typical 9 percent linter yield applies. [S0202] Recovered linters would be 55,000 × 0.60 × 0.09 = 2,970 tonnes. The remaining seed cannot be assigned the same recovery without knowing its use. The result is illustrative arithmetic, not a SODECOTON measurement.

GFT NOTE

GFT recommends separating three KPIs: seed-borne linter content, mechanically delinted seed share and weighed linter recovery. A pulp or absorbent-cotton proposal should not pass its feedstock gate until these measures are reconciled by gin and month, and a buyer has accepted the fibre specification.

2.4

Cotton stalks become useful fuel only after collection, drying and densification are costed

Field stalks sit outside the gin's seed-cotton balance. UNCTAD reports that stalks represent at least 80 percent of the cotton plant's total mass and that African farmers often uproot and destroy residues after harvest, frequently by burning, to meet pest-management requirements. [S17] This makes stalks abundant in agronomic terms but not free at the factory gate. Collection labour, drying, field retention, chipping, storage and transport stand between standing biomass and a usable fuel.

ITC estimates two to three tonnes of stalks per hectare, while its rain-fed caveat gives up to 1.3 tonnes per hectare under the conditions described. [S0201] These figures cannot be multiplied by Cameroon's seed-cotton tonnage to obtain a national stalk total. The required denominator is harvested hectares under defined growing conditions, followed by the recoverable dry share. Without those observations, a national estimate would conceal more uncertainty than it reveals.

UNCTAD's project work identifies briquettes and pellets as priority uses selected in Tanzania, Uganda, Zambia and Zimbabwe, with stalks also suitable for mushroom substrate and other products. [S17] [S18] The attraction is substitution for firewood, charcoal, coal or other fuels, not merely residue disposal. Yet UNCTAD also records that a briquetting plant needs raw material throughout the year and that cost-effective supply was the decisive challenge in an Indian case. [S37]

Exhibit 9, p. 37 preserves one documented reference case without turning it into a design rule. ITC cites a four tonne a day plant requiring about 1,000 tonnes of biomass a year, associated with 300 to 400 hectares and a 25 to 30 kilometre catchment radius. [S0201] These are screening assumptions for a particular model, not guaranteed minima for northern Cameroon.

EXHIBIT 09 / REFERENCE-CASE PARAMETERS

A documented briquetting reference case depends on a nearby year-round biomass catchment

4 tonnes/day

Reference throughput

Documented plant case

1,000 tonnes/year

Biomass requirement

Approximate annual input

300 to 400 ha

Catchment area

Reference average

25 to 30 km

Catchment radius

Reference logistics case

SOURCED [S0201] ITC reproduces a UNCTAD-derived reference case for a four tonne a day briquetting plant. Values are not a universal minimum viable scale or a Cameroon feasibility result. Local dry recoverable yield, collection cost, competing uses, storage and off-season feedstock must be measured.

Densification addresses a physical logistics problem rather than proving commercial viability. In a controlled Indian experiment, cotton-stalk briquettes reached a bulk density of 964 kilograms per cubic metre and durability of 0.923, using a 150 to 200 kilogram an hour briquetting system. [S0206] Those results demonstrate that loose stalks can be converted into a much denser, handleable fuel. They do not establish the delivered cost, emissions performance or boiler acceptance of briquettes made from Cameroonian residues.

A serious pilot should begin with farm clusters rather than a national total. For each cluster, measure wet and oven-dry stalk yield per hectare, the share that farmers can sell without undermining soil or pest management, chipper productivity, actual lorry

payload and storage loss. At the candidate plant, measure electricity per tonne, die wear, moisture, ash, durability and the buyer's combustion results. Off-season biomass may be necessary, but it must be identified and contracted rather than assumed.

The social contract matters as well. UNCTAD argues that stalk use can provide farmers with income from material they otherwise burn, while warning that investment must be inclusive. [S17] A collection programme should state the farm-gate price, who pays for uprooting and chipping, and how payments reach the producer. Otherwise the processor may report a low feedstock cost by transferring collection labour to unpaid households.

2.5

Spinning waste must be measured by stage because cleaning loss and comber noil have different values

The announced Camtext SA project provides a scale for screening, not an operating baseline. The inherited register records a target of 12,000 tonnes of fibre processed a year and optimal capacity around 2033. [R10] No waste should therefore be described as current Camtext output. The useful exercise is to show which measurements the future plant and existing regional spinners would need in order to recognise co-products.

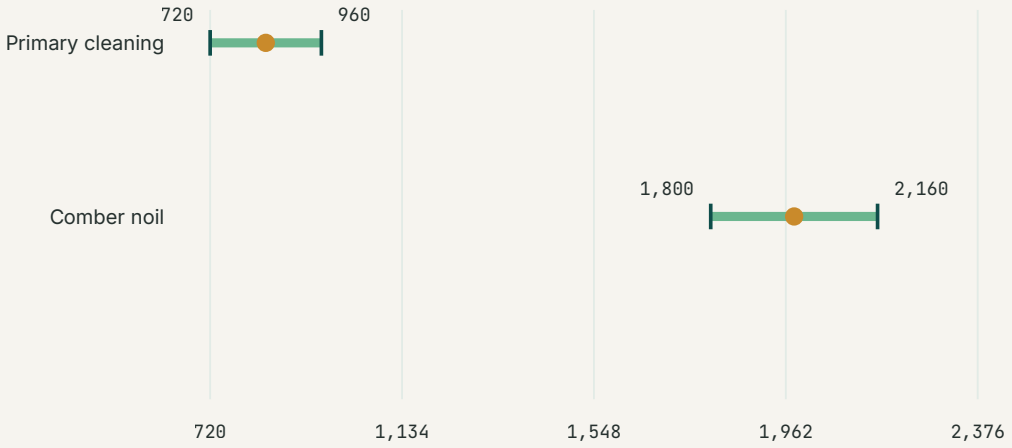
Opening and cleaning remove foreign matter and some good fibre. Carding continues individualisation and cleaning, while combing deliberately removes shorter fibres to improve the remaining sliver. A peer-reviewed spinning-waste chapter reports average primary waste of about 6 to 8 percent, composed of roughly 50 percent good fibre. It also reports that about 90 percent of the good-fibre elimination can be recovered as secondary raw material still containing about 6 percent trash. [S0203] The waste rate, its good-fibre share and the recovery rate are three different numbers. Multiplying them into a single clean-yarn figure without a stage balance would be misleading.

Combing is a separate choice, not a mandatory loss on every carded yarn line. ICAC reports that a comber removes about 15 to 18 percent of fibres from the sliver being processed. [S0202] That denominator is material presented to the comber, not necessarily the original lint bale. Comber noil is consequently a process co-product created to raise the quality of the main yarn, rather than an accidental floor sweeping.

Exhibit 10, p. 39 applies the two reference ranges independently to the announced 12,000 tonne processing target. Primary cleaning gives a screening range of 720 to 960 tonnes a year. Comber noil gives 1,800 to 2,160 tonnes only if an equivalent quantity is presented to combing. The two ranges must not be added: their process denominators differ, and the combing scenario presumes a combed product route. [R10] [S0202] [S0203]

EXHIBIT 10 / TONNES A YEAR OF STAGE-SPECIFIC WASTE, SCREENING SCENARIO

A 12,000 tonne lint target creates separate cleaning and combing scenarios, not one additive waste total



DERIVED [R10] [S0202] [S0203] Derived scenarios using the announced Camtext target of 12,000 t/year, which is not current output. Primary cleaning: 12,000 × 6 to 8 percent = 720 to 960 t, midpoint at 7 percent = 840 t. Comber noil: 12,000 × 15 to 18 percent = 1,800 to 2,160 t, midpoint at 16.5 percent = 1,980 t. Different denominators and routes; do not add.

Purity further separates the streams. The spinning-waste chapter gives a good-fibre ratio around 95 to 97 percent for comber and roving waste, compared with 35 to 55 percent for blowroom and card waste. Flat and filter stripping waste occupies an intermediate 65 to 80 percent range. [S0203] A tonne of comber noil and a tonne of blowroom droppings therefore cannot carry the same recovery assumption or sale specification.

Comber noil has several credible routes. ICAC documents its use alone or blended with virgin cotton in open-end rotor spinning, as well as absorbent cotton, hydro-entangled nonwovens and high-value paper after appropriate cleaning and purification. [S0202] In the cited open-end trials, adding noil at 25 to 35 percent of the blend did not significantly alter mechanical behaviour, although more virgin fibre improved tenacity. [S0202] This is evidence for controlled product trials, not permission to insert the same blend into every yarn count.

Dirty cleaning waste needs a different decision. Its recoverable fibre may justify reprocessing, but residual trash can defeat fine-yarn production and complicate chemical routes. The spinning-waste literature reports controlled reuse in selected yarn formulations and shows that yarn effects vary by waste type and blend ratio. [S0203] The mill should keep clean roving and sliver waste, comber noil, flat strips, blowroom droppings, filter dust and pneumafil in named containers. Mixing them for convenience destroys the information needed to route them.

The practical ledger is straightforward. For each shift and lot, record lint fed to the stage, main product forwarded, each waste stream weighed, moisture where relevant, and a periodic good-fibre and trash test. Reconcile the stage before aggregating the

mill. The performance review should ask whether a rise in waste reflects incoming cotton, machine settings, product mix or poor handling. Circularity then improves process control instead of becoming a parallel reporting exercise.

2.6

Greige fabric and yarn returns preserve value only when supplier boundaries are explicit

Fabric formation creates another set of pre-consumer streams: yarn ends, sliver and roving returns, selvedges, roll ends and greige fabric pieces. The spinning-waste literature distinguishes clean yarn and fabric forms from earlier fibre-cleaning waste, and shows that their recycling behaviour differs. [S0203] These streams should not be merged with comber noil merely because all are called spinning or textile waste.

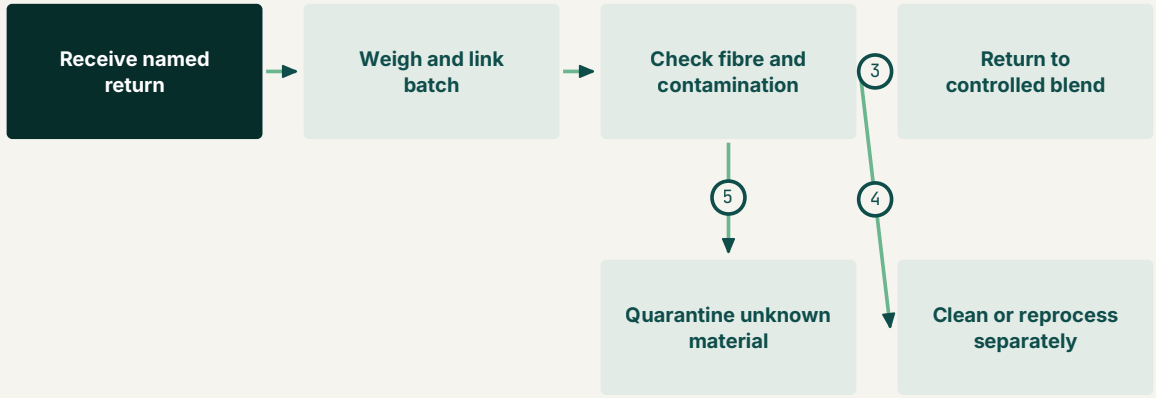
Greige material avoids consumer wear and has not passed through a dyehouse, but it is not automatically chemical-free. Warp size, knitting oils, storage soil and accidental synthetic contamination can remain. A receiving recycler needs composition, construction, moisture and contamination information before accepting it as a known cotton feedstock. The supplier's batch record is the first test; laboratory verification is the fallback when identity is incomplete.

Where a garment venture partners with spinning, knitting or weaving suppliers, the offtake agreement should define the return loop before production begins. It should name the owner of each stream, approved containers, bale or bag labels, weighing point, moisture basis, contamination tolerance, rejection procedure and transport responsibility. A price can then attach to a verified grade rather than to an ambiguous sack of factory sweepings.

Exhibit 11, p. 41 sets out the decision sequence. It is an illustrative operating design, not a claim that a particular Cameroon supplier already operates it.

EXHIBIT 11 /

Supplier returns need identity and contamination gates before they re-enter production



3. Verified clean
4. Recoverable with treatment
5. Unknown or rejected

ILLUSTRATIVE [S0203] Illustrative GFT operating recommendation informed by spinning-waste categories. It does not represent an implemented supplier process or a measured recovery rate.

This boundary also prevents false circularity claims. Returning a supplier's clean yarn waste to a controlled blend is different from purchasing an unknown mixed bale. The mass, source and destination must remain attached to the material. A greenfield garment maker can require that evidence in its supplier qualification without owning the upstream mill.

2.7

Aggregation overcomes scale barriers only when it preserves stream identity

UNCTAD's surveys in Tanzania, Uganda, Zambia and Zimbabwe identified limited raw-material supply as the root challenge for cotton by-product businesses. Some linter and hull quantities were too small for commercial-scale ventures, and even established oil expressers struggled with available supply. [S37] These findings are not Cameroonian measurements. They are a warning against buying machinery before proving delivered feedstock.

Cameroon has a potential coordination advantage because SODECOTON's inherited profile already links more than 220,000 producers to nine ginning plants and two oil mills. [R03] The inherited register also records an announced SODECOTON and CICAM industrial pole and the announced Camtext SA project, whose target is 12,000 tonnes

processed a year. [R08] [R09] [R10] Announcements and targets do not create current co-product volumes. They do, however, make a common measurement protocol across northern gins and the Garoua-Dibamba industrial axis worth designing now.

Aggregation should be selective. Cottonseed can move through existing oil-mill logistics, provided planting, feed and crushing claims on the same seed are reconciled. Linters and comber noil can justify separate bales because their value depends on grade and purity. Bulky stalks need a much tighter collection model because transport and storage can consume their fuel value. Dirty waste should not travel in a clean bale merely to make a regional tonnage target look larger.

2.8 NET RECOVERABLE SUPPLY, RATHER THAN GROSS RESIDUE MASS, RANKS THE OPPORTUNITIES

A co-product is not uncaptured simply because it has no invoice in the analyst's dataset. Seed may already be contracted for planting or feed. Noils may have an existing rotor-yarn buyer. Stalks may serve a soil or pest-management purpose. The relevant value is the improvement over the current use and disposal route, after collection, processing, rejects, transport, working capital and environmental controls are included. A higher gross selling price can still produce a worse net result.

The physical screen should use a chain of measured factors: saleable supply equals gross material generated, multiplied by collection coverage, process recovery and buyer acceptance. Each factor needs its own evidence and denominator. Collection coverage describes the share physically brought under control. Process recovery converts that material into a graded bale or product. Buyer acceptance measures how much of the offered grade passes the receiving specification. Multiplying a national harvest by only the first plausible yield skips most of the investment question.

For illustration, suppose a cluster contains 10,000 tonnes of seed-borne linters. Assume that 60 percent of the seed enters mechanical delinting, 90 percent of the contained linters are recovered into bales, and 95 percent of those bales pass the buyer's inspection. Accepted supply would be 10,000 × 0.60 × 0.90 × 0.95 = 5,130 tonnes. Every assumption is illustrative, and none is a Cameroonian measurement. The example shows why a theoretical content figure can overstate accepted supply by almost half before transport is even considered.

The same discipline applies to environmental claims. Mechanical delinting, bleaching, pulping, briquetting and re-spinning have different electricity, water, chemical and effluent boundaries. A route should be compared with the actual alternative, such as whole-seed feed, open burning, disposal or virgin fibre, rather than with an assumed zero-impact baseline. The assessment should record local energy and water per accepted tonne alongside the mass balance, so a recovery gain does not conceal an unacceptable processing burden.

Seasonality can also turn an annual surplus into a monthly shortage. Procurement records should show opening stock, monthly generation, monthly sales and closing stock for each grade. The investor then sizes storage and seed or residue purchasing finance from the observed cycle. This is particularly important where a plant expects year-round operation from a harvest concentrated in part of the year. Annual arithmetic alone cannot demonstrate continuous feedstock cover.

The proposed sequence is therefore evidence before equipment:

1. Reconcile every stream at its point of generation for a complete procurement season.
2. Assign ownership, moisture basis, grade, current use and destination to each lot.
3. Calculate dry, collectable and contractable supply by month, not just annual theoretical content.
4. Send representative samples to prospective buyers and obtain written specifications and trial results.
5. Run a measured pilot lot through the intended oil, feed, absorbent, rotor or briquette route.
6. Consider dedicated capacity only after delivered cost, buyer acceptance and year-round supply are demonstrated.

Exhibit 12, p. 43 summarises the resulting control logic. Its routes are candidates, not investment recommendations. The stop conditions are as important as the pathways because a failed quality gate should redirect material before further cost is added.

EXHIBIT 12 /

Each co-product needs its own measurement gate, candidate route and stop condition

Stream	First measurement	Candidate route	Stop or redirect condition
Cottonseed	Seed use and crusher balance	Oil, meal and hull products	Supply or product specification fails
Linters	Mechanical delinting and recovered mass	Absorbent cotton or graded pulp feedstock	Acid delinting or uncontracted quality
Gin motes	Recovered fibre, trash and moisture	Tested absorbent or other fibre route	Excess trash or unstable grade
Field stalks	Dry collectable supply and delivered cost	Briquette or pellet pilot	No year-round supply or boiler rejection
Primary spinning waste	Stage mass and good-fibre share	Controlled blend or separate recovery	Contamination or yarn failure
Comber noil	Sliver feed, noil mass and purity	Rotor yarn or absorbent products	Specification mismatch or better route
Greige returns	Batch identity and contamination	Controlled direct reuse	Unknown composition or finish

DERIVED [S17] [S0201] [S0202] [S0203] [S0206] [S37] Derived routing framework from the cited institutional and technical sources. Candidate routes require Cameroon-specific supply, quality, market and environmental assessment. No commercial recovery rate is implied.

WARNING

The national harvest entries are inherited source-text observations, and the original publication dates are not recorded in the shared register. International ginning, seed-composition, linter and spinning figures are reference values rather than Cameroonian plant measurements. None of the derived ranges in this chapter proves current available supply, investment returns or realised output.

GFT NOTE

GFT recommends one upstream co-product register spanning the gin, oil mill, spinner and field-collection pilot. Its minimum fields are source lot, dry mass, moisture, grade, current use, owner, destination, buyer test and realised recovery. This creates the evidence needed for later circularity accounting while immediately exposing avoidable mixing and disposal.

The commercial conclusion is deliberately narrower than the resource promise. Cottonseed crushing and controlled noil reuse may be sensible early candidates because established processes and identifiable markets exist. Linter purification, absorbent cotton and stalk densification deserve measured pilots where feedstock and buyers are proven. A regional dissolving-pulp investment belongs later in the sequence, after contracted cellulose supply and process economics are known. This chapter provides an industrial screening framework, not investment advice.

The harvest creates the possibility of value; the boundary record proves what can be recovered.

CHAPTER SOURCE NOTES

R01 Business in Cameroon. Publication date unrecorded; inherited source-text check.

S17 UNCTAD (UN Trade and Development). 2019-07-17.

R02 Fibre2Fashion; Business in Cameroon. Publication date unrecorded; inherited source-text check.

R05 Ecofin Agency. Publication date unrecorded; inherited source-text check.

R03 SODECOTON. Publication date unrecorded; inherited source-text check.

S0204 International Cotton Advisory Committee (ICAC). 2018-06.

S0201 International Trade Centre (ITC). 2020-12.

S18 UNCTAD (UN Trade and Development). 2021-05-28.

S16 World Trade Organization (WTO). 2024.

S0202 International Cotton Advisory Committee (ICAC). 2020-09.

S37 UNCTAD (UN Trade and Development). 2019-07-03.

S0205 BioResources. 2016-06-28.

S0207 UNCTAD (UN Trade and Development). 2019-07.

S0206 Biotechnology Research International. 2012-06-27.

R10 Ecofin Agency. Publication date unrecorded; inherited source-text check.

S0203 IntechOpen. 2019-03-19.

R08 Business in Cameroon. Publication date unrecorded; inherited source-text check.

R09 Ecofin Agency. Publication date unrecorded; inherited source-text check.

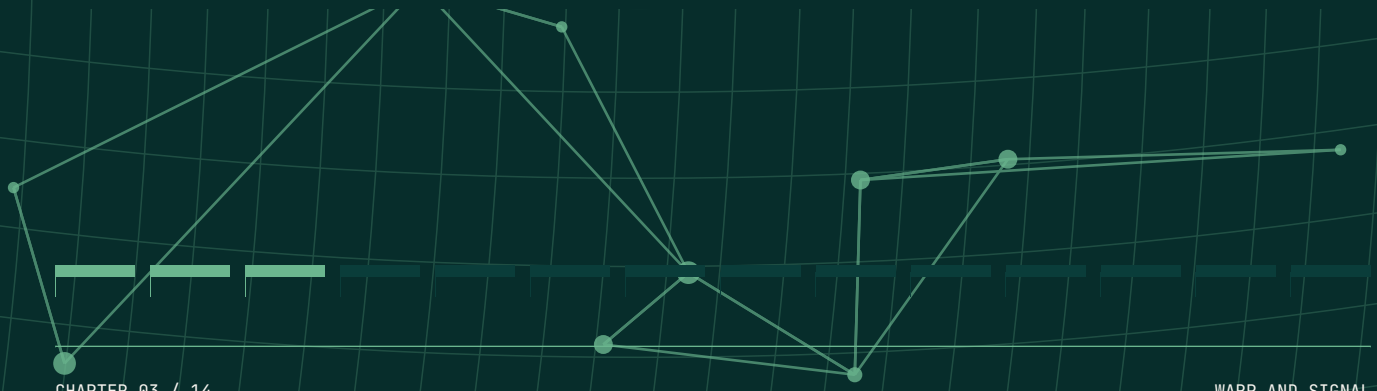
GREEN FUTURE TECH

LIMITED / HONG KONG SAR

03

Cutting-room marker loss and sewing defects consume 15 to 25 percent of purchased fabric

Fabric is the largest garment cost and the factory's cleanest potential secondary material. The saving comes from separating marker geometry, table execution and quality failure, then weighing each stream.



CHAPTER 03
DECISION TEST

Fabric is the largest garment cost and the factory's cleanest potential secondary material. The saving comes from separating marker geometry, table execution and quality failure, then weighing each stream.

The answer is to manage purchased fabric as a mass balance, not to treat a CAD marker percentage as factory yield. A 15 to 25 percent loss band is a useful planning scenario when inter-piece voids, spreading and roll remnants, defect removal and rejected output are all included. It is not a universal industry constant. Fabric commonly represents 50 to 60 percent of apparel cost, and one industry source gives the heuristic that a 2 percent fabric saving can add 1 percentage point to profit margin. That heuristic makes the cutting room commercially important, but it does not predict the result at any particular factory. [S32]

The evidence also warns against a single waste percentage. A 2020 paper on woven garment factories reports average unused fabric of 3.59 percent, completed apparel waste of 1.99 percent and hard waste of 2.15 percent, which sum to 7.73 percent under that study's definitions. The same paper recalls an earlier knit T-shirt study reporting 26.51 percent across cutting, panel checking, sewing and finishing. These studies do not share a product, boundary or waste classification, so their figures must not be averaged or presented as a contradiction to be resolved. [S0303] GFT's practical response is to establish the denominator at each process gate, weigh the physical streams and replace scenario allowances with factory evidence.

3.1

Fabric dominates unit cost, but total loss depends on the chosen boundary

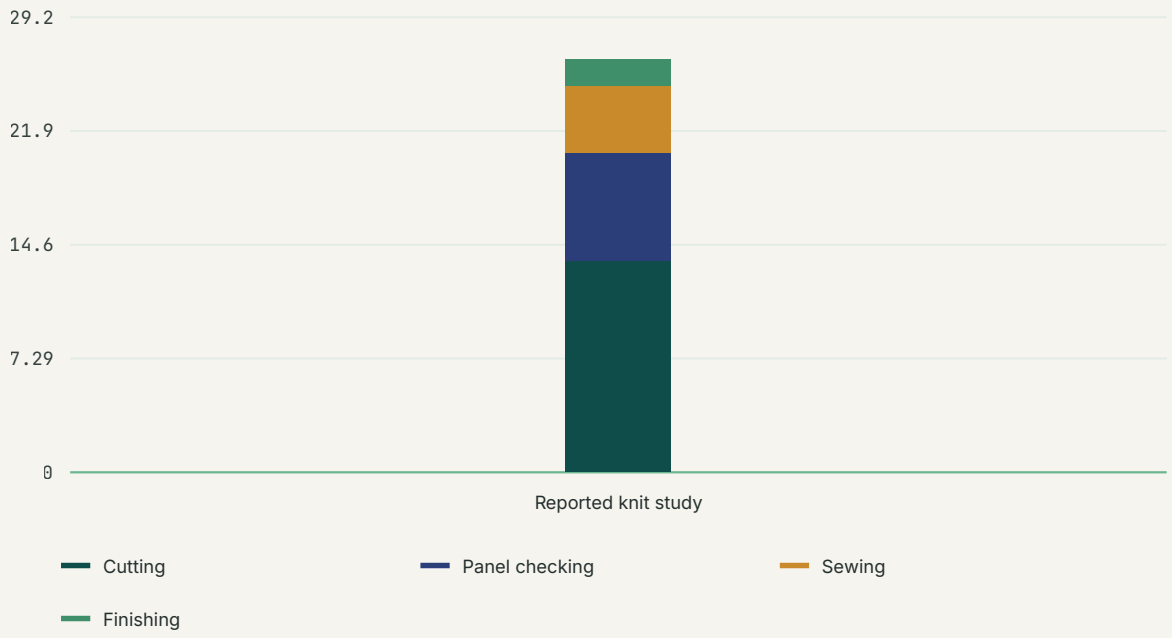
Marker efficiency answers a narrow geometric question: how much of a rectangular marker is occupied by pattern pieces? Total fabric yield answers a wider operational question: how much purchased fabric becomes accepted garments? The first excludes roll ends, fault removal and rejected panels unless the measurement boundary explicitly adds them. The second includes them. Confusing these measures can make a cutting room appear efficient while fabric continues to leave the process as remnants and seconds. [S32] [S33]

The commercial mechanism is direct. Fabric is purchased before cutting, so every avoidable kilogram of loss has already consumed cash. A poor marker uses more length for the same pattern area. A narrow roll can invalidate the planned width. A defect discovered after sewing has also absorbed labour and trims. The industry rule linking a 2 percent fabric saving to roughly 1 percentage point of margin is therefore best read as a prompt for sensitivity analysis, not as an accounting identity. Actual margin effects depend on selling price, fabric price, recovery value, labour and whether saved fabric really reduces purchases. [S32]

Exhibit 13, p. 47 shows the stage breakdown reported for the earlier knit T-shirt investigation. It is useful because it prevents cutting geometry from carrying the whole explanation. Cutting accounts for just over half of the reported total, while panel checking, sewing and finishing remain substantial.

EXHIBIT 13 / PERCENT OF INTAKE MATERIALS REPORTED BY THE CITED STUDY

A reported knit T-shirt study allocates 26.51 percent of intake across four stages



SOURCED [S0303] The 2020 IJSER paper reports these values as findings from a previous knit T-shirt study by two of its authors, not as results from its own five woven-factory sample. Values sum to 26.51 percent. They must not be combined with the paper's separate woven-factory averages.

The 2020 paper's own woven-factory result is narrower and different. Its three reported averages sum to 7.73 percent, derived here as 3.59 plus 1.99 plus 2.15. Unused fabric may remain usable, completed garments may be sold, and hard waste is a separate category. The earlier knit total instead follows material through named production stages. A factory adopting the 15 to 25 percent planning band must therefore state whether it means only hard scrap, all non-product fabric, or all purchased material that fails to become first-quality output. [S0303]

For GFT's illustrative annual planning case, 3.0 million garments at 220 to 280 grams each contain 660 to 840 tonnes of finished fabric. If total non-product loss is assumed at 15 to 25 percent of purchased mass, the purchase requirement is net output divided by 0.85 to 0.75. The outer arithmetic gives 776.5 to 1,120.0 tonnes purchased and 116.5 to 280.0 tonnes of non-product material. These are scenario bounds formed from independent low and high cases, not a confidence interval and not a GFT operating result. [S0303]

That calculation is deliberately conservative in its interpretation. It does not call every non-product tonne clean cotton, recyclable waste or avoidable loss. Some remnants can be reused without shredding. Some rejected garments can be repaired or sold as seconds. Some hard clips may contain sewing thread or other polymers. The first financial decision is to reduce the total. The second is to preserve the highest-value route for what remains.

Exhibit 14, p. 48 isolates the interaction between marker yield and rejected output. For this illustrative sensitivity test, a fabric-cost index of 100 represents perfect marker utilisation and perfect acceptance. Every other cell divides 100 by marker efficiency multiplied by first-pass fabric yield, both expressed as decimals. It assumes that a failed unit consumes its full fabric allocation and that no value is recovered. The model therefore tests exposure; it is not a profit forecast. [S32] [S33]

EXHIBIT 14 / FABRIC-COST INDEX PER ACCEPTED GARMENT, PERFECT YIELD = 100

Marker void and rejected output compound fabric cost when no value is recovered

	75 percent marker	80 percent marker	85 percent marker	90 percent marker
85 percent acceptance	157	147	138	131
90 percent acceptance	148	139	131	124
95 percent acceptance	140	132	124	117
100 percent acceptance	133	125	118	111

Cell scale: 111 to 157

DERIVED [S32] [S33] Derived illustrative sensitivity. Index = 100 / (marker efficiency x first-pass fabric yield), with both yields entered as decimals. Rows are first-pass fabric yield; columns are marker efficiency. Assumes full fabric loss on failed units and zero recovery, so ordinary repairable rework must not be inserted as a total-loss rate. Fabric-cost context comes from S32; marker-boundary method from S33.

The illustrative index reaches 156.9 at the weakest cell and 111.1 at the strongest. Even perfect acceptance does not remove the cost of marker void, while a strong marker does not remove the cost of rejected output. This is why the two measures belong in one operating review but must retain separate owners and corrective actions. The index deliberately excludes recovery credit, repair labour and selling price, so it cannot be converted into margin without additional factory data. [S32] [S33]

GFT NOTE

GFT recommends one governing KPI, purchased fabric kilograms per accepted garment, supported by separate measures for marker void, table remnants, defect splices, recut panels, sewing seconds and mixed trimmings. The planning band should remain visible until weighed orders replace it. A reduction in one category must not be accepted if another category rises by the same mass.

3.2

Marker geometry creates a measurable void, not a universal waste floor

The marker formula is total pattern-piece area divided by marker length multiplied by usable width, expressed as a percentage. Its complement, 100 minus marker efficiency, is the in-marker void. That void is not automatically purchased-fabric waste across the whole factory: it describes only the rectangle being planned. Nor is every void avoidable. Curved garment components, grain direction, size ratios, motif matching and shade constraints restrict how pieces may be placed. [S32] [S0301]

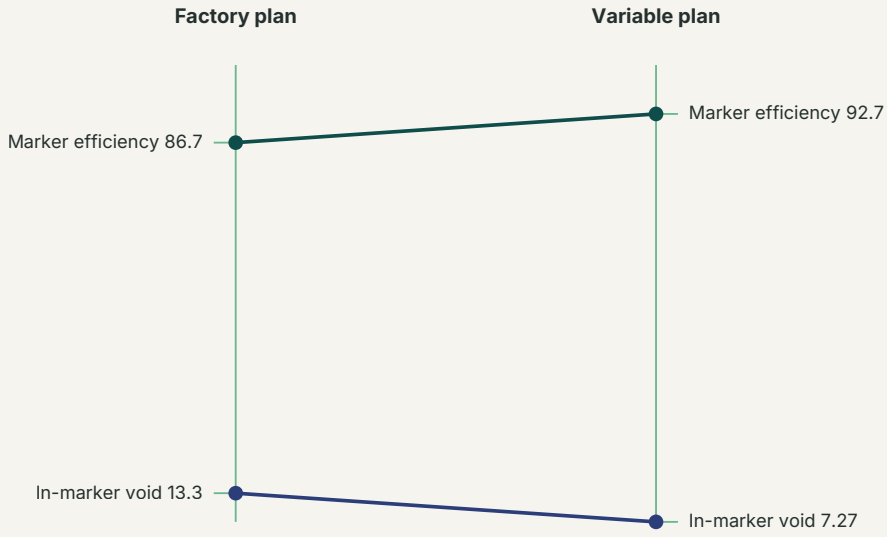
A 2016 experiment on a long-sleeve shirt demonstrates both the opportunity and the need for context. Using a fixed width and twelve garments per marker, the study reports average solid-size marker efficiency of 88.158 percent and mixed-size efficiency of 89.05 percent. The difference is 0.892 percentage points, while reported fabric consumption falls by 0.077 metres for the twelve-garment marker. The corresponding in-marker voids are 11.842 and 10.95 percent. These are observed results for one pattern set and marker configuration, not evidence that every mixed marker saves a fixed amount. [S0301]

The study also records lower efficiencies when fabric characteristics constrain placement. Its check, balancing, selvedge and group markers range from 84.87 to 86.48 percent efficiency. Directional or asymmetric fabric can require one-way placement, while width-wise or length-wise shade variation can divide the marker into restricted zones. The engineering response is not to sacrifice garment quality for a higher percentage. It is to compare feasible markers under the same grain, shade, size and quality rules. [S0301]

A 2024 single-jersey study provides a larger contrast. Its factory plan achieved 86.72 percent efficiency, while the best proposed combination of variable widths and size sets reached 92.73 percent. The reported gain is 6.01 percentage points. **Exhibit 15**, p. 50 converts both efficiencies into their in-marker complements, making clear that the comparison concerns marker area rather than total factory waste. [S0302]

EXHIBIT 15 / PERCENT OF MARKER AREA

Variable widths and size sets raise marker efficiency and reduce the in-marker void



DERIVED [S0302] Sourced marker efficiencies are 86.72 percent for the factory plan and 92.73 percent for the proposed plan in one single-jersey study. In-marker void is derived as 100 minus efficiency: 13.28 and 7.27 percent. This is not a plant-wide waste comparison or a guaranteed saving for another style.

An efficiency gain in percentage points is not the same as the same percentage reduction in purchases. If pattern area is unchanged, marker area scales with the reciprocal of efficiency. The useful test is therefore fabric issued per accepted garment after the new marker enters production. Theoretical nesting gains can be erased by additional lays, more end allowances, difficult size ratios or extra handling time. CAD also does not guarantee a better result than an experienced planner under every constraint. [S0301] [S33]

Marker approval should consequently carry two records. The first is the digital plan, including usable width, pattern area, marker length, sizes, grain and matching rules. The second is the realised lay, including fabric issued, panels cut, recuts and every residual stream. Comparing like with like prevents a planner from claiming a saving that the table never delivered. It also reveals when a modest but repeatable gain is worth more than an exceptional marker that cannot be reproduced across rolls.

A disciplined marker review begins with constraints before optimisation. Confirm that every component is present, grain lines are respected and matched motifs meet the product specification. Then test size combinations and feasible widths. Only after those checks should the team compare efficiency. This order matters because an attractive layout that moves a seam, distorts a motif or mixes a shade zone is not a saving. It is a quality cost transferred downstream.

Pattern engineering can widen the options, but it needs the same evidence. Splitting a large component may create a better nesting shape while adding a seam and sewing work. Tilting a component may reduce length while changing drape or appearance. Small components may fill voids only if their orientation and bundle identity remain

controlled. The acceptance test is total cost and accepted quality per garment, not the marker screenshot. Trials should retain the rejected alternatives so that the next style review can learn which constraints, rather than which planner, limited the result.

3.3

Table execution explains the gap between an efficient marker and actual consumption

The gap between planned and actual consumption is a diagnostic measure. Planned consumption comes from the approved marker and size ratio. Actual consumption starts with fabric issued to the lay and ends only when panels and residual streams are reconciled. iFactory's cutting-room guidance identifies width variation, end loss, splices and wrong markers as reasons for this gap. Those causes require different corrective actions, so a single monthly waste average cannot manage them. [S33]

Width is the first control. The plan should use measured usable width, not the nominal width on the supplier document. Rolls can then be grouped into width families and matched to an appropriate marker. If a narrower roll is spread against a marker designed for wider cloth, edge shortages and recuts can follow. If the planner simply adds allowance to every order, the factory may hide a supplier problem inside a permanent consumption premium. [S33]

Ends and splices require the same discipline. An end allowance may be necessary for cutting integrity, but its length and frequency should be recorded. A splice made for a normal roll transition differs from one made to remove a fault. The first points to lay planning and roll allocation. The second points to incoming quality. Keeping separate reason codes lets the plant distinguish routine process loss from chargeable supplier defects.

For an illustrative lay of 20 metres, an allowance of 2 centimetres at each end equals 0.04 metres, or 0.20 percent of lay length. The same absolute allowance on a 5 metre lay equals 0.80 percent. The arithmetic shows why lay length matters, but it does not prescribe an allowance: cutter type, fabric behaviour and quality requirements must set the real value. [S33]

The woven-factory study offers a related but distinct measurement. It reports usable fabric leftovers ranging from 2.97 to 4.43 percent across the five products studied. These are leftovers after orders, not a direct measurement of spreading end allowance. They nevertheless show why the ledger must distinguish usable roll or yardage remnants from hard cutting scrap. Combining them would understate reuse potential and obscure whether excess purchasing or table execution created the balance. [S0303]

Measurement quality determines whether these categories can be reconciled. Length and mass should not be mixed without a documented fabric-weight conversion. A returned roll needs to be deducted from gross issue, and a cardboard or plastic core needs to be excluded from net fabric weight. Panel counts should use a defined garment-equivalent convention when sizes differ. Otherwise, a change in size ratio can look like a consumption improvement even though the accounting unit has changed.

The scale reading also needs a material identity. A container of clean clips should be tied to the lays that filled it, while a mixed container should not be back-allocated to a style merely to make the records look complete. Where several lays share a container, the ledger should retain the group and its weighing time. Physical plausibility checks can then compare the recorded clip mass with marker area and fabric weight before a supervisor approves the balance.

A practical lay record therefore needs only a few unambiguous quantities: net fabric issued, measured usable width, marker length, plies, acceptable panel equivalents, recut panels, clean inter-piece clips, usable remnants, defect strips and unaccounted difference. The difference is an exception to investigate, not a balancing figure to rename as waste. GFT's later mass-balance chapter specifies the full ledger; the cutting-room requirement here is to preserve cause and material identity from the outset.

3.4

Earlier defect interception preserves more than the faulty fabric

The inherited evidence register summarises inspection literature in which manual visual inspection achieves 60 to 70 percent accuracy and misses 20 to 30 percent of defects. It records computer vision above 90 percent accuracy across more than 40 defect types and line-scan inspection at up to 60 metres a minute. These are literature benchmarks retained in the register, not a current acceptance test for a specified camera, fabric or factory. [R29]

Detection accuracy is not itself a waste-saving percentage. For an illustrative population of 100 defects, a 65 percent detection rate intercepts 65 and a 90 percent rate intercepts 90. The difference is 25 earlier interceptions, not a 25 percent reduction in purchased fabric. The saving depends on defect location, size, severity, the length that must be removed and whether the fault would otherwise have caused a recut panel, a repaired garment or a rejected unit. [R29]

Location determines how much value remains at risk. A fault mapped on an incoming roll can be cut out as an unsewn strip and logged against the supplier. The same fault found after cutting may require a replacement panel and another cutting operation. Found at final audit, it can consume the panel, sewing labour, thread, trims and pressing already applied. Early inspection therefore protects conversion cost as well as material. The business case should count the route each defect would otherwise have taken rather than applying one average saving to every detected fault. [R29] [S33]

A usable roll map contains more than a defect count. It needs roll identity, position along and across the fabric, defect class, dimensions, image or inspector confirmation, and the disposition decision. During spreading, the operator can then place a splice deliberately or show that a fault falls inside an inter-piece void. The quality team can compare supplier lots on defects per inspected length, while the cutting team can measure metres removed by cause. These are different decisions supported by the same observation.

Automation also needs a manual exception path. Fabric texture, colour, reflectance and defect presentation can affect classification, and the register's benchmarks do not establish performance on every Cameroon cotton construction. A deployment should begin with labelled local rolls, an agreed defect taxonomy and blind comparison against competent inspectors. Acceptance should measure false negatives and false positives by defect class, not only aggregate accuracy. [R29]

> **GFT NOTE**
>
> GFT recommends placing roll inspection before spreading and linking its defect coordinates to the lay record. Buy the business case in stages: prove reliable interception on actual fabric families, quantify avoided recuts and rejected garments, then decide whether higher line speed or broader defect coverage is justified. Do not book a fabric saving from camera accuracy alone.

3.5

Sewing quality decides whether cut panels become garments or secondary streams

The earlier knit study assigns 6.91 percent of intake to panel checking, 4.31 percent to sewing and 1.72 percent to finishing. These figures are not directly transferable to another factory, but they demonstrate why material loss cannot be managed only in the cutting room. A factory may improve its marker and still lose the benefit through damaged panels, repeated handling, irreparable seams or final rejection. [S0303]

Rework, seconds and scrap must remain separate categories. Rework returns a garment to the process and consumes additional labour, but it does not necessarily destroy the fabric. A second-quality garment may remain wearable and saleable through an approved channel. Scrap is material that cannot re-enter the intended product route. Treating every first-pass failure as a total fabric loss overstates waste; hiding irreparable failures inside rework understates it.

For this chapter's calculation, first-pass yield means units accepted without rework divided by units started, expressed as a percentage. It needs a companion material measure: accepted garment mass plus documented seconds, repairable work and scrap. This pairing stops a line from improving its reported yield by reclassifying defective units. It also lets the plant value the labour and material consequences separately.

The cost record should follow that disposition rather than applying one defect cost to every failure. Repairable rework carries additional handling and labour while preserving the garment. A wearable second may carry a price reduction and an approved alternative destination. An irreparable unit carries its material and accumulated conversion cost, less any verified recovery credit. This separation prevents two common errors: counting repaired garments as total waste, and assuming that every rejected garment can recover its full fabric value.

Defect Pareto analysis should use the same dispositions. A frequent minor seam fault may consume more labour than a rare catastrophic fault, while the rare fault may destroy more material. Ranking only by defect count can therefore direct attention to the

wrong loss. The review should compare frequency, affected mass, rework time and final route, then assign the corrective action to the process that created the defect rather than the station that happened to find it.

Overlock and safety-stitch trimming creates another distinct stream. Where polyester or core-spun thread is used, the trim combines cotton lint with non-cellulosic thread. It should not enter the clean inter-pattern clip container by default. The practical control is a dedicated receptacle at the relevant station, with the thread specification linked to the product bill of materials. A cellulosic thread specification may simplify later recovery, but the actual bale still requires inspection rather than an assumed purity claim.

Destructive testing belongs in the same material ledger, even though its purpose is quality assurance rather than process failure. Where tensile, seam, pilling or other buyer-required tests destroy a sample, the laboratory should issue a sample identity and record its mass and disposition. Predictable test remnants can then be routed correctly, and testing cannot become an unexplained drain on production stock. This is an operating control recommended by GFT, not a claim that testing forms a fixed share of fabric loss.

Supervisor action should follow the defect's first occurrence. A skipped-stitch cluster calls for machine and operator checks. Shade mixing calls for bundle and roll identity control. Panel damage calls for handling changes. Repeated recuts from one supplier lot call for an incoming-quality exception. The measure is useful only when it triggers a named response before more material follows the same route.

3.6

Forecasting and digital sampling prevent losses before the lay is planned

Pre-consumer loss also includes prototypes, samples, cancelled orders and unsold production. These streams sit outside marker efficiency but still embody purchased fabric. The European Environment Agency estimates that 82 percent of EU textile waste in 2020 was post-consumer, leaving 18 percent derived here as manufacturing or unsold textiles. The agency cautions that data on pre-consumer categories such as unsold retail textiles are limited, so the residual must not be presented as a precise factory-waste share. [S12]

Demand forecasting addresses a different failure from marker nesting. A perfect marker cannot rescue an order whose size, colour or quantity was wrong. The inherited register summarises McKinsey's State of Fashion 2025 as reporting forecast-error reductions of 20 to 50 percent and inventory-cost reductions of 35 to 40 percent from AI at scale in fashion. These are potential effects reported across the sector, not guaranteed results for a new Cameroon plant, and they depend on usable sales and order history. [R27]

A cold-start factory should consequently begin with smaller, traceable order batches and explicit assumptions rather than a sophisticated forecast built on sparse data. Record the forecast, the actual order, the size and shade curve, cancellations, replen-

ishment and unsold balance by style. Once that history exists, a model can be tested against a naive baseline. Forecast value should be judged by avoided overproduction and stockouts, not by model complexity.

Digital design and sampling can prevent another early loss. The inherited register describes apparel AI work in 2023 and 2024 as mainly design-side image generation, followed by later multi-model pipelines covering fabric construction, shade, weave and silhouette, with physics-constrained simulation emerging in 2025 and 2026. [R30] [R31] This supports virtual review and fewer unnecessary iterations, but it does not prove that every physical fit or performance sample can disappear.

The operating rule is to give every sample a decision purpose. A digital silhouette review may remove one physical iteration. A buyer fit approval may still require cloth. A durability claim still needs appropriate testing. Recording metres and garments used by sample type reveals which approvals genuinely change and which are habitual. This chapter therefore treats forecasting and sampling as prevention controls, while later chapters examine unsold-stock rules and digital design in greater detail.

3.7

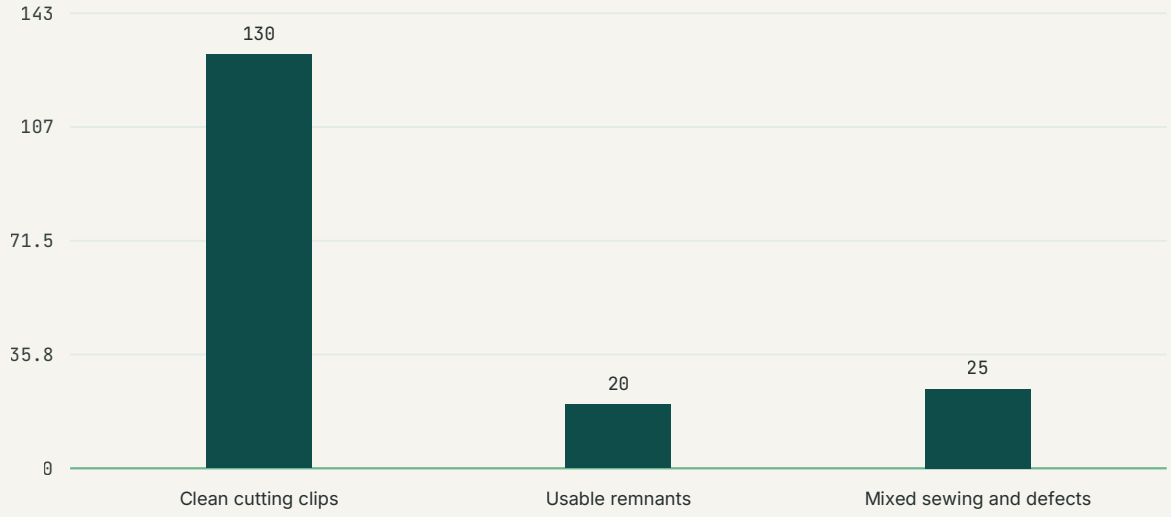
A segregated annual balance converts the loss band into recoverable material

The annual case becomes useful only when its total is divided by physical form and next use. Large usable remnants should be considered for recutting into suitable components or products before shredding. Clean inter-pattern clips retain the fabric lot's known identity and should remain separate by composition and shade. Mixed sewing trimmings and irreparable garment components need their own route because thread, labels and trims may change their suitability. These are material-handling choices, not evidence of a buyer or a realised recycling price.

Exhibit 16, p. 56 presents one internally consistent illustrative year. It assumes 3.0 million accepted garments at 250 grams each, 925 tonnes of purchased fabric and 175 tonnes of non-product material. The resulting loss is 18.9 percent of purchased mass, inside the chapter's 15 to 25 percent planning band. The model assigns 130 tonnes to clean cutting clips, 20 tonnes to usable large remnants and 25 tonnes to mixed sewing and defect streams. Every allocation is an assumption to be replaced by scales, not an observed GFT output.

EXHIBIT 16 / TONNES A YEAR, ILLUSTRATIVE SCENARIO

An illustrative annual balance separates 175 tonnes into three material grades



ILLUSTRATIVE Illustrative model only. Inputs: 3.0 million accepted garments x 0.250 kg = 750 tonnes of accepted fabric; assumed purchases = 925 tonnes; non-product material = 175 tonnes, or 18.9 percent of purchases. Assumed allocation: 130 tonnes clean cutting clips, 20 tonnes usable remnants and 25 tonnes mixed sewing and defect material. No revenue, recovery yield or GFT result is implied.

WORKED EXAMPLE: RECONCILE THE ANNUAL MODEL BEFORE VALUING IT

Start with the illustrative accepted output: 3,000,000 garments x 0.250 kilograms = 750,000 kilograms, or 750 tonnes. Add the three assumed residual streams: 130 + 20 + 25 = 175 tonnes. Purchased fabric must therefore be 750 + 175 = 925 tonnes, and non-product material is 175 / 925 × 100 = 18.92 percent of purchases, rounded to 18.9 percent. Only the 130 tonne clean-clip stream is a candidate for a high-purity cotton bale. The 20 tonne remnant stream should be assessed for direct reuse first, while the 25 tonne mixed stream needs contamination checks. The model demonstrates mass balance, not a sales forecast or investment return.

The calculation exposes a common overstatement: the whole 175 tonne balance cannot be described as high-purity recycling feedstock. In this scenario, only 130 tonnes meets that description by assumption. Its real value would still depend on composition, shade, moisture, contamination, bale integrity and a buyer's acceptance test. The other streams are not worthless, but they require different decisions and should not inherit the clean stream's price or recovery yield. [S0303]

Remnant reuse needs a technical release just as bulk cutting does. The remnant record should retain dimensions, usable width, fabric construction, shade, roll identity and any nearby defects. A product team can then match it to a component or small product whose grain and quality rules fit. If those data are absent, a visually generous remnant may still be unusable, and labour spent searching through unlabelled pieces can exceed the material saving.

Prevention remains the first priority. A tonne avoided through a better marker or earlier defect interception reduces purchasing rather than creating a recycling opportunity. Direct reuse of a suitable remnant preserves more of the fabric's existing form

than shredding. Recycling then handles material that cannot practicably return as cloth. Disposal is the final route, not the default description for everything outside the garment.

The management review should close the loop monthly. Compare purchased kilograms per accepted garment with the marker plan, then reconcile each residual grade to weighed inventory and documented dispatches. Investigate changes by style, supplier lot and production team. A fall in clean clips may be good news if total consumption fell, or bad news if clips moved into mixed waste. Only the full balance distinguishes those outcomes.

> **GFT NOTE**
>
> GFT recommends three physical controls before any recycling contract is discussed: labelled containers at the point of generation, a scale at each material transfer, and a monthly reconciliation of purchases, accepted output, stock and residual destinations. Commercial claims should follow measured clean tonnage and buyer acceptance, never the chapter's illustrative 175 tonne total.

The cheapest recycled fibre is the fabric that never became waste.

CHAPTER SOURCE NOTES

S32 Textile Learner. 2023-08-26.

S0303 International Journal of Scientific & Engineering Research (IJSER). 2020-11.

S33 iFactory. 2026-10-26.

S0301 Scientific & Academic Publishing, International Journal of Textile Science. 2016.

S0302 Union of Textile Engineers and Technicians of Serbia, Tekstilna Industrija. 2024.

R29 MDPI; industry inspection literature. Publication date unrecorded; inherited source-text check.

S12 European Environment Agency (EEA). 2024-04-15.

R27 McKinsey, The State of Fashion 2025. Publication date unrecorded; inherited source-text check.

R30 Design Journal (Taylor and Francis). Publication date unrecorded; inherited source-text check.

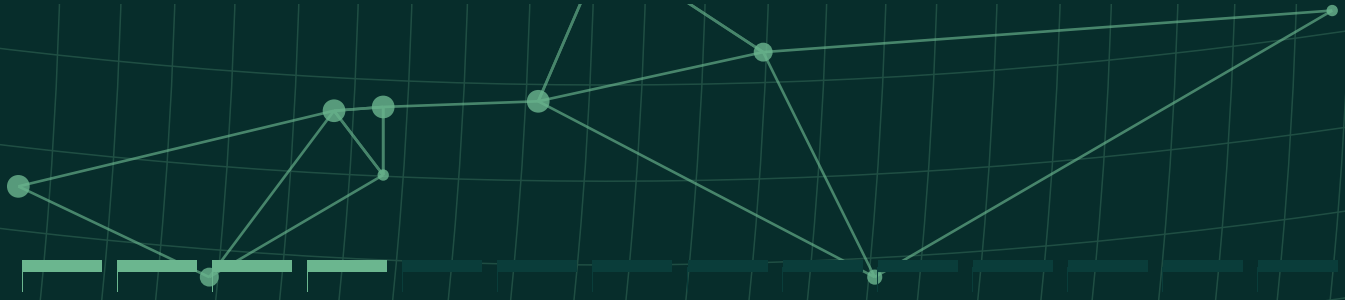
R31 arXiv 2509.04705. Publication date unrecorded; inherited source-text check.

GREEN FUTURE TECH
LIMITED / HONG KONG SAR

04

Point-of-generation sorting and near-infrared spectroscopy govern recycling feedstock purity

Mixed textile waste is nearly worthless because different polymers require incompatible recycling chemistries, making cutting-table segregation and near-infrared spectral classification the gatekeepers of circular value.



CHAPTER 04
DECISION TEST

Mixed textile waste is nearly worthless because different polymers require incompatible recycling chemistries, making cutting-table segregation and near-infrared spectral classification the gatekeepers of circular value.

Textile recycling is governed first by analytical chemistry and thermodynamics rather than by shredding mechanics. When offcuts from different production runs or discarded garments are combined into an unverified bale, their commercial value collapses toward zero or becomes a disposal liability [S24] [S27] [S0403]. Every high-value recovery route, whether mechanical open-end rotor spinning or chemical cellulose dissolution into regenerated fibres, operates within strict polymer and contaminant tolerances [S20] [S34] [S35]. A bale of nominally 100 percent cotton clips contaminated with just 1 to 3 percent polyurethane elastane or polypropylene packaging twine fouls the saw-tooth wire of a mechanical garnetting cylinder and leaves insoluble gel particles inside a chemical dissolving bath [S26] [S35] [S0406]. In the United States, where sorting bottlenecks leave mixed waste streams unverified, the Environmental Protection Agency recorded that around 85 percent of used clothes and textiles entered landfills or incinerators [S27]. Across garment hubs from North Africa to Bangladesh, informal waste handlers routinely sweep pure cotton cutting clips into mixed bags alongside synthetic scraps, destroying up to three-quarters of the feedstock price before the material leaves the factory compound [S24] [S25] [S0403].

Solving this feedstock purity problem does not require a greenfield African garment manufacturer to install a multimillion-euro automated optical sorting facility on its own shop floor [S0402]. Instead, engineering economics point to a two-tier sorting architecture tailored to Cameroon's industrial geography ({{xr:wp11-04-two-tier-sorting}}). At Tier 1, inside the Cut-Make-Trim (CMT) factory, operators segregate offcuts directly at the cutting table by roll batch, fibre composition, knit or woven construction, and shade family before entropy rises [S10] [S0402]. Because every fabric roll spread on a cutting table carries a known supplier specification, such as 100 percent SODECOTON combed cotton lint spun and woven domestically [R03] [R08], point-of-generation segregation captures near-100 percent compositional certainty at minimal capital cost using barcoded collection bins and a hydraulic vertical baler. At Tier 2, located at a regional spinning or recycling hub such as the planned Camtext SA complexes at Dibamba and Garoua or the announced SODECOTON-CICAM integrated pole [R08] [R09] [R10], near-infrared (NIR) spectroscopy operating between 900 and 1,700 nanometres audits incoming bales from external workshops [S26] [S0404]. Paired with supervised machine-learning classifiers achieving 91.7 percent composition accuracy and 92.6 percent binary elastane detection [S26], this two-tier system delivers certified feedstock to downstream spinners while keeping Phase 1 factory capital expenditure lean.

4.1

Unverified fibre composition forces mixed textile streams into incineration or low-grade downcycling

4.2 POLYMER INCOMPATIBILITY ACROSS MECHANICAL AND CHEMICAL RECOVERY ROUTES

Different textile polymers require incompatible mechanical settings and chemical solvents, meaning unverified mixed textile waste cannot be converted into high-value yarn [S26] [S27] [S0401]. In mechanical recycling, fabric clips pass through high-speed tearing cylinders clothed with hardened steel saw-tooth wire to open woven or knitted

structures back into staple fibres [S20] [S0405]. As the United States Government Accountability Office confirmed in July 2024, mechanical recycling is most effective for single-material textiles such as 100 percent cotton [S0401]. Natural cellulosic cotton fibres fracture cleanly along their fibrillar structure during controlled opening, yielding staple lengths between 6 and 21 millimetres suitable for re-blending with virgin cotton on open-end rotor spinning frames [S20] [S0405]. Synthetic thermoplastic filaments such as polyethylene terephthalate (polyester) or polyamide (nylon) exhibit higher tensile tenacity and lower melting points. When an unverified bale containing mixed cotton, polyester and nylon enters a tearing line calibrated for cotton, frictional heat softens the thermoplastic fractions while high tensile drag snaps adjacent cotton fibres into unspinnable dust and short linters [S20] [S26].

Chemical incompatibility in mixed bales is even more severe in regenerative polymer processing [S34] [S35]. Cellulosic chemical recycling routes dissolve cotton waste into a homogeneous spinning dope using direct solvents such as aqueous N-Methylmorpholine N-oxide (NMMO) in the Lyocell process, deep eutectic solvents (DES), ionic liquids, or derivatising sodium hydroxide and carbon disulphide reagent baths in viscose production [S34] [S35] [S36]. These solvents cleave intermolecular hydrogen bonds within cellulose while reducing the degree of polymerisation (DP) from native cotton levels near 2,409 down to the 500 to 700 range required for wet spinning [S34]. Polyester, nylon and acrylic polymers do not dissolve in aqueous NMMO or alkaline cellulose baths; instead, they remain as suspended solid particulates that blind high-pressure spinneret filtration packs [S34] [S35]. Conversely, thermo-mechanical melt extrusion or glycolytic depolymerisation of polyester operates between 180 and 280 degrees Celsius, where cotton cellulose chars and releases acidic degradation compounds that discolour and embrittle the recycled polyester melt [S35] [S0401].

4.3 WHY GARMENT CARE LABELS FAIL AS AN INDUSTRIAL SORTING SIGNAL

In post-consumer collection systems and informal pre-consumer scrap yards, sorters cannot rely on sewn garment care labels to establish polymer purity [S26] [S27] [S0401]. Consumer care labels are frequently removed by wearers, faded by laundering, or absent altogether in factory cutting-room clips and overlock trimmings [S26] [S27]. Even when a printed label remains legible on a rejected garment second, regulatory labelling tolerances in major markets permit a garment sold as "100 percent cotton" to contain up to 2 or 3 percent functional fibres, decorative threads or elastic reinforcements without disclosure on the main composition line [S20] [S26]. Laboratory audits across European and North American sorting trials confirm that a substantial fraction of commercial apparel carries inaccurate composition declarations due to upstream fabric substitution or multi-component trim assemblies [S20] [S26] [S0401].

Manual tactile and visual sorting, the traditional practice in rag-grading warehouses, cannot overcome this information deficit [S24] [S26]. Experienced human graders can distinguish heavy denim from polyester chiffon by hand feel and sort garments into re-wear categories at several hundred kilograms per shift [S20] [S24]. Human senses cannot, however, reliably differentiate a 100 percent combed cotton single jersey from an 85/15 cotton-polyester blend or a 97/3 cotton-elastane plated knit once silicone softeners or reactive dyes alter the surface handle [S26] [S27]. When manual sorters misclassify even a small share of blended or stretch fabrics into a pure cotton

bin, the compressed bale inherits the technical classification of its worst contaminant, forcing processors to downgrade the lot to low-margin insulation felt, mattress stuffing or incineration [S20] [S24] [S26].

4.4 TRACE ELASTANE AND POLYOLEFIN CONTAMINATION MECHANISMS

Trace contamination inside nominally pure cotton bales illustrates why downstream recyclers enforce strict rejection clauses ({{xr:wp11-04-contaminant-thresholds}}). Polyurethane elastane (spandex) is frequently core-spun or plated into cotton knits and twills at mass fractions of 1 to 5 percent for stretch [S26] [S35]. During mechanical tearing and carding, elastomeric filaments do not fracture into discrete staple lengths; instead, they stretch, snap back into tight coils, and wrap around the metallic carding clothing of cylinders and doffers [S20] [S26]. Accumulated elastane wraps create friction hotspots, hook damage on card wires, and dense polymer neps that cause end-breaks on open-end rotor spinning frames [S20] [S0405]. Polyolefin contaminants, notably polypropylene bale twine and polyethylene packaging film swept from warehouse floors, introduce a parallel defect: shredded polyolefin splinters pass into ecru yarn, refuse to absorb reactive cotton dyes during wet processing, and appear as undyed flecks across the finished fabric face [S10] [S24] [S0402].

In chemical cellulosic recycling, trace elastane and transition-metal contaminants threaten both product quality and reactor safety [S34] [S35] [S0406]. Dissolution studies published in *Membranes* demonstrate that when waste cotton containing elastane is processed in sulfuric acid or cold sodium hydroxide and urea solvent systems, elastane filaments are only partially hydrolysed in acid and remain intact in alkaline-urea baths, interrupting the structural continuity and transparency of regenerated cellulose films [S0406]. In industrial NMMO Lyocell reactors, undissolved polyurethane gels clog sintered metal filters prior to air-gap wet spinning [S35]. Simultaneously, metallic dust introduced when clips touch bare concrete floors elevates iron levels; dissolving pulp specifications require iron to remain below 15 to 20 parts per million (achieved at 17.01 ppm in deep eutectic solvent depolymerisation trials) because free iron ions catalyse runaway exothermic decomposition of NMMO solvent [S34] [S35].

EXHIBIT 17 / PROCESS THRESHOLDS

Contaminant tolerance thresholds differ across mechanical open-end spinning, lyocell dissolution and non-woven airlay routes

Recycling route	Min. cotton (%)	Max. elastane (%)	Max. polyester (%)	Metal / hard trim limit	Primary industrial failure mode if exceeded
Mechanical tearing for fine rotor yarn (Ne 16 to Ne 30)	> 98.0%	< 0.5%	< 2.0%	0.0% (zero metal)	Card cylinder wire wrapping, yarn neps, rotor end-breaks and undyed synthetic flecks
Mechanical tearing for coarse rotor/core yarn (Ne 6 to Ne 14)	> 92.0%	< 1.5%	< 8.0% (known blend)	0.0% (zero metal)	Tearing pin breakage and spark ignition from metal fasteners; uneven yarn count CV%
Chemical Lyocell / NMMO direct cellulose dissolution	> 96.0%	< 0.2%	< 1.0%	Fe < 17 to 20 ppm	Insoluble polyurethane gels blinding spinnerets; iron-catalysed exothermic NMMO decomposition
Chemical DES / alkaline-urea depolymerisation to pulp	> 95.0%	< 0.5%	< 3.0% (filtered)	Fe < 20 ppm; low ash	Interrupted regenerated cellulose morphology (NaOH/urea) and alpha-cellulose below 98.80%
Non-woven airlay / needle-punch insulation and automotive felt	> 60.0%	< 5.0%	Up to 40.0%	0.0% hard hardware	Low economic realisation (downcycled cascade); hard trims damage garnetting teeth

DERIVED [S20] [S26] [S34] [S35] [S0405] [S0406] Thresholds synthesised from Textile Exchange GRS/RCS V2.0 technical guidance (S0405), University of Groningen NIR sorting specifications (S26), DES dissolving pulp benchmarks (S34), VTT polycotton review (S35) and MDPI elastane dissolution studies (S0406).

4.5

Cutting-table segregation by shade and weave captures pure feedstock before entropy rises

4.6 THE THERMODYNAMICS AND UNIT ECONOMICS OF ZERO-MIXING DISCIPLINE

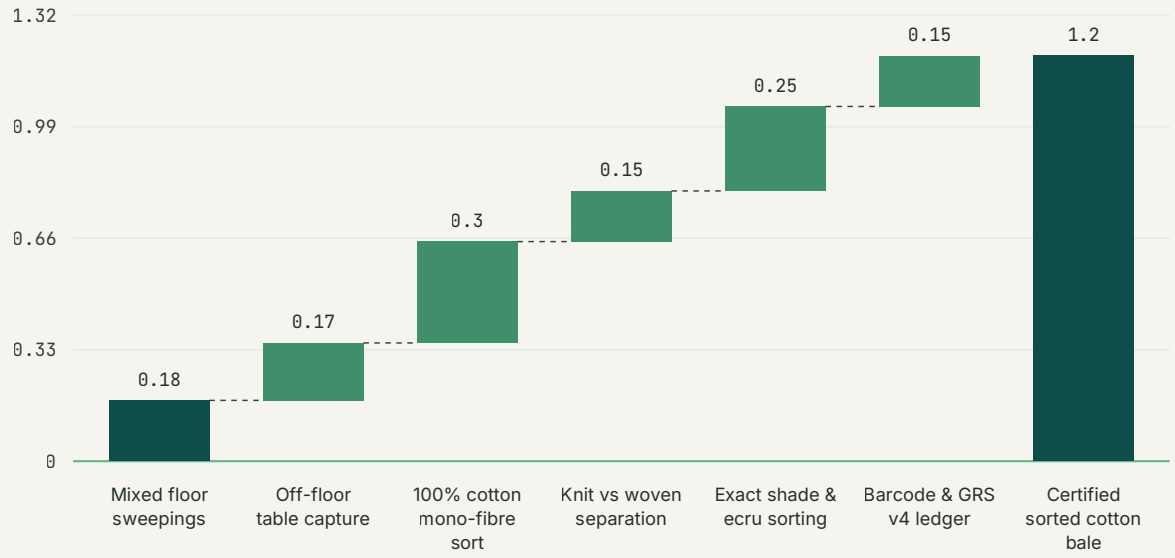
In industrial waste management, mixing distinct material streams increases informational and physical entropy, and the unit cost of reversing that mixing rises sharply with every downstream handling step [S10] [S24] [S0402]. When cutting-room offcuts

from an ecru 100 percent combed cotton jersey lay, a navy 65/35 polycotton twill lay, and a black 96/4 cotton-elastane rib lay are swept into a single floor sack, recovering pure cellulosic feedstock later requires transporting the mixed mass to a sorting plant, paying manual graders or running optical lines, and absorbing a 15 to 25 percent reject loss of cross-contaminated pieces [S20] [S24] [S26]. In UNIDO's Morocco pilot for recycled-content yarn manufacturing, post-collection segregation and logistics represented the primary cost hurdle for recyclers, with transport alone accounting for 30 to 40 percent of total textile-waste recycling cost [S24]. Shipping unsegregated bales containing unusable blends means paying freight on material that the spinner must ultimately discard [S24] [S25].

Inside a garment factory's cutting room, by contrast, compositional entropy is zero at the exact moment the straight-knife or computer-numerical-control (CNC) cutter slices through the fabric lay [S10] [S33] [S0402]. Every fabric roll issued from the warehouse to the spreading table arrives with a verified mill test certificate, supplier batch number, exact polymer percentage, yarn count, fabric construction (single jersey, interlock, piqué or woven twill), areal weight in grams per square metre (GSM), and dye shade code [S10] [S28] [S33]. For a Cameroon manufacturer sourcing domestic cloth spun from SODECOTON lint, where above 99 percent of national cotton output is classed in the top two international grades [R03], the cutting room holds virgin-grade cellulosic provenance data in its production work order before a cut is made. As the Global Fashion Agenda's *Upstream Circularity Playbook* emphasises, placing dedicated collection bins by composition and colour at the end of each cutting table prevents clippings from landing on the factory floor, eliminating sweep dust and oil stains while increasing the revenue manufacturers earn from waste streams ({{xr:wp11-04-sorting-value-waterfall}}) [S0402].

EXHIBIT 18 / US$/KG

Colour and composition sorting at the cutting table preserves 3.0 to 4.5 times the bale value of mixed floor sweepings



ILLUSTRATIVE [S10] [S24] [S28] [S0402] [S0403] Illustrative factory-gate price build-up per kilogram of pre-consumer cotton cutting clips calibrated to UNIDO Switch2CE Bangladesh jhut price bands (US$0.10 to US$3.00/kg depending on quality and sorting, S0403) and UNIDO Morocco / Reverse Resources pre-consumer cotton clip benchmarks (S10, S24, S0402).

4.7 STANDARD OPERATING PROCEDURES FOR LAY-BY-LAY CUTTING-TABLE CAPTURE

Operationalising point-of-generation sorting requires embedding waste capture into the standard minute value (SMV) of the cutting-room workflow rather than treating scrap collection as a janitorial task [S32] [S33] [S0402]. In GFT's Performance-Management System (PMS) design, cutting-room performance is governed by roll-by-roll reconciliation, comparing planned consumption from computer-aided design (CAD) marker efficiency against actual fabric weight consumed on the table [S32] [S33]. Extending this reconciliation to offcuts requires a four-step operating procedure executed between successive lays:

1. **Pre-lay bin assignment and barcode pairing.** When the cutting supervisor generates the spreading ticket for an order, the terminal prints a companion waste-lot barcode label encoding the fabric batch ID, fibre composition (`100% CO`), structure (`KNIT-SJ-180GSM`), dye family (`NAVY-REACT-04`), and chemical compliance status [S10] [S28]. This label is clipped to a wheeled polyethylene liner bag positioned flush with the discharge end of the cutting table [S0402].
2. **Direct off-table chute discharge during bundle stripping.** As operators remove numbered garment pattern bundles from the cut lay, all inter-pattern skeleton clips, selvedges and end-bits are pushed directly off the clean melamine table surface into the assigned liner bag [S33] [S0402]. Any scrap that falls onto the floor is swept into a quarantined Grade C sack so sewing-machine oil, metal staples or floor grit never enter spinning-grade bales [S0402].

3. **Inter-lay table clear-down before fabric or shade changes.** Whenever the spreading schedule switches fibre type, knit-versus-woven structure, or shade family, operators seal the active liner bag, weigh it on a digital platform scale linked to the cutting-room dashboard, and attach a fresh liner bag before the first ply of the new roll is spread [S10] [S33] [S0402].

4. **Segregated intermediate staging and vertical baling.** Weighed liner bags are staged in colour-coded warehouse cages until 150 to 250 kilograms of a single composition and shade family accumulate to press a uniform bale in a hydraulic vertical baler, wrapped in cotton canvas rather than friable polypropylene twine [S24] [S0402].

4.8 PRESERVING CELLULOSE CHAIN LENGTH AND WATER BUDGETS THROUGH SHADE SORTING

Segregating cutting clips by exact colour family at the cutting table delivers an environmental and technical dividend extending into downstream spinning and wet processing [S24] [S35] [S0402]. When cotton waste of multiple colours is mixed, a recycler attempting to spin versatile yarn must either card the mixed colours into a heather grey-brown melange yarn of limited market scope, or subject the shredded fibres to aggressive chemical stripping and oxidative bleaching using sodium hypochlorite, hydrogen peroxide or hydrosulphite baths [S20] [S24] [S35]. Chemical dye stripping attacks the glycosidic linkages of the cotton cellulose polymer alongside the chromophore molecules, reducing DP and single-fibre tenacity after the fibre has already suffered mechanical shortening during tearing [S20] [S35] [S0405].

Colour-sorted cotton clips bypass stripping and re-dyeing entirely [S24] [S0402]. When a spinner receives a pure bale of navy-blue 100 percent cotton jersey clips segregated at the cutting table, the opened fibres retain their original reactive dye shade and can be blended directly with colour-matched virgin cotton or spun as 100 percent pre-coloured recycled rotor yarn [S24] [S0405]. As analysed in our companion white paper on wet processing and effluent stewardship (wp06), dyeing and finishing dominate a textile mill's thermal energy, freshwater withdrawal and chemical oxygen demand. Preserving the embodied dye, water and thermal energy already invested in the fabric roll avoids secondary wet-processing effluent while preserving maximum cellulose chain length [S24] [S35] [S0402].

> **GFT NOTE: CUTTING-TABLE WASTE ACCOUNTING IN THE GFT PERFORMANCE-MANAGEMENT SYSTEM**
>
> In GFT's Performance-Management System (PMS) architecture (Section 4, Shop-Floor Metrics and Visual Management), cutting-room efficiency is tracked through CAD Marker Efficiency (target 82 to 88 percent by style) and Actual-versus-Planned Fabric Consumption Variance [S32] [S33]. Adding a third terminal scan at the cutting table, **Segregated Grade-A Clip Recovery Rate (%)**, reconciles total roll weight issued from the warehouse (M_{roll}) against bundled garment panels sent to sewing (M_{panels}), Grade A composition-and-shade-sorted clips ($M_{\text{clip,A}}$), and unsegregated floor losses (M_{floor}). Setting an operational KPI target of $M_{\text{clip,A}} / (M_{\text{roll}} - M_{\text{panels}}) \ge 96\text{ percent}$ aligns operator incentives with zero-cost point-of-generation sorting [S33] [S0402].

4.9

Digital waste mapping platforms connect factory cutting rooms to certified recycling off-takers

4.10 LESSONS FROM REVERSE RESOURCES AND UNIDO SWITCHMED WASTE MAPPINGS

Historically, even when individual garment factories maintained tidy cutting rooms, pre-consumer textile waste failed to reach fibre-to-fibre recyclers because the secondary trade operated through opaque, cash-based informal brokerage networks [S10] [S24] [S0403]. Field evidence from major garment export hubs demonstrates both the scale of this hidden resource and the value lost to informal mixing. In Bangladesh, the UNIDO Switch to Circular Economy Value Chains (Switch2CE) report published in February 2025 documented that ready-made garment factories generated approximately 830,000 tonnes of pre-consumer cutting waste (*jhut*) in 2023, with an average factory producing 700 to 750 kilograms daily [S0403]. Depending on purity, piece size and colour sorting, *jhut* prices ranged across a thirty-fold spread from US$0.10 to US$3.00 per kilogram [S0403]. Across North Africa, UNIDO SwitchMed and Closed Loop Fashion mappings established that Egypt (212,000 tonnes), Morocco (83,200 tonnes) and Tunisia (31,100 tonnes) together generate 326,300 tonnes of post-industrial textile waste annually [S25]. In Morocco alone, 42 percent of that waste comprises cotton-rich blends and 14 percent is pure 100 percent cotton (56 percent high-value recycling potential), yet informal handlers routinely degraded its value by co-mingling sorted factory bags during collection [S24] [S25].

Digital waste-mapping platforms such as Reverse Resources proved across Asian, European and North African pilots that making factory-floor waste visible, standardised and traceable enables direct business-to-business supply contracts between garment makers and industrial recyclers [S10] [S25] [S0403]. As Reverse Resources noted in June 2024, as global textile-to-textile recycling technologies scale from handling 12,000 tonnes toward over 200,000 tonnes per year, the primary bottleneck is the lack of clean, traceable and scalable waste supply chains [S10]. Between January 2022 and August 2024, digital tracking on the Reverse Resources platform in Bangladesh alone registered 21,170,642 kilograms of pre-consumer textile waste by fibre composition across participating factories, creating the transparent inventory data required for spinners to commit capital to recycling lines [S0403].

4.11 STANDARDISED DIGITAL BALE LEDGERS AND CHEMICAL COMPLIANCE ATTRIBUTES

Transforming a physical bale of cutting clips from discounted scrap into bankable industrial feedstock requires capturing structured metadata when the bale is pressed [S10] [S28] [S40]. Under the international circularity framework established by ISO 59004:2024, ISO 59020:2024 and ISO 59014:2024 on traceability in secondary materials recovery, secondary material flows must carry verifiable boundary

definitions and provenance records [S21] [S39] [S40]. In practical factory terms, a digital bale ledger entry generated by the warehouse barcode scanner records seven attributes:

- **Unique Bale Identifier and Origin Timestamp:** A serialized GS1-compatible barcode or QR code linking the compressed bale to the CMT factory Scope Certificate, cutting table number and packing date [S28].
- **Exact Polymer Composition and Blend Tolerance:** Verified percentages derived from the parent fabric roll's mill test report (`100.0% Cotton, 0.0% Elastane`), distinguishing mono-material cellulosic lots from polycotton blends [S10] [S26] [S28].
- **Fabric Structure and Yarn Count Class:** Classification into loose knit (single jersey, rib, fleece) versus tight woven (poplin, twill, denim) structures; knit clips open with lower mechanical energy and yield longer recovered staple fibres during garnetting than tightly twisted wovens [S20] [S24] [S0405].
- **Colour Family and Dye Chemistry:** Standardised shade group (greige, bleached white, light pastel, medium reactive, dark navy/black, or indigo) enabling spinners to blend colour-matched lots without bleaching [S24] [S0402].
- **Gross, Tare and Net Mass (kg) at Standard Regain:** Calibrated platform scale weight adjusted for packaging tare, feeding directly into the facility's mass-balance ledger [S28] [S40].
- **Chemical Compliance Pedigree:** Verification that the parent fabric roll conformed to the Zero Discharge of Hazardous Chemicals (ZDHC) Manufacturing Restricted Substances List (MRSL) or OEKO-TEX Standard 100, satisfying Global Recycled Standard (GRS v4) chemical criteria [S28] [S0402].
- **Custody Status and Destination Off-taker:** Digital link to the shipping manifest and Transaction Certificate (TC) issued when ownership transfers to a certified shredder or pulp mill [S28] [S0405].

4.12 CONVERTING INFORMAL CASH SCRAP INTO AN AUDITABLE B2B REVENUE LINE

For a greenfield garment manufacturer in Cameroon, implementing a digital waste ledger from Day 1 eliminates a well-known governance and financial leakage point [S10] [S0402] [S0403]. In many garment clusters, unrecorded cash sales of cutting-room scrap operate outside formal company books, creating perverse incentives for supervisors to over-order fabric rolls or inflate marker waste allowances [S33] [S0403]. When every kilogram of incoming roll weight must balance against outgoing sewn garments and barcoded clip bales inside the enterprise resource planning (ERP) and PMS database, physical leakage is immediately flagged as an inventory variance [S28] [S33].

Commercially, aggregating verified digital inventories allows a medium-scale CMT plant to participate in formal regional and international offtake tenders [S10] [S24] [S25]. Instead of selling ungraded bags at the factory gate for US$0.10 to US$0.20 per kilogram to local middlemen, a factory holding a digital inventory of 30 to 50 tonnes of barcoded, shade-sorted, elastane-free 100 percent Cameroon cotton clips can contract directly with regional open-end spinners (such as Camtext SA or SODECOTON-CICAM as domestic spinning lines come on stream) or export container loads to Mediterranean and European recyclers at structured B2B prices [R08] [R09]

[R10] [S24] [S25] [S0403]. This digital traceability pipeline connects to the plant's broader quality data architecture (wp16) and provides the raw-material foundation for EU Digital Product Passports (wp17).

4.13

Near-infrared spectroscopy between 900 and 1,700 nanometres identifies molecular polymer fingerprints

4.14 VIBRATIONAL PHYSICS OF C-H, O-H AND N-H BONDS IN THE NEAR-INFRARED SPECTRUM

While cutting-table segregation solves purity for a disciplined CMT plant's own offcuts, a regional recycling hub aggregating bales from smaller garment workshops, tailoring clusters, or post-consumer take-back programmes cannot trust paper declarations alone [S24] [S26] [S27]. To verify incoming bales rapidly and non-destructively, industrial sorting centres rely on near-infrared (NIR) reflectance spectroscopy [S26] [S27] [S0404]. The near-infrared spectrum spans wavelengths from roughly 750 to 2,500 nanometres, with industrial indium gallium arsenide (InGaAs) photodiode array sensors typically operating between 900 and 1,700 nanometres [S26] [S0404]. When a halogen light source illuminates a textile sample, photons in this window excite overtone and combination vibrational modes of covalent molecular bonds, specifically carbon-hydrogen (C-H), oxygen-hydrogen (O-H), and nitrogen-hydrogen (N-H) functional groups [S26] [S27].

Because every textile polymer possesses a distinct chemical backbone, each fibre family absorbs near-infrared radiation at characteristic resonant wavelengths and reflects the remaining light into the spectrometer's optical grating [S26] [S27] [S0404]:

- **Cellulose (Cotton, Viscose, Lyocell):** Dominated by hydroxyl (O-H) groups on the anhydroglucose ring and aliphatic C-H bonds. Cotton exhibits a broad first overtone O-H stretching absorption band between 1,420 and 1,490 nanometres, alongside aliphatic C-H stretching features around 1,190 to 1,220 nanometres [S26] [S27] [S0404].
- **Polyethylene Terephthalate (Polyester):** Characterised by an aromatic benzene ring and ester linkages. Polyester produces a sharp aromatic C-H first overtone absorption peak near 1,660 nanometres (and a second overtone near 1,130 nanometres), sitting in a spectral trough where pure cotton shows minimal absorption [S26] [S27].
- **Polyamide (Nylon 6 and Nylon 6,6) and Protein Fibres (Wool, Silk):** Contain repeating amide (CO-NH) linkages that display diagnostic N-H first overtone absorption bands between 1,480 and 1,530 nanometres, allowing optical separation from both cellulosics and polyesters [S26] [S0404].
- **Polyurethane-Urea (Elastane / Spandex):** Combines polyether or polyester soft segments with urethane and urea hard segments, generating identifiable N-H urethane absorption shoulders near 1,500 to 1,540 nanometres and aliphatic polyether C-H bands around 1,180 to 1,210 nanometres and 1,690 to 1,720 nanometres [S26].

4.15 NIST'S OPEN NIR-SORT REFERENCE DATASETS FOR CALIBRATION AND BENCHMARKING

Until recently, proprietary lock-in of spectral libraries held by equipment vendors hindered smaller regional recyclers from deploying automated spectroscopic sorting [S26] [S27]. In January 2025, the United States National Institute of Standards and Technology (NIST) addressed this barrier by releasing an open-access reference database of near-infrared spectral fingerprints for textile recycling [S27]. Expanded through July 2026 as the **Near Infrared Spectra of Origin-defined and Real-world Textiles (NIR-SORT)** repository (versions 1.0 and 2.0), the dataset recorded 516 downloads by 395 unique users worldwide by February 2026 [S0404].

NIST's NIR-SORT 2.0 library provides a calibration standard for regional sorting facilities [S0404]. The repository contains reflectance spectra for 90 known-provenance fabrics, 12 pre-consumer manufacturing waste fabrics, and 11 post-consumer garments, supplemented in version 2.0 by 12 custom-dyed fabrics, 61 custom-blended samples, 8 undyed fabrics spanning three additional fibre families, and 12 additional pre-consumer fabrics [S0404]. Crucially for African industrial deployment, NIST recorded spectra across both benchtop Fourier-transform NIR (FT-NIR) instruments and compact handheld NIR devices, accompanied by ground-truth physical measurements of fabric thickness, areal density, air permeability, yarn linear density, twist, thread count and colour coordinates [S27] [S0404]. By downloading NIR-SORT 2.0, an engineering team at a Cameroon regional textile hub can pre-train and validate chemometric models across benchtop and portable spectrometers before scanning local bales [S26] [S0404].

4.16 BENCHTOP QUALITY-ASSURANCE SCANNERS VERSUS HIGH-SPEED PNEUMATIC CONVEYOR LINES

In industrial practice, NIR spectroscopy is deployed across two hardware configurations whose capital cost and throughput differ by two orders of magnitude [S20] [S26] [S0402] [S0404]:

1. **Handheld and Benchtop NIR Quality-Assurance Analysers (Batch Auditing):** A portable or benchtop InGaAs spectrometer (operating across 900 to 1,700 nanometres) is pressed directly against sample swatches drawn from incoming pre-consumer bales [S26] [S0404]. Each scan takes 1 to 3 seconds, requires zero sample destruction, and outputs a pass/fail composition verification and elastane alert to the warehouse tablet [S26] [S0404]. With illustrative hardware costs of US$5,000 to US$25,000 per unit, a benchtop or handheld NIR station can audit every bale arriving at a regional spinning mill from 10 to 20 surrounding CMT factories.
2. **High-Speed Hyperspectral Conveyor Sorting Lines (Continuous Piece Ejection):** In high-volume post-consumer sorting plants (such as European facilities operating TOMRA Autosort or Picvisa Ecoclip optical lines), loose garments or fabric pieces travel at 2 to 3 metres per second along an illuminated conveyor belt beneath an overhead NIR hyperspectral line-scan camera [S20] [S26] [S0402]. The camera classifies each item in milliseconds and triggers high-pressure pneumatic air nozzles to eject each textile piece into its designated polymer bin [S20] [S26] [S0402]. While conveyor systems process 1 to 5 tonnes per hour, they require

multi-million-euro capital investment and continuous compressed-air power, making them suited to centralized metropolitan hubs rather than individual garment factories [S20] [S0402].

4.17

Machine-learning classifiers on NIR spectra achieve 91.7 percent composition accuracy and 92.6 percent elastane detection

4.18 WHY POLYCOTTON BLENDS AND CORE-SPUN ELASTANE DEFEAT SIMPLE LINEAR RULES

If every textile sample were an undyed sheet of 100 percent pure polymer, a two-wavelength ratio threshold could separate cotton from polyester with near-perfect reliability [S26] [S27]. Real-world textiles violate these ideal conditions in three ways [S26] [S0404]. First, fabrics vary in surface geometry, thickness, weave tightness and moisture content, causing baseline offsets and light-scattering variations across the reflectance spectrum, while dark carbon-black pigments attenuate signal-to-noise ratios [S26] [S0404]. Second, in intimate polyester-cotton blends (such as 65/35 PES/CO shirting) and plated knits, the reflectance spectrum is a non-linear superposition of cellulosic O-H and ester aromatic C-H bands whose apparent ratio shifts with yarn surface migration [S26] [S35]. Third, elastane filaments in stretch cotton fabrics are typically present at only 1 to 5 percent by mass and are physically buried as the core of a core-spun cotton yarn [S26] [S35]. Because near-infrared photons penetrate only a few hundred micrometres into the fabric surface, the cotton sheath masks the polyurethane core, leaving faint spectral perturbations in the 1,180 to 1,220 nanometre and 1,500 to 1,700 nanometre bands that linear threshold rules miss [S26].

4.19 FEATURE ENGINEERING AND MODEL BENCHMARKS FROM THE UNIVERSITY OF GRONINGEN STUDY

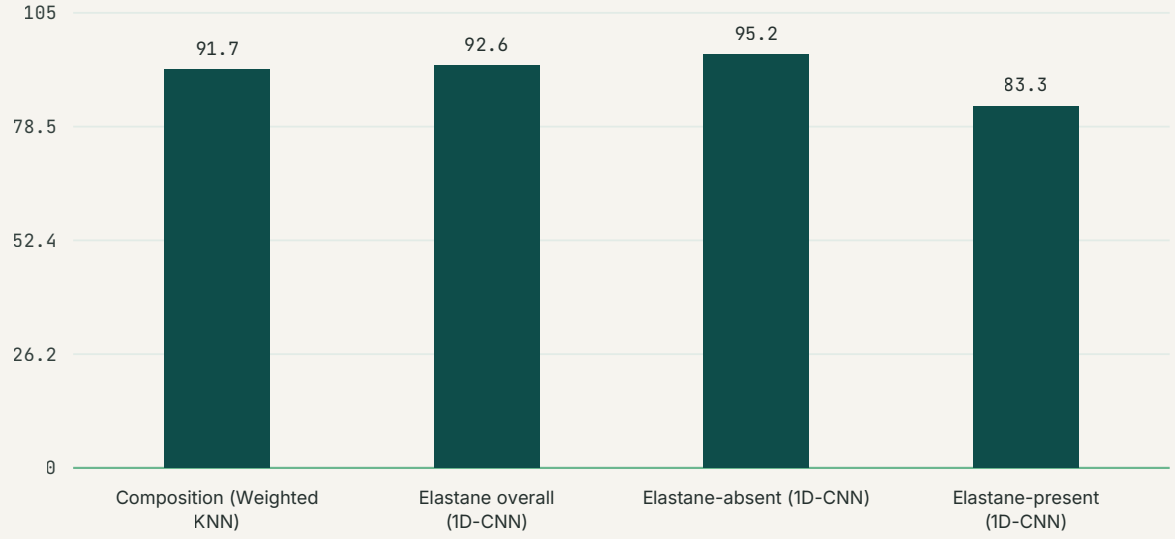
To overcome spectral masking and non-linear blend interference, modern optical sorting pipelines combine spectral preprocessing with supervised machine learning [S26]. In an April 2026 research investigation at the University of Groningen, Temmo Rijken evaluated machine-learning classification pipelines across 181 certified textile samples scanned in the 900 to 1,700 nanometre NIR wavelength range [S26]. Rather than feeding raw reflectance values into a classifier, the pipeline extracted a multi-domain feature set combining smoothed spectral derivatives (removing baseline offsets from texture and colour), targeted band-ratio indices, and discrete wavelet transform coefficients that isolate localized high-frequency absorption shoulders [S26].

Across multi-class composition identification spanning mono-materials and commercial blends, a **Weighted K-Nearest Neighbours (Weighted KNN)** classifier achieved the highest overall test accuracy at **91.7 percent**, demonstrating that common mono-materials and multi-fibre blends can be distinguished reliably in the 900 to 1,700 nanometre window ({{xr:wp11-04-nir-ml-accuracy}}) [S26]. For binary detection of hidden elastane, a **one-dimensional Convolutional Neural**

Network (1D-CNN) operating on the preprocessed spectral curve achieved an overall accuracy of **92.6 percent**, comprising **95.2 percent** specificity on elastane-absent samples and **83.3 percent** sensitivity on elastane-present samples [S26].

EXHIBIT 19 / PERCENT

Machine-learning NIR classifiers achieve 91.7 percent composition accuracy and 92.6 percent binary elastane detection



SOURCED [S26] Sourced from University of Groningen (April 2026) evaluation of 181 certified textile samples across 900 to 1,700 nm (S26). Multi-class composition uses Weighted KNN; binary elastane detection uses a 1D Convolutional Neural Network (1D-CNN).

MULTI-SCAN BAYESIAN CONSENSUS FOR BALE-LEVEL ELASTANE QUARANTINE

When a regional recycling hub audits an incoming compressed bale using a benchtop or handheld 900 to 1,700 nm NIR probe, taking k independent scans across different fabric layers amplifies the single-scan 1D-CNN sensitivity ($p_s = 0.833$) and specificity ($p_a = 0.952$) reported in the University of Groningen study [S26]. If an entire cutting-lay bale was produced from a single core-spun elastane fabric lot, the probability of missing elastane across $k = 3$ independent swatch scans drops to $(1 - p_s)^3 = (1 - 0.833)^3 = 0.0047$, yielding a **99.53 percent** lot-level detection probability [S26]. Conversely, applying a majority-vote rule (requiring at least 2 of 3 scans to flag elastane before quarantining a bale) reduces the false-positive rejection rate on pure elastane-free cotton bales from $1 - 0.952 = 4.8\text{ percent}$ down to $3(0.048)^2(0.952) + (0.048)^3 = \mathbf{0.67\text{ percent}}$ [S26]. A three-scan protocol requiring under 10 seconds per bale thus achieves over 99 percent lot-level quarantine security [S26].

4.20 SHARED EDGE-INFERENCE HARDWARE WITH GFT'S COMPUTER-VISION FABRIC INSPECTION

A practical advantage of deploying machine-learning NIR classification within GFT's digital manufacturing blueprint is that the required compute infrastructure already exists on the factory floor [R28] [R29]. In GFT's Digital Strategy (Section 3, Tier-2 Quality Inspection, and Section 5, Reference Architecture), the plant deploys automated computer-vision camera bars above fabric inspection and spreading tables to

detect weaving and knitting defects [R28] [R29]. Academic benchmarks show that deep-learning fabric inspection models achieve 92.3 to 97.2 percent defect detection accuracy at speeds up to 60 metres per minute (versus 60 to 75 percent accuracy at 10 to 15 metres per minute for human inspectors), while commercial systems such as Smartex on circular knitting machines cut defective fabric production by 85 percent [R28] [R29].

Executing a Weighted KNN or compact 1D-CNN model on a 256-channel 1D near-infrared spectrum requires fewer than 50,000 floating-point operations and completes in under 2 milliseconds on an industrial edge gateway [S26]. As detailed in our companion white paper on edge-to-dashboard reference architecture (wp18), the NIR sensor connects via USB or Ethernet to the same local edge node that runs the computer-vision inspection pipeline and logs results directly into the shop-floor PostgreSQL/TimescaleDB database, operating offline without cloud latency.

4.21

Physical preprocessing must remove trims, seams and coatings before baling or shredding

4.22 CLEAN CUTTING-TABLE CLIPS VERSUS WHOLE-GARMENT REJECTS AND POST-CONSUMER DISCARDS

Upstream sorting does not end with polymer identification; physical preprocessing must also match the mechanical state of the textile waste to the opening equipment [S20] [S24] [S0405]. Cutting-table clips generated before the sewing line consist purely of flat, single-ply fabric pieces free of metal fasteners, buttons, zippers, interlinings or foreign sewing threads [S0402] [S0405]. Provided they are segregated at the cutting table, these clips bypass mechanical de-trimming and proceed directly to baling and guillotine size reduction into 20 to 50 millimetre squares prior to mechanical tearing [S20] [S0405].

By contrast, sewing-line quality rejects (the 1 to 3 percent of garments that fail Acceptable Quality Limit inspection and cannot be reworked), overlock edge trimmings, unsold deadstock, and post-consumer garments are composite assemblies [S20] [S26] [S0401]. An assembled cotton shirt or trouser contains brass or steel zippers, copper denim rivets, polyester buttons, woven polyester care labels, fusible resin collar interlinings, elastane waistbands, and polyester core-spun seam threads [S20] [S26] [S35]. Mixing whole garment rejects into a bale of clean cutting clips contaminates the batch with hard trims and synthetic seam threads, downgrading clean clips to the processing cost of post-consumer rags [S24] [S0402].

4.23 MECHANICAL HAZARDS OF HARD TRIMS AND TEXTILE EXCHANGE GRS V2.0 RULES

Feeding un-trimmed garments containing metal zippers, rivets or hard buttons into a high-speed mechanical tearing line creates severe mechanical and fire hazards [S20] [S23] [S0405]. Tearing cylinders rotate at high peripheral speeds with sub-millimetre clearances between hardened steel pins or saw-tooth wire [S20]. When a metal zipper slider or rivet strikes the rotating cylinder, it snaps steel pins, gouges carding wire, and throws incandescent friction sparks into an atmosphere saturated with dry, aerated cotton lint [S20]. Dust-spark ignition inside tearing and pneumatic ducts is a

primary fire hazard in mechanical recycling plants, requiring magnetic metal traps, heavy-part gravimetric drops, and infrared spark-detection suppression systems on lines processing whole garments [S20].

Textile Exchange's *Guide to Recycled Materials V2.0* (GRS-202-V2.0-2025.07.01 and RCS-202-V2.0-2025.07.01, effective July 2025) codifies the regulatory boundary between physical preprocessing and certified recycling [S0405]. Under the standard, opening, cleaning, sorting, screening, contamination removal, baling and size conversion are classified as **material concentration** steps prior to mechanical shredding [S0405]. The guide also establishes strict audit thresholds based on fibre physics: pre-consumer garment cutting waste typically yields reclaimed cotton staple lengths between **6 and 21 millimetres** after tearing (and 5 to 18 millimetres for post-consumer waste) [S0405]. Consequently, Textile Exchange mandates that only products containing mechanically recycled cotton with a yarn count coarser than **Ne 34** (<Ne 34) and a fibre length shorter than **22 millimetres** (<22 mm) may be certified to the Recycled Claim Standard (RCS) or Global Recycled Standard (GRS) without mandatory additional due diligence by the certification body [S0405].

4.24 DE-TRIMMING PROTOCOLS AND CHEMICAL COATING EXCLUSIONS

To protect downstream tearing cylinders and satisfy GRS v4 and European Extended Producer Responsibility (EPR) standards, factory preprocessing must physically separate three restricted fractions before baling [S20] [S23] [S28] [S0405]:

- **Guillotine and manual de-trimming of rejected seconds:** Unsellable garment seconds have their zippers, buttons, metal snaps, leather patches and elastic waistbands excised using pneumatic guillotines or trim saws prior to baling, while automated regional hubs use coarse shredding followed by air-density classifiers and over-band magnets [S20] [S24].
- **Overlock seam-trim quarantine:** When a 100 percent cotton garment is sewn with conventional polyester filament thread, the narrow strips trimmed by four-thread overlock machines contain 10 to 25 percent polyester thread by weight. Unless the garment uses 100 percent cotton or lyocell sewing thread (Chapter 07), overlock trimmings must be bagged separately from cutting-table clips and routed to non-woven insulation [S24] [S35].
- **Plastisol print and fluorocarbon finish exclusion:** Panels bearing heavy polyvinyl chloride (PVC) and phthalate plastisol screen prints, polyurethane coatings, or per- and polyfluoroalkyl substance (PFAS) water-repellent finishes cannot enter GRS-certified recycling loops [S23] [S28]. Plastisol inks smear across carding cylinders and fail GRS v4 chemical limits [S28], while under Refashion's 2026 Eco-Modulations Guide in France, components and coatings that obstruct sorting or endanger recycling incur mandatory financial penalties [S22] [S23].

OPERATIONAL HAZARD: NEVER CO-BALE SEWING-FLOOR SWEEPINGS WITH CUTTING-TABLE CLIPS

Sewing-floor sweepings contain broken high-carbon steel sewing needles, trimmer blades, polyester thread tails, and silicone needle-cooler oil. A single broken needle fragment embedded inside a compressed bale of Grade A cutting clips can shatter hardened tearing teeth, ignite a lint fire in the shredder hood, or push iron contamination above the 17 to 20 ppm safety ceiling of an NMMO Lyocell dissolving reactor [S20] [S34]. Factory rules must enforce strict separation between the cutting room (Grade A clips) and the sewing floor (quarantined sweepings passed through a needle detector).

4.25

A two-tier sorting architecture suits Cameroon's industrial geography at minimal capital cost

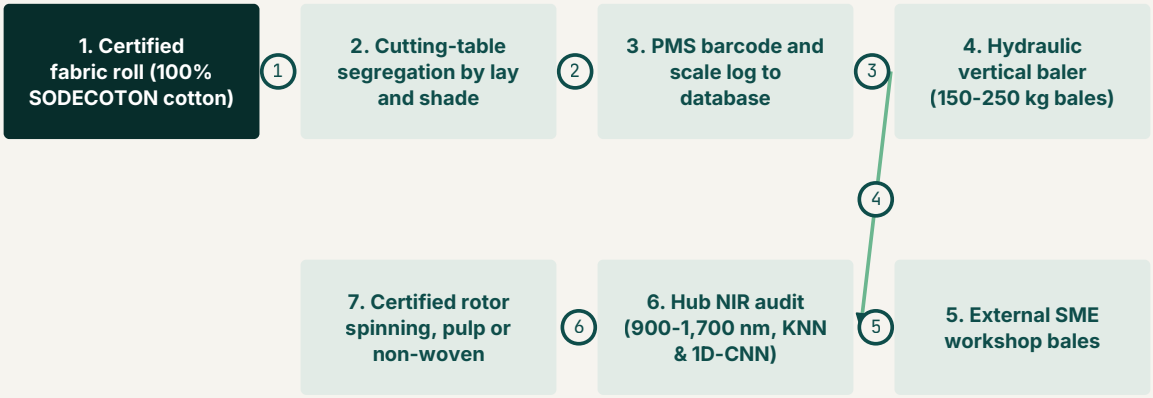
4.26 CAPITAL-CONTAINMENT LOGIC FOR A 3.0 MILLION GARMENT A YEAR CMT PLANT

Industrial engineering scale analysis shows why a greenfield garment manufacturer in Cameroon should split sorting responsibilities across a two-tier regional architecture rather than over-capitalising its own factory floor ({{xr:wp11-04-two-tier-sorting}}) [S0402]. In GFT's Feasibility Study (Sections 5 and 12), the Phase 1 blueprint centres on a capital-disciplined CMT garment operation scaling to an illustrative capacity of 3.0 million garments per year before undertaking heavy upstream spinning or weaving investments. At a typical marker consumption of 250 to 350 grams of fabric per garment and an average cutting-room waste fraction of 15 to 20 percent [S32] [S33], a 3.0 million piece factory processes 900 to 1,050 tonnes of fabric per year and generates an illustrative **135 to 210 tonnes per year** of pre-consumer cutting clips (450 to 700 kilograms per working day, matching the 700 to 750 kg/day average recorded across Bangladeshi RMG plants [S0403]).

Installing an automated conveyor-based hyperspectral NIR and pneumatic sorting line (processing 1 to 3 tonnes per hour, or 3,000 to 9,000 tonnes per year) inside a single CMT factory generating 180 tonnes per year would leave the optical machinery idle for over 97 percent of the year while burdening Phase 1 with US$500,000 to US$1.5 million in unnecessary capital expenditure [S20] [S0402]. Because the CMT plant already knows the exact composition and shade of every fabric roll spread on its own cutting tables [S10] [S33], scanning its own freshly cut clips with a high-speed conveyor camera is redundant [S0402].

EXHIBIT 20 / PROCESS ARCHITECTURE

Two-tier sorting separates zero-cost cutting-table segregation at the CMT plant from NIR spectroscopic verification at the regional hub



1. Spread lay
2. Off-floor capture
3. Grade A bags
4. B2B shipment
5. Unverified bales
6. >99% lot purity

ILLUSTRATIVE [R08] [R09] [R10] [S10] [S26] [S0402] [S0404] Architecture designed for GFT's Phase 1 CMT factory (illustrative 135 to 210 t/yr cutting waste) interfacing with regional spinning/recycling hubs such as Camtext SA at Dibamba/Garoua (R08, R09) or SODECOTON-CICAM (R10).

4.27 TIER 1 AT THE CMT PLANT AND TIER 2 AT THE DIBAMBA OR GAROUA REGIONAL HUB

Instead, the two-tier sorting architecture allocates tasks to the industrial node where unit cost is lowest ({{xr:wp11-04-two-tier-sorting}}):

- **Tier 1 (On-Site CMT Factory Floor, Zero-Mixing Segregation and Baling):** At the garment plant, capital investment is limited to colour-coded rolling bins (illustrative US$1,500 across 10 cutting tables), a digital platform scale integrated with the PMS terminal (US$800), a thermal barcode printer (US$500), and one industrial hydraulic vertical baler (illustrative capital cost **US$8,000 to US$15,000** landed in Douala). Cutting-room helpers remunerated above Cameroon's statutory minimum wage (SMIG of XAF 43,969 per month as of 2024, or within GFT's semi-skilled wage structure [R14] [R32]) execute lay-by-lay bag changes during table stripping. Because incoming rolls carry verified mill certificates, Tier 1 achieves **>99 percent compositional purity** on internal cutting clips through process discipline alone [S10] [S0402].
- **Tier 2 (Regional Spinning or Recycling Hub, NIR Spectroscopic Verification and Tearing):** High-throughput mechanical tearing lines require 2,000 to 5,000+ tonnes per year of feedstock for competitive amortisation [S10] [S20] [S24]. In Cameroon, the natural host for Tier 2 aggregation is a regional textile pole, such as

Camtext SA (structured to process 12,000 tonnes per year of local cotton under a 180 billion XAF / US$300 million investment plan across spinning and weaving units in Garoua and a finishing and garment complex in Dibamba [R08] [R09]) or the announced **SODECOTON-CICAM** integrated pole [R10]. Because the hub aggregates bales from dozens of third-party garment workshops and tailors alongside GFT, it installs a benchtop or conveyor **900 to 1,700 nanometre NIR spectrometer** (illustrative capital cost US$12,000 to US$35,000 for a benchtop/handheld QA station) calibrated with NIST's NIR-SORT 2.0 database and the University of Groningen's Weighted KNN and 1D-CNN models [S26] [S0404]. Every incoming bale is spectroscopically audited before tearing, quarantining hidden elastane or polycotton mis-sorts before they contaminate the regional spinning batch [S26] [S0405].

WORKED EXAMPLE: ANNUAL P&L AND PAYBACK OF TIER 1 CUTTING-TABLE SORTING FOR A CAMEROON CMT FACTORY

Consider an illustrative Phase 1 Cameroon CMT garment factory operating at steady-state capacity of **3.0 million garments per year** and consuming **950 tonnes of fabric annually** (760 tonnes of 100 percent SODECOTON cotton knits and wovens, and 190 tonnes of 65/35 polycotton institutional uniform twill) [R03] [S32]. At a 17.5 percent average cutting-room scrap rate (marker clips, end-bits and selvedges) [S32] [S33], the cutting room generates an illustrative **166.25 tonnes per year** of pre-consumer textile waste (133.0 tonnes of pure 100 percent cotton clips and 33.25 tonnes of polycotton clips) [S32] [S33].

- **Baseline Scenario (Unsegregated Floor Sweepings):** Offcuts from cotton and polycotton lays are swept off the floor into mixed sacks. At illustrative unsegregated scrap prices of **US$0.15 per kilogram** (US$150 per tonne, consistent with the lower end of the US$0.10 to US$3.00/kg *jhut* range in Bangladesh and North African mixed-waste baselines [S24] [S0403]), illustrative annual scrap revenue is $\text{Revenue}_{\text{mixed}} = 166,250\text{ kg} \times \text{US\$} 0.15/\text{kg} = \text{US\$}24,938/\text{year}$ (approximately XAF 15.0 million/year) [S24] [S0403].
- **Tier 1 Segregated Scenario (Off-Table Shade, Structure and Composition Sorting):** The factory makes an illustrative capital investment of **US$12,500** in a hydraulic vertical baler, rolling bins, platform scale and PMS barcode integration [S0402]. Of the 133.0 tonnes of pure cotton waste, an illustrative 96 percent (**127.68 tonnes**) is captured off-table as Grade A shade-sorted, elastane-free 100 percent cotton bales sold to a regional spinner or export off-taker at **US$0.85 per kilogram** (conservative mid-tier sorted cotton clip price well below the US$3.00/kg ceiling [S24] [S0403]). The 33.25 tonnes of segregated 65/35 polycotton clips (at 96 percent capture, **31.92 tonnes**) are sold for non-woven insulation at **US$0.30 per kilogram**, and the remaining 4 percent floor sweepings (**6.65 tonnes**) fetch **US$0.10 per kilogram**, giving an illustrative sorted revenue of $\text{Revenue}_{\text{sorted}} = (127,680 \times 0.85) + (31,920 \times 0.30) + (6,650 \times 0.10) = \text{US\$}108,528 + \text{US\$}9,576 + \text{US\$}665 = \text{US\$}118,769/\text{year}$ [S24] [S0403].
- **Net Annual Operating Gain and Simple Payback:** Deducting illustrative incremental operating costs of **US$6,200 per year** (one dedicated baler operator at US$1,800/year fully loaded above the XAF 43,969/month SMIG baseline [R14], cotton bale strapping/wrap at US$3,200/year, and 3,600 kWh of hydraulic baler electricity plus maintenance at US$1,200/year) yields an illustrative net annual cash-flow uplift of $\Delta\text{EBITDA} = (\text{US\$}118,769 - \text{US\$}24,938) - \text{US\$}6,200 = +\text{US\$}87,631/\text{year}$ (approximately XAF 52.6 million/year) [R14] [S0403]. Against the illustrative US$12,500 Tier 1 equipment outlay, simple capital payback is achieved in **1.7 months** (52 days), while generating 127.7 tonnes per year of GRS-auditable 100 percent Cameroon cotton feedstock for Chapter 05's mechanical rotor-spinning loop [S28] [S0405].

Mixed textile waste is a chemical liability, whereas segregated, spectroscopically verified cutting clips are an industrial asset: by pairing zero-cost lay-by-lay sorting at the factory cutting table with machine-learning near-infrared verification at the regional spinning hub, a Cameroon manufacturer captures pure cellulosic feedstock with a capital payback under two months.

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R03 SODECOTON. Publication date unrecorded; inherited source-text check.

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05

Mechanical cotton recycling offers the lowest capital threshold but penalises staple length

Mechanical tearing and garnetting require a fraction of the capital, water and energy of chemical plants, but fibre shortening limits pure recycled yarn counts unless blended with long-staple virgin cotton.

CHAPTER 05
DECISION TEST

Mechanical tearing and garnetting require a fraction of the capital, water and energy of chemical plants, but fibre shortening limits pure recycled yarn counts unless blended with long-staple virgin cotton.

Mechanical cotton recycling is the only fibre-to-fibre recovery route that matches the capital envelope, utility constraints and feedstock volumes of an emerging African textile cluster in its first two operational phases. [S20] [S24] By opening sorted cutting-room clips and spinning-mill waste across progressively finer pinned cylinders, a mechanical tearing line converts fabric scrap back into spinnable staple fibre without the corrosive solvents, high-pressure reactors or 50,000-tonne minimum annual feedstock thresholds required by chemical dissolving-pulp mills (illustrative engineering benchmark). [S20] [S35] [S0501] That capital efficiency comes with an unavoidable physical trade-off: high-speed mechanical pins rupture twisted yarns by tensile force, reducing average cotton staple length and raising short-fibre content to between 45 and 78 percent. [S0501] [S0502] For a greenfield cotton-to-garment programme in Cameroon, the engineering solution is not to await distant chemical reactors, but to pair point-of-generation shade sorting at the cut-make-trim (CMT) table with open-end rotor spinning that blends 20 to 35 percent mechanically torn pre-consumer clips into 65 to 80 percent long-staple virgin SODECOTON lint. [R03] [R06] [S24] [S0501]

5.1

Mechanical tearing opens fabric clips into loose fibres through progressive pinned cylinders

Mechanical textile recycling, historically termed garnetting or shoddy pulling, is the most technologically mature and industrially established method for recovering pre-consumer cotton waste. [S20] [S24] [S0502] Across global spinning supply chains in 2022, roughly 6.7 million tonnes of recycled fibres were recovered from manufacturing waste streams and fed back into staple spinning and non-woven systems, out of 10.7 million tonnes of recoverable production losses generated across yarn, fabric and garment factories. [S0501] Specifically, Rieter's global mass balance records 5.4 million tonnes a year of yarn production loss (6 percent of yarn output), 2.7 million tonnes a year of fabric production loss (3 percent of yarn) and 4.5 million tonnes a year of garment production loss (5 percent of fabric across 90.7 million tonnes of ready-made fabrics). [S0501] Most mechanically recycled fibres processed by commercial spinners today originate from post-industrial (pre-consumer) waste because clean factory offcuts require substantially less mechanical work to open than worn post-consumer garments. [S24] [S0501]

5.2 ROTARY CUTTING AND OIL EMULSION CONDITIONING PREPARE CLIPS FOR THE TEARING DRUMS

The mechanical recovery sequence begins before fabric scraps touch a toothed cylinder. [S24] [S0502] Incoming bales of pre-consumer 100 percent cotton clips, segregated by shade and fabric structure at the garment factory cutting table as established in Chapter 4, are first inspected and passed through metal and foreign-part detectors to prevent steel staples or stray hardware from striking high-speed pins and causing spark hazards. [S26] [S0501] Rotary guillotine or rotary blade cutters then slice irregular inter-pattern cutting scraps into uniform strips measuring an illustrative 2 to 5 centimetres in width. [S20] [S0502] Uniform piece geometry prevents large fabric tails from wrapping around feed rollers and ensures a constant mass flow into the opening line (illustrative process benchmark). [S0501] [S0502]

Once cut to size, the conditioned cotton strips are sprayed with an illustrative 1 to 2 percent aqueous spinning-oil or polyethylene glycol lubricant emulsion and held in conditioning chambers for 12 to 24 hours so moisture and lubricant penetrate the yarn core. [S0502] Doctoral experimental research at the University of Boras in January 2025 confirmed that lubricant pre-treatment lowers inter-fibre and yarn-to-metal friction during mechanical tearing, directly mitigating cotton fibre shortening and reducing thermal stress across the tearing cylinders. [S0502] Conditioning also dissipates static electricity and suppresses breathable cellulose dust in the tearing hall. [S0501] [S0502]

5.3 PROGRESSIVE SAW-TOOTH CYLINDERS UNTWIST YARNS INTO A CONDITIONED FIBROUS WEB

After conditioning, a pneumatic chute feeds the lubricated fabric strips onto a compressed feed apron held by spring-loaded or hydraulically weighted nip rollers. [S0501] [S0502] As the nip rollers advance the cloth at a controlled linear speed, the first high-speed tearing cylinder (the licker-in or breaker drum), clothed with coarse, hardened steel pins or saw-tooth wire, strikes the protruding fabric edge. [S20] [S0501] Rather than chopping the cloth transversely, the pins comb and pull weft and warp threads out of the woven or knitted interlacements. [S0501] [S0502]

Industrial tearing lines arranged for apparel-grade cotton recovery typically deploy four to six sequential tearing cylinders in series. [S20] [S24] Each successive drum carries a higher pin density (finer wire gauge and closer tooth pitch) and rotates at an adjusted peripheral speed to open smaller yarn fragments without pulverising already liberated single fibres (illustrative machine configuration). [S0501] [S0502] Above and below each main cylinder, aerodynamic separator knives and perforated condenser cages divide the material stream by mass and aerodynamic drag. [S0501] Fully opened individual fibres float upward onto the condenser screen to form a fleece web, while heavier unopened yarn bits and miniature fabric flecks drop out by gravity and centrifugal force onto a return conveyor that loops them back to the preceding cylinder for a second pass. [S0501] [S0502]

Because the entire opening cascade relies on mechanical shear, aerodynamic classification and trace lubricant conditioning, it consumes zero harsh mineral acids, zero organic dissolving solvents and minimal process water. [S20] [S24] Life-cycle assessments reviewed by the European Commission and UNIDO consistently show that mechanical tearing carries the lowest capital cost, lowest energy intensity and smallest chemical footprint of any fibre-to-fibre recycling pathway. [S20] [S24] [S0502]

5.4 CARDING AND AUTOLEVELER DRAWFRAMES REMOVE RESIDUAL YARN BITS BEFORE SPINNING

Opening fabric clips on a four-to-six-cylinder tearing line is only half of the mechanical preparation process; the resulting baled recycled fleece still contains residual unopened thread ends, entangled fibre neps and wide length variations that must be resolved in the spinning mill blowroom and carding room. [S0501] In modern recycling spinning lines such as Rieter's Com4recycling configuration, torn cotton bales are metered through a precision multi-hopper blender (operating within a 1 percent dosing tolerance) alongside virgin carrier cotton and fed to high-performance cards equipped with intensive licker-in tuft opening, a long pre-carding zone and flexible or semi-rigid revolving flats designed specifically to open residual yarn remnants without snapping additional fibres. [S0501]

Directly coupling the card to an autoleveler drawframe module with narrow cylinder distances and a 35 millimetre main drafting zone guides short recycled fibres securely while reducing the number of drawframe passages required before rotor or ring spinning. [S0501] Where finer ring or compact yarns are targeted, an optional combing stage extracts the shortest fibre fraction and neps as comber noil, which is then routed into the open-end rotor spinning line so zero spinnable cellulose is wasted. [S0501]

5.5

High-speed tearing shortens cotton staple length and raises short-fibre content

The central engineering penalty of mechanical cotton recycling is structural fibre breakage during opening. [S20] [S0501] [S0502] To liberate a single cotton fibre from a spun yarn that is itself locked inside a woven twill or knitted jersey loop, the cylinder pins must overcome both the frictional twist binding the fibres together and the loop or crimp resistance of the fabric. [S35] [S0502] Whenever the frictional grip holding a fibre inside the yarn exceeds the single-fibre breaking load of cotton cellulose, the tooth ruptures the fibre shaft rather than pulling it out intact. [S0501] [S0502]

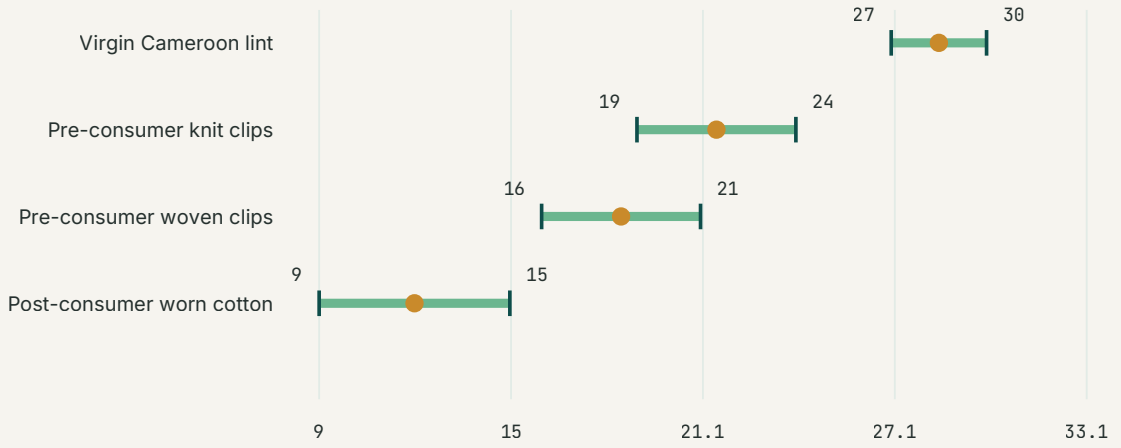
5.6 TEARING TRANSFORMS A NARROW VIRGIN LENGTH DISTRIBUTION INTO A SHORT-FIBRE-HEAVY PROFILE

In virgin cotton spinning, upland lint ginned by SODECOTON across its nine northern Cameroon plants typically offers an upper-half mean staple length of 27 to 30 millimetres and a relatively narrow length distribution (illustrative regional lint benchmark based on SODECOTON profile). [R03] [S0501] By contrast, mechanically torn cotton exhibits a left-shifted length distribution with a shortened mean staple length, a severely elevated Short-Fibre Content (SFC, defined by spinning instrument standards as the mass or number share of fibres shorter than 12.7 millimetres), a high nep count and residual unopened yarn pieces. [S0501] [S0502]

As shown in **Exhibit 21**, p. 83, the severity of staple shortening depends directly on the structural history of the input waste. [S20] [S24] [S0501] Pre-consumer knitted cutting clips, such as single-jersey or interlock T-shirt offcuts spun with lower twist multipliers and open loop geometry, release their fibres with less mechanical resistance, retaining an illustrative upper-quartile staple length of 19 to 24 millimetres. [S24] [S0502] Tightly woven pre-consumer fabrics such as high-twist denim or workwear twill require more aggressive pin action, dropping recovered staple length into an illustrative 16 to 21 millimetre band. [S24] [S0502] Post-consumer worn garments, already weakened by consumer abrasion, household laundering and alkaline detergents, suffer severe fragmentation during tearing, frequently falling to a mean length of 9 to 15 millimetres. [S20] [S0501]

EXHIBIT 21 / STAPLE LENGTH IN MILLIMETRES (MM)

Mechanical tearing reduces cotton staple length from 27 to 30 mm virgin lint to 16 to 24 mm on pre-consumer clips and under 15 mm on post-consumer waste



ILLUSTRATIVE [S20] [S24] [S35] [S0501] [S0502] Illustrative engineering staple-length bounds across four cotton feedstock categories after five-cylinder mechanical tearing, grounded in Rieter recycling classifications (S0501) and University of Boras tearing mechanics (S0502). Values are not a measured GFT factory result.

What **Exhibit 21**, p. 83 establishes is a strict physical boundary for circular factory design: pre-consumer knit and woven cutting clips remain within a spinnable staple window when paired with virgin carrier lint, whereas post-consumer rag waste loses more than half of its original length. [S20] [S0501] What the range chart cannot establish without empirical bale testing is the exact length distribution of a specific factory lot, which varies with yarn twist, dye chemistry, moisture regain and cylinder pin wear. [S0501] [S0502]

5.7 INDUSTRIAL RAW-MATERIAL CLASSIFICATION GOVERNS DOWNSTREAM SPINNING SETTINGS

To move mechanical recycling from trial-and-error art to repeatable industrial engineering, machinery supplier Rieter established a quantitative four-tier raw-material classification comparing mechanically recycled cotton lots against a virgin cotton reference. [S0501] **Exhibit 22**, p. 84 reproduces those published industrial benchmarks across short-fibre content, mean fibre length and the 5-percent longest fibre span. [S0501]

EXHIBIT 22 / PERCENT (%) AND MILLIMETRES (MM)

Rieter's industrial recycling classification shows short-fibre content rising from 24 percent in virgin cotton to between 45 and 78 percent in mechanically torn lots

Raw material grade	Short-fibre content (%)	Mean fibre length (mm)	5% fibre length (mm)	Primary feedstock origin
Virgin cotton reference	24	21	34	Standard ginned virgin upland cotton bale
Very good recycled	45	17	31	Conditioned pre-consumer loose knit clips and yarn waste
Good recycled	55	14	29	Pre-consumer jersey and medium-weight woven cutting scraps
Medium recycled	60	13	28	Tightly woven pre-consumer denim clips and mixed offcuts
Poor recycled	78	10	22	Harshly torn post-consumer worn and laundered garments

SOURCED [S0501] Sourced directly from Rieter Recycling Spinning Systems technical documentation (2023-07-13, page 11, S0501). Short-fibre content denotes fibres below the standard threshold; 5% fibre length denotes the upper span exceeded by the longest 5 percent of fibres.

The empirical figures in **Exhibit 22**, p. 84 explain why spinning mills cannot treat recycled cotton as a one-for-one drop-in substitute for ginned bales. [S0501] Even in the "Very good" recycled category typical of well-sorted pre-consumer knit cutting clips, short-fibre content nearly doubles from 24 percent to 45 percent while mean fibre length drops from 21 millimetres to 17 millimetres. [S0501] In the "Medium" and "Poor" categories, short-fibre content reaches 60 to 78 percent and mean length falls to between 10 and 13 millimetres. [S0501]

University of Boras tearing experiments further demonstrate that fabric construction and feed orientation strongly influence which grade a tearing line achieves. [S0502] Fabrics with lower weave density and longer yarn floats experience lower inter-yarn friction and preserve longer fibres during opening, whereas aligning woven strips along one thread system improves material opening and reduces fibre length loss. [S0502] Separating loose single-jersey knit clips from dense woven twill clips at the cutting table (Chapter 4) therefore allows the tearing operator to set cylinder speeds and nip distances separately for each fabric class rather than over-tearing delicate knits. [S24] [S0501] [S0502]

5.8

Blending 20 to 50 percent mechanically recycled cotton with virgin SODECOTON lint restores yarn tenacity

Because a sliver composed exclusively of 10 to 17 millimetre torn fibres lacks inter-fibre cohesion under drafting tension, attempting to spin 100 percent mechanically recycled cotton into medium or fine apparel counts causes excessive floating fibres, drafting waves, thick-and-thin defects and frequent yarn breaks. [S0501] Weaving and high-speed circular knitting machines typically require a minimum yarn breaking tenacity of roughly 8 to 10 centinewtons per tex (cN/tex) and controlled mass unevenness (CVm%) to run without costly machine stops (illustrative spinning and knitting threshold). [S24] [S0501] Restoring that structural backbone requires blending mechanically recovered cotton with longer carrier fibres. [S20] [S24] [S0501]

5.9 VIRGIN CAMEROON COTTON SERVES AS A MONO-MATERIAL CARRIER FIBRE SUPERIOR TO SYNTHETIC POLYESTER

Historically, many commercial waste spinners blended mechanically recycled cotton with 35 to 50 percent virgin or recycled polyethylene terephthalate (polyester, PES) staple fibre because polyester offers uniform cut length (38 millimetres) and high tensile strength. [S24] [S0501] From a circularity and regulatory standpoint, however, introducing polyester carrier fibre into pure cotton cutting waste is a strategic mistake. [S35] [S0501] As detailed in Chapter 7, turning a 100 percent cotton waste stream into an intimate polycotton blend creates a composite yarn that cannot be mechanically or chemically recycled a second time without expensive hydrothermal or solvent fractionation, and it forfeits mono-material design advantages under European Extended Producer Responsibility (EPR) schemes. [S23] [S35]

In Cameroon, a far better engineering solution sits on the doorstep of the spinning mill. [R01] [R06] Cameroon produced 330,000 tonnes of seed cotton in 2022, 314,455 tonnes in 2023 and about 340,000 tonnes in 2024, with 2025 projections exceeding 350,000 tonnes across more than 220,000 northern producers supported by SODECOTON, yet exports roughly 95 percent of its lint raw. [R01] [R02] [R03] [R06] Using long-staple virgin SODECOTON lint (50 to 80 percent of the blend) as the natural carrier fibre for mechanically torn pre-consumer cutting clips (20 to 50 percent of the blend) keeps the entire yarn 100 percent cellulosic and 100 percent Cameroonian in origin. [R03] [R06] [S0501]

5.10 OPEN-END ROTOR SPINNING TOLERATES HIGH SHORT-FIBRE CONTENT AND ACHIEVES COMMERCIAL YARN QUALITY

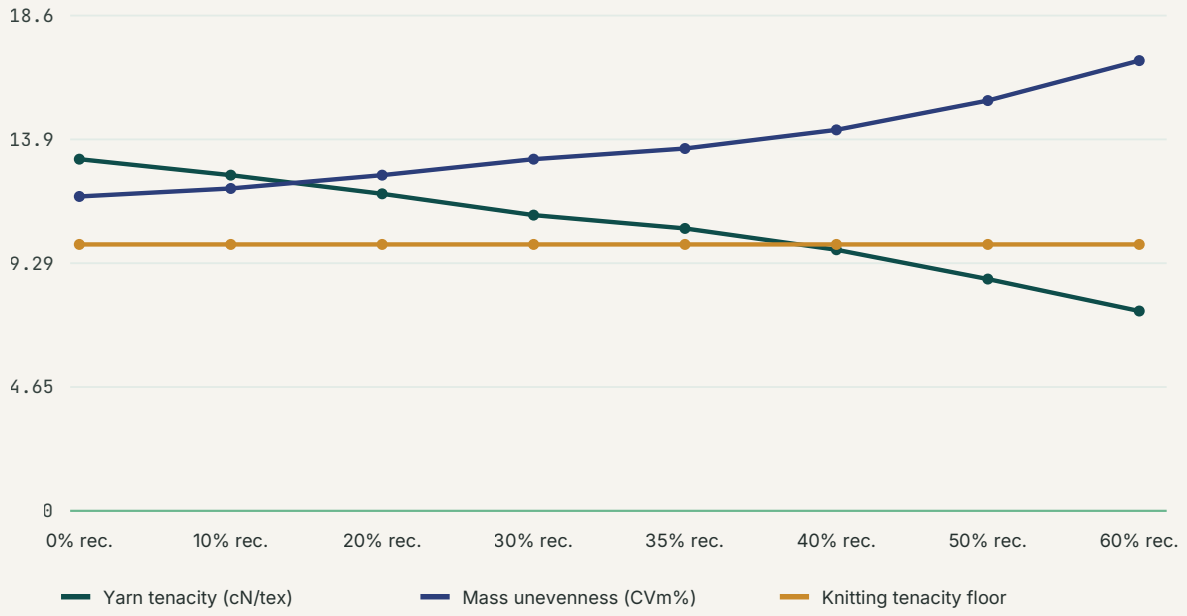
While specialized compact and ring-spinning lines equipped with narrow 35 millimetre autoleveler drawframe drafting zones, 36 millimetre active cradles with stepped nose bars and overhead travelling cleaners can process recycled cotton blends into softer finer yarns, open-end (rotor) spinning remains the primary industrial workhorse for mechanically recycled cotton. [S24] [S0501] In rotor spinning, drawframe sliver is fed directly to an opening roller that separates individual fibres into an air stream and deposits them inside the V-groove or narrow T-groove of a high-speed spinning rotor rotating at 60,000 to 110,000 revolutions per minute (illustrative machine speed range). [S0501]

Centrifugal force condenses the fibres into a multi-layered ring inside the rotor groove before twist is inserted from the take-off nozzle, completely bypassing the roving frame and the high-tension roller drafting zone where short fibres cause end breaks in ring spinning. [S0501] Industrial rotor recycling lines published by Rieter (such as the R 37 and fully automatic R 70 rotor systems paired with the C 81 card and RSB-Module 50/55 drawframe) spin 100 percent cotton yarns in the count range of Ne 3 to Ne 25 containing up to 50 percent mechanically recycled cotton, and blends with man-made fibres containing up to 70 percent recycled cotton. [S0501]

Exhibit 23, p. 86 illustrates how yarn breaking tenacity (in cN/tex) and mass unevenness (CVm%) evolve across increasing shares of mechanically recycled pre-consumer cotton blended with virgin Cameroon cotton for an illustrative Ne 20 (30 tex) open-end rotor knitting yarn. [S20] [S24] [S0501]

EXHIBIT 23 / TENACITY (CN/TEX) AND UNEVENNESS (CVM%)

Open-end rotor yarn tenacity remains above the 10 cN/tex commercial knitting floor up to a 35 percent mechanically recycled cotton blend



ILLUSTRATIVE [S20] [S24] [S0501] Illustrative engineering performance curves for an Ne 20 (30 tex) 100 percent cotton open-end rotor yarn blending mechanically torn pre-consumer clips ('Very good/Good' grade, S0501) with virgin upland cotton lint at 0 to 60 percent recycled share. Commercial circular-knitting floor is 10.0 cN/tex.

As **Exhibit 23**, p. 86 demonstrates, blending 20 to 35 percent mechanically recycled pre-consumer cotton with 65 to 80 percent virgin cotton maintains rotor yarn tenacity between 10.6 and 11.9 cN/tex and keeps yarn unevenness (CVm%) between 12.6 and 13.6 percent, comfortably clear of the 10.0 cN/tex commercial knitting threshold. [S24] [S0501] Once the recycled share pushes past 40 to 50 percent on an Ne 20 count, tenacity drops below 10.0 cN/tex and unevenness climbs above 14.3 percent, restricting higher recycled shares (40 to 50 percent) to coarser Ne 6 to Ne 12 denim weft or towel yarns where a larger number of fibres in the yarn cross-section compensates for shorter staple length. [S24] [S0501]

Crucially, a 20 to 35 percent mechanically recycled cotton blend satisfies the strict 20 percent minimum recycled-content threshold required to display the Textile Exchange Global Recycled Standard (GRS v4) consumer logo and to claim eco-modulation fee bonuses under European EPR rules. [S23] [S28] Because these curves represent an illustrative engineering baseline for Ne 20 rotor yarn, every spinning mill must empirically qualify its own blend curve across specific card clothing, rotor groove geometry and nozzle types before committing to bulk garment specs. [S0501]

GFT NOTE

In GFT's Cameroon textile programme, Phase 1 garment production focuses on cut-make-trim operations while partnering upstream for spinning and knitting rather than building a capital-heavy spinning mill on Day 1 (GFT Feasibility Study, Section 5). [R09] [R10] GFT recommends structuring a closed-loop tolling or buy-back clause with domestic and regional spinning partners (such as the planned Camtext SA pole processing 12,000 tonnes a year at Dibamba and Garoua, or the SODECOTON-CICAM pole). [R08] [R09] [R10] Under this protocol, the CMT factory delivers shade-sorted 100 percent cotton cutting clips in weighed, barcoded bales to the spinner and takes back Ne 16 to Ne 24 open-end rotor jersey and piqué fabrics blended at 25 percent recycled pre-consumer clips and 75 percent virgin SODECOTON lint, accompanied by a GRS v4 Transaction Certificate. [R03] [S28] [S0501]

5.11

UNIDO SwitchMed pilots in Morocco and Tunisia prove the commercial viability of local pre-consumer cotton loops

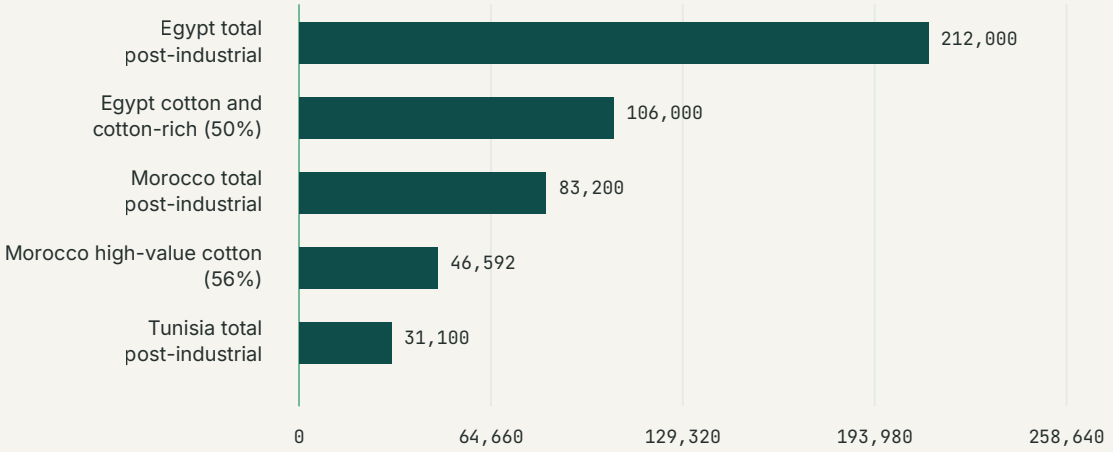
Sponsor boards and development-finance institutions evaluating circular textile investments in West and Central Africa do not need to rely on theoretical European laboratory models. [S24] [S25] Between 2019 and 2025, the United Nations Industrial Development Organization (UNIDO), operating under the EU-funded SwitchMed and SWITCH to Circular Economy Value Chains (SWITCH2CE) programmes, executed empirical waste mappings and industrial mechanical-recycling pilots across Egypt, Morocco and Tunisia. [S24] [S25] [S0503]

5.12 NORTH AFRICAN GARMENT HUBS GENERATE LARGE CONCENTRATED VOLUMES OF FACTORY OFFCUTS

As summarised in **Exhibit 24**, p. 88, UNIDO and Closed Loop Fashion waste-mapping studies established that the textile and apparel industries across Egypt, Morocco and Tunisia generate 326,300 tonnes of post-industrial (pre-consumer) textile waste every year: 212,000 tonnes in Egypt, 83,200 tonnes in Morocco and 31,100 tonnes in Tunisia. [S24] [S25] In Egypt, approximately half of the 212,000 annual tonnes (around 106,000 tonnes) consists of cotton or cotton-rich materials. [S0503] In Morocco's 83,200-tonne annual pre-consumer stream, UNIDO's 2021 mapping revealed that 42 percent (roughly 34,944 tonnes) comprises cotton-rich blends and 14 percent (roughly 11,648 tonnes) comprises pure 100 percent cotton fibres, representing 56 percent (46,592 tonnes) of high-value cotton-based feedstock ready for recovery. [S24] [S25]

EXHIBIT 24 / TONNES PER YEAR (T/YR)

North African garment hubs generate 326,300 tonnes a year of post-industrial waste led by Egypt, Morocco and Tunisia



SOURCED [S24] [S25] [S0503] Sourced from UNIDO SwitchMed and Closed Loop Fashion post-industrial textile waste mapping reports (S24, S25, S0503). Morocco high-value cotton stream (46,592 t/yr) is the derived sum of 42 percent cotton-rich blends and 14 percent pure 100 percent cotton out of 83,200 t/yr (S24).

Exhibit 24, p. 88 confirms that export-oriented garment clusters in Africa generate massive concentrated pools of cotton-rich pre-consumer offcuts. [S24] [S25] [S0503] However, UNIDO's field audits also exposed why that value was previously lost: surveyed garment factories lacked internal cutting-table segregation routines, allowing informal collectors to mix white 100 percent cotton clips with coloured denim and synthetic blends. [S24] [S25] While post-industrial waste volumes are documented across these three North African countries, equivalent empirical census figures for Central African CMT workshops do not yet exist and must be built from factory-floor logs as Cameroon expands local processing from 5 percent toward its 50 percent 2030 target. [R06] [R07]

5.13 EMPIRICAL RESULTS FROM MOROCCO, TUNISIA AND EGYPT VALIDATE THE BLENDED RECYCLED COTTON MODEL

In Morocco, UNIDO partnered with denim manufacturer EVLOX at Settat and technical experts from the Centre for Applied Research and Textile Innovation (CETI) to audit five local garment makers located within a 70 kilometre radius that together generate roughly 500 tonnes of cutting waste a year. [S24] Because the factories initially had no in-house sorting, EVLOX segregated the waste centrally, recovering 160 tonnes of pure cotton cutting waste over four months (50 tonnes of white cotton waste and 110 tonnes of denim-coloured cotton waste). [S24] UNIDO calculated that those 160 tonnes of sorted clips, when mechanically torn and spun into denim yarn at a 20 percent recycled cotton blend ratio, yield 1,204,364 metres of denim fabric (at 0.55 kilograms per metre), sufficient to manufacture 926,434 pairs of jeans. [S24]

Crucially, the Moroccan pilot uncovered a vital unit-economics lesson for African factory design: post-collection sorting at a central warehouse is expensive, and transport costs alone account for 30 to 40 percent of the total cost of recycling textile

waste. [S24] Consequently, UNIDO and EVLOX shifted to training the five garment factories to perform "in-factory" segregation at the cutting table within the 70 kilometre cluster. [S24]

In Tunisia, a parallel UNIDO SwitchMed pilot initiated in 2022 in collaboration with international denim brand DIESEL (part of the OTB Group, with worldwide sales of EUR 1,900 million) demonstrated closed-loop processing inside an integrated domestic recycling, spinning and weaving mill. [S0503] A first batch of 7.5 tonnes of segregated denim cutting waste was mechanically torn and spun locally into 46,000 metres of new denim fabric containing at least 20 percent recycled cotton. [S0503] By the end of 2024, the Tunisian pilot had produced more than 88,000 pairs of commercial denim jeans with at least 20 percent mechanically recycled content and saved up to 35.4 tonnes of carbon dioxide equivalent (CO2-eq) emissions compared with virgin cotton baselines. [S0503] In Egypt, UNIDO's pilot connected 11 textile and garment waste generators with three domestic recyclers, valorising 2,400 tonnes of post-industrial textile waste between June 2023 and April 2024. [S0503]

These three North African industrial pilots prove that a 20 percent mechanically recycled pre-consumer cotton blend is commercially accepted by global buyers, technically executable on standard rotor-spinning and weaving equipment, and financially dependent on sorting clips inside the garment factory before transport. [S24] [S0503]

5.14

Colour-sorted mechanical recycling eliminates dyehouse water, steam and chemical effluent

Beyond capital parsimony, the greatest operational advantage of mechanical cotton recycling over chemical cellulosic regeneration is pigment preservation. [S24] [S35] When pre-consumer cotton cutting clips are segregated by shade family at the cutting table (unbleached greige, bleached white, heather grey, navy, black, indigo denim or earth tones), the mechanically opened fibres retain their covalent reactive, vat or sulphur dye bonds intact. [S24] [S34]

5.15 MELANGE FIBRE BLENDING REPLACES WET-PROCESSING BATHS ON RECYCLED YARN LOTS

In conventional textile manufacturing, wet processing (scouring, bleaching, dyeing, washing and heat-setting) is the primary consumer of water, thermal steam and hazardous chemicals, contributing heavily to the textile sector's position as the third-highest user of water and land globally. [S24] [S38] When a chemical recycler dissolves cotton waste into pulp for viscose or Lyocell spinning, existing dyes must be stripped with aggressive alkaline, acid or oxidative bleaching agents, and the regenerated white fibre must then be dyed all over again (Chapter 6). [S34] [S35] [S36]

Mechanical recycling short-circuits this entire wet-processing loop. [S24] [S0501] By weighing colour-sorted pre-consumer cotton clips into precision blowroom blenders (such as multi-hopper weigh-pan blenders operating within a 1 percent dosing tolerance), spinners formulate exact heather and melange shades optically in the dry fibre

state. [S0501] If a school uniform or urban polo order calls for charcoal heather or indigo marl, the spinner blends mechanically torn black or navy cutting clips directly with unbleached or white virgin SODECOTON cotton lint. [R03] [S24]

Avoiding re-dyeing on the recycled cotton fraction saves an illustrative 50 to 100 litres of process water, 1.5 to 3.0 kilowatt-hours (kWh) of thermal boiler energy and 150 to 300 grams of salts and auxiliary chemicals per kilogram of recycled fibre (illustrative wet-processing benchmark, cross-referenced with companion paper wp06). [S24] For a greenfield textile cluster operating in northern Cameroon around Garoua (where seasonal water stewardship is vital) or along the Douala-Dibamba industrial corridor (where grid power reliability and effluent treatment charges are key operating constraints in GFT's Feasibility Study, Sections 5 and 10), dry optical shade blending directly lowers utility expenditure per garment. [R08] [R10]

5.16 SHOP-FLOOR SUSTAINABILITY KPIS CAPTURE WATER AND ENERGY AVOIDANCE PER UNIT

In Deliverable 2 of GFT's Cameroon textile programme (Performance-Management System Design), the Sustainability KPI family tracks three physical intensity metrics from Shift 1: water per unit, energy per unit and waste per unit. [S40] When the factory routes colour-sorted cutting clips into un-dyed melange rotor yarns for its domestic casualwear and institutional knitwear lines, it achieves a dual improvement in the Performance-Management System ledger: net waste per garment falls because cutting clips re-enter the raw-material bill of materials, and embodied water and energy per garment fall because the recycled fraction bypasses the dyehouse. [S28] [S40]

To preserve this advantage, cutting-room supervisors must strictly enforce shade separation rules. [S24] Mixing red, yellow and navy clips in the same gaylord bin produces a muddy brown-grey fibre web that can only be over-dyed black or relegated to hidden non-woven padding, forfeiting the clean melange premium. [S24] [S25]

5.17

Short-fibre carding waste and mixed overlock trims feed profitable non-woven industrial symbiosis

A rigorous engineering mass balance must account for the fractions of factory waste that cannot be spun into apparel yarn. [S28] [S40] Even in a well-tuned mechanical tearing and rotor-spinning loop, two secondary streams fall outside the spinnable window:

1. **Tearing and carding short-fibre droppings:** During five-cylinder garnetting and subsequent high-production carding, roughly 15 to 25 percent of the input clip mass is ejected beneath the licker-in, flats and rotor trash channels as ultra-short cellulose lint (shorter than 8 to 10 millimetres), seed-coat fragments and cyclone dust (illustrative tearing and carding loss range). [S0501] [S0502]

2. **Mixed sewing-room overlock and polycotton trims:** As quantified in Chapter 3, overlock seam trimmings (15 to 30 tonnes a year in a 3.0 million garment factory, illustrative model) and institutional uniform polycotton lays contain polyester sewing threads, elastane waistbands or synthetic blends that are quarantined away from pure 100 percent cotton cutting bales. [S24] [S35]

5.18 AIRLAID AND NEEDLE-PUNCHED NON-WOVENS CONVERT UNSPINNABLE LINT INTO CONSTRUCTION INSULATION

Rather than sending short-fibre card droppings and mixed sewing trims to municipal dumpsites or cement kilns, industrial symbiosis routes them into technical non-woven manufacturing. [S24] [S0503] Unlike ring or rotor spinning, which requires 15 to 30 millimetre fibres twisted into a linear yarn, aerodynamic airlaid web formation and mechanical needle-punching consolidate 5 to 15 millimetre mixed fibres into dense three-dimensional mats bonded either by barbed felting needles or by 10 to 15 percent low-melt bicomponent thermoplastic binder fibres (illustrative non-woven process specification). [S24] [S0503]

UNIDO's SwitchMed industrial symbiosis pilot in Morocco provides a verified commercial case study of this exact route. [S0503] Out of Morocco's 83,000 tonnes of annual textile waste, roughly one-third consists of synthetic and mixed-fibre blends unsuitable for efficient textile-to-textile yarn spinning. [S0503] In 2022, UNIDO partnered with Moroccan construction-materials manufacturer Novimat to convert lower-grade post-industrial textile waste into non-woven thermal and acoustic building insulation panels. [S24] [S0503] UNIDO documented that Morocco imported 15,000 tonnes of conventional insulation materials (polystyrene and mineral wool) in 2022 valued at 256 million Moroccan dirhams (EUR 23 million), equivalent to roughly 2.5 million square metres of domestic insulation demand. [S0503] By shredding lower-grade factory offcuts and thermo-bonding them into insulation boards, Novimat demonstrated a profitable domestic import-substitution product that absorbs the exact waste fractions yarn spinners reject. [S0503]

5.19 REGIONAL APPLICATIONS ACROSS CAMEROON AND CEMAC SPAN BUILDING PANELS, MATTRESSES AND AGRO-TEXTILES

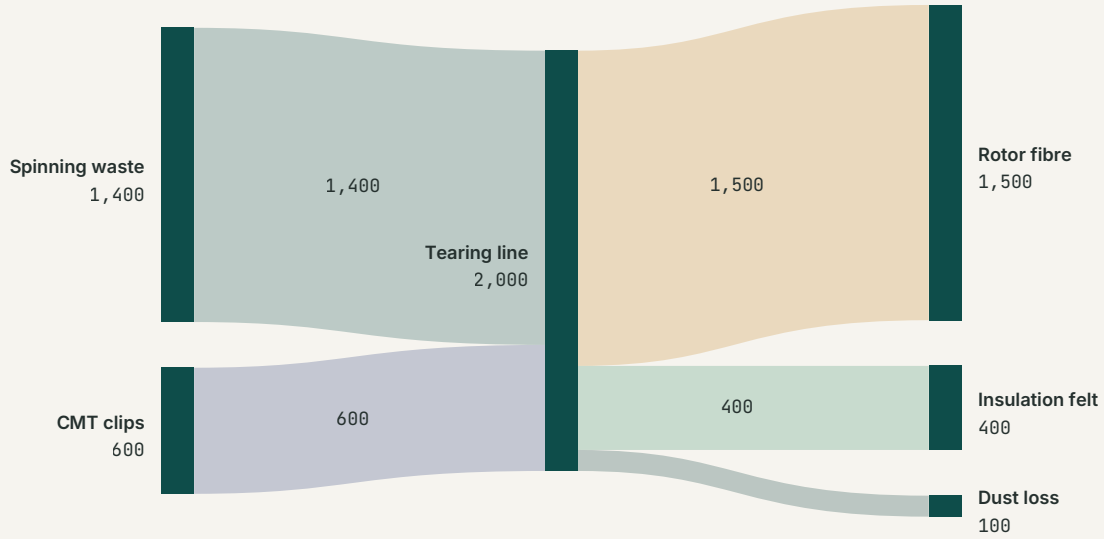
Applying the Novimat industrial symbiosis model to Cameroon and the wider Central African Economic and Monetary Community (CEMAC) opens immediate regional secondary markets for unspinnable factory residues: [S24] [S0503]

- **Thermal and acoustic building insulation:** Urban construction in Douala and Yaounde relies on imported mineral wool and polyurethane foam panels to insulate metal-roofed commercial buildings against tropical solar heat gain and rain noise; high-density cotton-waste acoustic felts treated with boron flame retardants provide a locally manufactured substitute. [S24] [S0503]
- **Mattress padding and furniture upholstery felts:** Domestic mattress and upholstery workshops across Cameroon consume shoddy felt pads (wadding or punched felt) layered over springs and timber frames, a market traditionally supplied by coarse mechanical garnetting lines. [S0501]
- **Automotive acoustic liners and industrial oil-absorbent mats:** Needle-punched recycled cotton-polycotton mats absorb mechanical vibration and workshop oil spills in transport and industrial maintenance depots. [S20] [S0503]

- **Biodegradable agricultural mulch mats:** Pure 100 percent cotton carding dust and ultra-short linter droppings (free of synthetic threads) can be needle-punched into biodegradable weed-suppression mats for horticulture, decomposing into soil organic matter after harvest. [S16] [S17]

EXHIBIT 25 / TONNES PER YEAR (T/YR)

A 2,000 tonne a year regional mechanical tearing module converts spinning waste and CMT clips into 75 percent rotor fibre, 20 percent non-woven felt and 5 percent dust loss



ILLUSTRATIVE [R10] [S24] [S28] [S0501] Illustrative conserved mass balance for a regional mechanical recycling line scaled at 2,000 t/yr, fed by 1,400 t/yr of spinning-mill card/comber waste (at Camtext SA 12,000 t/yr scale, R10) and 600 t/yr of sorted CMT cutting clips from regional garment plants, routing outputs to rotor yarn (S0501) and non-woven insulation symbiosis (S24).

As **Exhibit 25**, p. 92 shows, coupling high-value rotor spinning with non-woven industrial symbiosis raises total material recovery of the 2,000-tonne annual waste input to 95 percent (1,500 tonnes into apparel yarn and 400 tonnes into non-woven insulation), leaving only 5 percent (100 tonnes) as unrecoverable cyclone micro-dust that can be briquetted with cotton stalks for industrial boiler fuel (Chapter 2). [S17] [S24] [S0501] This illustrative cluster mass balance demonstrates how process stages interlock, though actual yield splits between rotor fibre and non-woven droppings must be logged empirically per lot to satisfy GRS v4 chain-of-custody audits. [S28]

5.20

Modular mechanical tearing lines match the capital and power envelope of African industrial parks

The decisive question for an industrial sponsor in Cameroon is where the mechanical tearing line should sit, how much capital it requires, and what minimum annual tonnage is needed to run it at profitable utilisation. [R12] [S37]

5.21 MINIMUM EFFICIENT SCALE REQUIRES AGGREGATING WASTE AT THE REGIONAL SPINNING POLE

As UNCTAD's cross-country assessments of African cotton by-products emphasise, standalone processing ventures fail when raw-material supply is too small or geographically fragmented to keep machinery loaded across shifts. [S37] Incumbent CICAM's historical financial losses in Cameroon, where July 2023 plant utilisation stood at 10.83 percent at CICAM 2, 33.7 percent at Garoua and 48.9 percent at CICAM 1 (costing roughly CFAF 2 billion in 2020), serve as a permanent warning against installing underutilised industrial hardware. [R12]

Consider the throughput arithmetic for GFT's illustrative greenfield CMT factory (estimate, GFT Feasibility Study). [S32] At a nameplate output of 3.0 million garments a year, the cutting and sewing floors generate an estimated 135 to 210 tonnes of pre-consumer cotton waste annually (Chapter 3). [S32] [S33] By contrast, even a compact industrial four-to-six-cylinder mechanical tearing line has a rated throughput of roughly 250 to 500 kilograms per hour, corresponding to 1,500 to 3,000 tonnes a year across two-shift or three-shift operation, at an illustrative machinery capital cost of US$600,000 to US$1.5 million (roughly 365 million to 915 million XAF at reference exchange rates) and an electrical connected load of 150 to 300 kilowatts. [R32] [S20]

If a single 3.0 million garment CMT factory purchased a 2,000-tonne-per-year mechanical tearing line solely for its own 150 tonnes of annual cutting clips, the tearing line would run at 7.5 percent capacity utilisation, guaranteeing negative return on invested capital (illustrative utilisation calculation). [R12]

Co-locating the modular tearing line inside a regional spinning pole solves the utilisation equation immediately. [R08] [R09] [R10] In Cameroon, two major industrial poles are slated to anchor domestic cotton transformation toward the 50 percent SND30 target by 2030: the announced merger of SODECOTON and CICAM, and the US$300 million (180 billion XAF) Camtext SA integrated cotton-to-textile project backed by Panafritex and Arise alongside SODECOTON, CNPS and Marlo (announced 12 November 2025, designed to process 12,000 tonnes of cotton fibre a year with roughly 12,000 jobs at the Dibamba hub and 3,000 at Garoua). [R07] [R08] [R09] [R10]

As calculated in Chapter 2, a 12,000-tonne-per-year spinning mill generates an estimated 960 to 2,160 tonnes a year of clean blowroom droppings, carding strips, comber noils and yarn waste on site. [R10] [S0501] Combining 1,400 tonnes a year of internal spinning-mill waste with 600 tonnes a year of shade-sorted cutting clips collected from three to four regional CMT factories (including GFT's venture) along the Douala-Dibamba corridor delivers the exact 2,000 tonnes a year needed to run a modular tearing and rotor-blending line above 80 percent capacity utilisation. [R10] [S24]

METHOD

System boundary and calculation method for mechanical cotton recycling unit economics

To evaluate whether in-factory clip sorting and regional mechanical tearing create positive margin, GFT defines a transparent engineering cost boundary from the CMT cutting table to the spinning mill drawframe: [S24] [S28] [S40]

1. **Physical mass balance per input tonne (1,000 kg of conditioned, shade-sorted 100% cotton CMT clips):** Spinnable torn fibre output equals input clip mass minus the short-fibre dropping fraction routed to non-woven insulation (15 to 22 percent) and unrecoverable cyclone dust loss (4 to 6 percent), giving 720 to 810 kg of spinnable fibre per tonne of input clips (illustrative central yield 750 kg, or 75 percent). [S24] [S0501] [S0502]
2. **Conversion cost per tonne of input clips:** Total tearing conversion cost sums five operational components: cutting-table baling strapping and vertical baler amortisation (estimated at US$18/tonne); short-haul corridor transport within 70 km (Douala to Dibamba hub, estimated at US$25 to US$35/tonne, avoiding the 30 to 40 percent transport cost burden observed in uncoordinated collection); electrical power for cutting, conditioning and five-cylinder tearing (320 to 420 kWh/tonne at an illustrative tariff of US$0.12/kWh = US$38 to US$50/tonne); tearing-line crew wages benchmarked against Cameroon's XAF 43,969/month minimum wage and US$359/month cross-sector average (= US$30 to US$45/tonne); and saw-tooth wire re-clothing, spinning oil emulsion (1.5 percent mass) and 7-year equipment depreciation on a US$900,000 modular line running at 2,000 tonnes/year (= US$125 to US$155/tonne). [R14] [R15] [S20] [S24] [S0502]
3. **Net raw-material cost advantage per kilogram of blended rotor yarn:** Compare the all-in cost of mechanically recovered cotton fibre (clip purchase credit plus tearing conversion minus non-woven co-product sales credit, divided by 750 kg spinnable yield) against landed virgin ginned cotton lint plus avoided dyehouse water and energy costs when spinning pre-dyed melange lots. [S24] [S0501]

WORKED EXAMPLE

Illustrative unit economics of a 150-tonne annual CMT clip loop on the Douala-Dibamba corridor

Consider an illustrative annual mass and financial reconciliation for GFT's baseline 3.0 million garment a year CMT plant delivering 150 tonnes a year of shade-sorted 100 percent cotton cutting clips to a partnered regional tearing and rotor-spinning hub at Dibamba (all monetary figures are illustrative planning estimates using a reference rate of 1 US$ = 610 XAF, grounded in the 655.957 XAF/EUR peg): [R09] [R10] [R32]

- **Baseline linear disposal (unsorted floor sweepings):** When cutting scraps are swept together unsorted, local scrap brokers pay an illustrative US$0.08/kg (US$80/tonne, or 48,800 XAF/tonne), yielding **US$12,000 (7.32 million XAF) a year** for 150 tonnes.
- **Circular sorted bale credit at CMT factory gate:** By segregating 100 percent cotton clips by shade family at the cutting table and compressing them into 250 kg barcoded bales, the CMT plant supplies graded "Very good / Good" feedstock (S0501) valued at an illustrative **US$0.35/kg (US$350/tonne, or 213,500 XAF/tonne)**, generating **US$52,500 (32.03 million XAF) a year** in direct scrap revenue or yarn-invoice credits, a **4.38 times increase** over mixed sweepings. [S10] [S24] [S0501]
- **Tearing hub mass balance (on the 150-tonne CMT batch):** Processing 150,000 kg of sorted clips through the regional five-cylinder tearing line yields **112,500 kg** (75 percent) of spinnable mechanically recycled cotton fibre, **30,000 kg** (20 percent) of short-fibre card droppings sold to a local non-woven insulation maker at an illustrative US$0.20/kg (**US$6,000** co-product credit), and **7,500 kg** (5 percent) of cyclone dust briquetted for boiler fuel. [S17] [S24] [S0501] [S0503]
- **Delivered cost and yarn savings:** At an input clip credit of US$350/tonne plus tearing conversion and corridor transport of US$260/tonne minus the US$40/tonne non-woven co-product credit, net cost is US$570 per input tonne. Divided across 750 kg of spinnable fibre yield, recovered fibre enters the rotor-spinning blowroom at **US$0.76/kg (463.6 XAF/kg)** versus an illustrative **US$1.85/kg (1,128.5 XAF/kg)** for virgin ginned lint, saving **US$1.09/kg**. Across 112,500 kg of spinnable fibre blended at 25 percent into 450,000 kg of GRS-certified Ne 20 rotor yarn, raw-fibre savings equal **US$122,625 (74.80 million XAF) a year**, while avoiding wet re-dyeing on pre-coloured melange lots saves an additional illustrative **5.63 million to 11.25 million litres of water** and **168,750 to 337,500 kWh of thermal energy** annually. [S24] [S28] [S0501]

WARNING

Unresolved operational constraints and verification conditions

Three operational hazards can invalidate mechanical cotton recycling economics if left unmanaged:

1. **Hidden elastane and synthetic sewing-thread contamination:** Core-spun elastane knits or polyester-sewn rework panels entering pure cotton bins wrap around tearing cylinder teeth and carding flats, causing nep spikes and yarn breaks. [S26] [S35] *Resolution:* Enforce strict cutting-table bin discipline per lay (Chapter 4) and verify external bales with 900 to 1,700 nm Near-Infrared (NIR) spectroscopy before feeding the tearing apron. [S26]
2. **Fire and dust explosion risk in the tearing room:** Dry cotton cellulose dust ignites rapidly if a steel tearing pin strikes a metal zipper, rivet or stone inside an unsorted bale. [S0501] *Resolution:* Mandate electronic metal detection on the feed conveyor, 1 to 2 percent lubricant emulsion conditioning, continuous under-card pneumatic dust extraction and automated spark-extinguishing dampers inside the cyclone ductwork. [S0501] [S0502]
3. **Over-blending beyond the yarn count tenacity ceiling:** Pushing mechanically recycled content above 35 to 40 percent in medium-count knitting yarns (Ne 20 to Ne 24) causes yarn tenacity to dip below 10 cN/tex, triggering needle breaks and fabric holes on circular knitting machines that wipe out raw-material savings through lower first-pass yield. [S0501] *Resolution:* Lock recycled blend ratios at 20 to 30 percent for knitted apparel, test every yarn lot on a tensile tester before knitting, and log knitting machine stops against yarn batch IDs in GFT's Performance-Management System. [S28] [S0501]

Mechanical tearing does not erase the laws of cellulose mechanics: pins shorten fibres, and short fibres need a longer virgin carrier to hold twist. [S0501] [S0502] Yet when an industrial cluster pairs zero-cost shade sorting on the CMT cutting floor with open-end rotor spinning of local virgin cotton and non-woven symbiosis for short card droppings, mechanical recycling recovers 95 percent of factory waste mass at a capital threshold that an African textile corridor can finance and operate today. [R09] [S24] [S0503] Where cotton residues are already too short for mechanical rotor spinning, such as ginning linters, comber noils or multi-cycled rags, the circular loop hands off from mechanical pins to the chemical dissolving-pulp reactors examined in Chapter 6. [S34] [S36] [S37]

The tearing drum shortens the fibre, but the Virgin-and-Clip blend lengthens the life of the harvest.

CHAPTER SOURCE NOTES

S20 European Commission and Refashion. 2021-11.

S24 United Nations Industrial Development Organization (UNIDO). 2023-11.

S35 VTT Technical Research Centre of Finland and MDPI Textiles. 2026-07-31.

S0501 Rieter Machine Works Ltd. 2023-07-13.

S0502 University of Boras. 2025-01-30.
R03 SODECOTON. Publication date unrecorded; inherited source-text check.
R06 Cameroon Trade Hub. Publication date unrecorded; inherited source-text check.
S26 University of Groningen. 2026-04-22.
S23 Refashion. 2026-01-27.
R01 Business in Cameroon. Publication date unrecorded; inherited source-text check.
R02 Fibre2Fashion; Business in Cameroon. Publication date unrecorded; inherited source-text check.
S28 TraceWeave. 2026-07-27.
R09 Ecofin Agency. Publication date unrecorded; inherited source-text check.
R10 Ecofin Agency. Publication date unrecorded; inherited source-text check.
R08 Business in Cameroon. Publication date unrecorded; inherited source-text check.
S25 Closed Loop Fashion and UNIDO SwitchMed. 2022.
S0503 United Nations Industrial Development Organization (UNIDO) and UNCRD. 2025-03-05.
R07 Ecofin Agency. Publication date unrecorded; inherited source-text check.
S34 National Library of Medicine (PubMed). 2026.
S38 European Commission Directorate-General for Environment. 2024.
S36 Chemical Engineering Transactions (AIDIC). 2024.
S40 International Organization for Standardization (ISO). 2024-05.
S16 World Trade Organization (WTO). 2024.
S17 UNCTAD (UN Trade and Development). 2019-07-17.
R12 Business in Cameroon. Publication date unrecorded; inherited source-text check.
S37 UNCTAD (UN Trade and Development). 2019-10.
S32 Textile Learner. 2023-08-26.
S33 iFactory. 2025.
R32 Wise; XE. Publication date unrecorded; inherited source-text check.
R14 WageIndicator. Publication date unrecorded; inherited source-text check.
R15 wage.is. Publication date unrecorded; inherited source-text check.
S10 Fashion for Good and Reverse Resources. 2024-06.

GREEN FUTURE TECH
LIMITED / HONG KONG SAR

06

Chemical cellulosic regeneration overcomes fibre shortening through controlled depolymerisation

When cotton fibres are too short for mechanical spinning, chemical recycling dissolves cellulose chains into high-purity pulp for viscose and lyocell filaments, provided degree of polymerisation and solvent recovery are tightly controlled.

CHAPTER 06
DECISION TEST

When cotton fibres are too short for mechanical spinning, chemical recycling dissolves cellulose chains into high-purity pulp for viscose and lyocell filaments, provided degree of polymerisation and solvent recovery are tightly controlled.

Chemical cellulosic regeneration solves the physical limit of mechanical textile recycling by operating at the macromolecular scale rather than the staple-fibre scale. [S34] [S35] When pre-consumer cotton offcuts, spinning comber noils, carding strips or ginning linters are too short to hold twist in an open-end rotor groove, chemical pre-treatment cleaves and purifies the underlying cellulose chains into dissolving pulp. [S36] [S37] Dissolved into a homogenous spinning dope and extruded through precision spinnerets, regenerated man-made cellulosic fibres (MMCFs) such as viscose, modal and lyocell emerge as continuous filaments or uniform staple fibres with virgin-equivalent tenacity and lustre. [S34] [S36] Yet chemical regeneration is a continuous process industry governed by strict polymer rheology, trace-metal tolerances below 20 parts per million, and capital thresholds exceeding US$140 million for standalone commercial mills. [S34] [S0601] For a greenfield cotton-to-garment venture in Cameroon, the engineering decision is one of disciplined sequencing: use zero-capex shop-floor sorting to capture and grade pure cellulosic residues today, monetise non-spinnable linters and short waste as certified feedstock for existing viscose and lyocell producers in Phases 1 and 2, and defer domestic chemical reactor capital until regional cluster volumes cross commercial breakeven in Phase 3. [R06] [R10] [S36]

6.1

Chemical regeneration resets physical fibre length by dissolving cotton cellulose at the macromolecular level

Mechanical garnetting and carding treat the cotton fibre as an intact physical cylinder pulled apart from woven or knitted yarns by saw-tooth pins. [S20] [S24] Because every pass over a pinned drum ruptures fibres, mechanical recycling shortens staple length and raises the short-fibre index, imposing a ceiling on yarn fineness and requiring carrier blends of 50 to 80 percent virgin cotton lint in apparel applications. [S20] [S24] Chemical cellulosic regeneration bypasses this downcycling ceiling by dissolving the solid cotton fibre into individual poly-(beta-1,4-D-anhydroglucopyranose) chains in solution and precipitating them anew through wet or dry-jet wet spinning. [S34] [S35] [S36]

6.2 DISSOLVING CELLULOSE CONVERTS SHORTENED COTTON WASTE INTO CONTINUOUS FILAMENT DOPE

In a chemical regeneration line, physical staple length at the reactor inlet has zero bearing on the physical length of the extruded product. [S35] [S36] Whether incoming cellulose originates from 28-millimetre virgin ginned lint, 18-millimetre mechanically torn cutting clips, 10-millimetre spinning comber noils, or 4-millimetre cottonseed linters, dissolution erases prior fibre morphology and mechanical surface fibrillation. [S34] [S36] [S0602] Once purified cellulose pulp is dissolved into an alkaline xanthate viscose dope or a direct solvent such as aqueous N-Methylmorpholine N-oxide (NMMO), ionic liquids, or deep eutectic solvents, metering pumps force the solution through spinneret capillaries measuring 40 to 60 micrometres in diameter. [S34] [S35]

As the liquid jets enter the coagulation bath, mass transfer regenerates solid cellulose II crystal structures oriented along the filament axis by godet drawing. [S34] [S35] The plant can wind the coagulated strands as continuous multifilament yarns or crimp and

cut them to any commercial staple length (such as 38 millimetres for ring spinning). [S35] [S36] Chemical regeneration is thus the only industrial route capable of converting zero-twist mill dust, comber noils, and multi-cycled mechanically shortened cotton back into fine shirtings and filament fabrics without sacrificing tenacity. [S20] [S35] [S36]

6.3 COTTON WASTE OUTPERFORMS WOOD CHIPS IN ALPHA-CELLULOSE PURITY WHILE SPARING FOREST LAND

Conventional commercial dissolving pulp is manufactured from hardwood and softwood chips using pre-hydrolysis kraft (PHK) or acid sulphite (AS) pulping. [S36] [S0602] Because raw wood contains only 40 to 50 percent cellulose embedded in 20 to 30 percent lignin and 20 to 35 percent hemicelluloses, wood-pulp mills run energy-intensive digesters and bleaching towers merely to strip away half of the harvested tree mass. [S34] [S36] [S0602] Even after refining, reference acid sulphite dissolving wood pulp exhibits an alpha-cellulose purity of roughly 92.3 percent alongside residual pentosans. [S36]

By contrast, mature cotton lint, spinning waste, and unbleached pre-consumer cutting clips consist of 90 to over 99 percent alpha-cellulose. [S34] [S36] [S0602] Laboratory characterisation of three pre-consumer 100 percent cotton fabrics (Cot 1, Cot 7, and Cot 33) at Durban University of Technology confirmed untreated alpha-cellulose contents of 99.4 percent, 99.0 percent, and 99.1 percent respectively, beating the 92.3 percent wood dissolving pulp baseline by nearly 7 percentage points. [S36] Untreated cotton fabrics also showed 18 percent sodium hydroxide alkali solubility (S18, measuring degraded hemicellulose and gamma-cellulose) of only 0.28 to 1.14 percent and 10 percent alkali solubility (S10) of 0.80 to 1.24 percent, compared with 4.94 percent S18 and 10.50 percent S10 in reference wood pulp. [S36]

Substituting cotton textile waste and linters for wood dissolving pulp starts with a lignin-free feedstock rich in alpha-cellulose. [S34] [S36] European Commission analyses establish that textiles rank fourth highest among European Union consumption categories for overall environmental and climate impact and third highest for water and land use. [S38] Diverting pre-consumer cotton clips and linters into dissolving pulp displaces forestry land use and reduces textile carbon dioxide emissions by up to 33 percent when circular recycling replaces virgin extraction. [S36] [S38]

6.4

Waste cotton's high degree of polymerisation must be tuned from above 2,000 down to the 500 to 700 window

If cotton waste has higher alpha-cellulose purity than wood pulp, why cannot a spinner feed shredded cotton clips directly into a viscose or Lyocell dissolver? [S34] [S36] The primary chemical obstacle is the excessively high Degree of Polymerisation (DP) and intrinsic viscosity of native and pre-consumer cotton cellulose. [S34] [S36] Degree of polymerisation measures the average number of anhydroglucose monomer units linked inside a cellulose chain; scoured and dyed pre-consumer cotton textiles retain a DP above 2,000, such as the baseline DP of 2,409 measured in recent deep eutectic solvent trials. [S34]

6.5 EXCESSIVE MACROMOLECULAR CHAIN LENGTH CAUSES HYDROGEN-BOND ENTANGLEMENT AND FILTER BLOCKAGE

Commercial viscose and Lyocell lines are engineered around wood dissolving pulps whose DP has been lowered into a window of 500 to 900 (and aged down to 250 to 350 in alkali cellulose prior to xanthation). [S34] [S36] Because every anhydroglucose ring carries three hydroxyl groups that form dense intramolecular and intermolecular hydrogen bonds, a polymer chain of 2,409 glucose units exhibits severe hydrodynamic entanglement in solution. [S34] [S35]

Size-exclusion chromatography (SEC) of untreated pre-consumer cotton fabrics quantifies this macromolecular gap. [S36] In the Durban University of Technology study, untreated cotton fabrics Cot 1 and Cot 7 recorded weight-average molecular masses (Mw) of 975,078 g/mol and 961,810 g/mol, and number-average molecular masses (Mn) of 448,006 g/mol and 566,816 g/mol. [S36] Commercial acid sulphite wood pulp (AS DWP) recorded an Mw of 204,865 g/mol and Mn of 113,041 g/mol, while pre-hydrolysis kraft (PHK) wood pulp recorded an Mw of 412,185 g/mol and Mn of 219,498 g/mol. [S36]

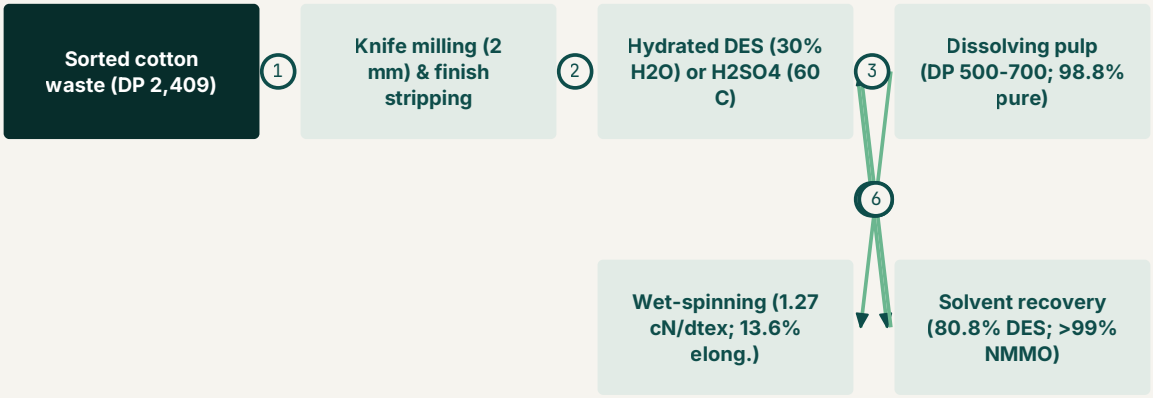
With four times the molecular mass of acid sulphite wood pulp, untreated cotton fabrics exhibited cupriethylenediamine intrinsic viscosities between 1,313 and 1,415 mL/g (1,415 mL/g for Cot 1, 1,313 mL/g for Cot 7, and 1,397 mL/g for Cot 33), far above the 400 to 600 mL/g viscose window (502 mL/g for AS DWP). [S36] Attempting to dissolve DP 2,409 cotton waste directly produces an unpumpable gel that blinds candle filters, raises the Treiber filter-clogging value (Kw), and ruptures filaments at the spinneret. [S34] [S36]

6.6 HYDRATED DEEP EUTECTIC SOLVENTS ACHIEVE CONTROLLED DEPOLYMERISATION AT 30 PERCENT WATER CONTENT

Overcoming the viscosity barrier requires controlled cleavage of glycosidic bonds without over-hydrolysing chains into sugars or collapsing pores through hornification. [S34] [S35] [S36] Peer-reviewed research published in 2026 demonstrated a solvent-mediated strategy using a hydrated deep eutectic solvent (DES) of choline chloride, lactic acid, and water to convert waste cotton textiles into dissolving pulp. [S34] By tuning the water content to 30 percent, researchers controllably reduced the DP of waste cotton pulp from 2,409 into the target 500 to 700 window while preserving chemical composition and cellulose I crystallinity. [S34] The process sequence from high-DP cotton waste to wet-spun filament is mapped in **Exhibit 26**, p. 102. [S34] [S35] [S36]

EXHIBIT 26 / PROCESS STAGE

Targeted depolymerisation converts DP 2,409 cotton waste into DP 500 to 700 dissolving pulp for viscose and Lyocell wet-spinning



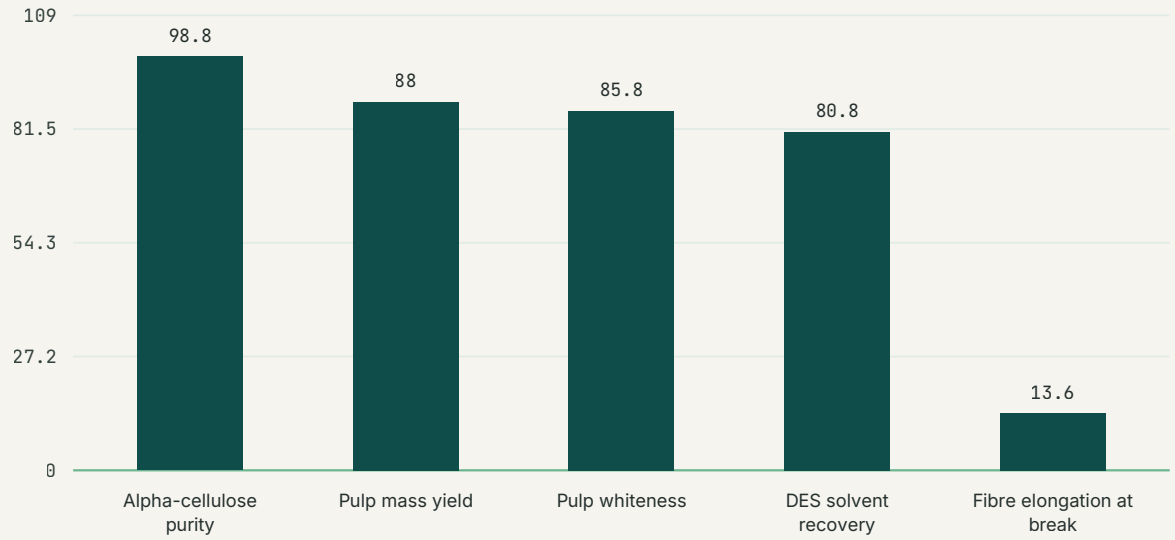
1. 100% cotton clips/noils
2. Swollen cellulose
3. 88.01% pulp yield
4. Spent liquor
5. Recycled solvent
6. Homogeneous dope

SOURCED [S34] [S35] [S36] Chemical process sequence synthesising hydrated choline chloride / lactic acid / water (30% H2O) deep eutectic solvent depolymerisation (S34), sequential acid/alkaline viscosity tuning (S36), and closed-loop solvent recovery and wet-spinning (S34, S35).

As shown in **Exhibit 26**, p. 102, controlling the depolymerisation window between DP 500 and 700 bridges the gap between raw textile waste and filament extrusion, though process-flow diagrams cannot establish continuous reactor heat-transfer performance. [S34] [S35] Quantitative pulp and fibre metrics from the hydrated DES route are presented in **Exhibit 27**, p. 103. [S34]

EXHIBIT 27 / PERCENT

Deep eutectic solvent depolymerisation achieves 98.80 percent alpha-cellulose purity and 88.01 percent pulp yield from waste cotton



SOURCED [S34] Experimental performance metrics from hydrated choline chloride / lactic acid / water (30% water content) depolymerisation of waste cotton textiles from DP 2,409 to DP 500-700, followed by wet-spinning into regenerated cellulose fibres (breaking strength 1.27 cN/dtex, iron content 17.01 ppm) (S34).

The benchmarks in **Exhibit 27**, p. 103 confirm five engineering realities for waste-cotton pulping: 98.80 percent alpha-cellulose purity, 88.01 percent gravimetric pulp yield (nearly double wood-chip pulping), 85.80 percent whiteness with 17.01 ppm iron content, 80.80 percent DES recovery, and wet-spun fibre tenacity of 1.27 cN/dtex at 13.63 percent elongation. [S34] While these laboratory results validate the macromolecular mechanism, an 80.80 percent DES recovery rate remains below the 99-plus percent recovery of industrial NMMO Lyocell plants. [S34] [S35]

6.7

Alkaline, acid and oxidative pre-treatments strip reactive dyes and adjust intrinsic viscosity for viscose integration

Existing commercial dissolving-pulp and viscose mills rely on aqueous acid hydrolysis, alkaline extraction, and oxidative bleaching to prepare cotton waste for regeneration. [S35] [S36] Before dyed or finished cotton textiles enter a viscose reactor, covalent reactive dyes, vat pigments, optical brighteners, and crosslinking resins must be cleaved so they do not form insoluble gel particles during xanthation. [S35] [S36]

6.8 SULPHURIC ACID HYDROLYSIS AND HYPOCHLORITE BLEACHING ALIGN INTRINSIC VISCOSITY WITH WOOD DISSOLVING PULP

In the 2024 Chemical Engineering Transactions study by Shangase, Chetty, and Wessels, researchers cut FTIR-verified 100 percent pre-consumer cotton waste into 2 to 3 square centimetre pieces, milled them through a 2-millimetre sieve, and evaluated two pre-treatments against Acid Sulphite Dissolving Wood Pulp (AS DWP). [S36]

Treatment A applied sulphuric acid hydrolysis (5 percent H2SO4 at 60 degrees Celsius across 10 to 120 minutes), reaching ideal post-pretreatment viscosity in 53 minutes for Cot 1 (419 mL/g) and 50 minutes for Cot 7 (442 mL/g). [S36] Treatment B applied hypochlorite bleaching at 60 degrees Celsius for 30 minutes, reaching 393 mL/g for Cot 1 and 389 mL/g for Cot 7. [S36] The analytical results across TAPPI viscosity, alkali solubility, ISO brightness, SEC molecular mass, and heavy-metal ash are compiled in **Exhibit 28**, p. 104. [S36]

EXHIBIT 28 / LABORATORY CHARACTERISATION (TAPPI / ISO / SEC)

Acid hydrolysis and hypochlorite bleaching align pre-consumer cotton waste viscosity, molecular mass and metal ash with wood dissolving pulp

Property (Unit)	AS DWP (Wood Ref)	UT Cot 1 (Raw)	TA Cot 1 (Acid)	TB Cot 1 (Bleach)	TA Cot 7 (Acid)
Intrinsic viscosity (mL/g)	502	1,415	419	393	442
Alpha-cellulose (%)	92.3	99.4	98.5	97.9	96.7
ISO brightness (%)	92.7	35.7	32.8	79.2	97.8
Alkali solubility S18 (%)	4.94	0.28	0.91	1.24	1.83
Number-average Mn (g/mol)	113,041	448,006	111,574	98,290	102,622
Weight-average Mw (g/mol)	204,865	975,078	222,112	250,971	296,521
Polydispersity (Mw/Mn)	2.8	2.2	2.1	2.6	2.9
Calcium Ca (mg/kg dry)	19	406	36	238	22
Magnesium Mg (mg/kg dry)	4	135	6	74	8

SOURCED [S36] Experimental data from Shangase, Chetty and Wessels (2024), Chemical Engineering Transactions Vol. 113, Tables 1, 2 and 3 (S36). AS DWP = Acid Sulphite Dissolving Wood Pulp reference; UT = Untreated pre-consumer 100% cotton fabric; TA = Treatment A (5% H2SO4 at 60 C for 50-53 min); TB = Treatment B (hypochlorite bleaching at 60 C for 30 min).

Inspecting **Exhibit 28**, p. 104 shows why pre-treatment must match the optical and mineral profile of incoming cotton waste. [S36] On dyed Cot 1 (35.7 percent brightness), acid hydrolysis (Treatment A) cut viscosity to 419 mL/g and calcium from 406 mg/kg to 36 mg/kg, but left dye chromophores intact at 32.8 percent brightness, whereas hypochlorite bleaching (Treatment B) cleaved the dye and raised brightness by 43.5 percentage points to 79.2 percent (and by 27.4 percentage points on dark Cot 33). [S36] On white Cot 7 (111.9 percent initial brightness due to optical brighteners), acid hydrolysis stripped brighteners to 97.8 percent brightness, reduced Mw from 961,810 g/mol to 296,521 g/mol, and stripped calcium from 478 mg/kg to 22 mg/kg and magnesium from 235 mg/kg to 8 mg/kg, matching reference wood pulp

(19 mg/kg Ca and 4 mg/kg Mg) while retaining 96.7 percent alpha-cellulose. [S36] After alkali ageing into viscose dope, the treated cotton achieved final DPs between 267 and 324, inside the 250 to 350 viscose spinning window, though continuous filament tenacity was not measured. [S36]

6.9 UNBLEACHED PRE-CONSUMER CUTTING CLIPS AND COMBER NOILS BYPASS AGGRESSIVE DYE STRIPPING

Aggressive hypochlorite bleaching on dyed fabrics raised the TAPPI T 430 cm:2009 copper number (oxidative damage) from 0.21 to 9.70 on Cot 7 and from 0.162 to 4.95 on Cot 33 (over-depolymerising Cot 33 to 145 mL/g), whereas mild acid hydrolysis kept copper numbers at 1.00 to 2.10, matching the 1.27 wood-pulp reference. [S36] In Cameroon, four cellulosic streams arise in an unbleached or white state prior to dyeing: SODECOTON cottonseed linters (9,000 to 15,000 tonnes a year across a 340,000 tonne crop), spinning card strips and comber noils at Camtext SA or CICAM scale (960 to 2,160 tonnes a year on 12,000 tonnes of lint), greige selvedges, and unbleached CMT cutting clips. [R01] [R03] [R10] [S37] Segregating unbleached clips at the cutting table allows pulp off-takers to use mild acid or hydrated DES viscosity tuning alone, preserving >98 percent alpha-cellulose and ~88 percent pulp yield. [S34] [S36]

> **GFT NOTE**
>
> **Quarantine optical brighteners and reactive dyes away from chemical pulp bales.** In GFT's cutting-room segregation protocol, unbleached ecru cotton clips and natural spinning noils must never be mixed into the same bale as optically brightened white shirting or dark reactive-dyed twill. [S10] [S36] Unbleached cotton requires only mild acid or DES viscosity adjustment to strip calcium and magnesium down to wood-pulp tolerances (22 to 36 mg/kg Ca), whereas dyed and optically brightened fabrics require oxidative bleaching that raises copper numbers and reagent costs. [S34] [S36] Recording the exact dye and finish class on every bale tag in GFT's Performance-Management System allows dissolving-pulp buyers to bypass pre-bleaching and pay a purity premium. [S28] [S36]

6.10

Direct solvent spinning via NMMO (Lyocell) and ionic liquids avoids carbon disulphide emissions

Once waste cotton is depolymerised into dissolving pulp, its environmental footprint and capital threshold depend on the spinning chemistry: derivatising routes (viscose xanthate and cellulose carbamate) versus direct dissolution routes (NMMO Lyocell, ionic liquids, and deep eutectic solvents). [S34] [S35] [S36]

6.11 XANTHATE DERIVATISATION IN CONVENTIONAL VISCOSE REQUIRES CARBON DISULPHIDE ABATEMENT

In conventional viscose production, dissolving pulp is steeped in 17 to 19 percent aqueous sodium hydroxide (NaOH), aged to DP 250 to 350, reacted with liquid carbon disulphide (CS2) into sodium cellulose xanthate, and extruded into an acidic bath containing sulphuric acid, sodium sulphate, and zinc sulphate. [S35] [S36] While viscose has a massive global installed base for co-processing recycled pulps, carbon

disulphide is a volatile neurotoxin and zinc sulphate requires strict effluent precipitation. [S35] Modern viscose plants require multi-stage gas-scrubbing units to recover 95 to 98 percent of sulphur emissions under Zero Discharge of Hazardous Chemicals (ZDHC) rules, making small greenfield viscose reactors inside emerging garment parks unsound. [S28] [S35]

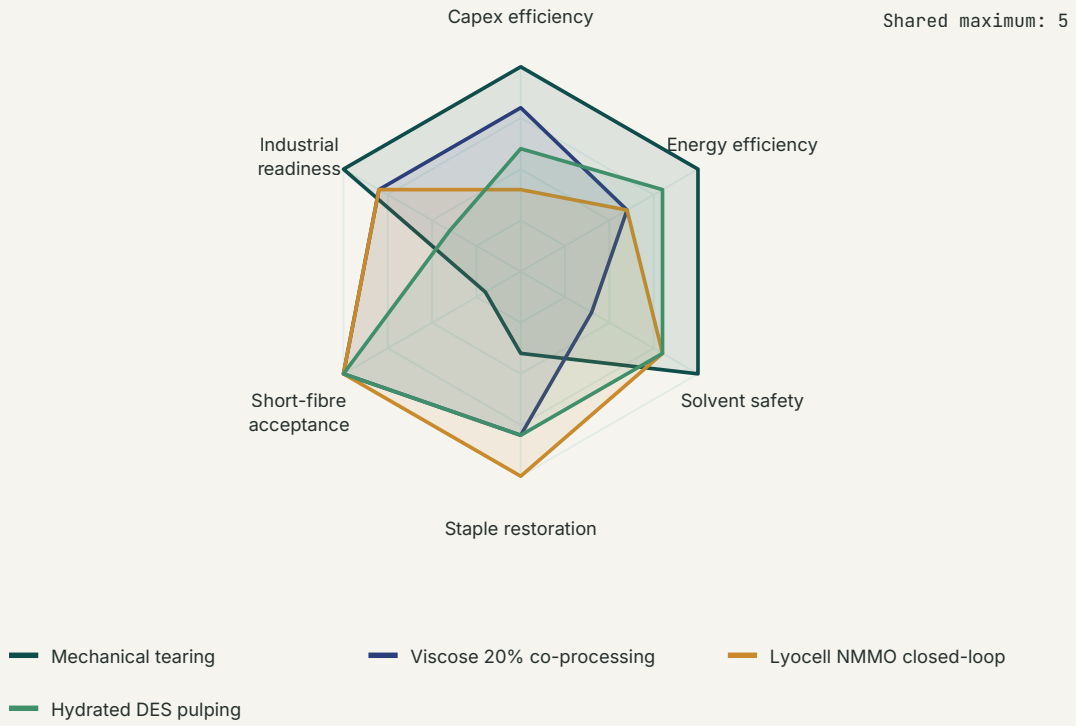
6.12 CLOSED-LOOP NMMO LYOCELL AND EMERGING IONIC-LIQUID OR CARBAMATE SYSTEMS RECOVER SOLVENT DIRECTLY

To avoid carbon disulphide, the Lyocell process dissolves cellulose directly in aqueous N-Methylmorpholine N-oxide (NMMO) at 90 to 120 degrees Celsius (around 13.3 percent water) and extrudes the dope across an air gap into an aqueous coagulation bath. [S35] [S0602] VTT's July 2026 review identifies NMMO dissolution as the closest direct-solvent route to widespread industrial implementation because it builds on commercial Lyocell lines (such as REFIBRA, NuCycl, and SaXcell), achieves up to 95 percent cellulose recovery, and recycles over 99 percent of the NMMO solvent. [S35]

Alongside NMMO, three next-generation platforms are advancing: (1) **Ionic liquids (Ioncell, DBNH-OAc, AmimCl, BmimCl)** dissolve cotton at 80 to 130 degrees Celsius for dry-jet wet spinning while keeping polyester purity at 92 to 96 percent, though solvent cost and recycling energy remain hurdles; (2) **Cellulose carbamate (CCA)** reacts activated pulp with urea at 120 to 180 degrees Celsius so the carbamate dissolves in cold aqueous sodium zincate (ZnO/NaOH) and spins on standard viscose machines without CS2; and (3) **Hydrated zinc chloride and deep eutectic solvents** depolymerise and dissolve cotton at 60 to 100 degrees Celsius once solvent recovery rises from 80.80 percent toward 98 percent. [S34] [S35] [S36] These routes are compared against mechanical tearing across six engineering axes in **Exhibit 29**, p. 107. [S20] [S34] [S35] [S36]

EXHIBIT 29 / NORMALISED ENGINEERING SCORE (1 = WORST, 5 = BEST)

Mechanical tearing, Lyocell NMMO regeneration, viscose co-processing and DES depolymerisation trade off capex against fibre quality



DERIVED [S20] [S34] [S35] [S36] Derived multi-criteria engineering comparison scored from 1 (lowest/poorest performance) to 5 (highest/best performance) across six operational dimensions: Capex efficiency (5 = lowest capital threshold), Energy efficiency (5 = lowest kWh/t), Solvent safety (5 = no toxic solvents), Staple restoration (5 = virgin-equivalent filament/staple), Short-fibre acceptance (5 = accepts <10 mm linters/dust), and Industrial readiness (5 = TRL 9 mature commercial scale) based on S20, S34, S35 and S36.

As **Exhibit 29**, p. 107 shows (noting that radar polygon area depends on axis ordering and is not a physical total), mechanical tearing scores 5 on capex, energy, solvent safety, and readiness (TRL 9), but 2 on staple restoration and 1 on short-fibre acceptance (<10 to 12 mm). [S20] [S24] Lyocell NMMO and viscose co-processing score 4 to 5 on staple restoration and short-fibre acceptance, but require heavy chemical plants or CS2 abatement, while hydrated DES pulping remains at pilot readiness (score 2). [S34] [S35] [S36]

6.13

Commercial lessons from first-generation chemical recyclers highlight feedstock cost and minimum scale

Chemical textile recycling is governed by plant minimum efficient scale, feedstock logistics, and pulp market pricing. [S10] [S0601] Between 2020 and 2025, first-generation standalone chemical recyclers collided with linear commodity economics. [S0601]

6.14 CAPITAL INTENSITY AND PRICE PREMIUMS EXPOSED STANDALONE GREENFIELD PULP MILLS TO LIQUIDITY RISK

Sweden's Renewcell, founded in 2012 to convert cotton-rich waste into Circulose dissolving pulp, operated a demonstration plant in 2019, listed on Nasdaq First North in November 2020, and invested about US$140 million to launch commercial production at a former paper mill in Ortviken in December 2022. [S0601] Despite proven chemistry, Renewcell filed for bankruptcy in February 2024 before Altor Equity Partners acquired its assets three months later. [S0601] A July 2024 analysis by Renewcell's former Chief Commercial Officer identifies four structural lessons: (1) projecting a 12-month breakeven against a 12-to-18-month apparel development cycle; (2) pricing Circulose above cyclical virgin wood-pulp troughs without binding mandates; (3) shipping waste from as far as Bangladesh to Sweden and shipping pulp back to Asian spinners; and (4) relying on non-binding brand pledges that stalled under margin pressure. [S10] [S0601] As Reverse Resources notes, scaling chemical recycling from 12,000 tonnes toward 200,000 tonnes a year requires clean, pre-sorted pre-consumer waste close to spinning hubs. [S10]

6.15 CO-PROCESSING 10 TO 20 PERCENT COTTON-WASTE PULP INSIDE EXISTING VISCOSE MILLS DE-RISKS CAPITAL

The antidote to the US$140 million standalone greenfield mill trap is **co-processing**: depolymerising cotton waste in a modular pre-treatment unit and blending it at **10:90 (10 percent)** or **20:80 (20 percent)** with conventional wood dissolving pulp inside an existing viscose or Lyocell plant. [S36] [S0601] In the Durban University of Technology trials, Treiber filterability tests (measuring filtration value Fw, filter-clogging value Kw, and 24 to 78 second falling-ball viscosity times) proved that raising the treated cotton share to 20 percent (the 20:80 blend) improved dope homogeneity, stability, and filterability (lower Kw) through stronger intermolecular cellulose connections. [S36] A 20:80 blend also meets the **20 percent minimum certified recycled content threshold** for Global Recycled Standard (GRS v4) labelling under algorithmic mass balance. [S28] [S36]

6.16

Trace impurities of iron, calcium and synthetic polymers poison chemical spinning dopes

In a chemical dissolving reactor, trace inorganic cations and synthetic polymers act as catalyst poisons and filter blockers. [S34] [S35] [S36]

6.17 TRANSITION METALS CATALYSE EXOTHERMIC NMMO DECOMPOSITION WHILE ALKALINE EARTH METALS CLOG SPINNERETS

Three contaminant classes must remain below strict parts-per-million (ppm, or mg/kg) tolerances: (1) **Transition metals (Fe, Cu, Mn, Cr, Ni)** catalyse N-O bond cleavage and rapid exothermic runaway in hot NMMO, requiring iron below 15 to 20 ppm (achieved at **17.01 ppm Fe** in S34, alongside 0.28 to 7.07 mg/kg Cu and 0.21 to 0.57 mg/kg acid-treated Cr in S36); (2) **Alkaline earth metals (Ca, Mg)** from hard water and floor dust measured **406 to 514 mg/kg Ca** and **90 to 235 mg/kg Mg** in untreated cotton (S36), blinding spinneret filters until dilute sulphuric acid hydrolysis stripped them to **22 to 36 mg/kg Ca** and **6 to 8 mg/kg Mg** (matching the **19 mg/kg Ca** and **4**

mg/kg Mg wood-pulp reference); and (3) **Synthetic polymers (elastane, polyester)** form deformable micro-gels or oligomers that plug spinneret orifices. [S26] [S34] [S35] [S36]

6.18 SHOP-FLOOR SEGREGATION AND ANALYTICAL BATCH CERTIFICATES GUARANTEE REACTOR-GRADE PURITY

Unlike post-consumer municipal rags, pre-consumer 100 percent cotton clips segregated on GFT's cutting tables (never touching concrete floors) combined with SODECOTON linters and Camtext SA comber noils start with near-zero synthetic or metal contamination. [R03] [R10] [S10] Pairing table sorting with regional benchtop NIR verification (91.7 percent composition and 92.6 percent elastane accuracy across 900 to 1,700 nm, S26, as benchmarked in European sorting trials, S17) enables a Cameroon cluster to issue an analytical batch certificate with every export lot documenting polymer purity, intrinsic viscosity, and ash content. [S17] [S26] [S28] [S36]

METHOD

6.19 MASS-BALANCE AND MACROMOLECULAR CALCULATION BOUNDARY FOR COTTON-TO-PULP CONVERSION

GFT applies a four-step calculation boundary across ginning, spinning, and cutting-room streams: [R01] [S34] [S36]

1. **Polymer chain cleavage ratio (R_{DP}):** Given initial cotton DP_0 and target pulp $\text{DP}_t \in [500, 700]$, average glycosidic scissions per chain are $N_s = (\text{DP}_0 / \text{DP}_t) - 1$ (3.0 scissions from $\text{DP}_0 = 2,409$ to $\text{DP}_t = 602$, reducing M_w from $\approx 968,000\text{ g/mol}$ into the $205,000\text{ to }296,000\text{ g/mol}$ viscose window). [S34] [S36]
2. **Bone-dry Dissolving Pulp Mass Yield (M_{pulp}):** From bone-dry cotton input M_{in}, output is $M_{\text{pulp}} = M_{\text{in}} \times (1 - L_{\text{mech}}) \times Y_{\text{chem}}$, where $L_{\text{mech}} \in [0.02, 0.04]$ (illustrative milling loss) and $Y_{\text{chem}} = 0.8801$ (S34). [S34] [S36]
3. **Solvent Makeup Requirement ($M_{\text{solv,make}}$):** For liquor ratio R_L and recovery η_{rec}, makeup per tonne of pulp is $M_{\text{solv,make}} = [R_L \times (1 - \eta_{\text{rec}})] / Y_{\text{chem}}$; raising η_{rec} from 0.8080 (S34) to 0.9950 (S35) cuts makeup mass by a factor of 38. [S34] [S35]
4. **GRS v4 Co-Processing Blend Balance (B_{GRS}):** Recycled share $F_{\text{rec}} = M_{\text{pulp}} / (M_{\text{pulp}} + M_{\text{wood}}) \ge 0.20$ (the 20:80 blend in S36), reconciled against empirical wet-spinning loss rates under GRS v4. [S28] [S36]

6.20

Cameroon's chemical circularity role is exporting graded cellulosic feedstock or co-processing linters before building reactors

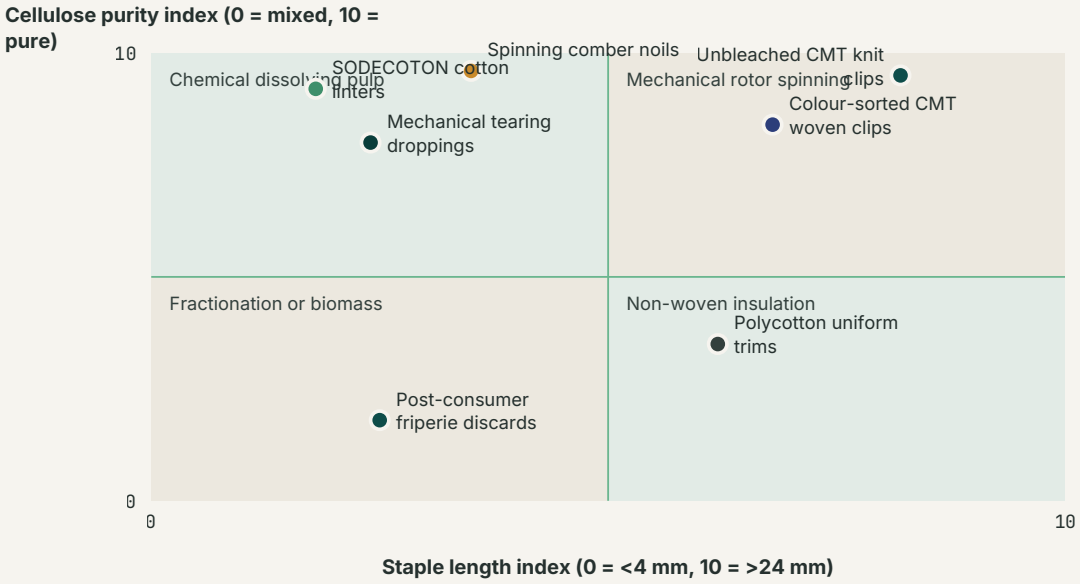
Containing Phase 1 capital to high-utilisation CMT operations while partnering upstream and downstream avoids premature chemical reactor capex. [R08] [R09] [R12] [S0601]

6.21 EXPORTING PURIFIED LINTERS, COMBER NOILS AND CARD DROPPINGS MONETISES NON-SPINNABLE FRACTIONS IMMEDIATELY

Long, clean CMT cutting clips (18 to 24 mm after opening) belong in regional open-end rotor spinning blended at 20 to 35 percent with virgin SODECOTON lint (Chapter 5). [R03] [S24] [S25] Conversely, three Cameroon streams are physically **too short** (<12 mm) for mechanical apparel spinning and should be aggregated for chemical dissolving pulp: (1) **SODECOTON cottonseed linters and gin motes** (estimated at 9,000 to 15,000 tonnes a year across nine gins from a 314,455 to 350,000+ tonne seed-cotton crop); (2) **Spinning comber noils and filter dust** at Camtext SA's 12,000 tonne a year hub (US$300 million / 180 billion XAF) and SODECOTON-CICAM (estimated at 600 to 1,200 tonnes a year of <12 mm virgin fibers); and (3) **Mechanical tearing droppings** (<10 mm, 10 to 15 percent of torn clip mass) plus high-twist woven clips. [R01] [R02] [R03] [R08] [R09] [R10] [S20] [S24] [S37] This allocation is mapped in **Exhibit 30**, p. 110. [S24] [S34] [S35] [S37]

EXHIBIT 30 / FIBRE LENGTH AND CELLULOSE PURITY INDEX (0 TO 10)

Feedstock allocation matrix routes long clips to mechanical rotor spinning and short linters or noils to chemical dissolving pulp



DERIVED [S24] [S34] [S35] [S37] Derived engineering allocation matrix plotting seven Cameroon textile and ginning waste fractions by recoverable staple length index (x-axis: 0 = <4 mm dust/linters, 5 = 12-16 mm short fibre, 10 = >24 mm long staple) and alpha-cellulose / mono-material purity index (y-axis: 0 = mixed post-consumer synthetics, 5 = dyed/blended industrial scrap, 10 = >98% unbleached pure cotton) based on S24, S34, S35, S36 and S37.

As **Exhibit 30**, p. 110 demonstrates, the upper-right quadrant (**Mechanical rotor spinning**) captures long CMT knit and woven clips, while the upper-left quadrant (**Chemical dissolving pulp**) captures short, high-purity SODECOTON linters, comber noils, and tearing droppings. [S24] [S34] [S36] [S37] Polycotton uniform trims route to **Non-woven insulation** (lower-right), while post-consumer friperie discards sit in the lower-left quadrant where chemical fractionation is uneconomic. [S24] [S29] [S35]

WORKED EXAMPLE

6.22 AGGREGATING A 5,000-TONNE CAMEROON CELLULOSIC FEEDSTOCK POOL FOR 20:80 VISCOSE CO-PROCESSING

Consider an illustrative regional aggregation model anchored on Cameroon's documented capacities: **3,800 tonnes a year** of centralized SODECOTON second-cut linters at Garoua (out of 9,000 to 15,000 tonnes available), **950 tonnes a year** of short (<12 mm) comber noils from Camtext SA's 12,000 tonne spinning capacity and CICAM Garoua, and **250 tonnes a year** of short tearing droppings (<10 mm, 150 tonnes) plus greige selvedges (100 tonnes) from GFT's illustrative 3.0 million garment CMT line and peer corridor workshops. [R01] [R03] [R10] [R12] [S24] [S37]

1. **Gross and bone-dry mass:** $3,800 + 950 + 250 = 5,000\text{ air-dry tonnes a year}$ at 7.0 percent cotton moisture regain, or $5,000 \times 0.93 = 4,650\text{ bone-dry tonnes a year}$ of >95 percent alpha-cellulose feedstock. [S34] [S36]
2. **Conversion to DP 500-700 dissolving pulp:** After 3.0 percent milling dedusting loss ($4,510.5\text{ bone-dry tonnes}$) and depolymerisation at the 88.01 percent yield in S34, output is **3,969.7 bone-dry tonnes a year** (**4,268.5 air-dry tonnes**) of 98.80 percent alpha-cellulose dissolving pulp. [S34] [S36]
3. **Downstream 20:80 co-processing multiplier:** Blended at the **20:80 ratio** validated in S36 ($4,268.5 / 0.20$), this pool enables partner MMCF mills to produce **21,342 tonnes a year of GRS v4 certified (20 percent recycled content) viscose or Lyocell fibre**. [S28] [S36]
4. **Illustrative export revenue:** At an illustrative FOB Douala price of US$480 to US$650 per tonne (converted near 570 XAF per US dollar under the 655.957 euro peg, R32), the 5,000-tonne baled pool generates an estimated **US$2.40 million to US$3.25 million (XAF 1.37 billion to XAF 1.85 billion) a year** in gross cluster revenue without domestic reactor capex (illustrative analytical model, not a GFT revenue forecast). [R32] [S26] [S28]

6.23 PHASE 3 CONDITIONS PRECEDENT GATE REGIONAL DEPOLYMERISATION INVESTMENT BEHIND PROVEN CLUSTER VOLUME

Consistent with GFT's four-phase programme spine (Feasibility Study Section 12) and Renewcell's lessons, committing capital to a domestic pre-treatment and dissolving-pulp module in Phase 3 (post-2030) requires four conditions precedent: (1) **Aggregated domestic feedstock above 15,000 tonnes a year** verified in PMS and ISO 59020 logs across SODECOTON, Camtext SA, and CMT plants operating above 75 percent utilisation; (2) **Binding multi-year take-or-pay offtake contracts** with MMCF spinners indexed to wood dissolving pulp plus a GRS v4 premium; (3) **Demonstrated >98 percent solvent recovery** (for DES/ionic liquids) or industrial hub effluent integration (for dilute acid/alkaline hydrolysis at Dibamba or Garoua); and (4) **Zero elastane and polyester carryover** enforced by NIR spectroscopy (Chapter 4) and mono-material design (Chapter 7). [R07] [R08] [R10] [S26] [S28] [S34] [S35] [S36] [S40] [S0601]

WARNING

6.24 UNRESOLVED CHEMICAL-RECYCLING RISKS AND VERIFICATION REQUIREMENTS

Decision-makers must track three technical and regulatory risks in the 2024 to 2026 evidence base: (1) **Solvent recovery gap in green eutectic systems**, where the 80.80 percent DES recovery rate leaves a 19.20 percent loss requiring membrane distillation to close above 98 percent; (2) **Cellulose hornification during thermal drying**, where temperatures above 100 to 150 degrees Celsius collapse cell-wall nanopores and raise filter-clogging values (K_w), requiring batch Treiber filterability and ball-fall testing; and (3) **Regulatory sub-targets under Ecodesign Regulation (EU) 2024/1781**, which may distinguish post-consumer waste from pre-consumer clips and linters on GRS v4 Transaction Certificates. [S28] [S34] [S35] [S36]

By respecting polymer physics and industrial scale thresholds, GFT's circularity blueprint captures the macromolecular value of Cameroon's cotton harvest without exposing the greenfield garment venture to premature chemical-plant capital risk. [R06] [S34] [S0601] Where Chapter 6 has established how pure cotton cellulose is depolymerised and regenerated when fibres become too short for mechanical spinning, Chapter 7 confronts the chemical and design challenge that arises when cotton is blended with synthetic polyester and elastane. [S35]

When mechanical pins can no longer hold the staple together, chemistry dissolves the thread so the polymer can be spun anew.

CHAPTER SOURCE NOTES

S34 National Library of Medicine (PubMed). 2026.

S35 VTT Technical Research Centre of Finland and MDPI Textiles. 2026-07-31.

S36 Chemical Engineering Transactions (AIDIC). 2024-11-02.

S37 UNCTAD (UN Trade and Development). 2019-10.

S0601 Stanford Social Innovation Review. 2024-07-24.

R06 Cameroon Trade Hub. Publication date unrecorded; inherited source-text check.

R10 Ecofin Agency. Publication date unrecorded; inherited source-text check.

S20 European Commission and Refashion. 2021-11.

S24 United Nations Industrial Development Organization (UNIDO). 2023-11.

S0602 Chalmers University of Technology. 2016.

S38 European Commission Directorate-General for Environment. 2024.

R01 Business in Cameroon. Publication date unrecorded; inherited source-text check.

R03 SODECOTON. Publication date unrecorded; inherited source-text check.

S10 Fashion for Good and Reverse Resources. 2024-06.

S28 TraceWeave. 2026-07-27.

S26 University of Groningen. 2026-04-22.

S17 UNCTAD (UN Trade and Development). 2019-07-17.

R08 Business in Cameroon. Publication date unrecorded; inherited source-text check.

R09 Ecofin Agency. Publication date unrecorded; inherited source-text check.

R12 Business in Cameroon. Publication date unrecorded; inherited source-text check.

S25 Closed Loop Fashion and UNIDO SwitchMed. 2022.

R02 Fibre2Fashion; Business in Cameroon. Publication date unrecorded; inherited source-text check.

S29 Pan African Climate Justice Alliance (PACJA). 2025-03-30.

R32 Wise; XE. Publication date unrecorded; inherited source-text check.

R07 Ecofin Agency. Publication date unrecorded; inherited source-text check.

S40 International Organization for Standardization (ISO). 2024-05.

GREEN FUTURE TECH
LIMITED / HONG KONG SAR

07

Elastane contamination and polycotton blends require design discipline before chemical fractionation

Separating polyester-cotton and elastane blends chemically demands selective solvents, careful energy and residue control, and proven outlets, so mono-material cotton design is the first recycling investment.

CHAPTER 07
DECISION TEST

Separating polyester-cotton and elastane blends chemically demands selective solvents, careful energy and residue control, and proven outlets, so mono-material cotton design is the first recycling investment.

The answer is to prevent incompatible polymer mixtures at the design specification, then keep every unavoidable blend in a declared stream with a named receiving process. Chemical fractionation is a conditional destination, not permission to mix fibres. Polycotton requires a choice between attacking polyester or removing cellulose. Elastane adds a separate polyurethane problem even at low mass share. For GFT's Cameroon textile programme, the practical default is a cellulosic bill of materials, mechanical stretch where product trials permit it, and dedicated polycotton or elastane bales where customer performance requirements make a blend necessary. A recycler should approve that stream before production scales.

This sequence puts design before solvent selection. It also puts evidence before a circularity claim. The factory must know the composition of every fabric roll, thread, label, interlining and elastic component. It must preserve that identity through cutting, baling and sale. Where no receiver has accepted the resulting fraction, the honest route is controlled storage, a lower-grade application or disposal under local rules, not an assumed fibre-to-fibre loop.

7.1

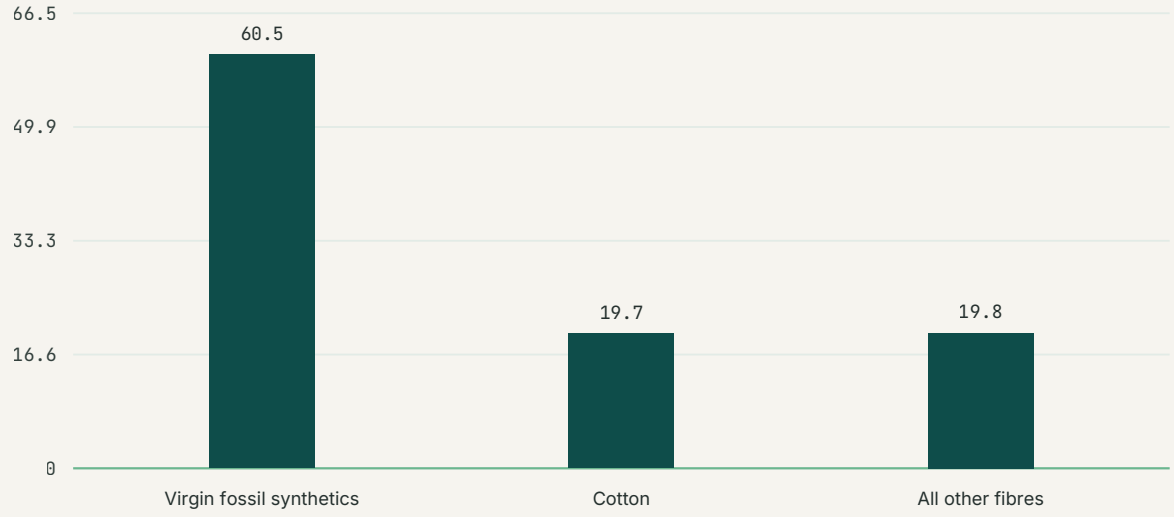
Synthetic fibres dominate global output, but blend architecture determines the recycling problem

Global fibre production reached 124 million tonnes in 2023. Virgin fossil-based synthetic fibres accounted for 75 million tonnes and cotton for 24.4 million tonnes. These are production volumes, not garment counts, and they do not show how much of each fibre entered any particular product category. [S0704] They nevertheless explain why cotton recycling cannot be designed as though cotton arrives alone. Polyester is present in the same fabric, the same seam or the same garment across many product specifications.

Exhibit 31, p. 116 converts those cited tonnages into shares of the same total. The residual category contains every fibre outside virgin fossil-based synthetics and cotton. It must not be read as recycled fibre or as one material family.

EXHIBIT 31 / PERCENT OF GLOBAL FIBRE PRODUCTION, 2023

Virgin fossil-based synthetics supplied three times cotton's 2023 tonnage



DERIVED [S0704] Derived from Textile Exchange: virgin fossil-based synthetics 75/124 = 60.5 percent; cotton 24.4/124 = 19.7 percent; residual (124 - 75 - 24.4)/124 = 19.8 percent. Rounded to one decimal place. The residual is heterogeneous and is not a recycled-fibre measure.

The exhibit establishes scale, not recyclability. A small mass of a second polymer can decide the process route. Nor does a fibre label describe the whole garment. A cotton body can carry polyester thread, a polyester care label, synthetic interlining and an elastane-containing waistband. The recycling boundary must therefore be the complete product and its bill of materials, not the largest fabric panel.

Three architectures create different tasks. An intimate blend places two fibres within one yarn, as in polycotton. An interwoven or plated construction keeps distinct yarns but locks them into one textile. A panelled or layered garment joins different textiles in one product. The first requires chemical fractionation if both polymers are to be recovered at high quality. The second may still require dissolution or selective degradation. The third offers a mechanical disassembly opportunity only where seams, layers and components can actually be separated at reasonable cost. The University of Groningen sorting study uses related distinctions between mono-material, blended, interwoven, panelled and layered textiles. [S26]

This is why the familiar phrase "cotton-rich" is not a process specification. It gives no threshold for the receiving recycler and says nothing about elastane, finishes or trims. The useful record states each declared constituent, its mass share, its location in the garment, its colour and finish, and the tests used to verify the declaration. Unknown components are treated as exceptions until laboratory or supplier evidence resolves them.

The functional reason for blending also matters. Polyester can contribute dimensional stability and durability, while cotton contributes moisture absorption and comfort. Elastane contributes stretch and shape retention. The VTT review identifies these combined properties as a reason for the widespread use of polyester-cotton blends, while also identifying their chemical dissimilarity as the central recycling difficulty.

[S35] Design for recycling does not deny the performance requirement. It asks whether knit geometry, yarn selection, garment fit or a removable component can meet that requirement with fewer permanent material bonds.

7.2

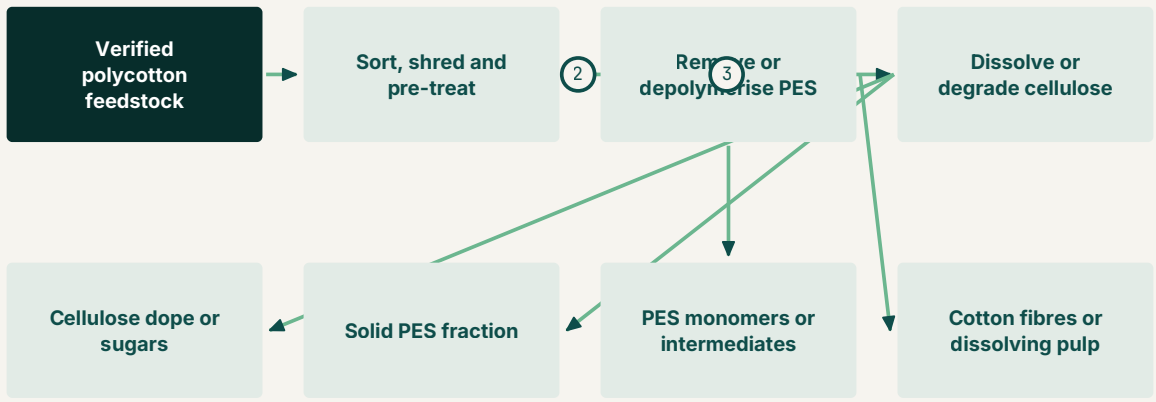
Polycotton fractionation must preserve a usable fraction, not merely split a fabric

Polycotton chemistry offers two principal strategies. The first removes or depolymerises polyester and retains cotton. The second dissolves or degrades cellulose and retains polyester. Within those branches, hydrolysis, glycolysis, methanolysis and aminolysis attack polyester in different ways. NMMO, ionic liquids, deep eutectic solvents and cold alkaline systems can dissolve cellulose. Acid or enzymatic hydrolysis can instead convert cellulose towards sugars, which sacrifices the cellulosic polymer chain as a textile fibre precursor. The 2026 VTT review sets out this taxonomy and compares the resulting fraction quality, reaction conditions and scale readiness. [S35]

Exhibit 32, p. 117 simplifies that taxonomy into the decision a feedstock owner must make. It does not imply that every route is commercially available or that both outputs always reach fibre quality.

EXHIBIT 32 /

Polycotton recovery branches by the polymer selected for removal



2. Polyester route
3. Cellulose route

SOURCED [S35] Simplified technical taxonomy from the VTT and MDPI review. Actual outputs depend on composition, dyes, finishes, reaction conditions and purification. This is not a GFT operating line or a claim of commercial availability in Cameroon.

The polyester-removal branch is attractive when the surviving cotton can remain a fibre or become suitable dissolving pulp. Alkaline hydrolysis converts polyester towards terephthalate and ethylene glycol while cotton is filtered as a solid. Glycolysis

targets bis(2-hydroxyethyl) terephthalate, while methanolysis targets dimethyl terephthalate and ethylene glycol. These are not interchangeable recipes. They differ in temperature, pressure, catalyst, purification burden and effect on the surviving cellulose. [S35]

The cellulose-removal branch is attractive when a clean solid polyester fraction can be filtered, washed and re-extruded, or when the dissolved cellulose has a demonstrated spinning outlet. NMMO is established in lyocell production, but its use in a blend still requires control of metals, finishes, viscosity and polyester separation. Ionic liquid and deep eutectic systems show laboratory potential, yet solvent recovery, solution viscosity and recovered polymer quality remain process-design questions. A cellulose hydrolysis route to glucose belongs to a fermentation or chemical platform, not automatically to fibre-to-fibre textiles. [S35]

Pre-treatment sits before both branches and can decide their economics. Dyes, finishing agents, metals and surface contamination can hinder solvent penetration, interfere with catalysts or destabilise the polymer. Shredding increases access for the reagent but does not remove those substances. The VTT review therefore treats pre-treatment as essential rather than optional for chemical polycotton recycling. [S35] A factory that records finish chemistry at fabric receipt gives the future recycler more useful evidence than a factory that records only "polycotton".

The correct output specification comes before reagent selection. A recycler buying solid cotton will test contamination and fibre or pulp quality. A recycler buying polyester monomer will test purity and the effects of dyes and catalysts. A recycler buying polyester solids will care about degradation, residual cellulose and melt-processing behaviour. A claim that "both fractions are recyclable" is incomplete until each fraction has its own measured quality and an actual destination.

> **METHOD**
>
> Use a two-output acceptance sheet for every fractionation trial. Record input mass by polymer and component, reagent and water inputs, reaction conditions, each recovered solid or liquid fraction, residues, and measured quality against the intended receiver's specification. Reconcile total mass and identify unmeasured losses. Do not report a combined recovery percentage that conceals an unusable fraction.

For a Cameroon garment venture, the near-term task is consequently feedstock stewardship rather than reactor ownership. Keep polycotton lays and their clips separate by declared ratio, shade and finish. Obtain a receiver's trial protocol before accumulating a large bale stock. Test representative material through that receiver, then compare delivered feedstock cost and accepted yield with a lower-grade but proven local outlet. This keeps a chemical option open without converting an emerging laboratory route into an unsupported investment assumption.

7.3

Fraction purity, cellulose damage and process scale defeat a simple recovery percentage

A high separation yield can still produce two low-value outputs. The first fraction may carry enough of the second polymer to obstruct its next process. The second may be chemically recovered but too degraded for its intended application. VTT's review identifies incomplete fraction purity, cellulose degree-of-polymerisation damage, limited recovery of high-quality polyester intermediates, high chemical consumption and insufficient industrial-scale demonstration as recurring barriers across polycotton routes. [S35] These are separate acceptance tests. One mass-balance number cannot summarise them.

Cellulose damage requires particular care. Alkaline conditions that remove polyester can reduce cellulose degree of polymerisation, while high-temperature glycolysis, methanolysis or solvent treatments can cause hornification and reduce subsequent dissolution reactivity. The effects depend on the actual chemistry and conditions, so a route name alone does not determine damage. The review reports, for example, intrinsic-viscosity loss in one polyester-viscose alkaline system and discusses milder enzymatic and solvent alternatives. [S35] The factory should therefore require measurements on its own recovered cotton, not infer spinnability from a photograph of clean-looking fibres.

Exhibit 33, p. 119 turns the review's recurring barriers into an illustrative screening model. Scores run from one for lower concern to three for higher concern. They are GFT's ordinal synthesis for comparing due-diligence questions, not experimental values and not a universal ranking of technologies.

EXHIBIT 33 / ILLUSTRATIVE CONCERN SCORE, 1 LOW TO 3 HIGH

Every polycotton route carries a distinct scale-up penalty

	Purity risk	Cellulose damage	Energy load	Scale evidence
Alkaline hydrolysis	3	3	2	2
Glycolysis	2	2	3	2
Methanolysis	2	3	3	3
Enzymatic PES removal	2	1	1	3
NMMO dissolution	2	2	2	2
Ionic liquid dissolution	2	2	2	3

Cell scale: 1 to 3

ILLUSTRATIVE [S35] Illustrative GFT screening based on the review's discussion of fraction purity, cellulose DP or hornification, energy demand and industrial demonstration. Scores are ordinal judgements, not measured efficiencies or technology readiness levels. Scale evidence scores the concern created by limited demonstration, so higher is worse on every axis.

The scores should not be averaged into a winner. A receiver with no tolerance for cellulose damage may reject a route regardless of its energy score. A monomer buyer may make purity the binding gate. A factory without solvent-recovery capability should treat that absence as a stop condition. The exhibit's purpose is to force separate evidence for each penalty before a process is shortlisted.

Feedstock logistics create another scale penalty. In UNIDO's Moroccan denim pilot, approximately 160 tonnes of cotton waste was gathered and sorted over four months, but the project reported high post-collection segregation costs and transport equal to 30 to 40 percent of total textile-waste recycling cost. The response included training garment makers in in-factory segregation. [S24] This evidence does not price a Cameroon plant. It does show why mixing at source can consume the margin that a later chemical recovery step is meant to protect.

A credible scale test therefore starts with a campaign of declared industrial material, not a small beaker of ideal fabric. It varies colour, finish, blend ratio and elastane presence across the actual supply. It measures reagent make-up, water and energy per accepted kilogram, solvent recovery, residue treatment, fraction quality and equipment downtime. It also repeats the trial long enough to expose fouling and variable feedstock. The review's call for more industrial-scale demonstration is a reason to demand this evidence, not a reason to assume it. [S35]

For an early-stage Cameroon cluster, this argues against treating polycotton fractionation as the default destination for every uniform or workwear clip. The first option is to prevent the blend where the use case permits. The second is to contract a proven external receiver for a defined bale. A local chemical reactor becomes a discussion only after sustained feedstock volume, receiver quality data, utility balances, residue permits and product offtake exist together.

7.4

Two percent elastane creates a process problem far beyond its mass share

Elastane is a segmented polyurethane whose soft and hard domains provide elastic recovery and chemical resilience. That architecture is useful in wear but troublesome in recycling. Low elastane content can reduce shredding efficiency, promote clogging and diminish the quality and spinnability of recovered fibres. Conventional removal approaches include thermal or enzymatic treatment and solvents such as dimethylformamide, dimethylacetamide and tetrahydrofuran, which bring toxicity and regulatory constraints. [S0701]

The Groningen sorting research describes disruption at elastane levels of 2 to 5 percent, including jammed shredders, clogged filters and contaminated output. Its experiments also show why detection cannot be reduced to reading a dominant fibre label: a sample described as 94 percent cotton and 6 percent elastane can enter a cotton composition class while still requiring a separate elastane-positive label. [S26] Composition classification and elastane screening are therefore two different controls.

Near-infrared screening helps, but it is not a purity certificate. In that study of 181 certified samples measured across 900 to 1,700 nanometres, the best overall composition classifier reached 91.7 percent accuracy. The binary elastane model reached 92.6 percent overall accuracy, with 83.3 percent accuracy on elastane-present samples and 95.2 percent on elastane-absent samples. The author presents the work as a proof of concept requiring further validation on worn and contaminated textiles. [S26] A recycler should use the result to design quarantine and secondary checks, not to waive them.

Selective removal is chemically possible, but recent laboratory evidence also shows the distance to a plant decision. In a 2025 study, dimethyl sulfoxide alone produced partial elastane mass loss under the tested conditions, while adding 0.1 percent by volume DBN enabled near-complete or complete mass loss across the reported temperature and time matrix. Tests used pre-consumer fabrics containing 94 percent cotton and 6 percent elastane, and 87 percent polyester and 13 percent elastane. The authors observed dimensional relaxation and largely preserved matrix-fibre morphology and tensile strength. [S0701]

Those results do not establish an operating process. The same paper states that solvent and catalyst recovery were not experimentally addressed, and it calls for assessment of recovery efficiency, DBN stability, life-cycle effects and closed-loop management. It also warns that DMSO thermal decomposition can become hazardous in the presence of strong acids or bases, including DBN. [S0701] A lower-temperature laboratory treatment can still require specialised calorimetry, ventilation, process interlocks and solvent-recovery design before scale-up.

Earlier work on cotton-elastane dissolution reinforces the need to name the intended output. In experiments on shirts containing 95 percent cotton and 5 percent elastane, elastane remained intact in a sodium hydroxide and urea system and interrupted the regenerated cellulose film structure. Lithium chloride and dimethylacetamide dissolved both polymers into a composite film. [S0703] Producing a composite packaging film is not the same as recovering clean cellulose for textile spinning. The target product determines whether retained or dissolved elastane represents a route, a contaminant or a different product altogether.

The operational response is to isolate elastane before it enters a pure-cotton balance. Rolls carrying stretch fabric receive distinct codes. Their markers, roll ends, clips, rejected panels and sewing-room trimmings inherit that code. Bales state the declared elastane share and the evidence behind it. Where composition is uncertain, the bale remains in quarantine until a validated test resolves it. This avoids allowing a small, visually invisible component to invalidate a much larger cellulosic stream.

> **WARNING**
>
> Do not transfer laboratory solvent conditions directly into a factory instruction. The studies cited here do not provide a complete industrial safety case, solvent-recovery balance or Cameroon operating permit. Any trial requires a competent process-safety review, compatible materials of construction, emissions and residue controls, and a receiver for both recovered outputs. This chapter is technical research, not legal or process-safety advice.

7.5

Mono-material design works only when the whole bill of materials follows it

The least burdensome separation step is the one never specified. The German Environment Agency's 2026 ecodesign study prioritises mono-materials because they are easier to sort and recycle across recycling methods. It also recommends that threads, labels and accessories use the same material as the main textile or be easy to remove, without compromising durability. [S0702] This is a whole-product rule. Changing the body fabric to cotton while leaving a mixed seam and trim package does not complete the task.

A cellulosic specification starts with the main fabric and sewing thread, then moves through interlining, labels, prints, buttons, elastic components and finishes. Each item receives one of three instructions: make it compatible with the cellulosic route, make it removable before shredding, or justify it as a declared exception with a separate recovery route. Directly printed care information can replace a sewn synthetic label where product rules permit. A non-textile button may be acceptable only when the receiver confirms that removal is practical. The decision is empirical, not a claim that every natural-looking component is process-compatible.

Exhibit 34, p. 122 applies this logic to a shirt. It is an illustrative design model, not a certified product or a statement that GFT has already manufactured the specification.

EXHIBIT 34 /

Six bill-of-material decisions prevent avoidable polymer mixing

Component	Mixed default	Design instruction	Release evidence
Main fabric	Polycotton	100 percent cotton where fit permits	Fibre and finish declaration
Sewing thread	Polyester core thread	Qualified cellulosic thread	Seam strength and recycling trial
Interlining	Fused synthetic	Cellulosic or removable option	Bond and disassembly test
Care information	Polyester satin label	Compliant direct print	Print durability and chemical review
Buttons	Fixed polyester	Removable non-textile option	Receiver-approved removal step
Stretch system	Elastane yarn	Mechanical knit or pattern ease	Fit, recovery and wash testing

ILLUSTRATIVE [S0702] Illustrative cellulosic design model applying UBA's mono-material, compatible-component and removability principles. Every substitution requires product-performance and receiver verification. It is not a certified garment, a GFT production result or an assurance that natural materials are accepted by every recycler.

The release-evidence column is as important as the substitution. Cotton thread that fails at the seam would shorten garment life and could create more waste than it avoids. A direct print that cracks or introduces an unacceptable chemical would fail a

different circularity gate. Mechanical stretch that loses shape after washing would not satisfy the wearer. The UBA study explicitly warns that material substitution should not compromise durability. [S0702] Design review must therefore combine recyclability with fit, seam performance, colourfastness, abrasion, dimensional stability and care testing.

This also changes the role of the technical specification. A conventional tech pack states what the garment is. A circular tech pack additionally states what each component becomes at end of life. It identifies the intended recycling family, removal instructions, restricted substitutions and the evidence required before a supplier change. A purchasing team cannot quietly replace cotton thread with polyester thread on price without reopening the recovery decision.

> **GFT NOTE**
>
> Adopt a cellulosic default, not a cotton-only slogan. For every new style, require a bill-of-materials map with fibre share, component location, finish chemistry, removal step and intended receiver. Reject an unverified synthetic substitution at sample approval. Where performance trials require elastane or polycotton, create a separate style family and waste code before cutting begins. The factory's performance-management record should carry those codes from fabric receipt to clip bale.

Supplier contracts need the same discipline. Composition tolerances, finish declarations and change-notification duties belong in the fabric and trim purchase specification. Incoming quality control samples against those declarations and escalates discrepancies before spreading. A missed trim substitution can affect every later offcut from that style. Early detection costs one roll review. Late detection can compromise a production campaign's bales.

7.6

Mechanical stretch and segregated uniforms preserve performance without pretending all blends disappear

Mono-material does not mean shapeless. Knit loops can provide stretch through structure, while pattern ease, rib geometry and yarn selection can provide fit and recovery without elastane in suitable products. The Groningen study notes that knitted structures can stretch without elastane, and the UBA work treats product-specific requirements and trade-offs as central to ecodesign rather than imposing one construction on every garment. [S26] [S0702] The design team still has to prove recovery, comfort and durability on the intended style.

A useful product review asks where stretch is actually needed. A neck rib, cuff, fitted waist or close-fitting body panel may have different requirements. One area may be solved through knit structure, another through garment ease, and a third through a removable elastic component. This zoned review is more precise than a binary choice between a fully elastane-free garment and a fully blended one. It also creates disassembly options when only one component carries the incompatible material.

Institutional uniforms require a separate decision. Buyers may specify polycotton for durability, dimensional stability or industrial laundering. A designer should test whether a cotton construction meets the actual laundering and abrasion protocol before requesting a specification change. If the buyer retains polycotton, the factory should not relabel the resulting clips as cotton. It should maintain a dedicated poly-cotton stream with declared ratio and finish, then contract the receiver and route before bulk production. UNIDO's Moroccan work on in-factory segregation and high post-collection sorting cost supports this early separation discipline. [S24]

WORKED EXAMPLE

An illustrative order of 10,000 garments at 250 grams each contains 2,500 kilograms of textile. Assume, solely for the arithmetic, a mixed specification of 65 percent polyester, 33 percent cotton and 2 percent elastane. The order contains 1,625 kilograms of polyester, 825 kilograms of cotton and 50 kilograms of elastane. A verified 100 percent cotton alternative would instead place all 2,500 kilograms in the cellulosic stream and remove the 50 kilogram elastane separation task. This compares material architecture only. It is not an observed GFT order, a life-cycle assessment or proof that the alternative meets the buyer's performance standard.

The worked example shows why prevention deserves attention before fractionation. It does not prove that cotton is always the better environmental or commercial choice. A longer-lasting polycotton uniform could outperform a short-lived cotton alternative under a different functional unit. The comparison must therefore include service life, laundering, repair, replacement rate and actual end-of-life route. Material purity is one design variable, not a complete sustainability assessment.

Change control completes the product strategy. Generative design tools can propose silhouettes, fabric constructions and specifications, but research on multi-model garment pipelines does not itself establish recyclability compliance. [R31] GFT's recommended rule layer sits after generation and before approval: check every proposed component against the permitted materials library, flag an incompatible combination, and require a named process route for exceptions. Human design, quality and production owners remain responsible for the release decision.

7.7

Circular design supports producer-responsibility readiness, but it does not guarantee a bonus

Design discipline has commercial value before any eco-modulated fee is calculated. It reduces the number of waste identities the factory must manage, preserves more clips in a single process family and gives buyers clearer composition evidence. It also makes supplier review easier: a short list of approved cellulosic components is simpler to audit than a changing mixture of fibres, finishes and trims. These operational benefits do not require an unsupported claim about regulatory eligibility.

France's Refashion system illustrates why the claim must remain specific. Its 2026 framework includes bonuses for durability, environmental certification and incorporation of recycled raw materials, alongside recyclability penalties. A product subject to a penalty is not eligible for a bonus. The published penalty criteria concern metallo-plastic fibres or wires and electrical or electronic components, subject to the stated traceability-device exclusions. [S22] [S23] Elastane is a recycling concern, but the sources opened here do not support calling it a standalone Refashion penalty criterion.

The recycled-material bonus has another important boundary. Refashion's 2026 guide states that material from production offcuts is not eligible for that bonus, and it also excludes material from unsold items. The guide sets collection or funding, facility and proximity conditions for eligible waste routes. [S23] A Cameroon manufacturer must therefore not promise that incorporating its own pre-consumer clips will automatically generate this French bonus. That claim would confuse a general recycled-content argument with one scheme's detailed eligibility rules.

Mono-material design is not itself listed as an automatic Refashion bonus in the cited framework. It can support recyclability and feedstock quality, while durability or recognised certification requires its own evidence. This distinction protects the design team from selling a fee benefit before the marketer, product reference and scheme year have been checked. It also keeps regulatory analysis separate from process engineering. The operational reading here is not legal advice, and current scheme documents should govern any actual declaration.

Recycled-content certification adds a separate chain-of-custody task. The TraceWeave implementation guide describes facility Scope Certificates, Transaction Certificates at changes of ownership and mass-balance records where virgin and recycled inputs share a process. It also warns that internally generated regrind or scrap capable of reuse in the same process should not simply be presented as certified pre-consumer input. [S28] The practical lesson is that a waste code and a recycled claim are not interchangeable. Certification scope and definitions must be confirmed with the relevant certification body.

A useful digital record follows the material rather than the marketing statement. At fabric receipt, it holds supplier composition, finish and change-control evidence. At cutting, it links the roll and lay to the resulting clip container. At baling, it records mass, shade, declared blend, elastane status, exceptions and receiving destination. At dispatch, it links the bale to the transaction and any required certificate. At the recycler, it requests accepted mass, rejection reason and output route. This chain lets the factory reconcile what was designed, cut, recovered and claimed.

The same record supports a measured exception policy. A style containing elastane should not disappear inside an average cotton percentage. A polycotton uniform order should not borrow the recovery performance of a cellulosic T-shirt line. A rejected bale should change the next design or sourcing decision, not merely the waste report. Production, design and quality teams should review these exceptions together because the cause may sit in a tech pack, a supplier substitution or a cutting-room practice.

The investment sequence follows from the evidence. First, establish composition and component control. Second, qualify cellulosic designs through wear and process trials. Third, segregate unavoidable blends and secure receiver acceptance. Fourth, evaluate chemical fractionation only with measured two-output quality, utility use, solvent recovery, residues and offtake. Skipping to the fourth step leaves the factory with sophisticated chemistry applied to an avoidable design problem.

Circularity under the Warp and Signal approach is consequently a specification discipline before it is a recycling technology. Production carries the material identity. Measurement preserves it. The recovery route succeeds only when both remain attached to the same physical batch. Where the evidence ends, the claim ends as well.

Design out the mixture, then measure the fraction that remains.

CHAPTER SOURCE NOTES

S0704 Textile Exchange. 2024-09-26.

S26 University of Groningen. 2026-04-22.

S35 VTT Technical Research Centre of Finland and MDPI Textiles. 2026-07-31.

S24 United Nations Industrial Development Organization (UNIDO). 2023-11.

S0701 Polymers (MDPI). 2025-12-06.

S0703 Membranes (MDPI). 2022-03-24.

S0702 German Environment Agency (Umweltbundesamt). 2026-02.

R31 arXiv 2509.04705. Publication date unrecorded; inherited source-text check.

S22 Refashion. 2026-01.

S23 Refashion. 2026-01-27.

S28 TraceWeave. 2026-07-27.

08

Imported second-hand clothing transfers uncompensated waste burdens onto African municipalities

European used-textile exports have nearly tripled since 2000 to around 1.4 to 1.7 million tonnes a year, shipping unrecyclable fast-fashion blends to African ports without transferring Extended Producer Responsibility funds. [S11] [S13]

CHAPTER 08
DECISION TEST

European used-textile exports have nearly tripled since 2000 to around 1.4 to 1.7 million tonnes a year, shipping unrecyclable fast-fashion blends to African ports without transferring Extended Producer Responsibility funds. [S11] [S13]

Circular textile industrial strategy in Cameroon and the wider Central African Economic and Monetary Community (CEMAC) cannot begin with post-consumer municipal rag collection, because the regional post-consumer waste stream is contaminated by imported synthetic fast-fashion discards. [S11] [S0801] Over two decades, used textiles exported from the European Union nearly tripled from slightly over 550,000 tonnes in 2000 to almost 1.7 million tonnes in 2019, remaining near 1.4 to 1.44 million tonnes a year through 2025. [S11] [S13] Although customs declarations classify these compressed bales as reusable second-hand clothing (traded as *friperie* in Francophone Africa and *mitumba* in East Africa), market audits across Accra, Nairobi and Douala confirm that 20 to 50 percent of arriving garments are damaged, stained, climatically unsuitable or degraded upon arrival. [S30] [S0802] Because 89 percent of discarded garments tested at African dumpsites contain fossil-fuel synthetic fibres, and because European Extended Producer Responsibility (EPR) schemes stop funding waste management once a container clears a European port, African municipalities absorb an uncompensated solid-waste, microplastic and open-burning liability. [S0801] [S0805] For Green Future Tech Limited (GFT), this trade asymmetry establishes two operational rules for its Cameroon textile programme: first, Phase 1 circularity must anchor on 100 percent traceable pre-consumer cutting clips and regional spinning co-products rather than street discards; second, commercial positioning must avoid price competition against dumped *friperie* and Asian contraband, competing instead on verified SODECOTON cotton provenance, measured durability and closed-loop industrial accountability. [R06] [S0803]

8.1

European Union exports of used textiles tripled between 2000 and 2019 to nearly 1.7 million tonnes a year

The global trade in post-consumer clothing is no longer a peripheral charitable outlet; it operates as a commodity export valve for overproducing apparel economies in the Global North. [S11] [S0801] European Environment Agency (EEA) trade assessments based on United Nations Comtrade records show that exports of used textiles from European Union Member States rose from slightly above 550,000 tonnes in 2000 to nearly 1.7 million tonnes in 2019. [S11] At that 2019 peak, exported used textiles averaged 3.8 kilograms per European citizen, equivalent to 25 percent of the 14.8 to 16 kilograms of clothing, footwear and household textiles consumed per person each year across the European Union. [S11] [S12] Subsequent monitoring through the EEA Circularity Metrics Lab confirms that annual export volumes have nearly doubled since 2005 and have remained on a high plateau averaging around 1.4 million tonnes a year since 2015, recording 1.44 million tonnes (or 3.2 kilograms per person) in the 2025 series. [S13]

8.2 LIMITED DOMESTIC RECYCLING CAPACITY IN EUROPE DRIVES SYSTEMATIC EXPORT RELIANCE

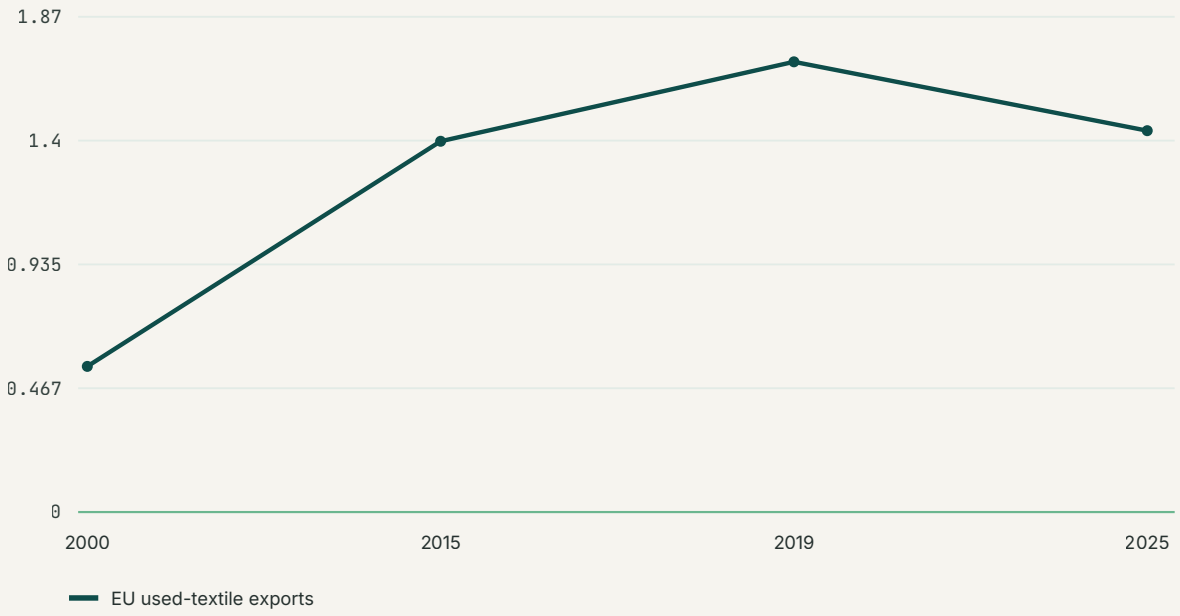
Europe exports this tonnage because its domestic reuse and fibre-to-fibre recycling infrastructure absorbs only a fraction of the post-consumer garments collected inside Member States. [S11] [S12] Across the European Union, total textile waste generation reached approximately 6.95 million tonnes in 2020, or about 16 kilograms per person, of which 4.4 kilograms per person (27.5 percent) was collected separately for reuse

and recycling while 11.6 kilograms per person (72.5 percent) entered mixed household rubbish destined for incineration or landfill. [S12] [S14] Because mandatory separate collection of textile waste took effect across all EU Member States on 1 January 2025 under the Waste Framework Directive, collection containers and sorting centres in countries such as Germany, the Netherlands and France face rising volumes of lower-grade garments diverted from general household waste. [S04] [S12] [S30] Without commensurate domestic mechanical and chemical recycling capacity inside Europe, export remains the primary clearance mechanism for collected post-consumer textiles. [S11] [S13]

The trajectory of European Union used-textile exports over this twenty-five-year window is plotted in **Exhibit 35**, p. 129.

EXHIBIT 35 / MILLION TONNES PER YEAR

European Union exports of used textiles rose from 550,000 tonnes in 2000 to 1.7 million tonnes in 2019 and 1.44 million tonnes in 2025



SOURCED [S11] [S13] Sourced from European Environment Agency (EEA) trade briefings (2023) and EEA Circularity Metrics Lab (2026). Export volumes rose from slightly over 0.55 million tonnes in 2000 to an average of around 1.40 million tonnes per year from 2015 onward, peaking near 1.70 million tonnes in 2019 (3.8 kg per person) and standing at 1.44 million tonnes in 2025 (3.2 kg per person).

As **Exhibit 35**, p. 129 demonstrates, the shift between 2000 and 2025 permanently rebased export mass above 1.4 million tonnes a year. [S11] [S13] What the aggregate tonnage line in **Exhibit 35**, p. 129 cannot show on its own, however, is the decline in polymer purity and resale durability of each exported tonne over the same period. [S11] [S0801]

8.3 FAST-FASHION PRICE DEFLATION AND SYNTHETIC BLENDS DEGRADE EXPORT BALE QUALITY

Two decades ago, a larger share of European donated clothing consisted of heavier cotton, wool and linen garments capable of surviving multiple resale cycles. [S11] [S0802] Between 1996 and 2018, however, retail clothing prices in the European

Union fell by over 30 percent relative to inflation, while global apparel sales nearly doubled from US$1 trillion in 2002 to just under US$2 trillion in 2023. [S0801] Driven by fast-fashion brands releasing up to 52 micro-collections a year and ultra-fast-fashion platforms listing thousands of new styles daily, global fibre production hit a record 124 million tonnes in 2023, of which fossil-based synthetics such as polyester, nylon and acrylic accounted for 75 million tonnes, or over 60 percent of output. [S01] [S02] [S0801]

When consumers in high-income markets discard low-cost synthetic garments after only a few wears, sorting operators in Europe face narrowing margins: manual grading labour is costly, whereas the resale value of worn ultra-fast-fashion items in European thrift shops is negligible. [S11] [S30] Commercial sorting hubs therefore compress lower-grade mixed garments into 45-to-55-kilogram export bales declared under Harmonised System (HS) code 6309 ("worn clothing and other worn articles") and ship them abroad. [S11] [S0801] According to the EEA's destination breakdown for 2019, 46 percent of all EU used-textile exports were shipped to Africa, while 41 percent went to Asia, where shipments largely enter dedicated economic zones for downcycling into industrial wiping rags, mattress filling, or re-export to African markets. [S11] The remaining 13 percent (derived arithmetic: 100 percent minus 46 percent minus 41 percent) moved to rest-of-world destinations. [S11]

8.4

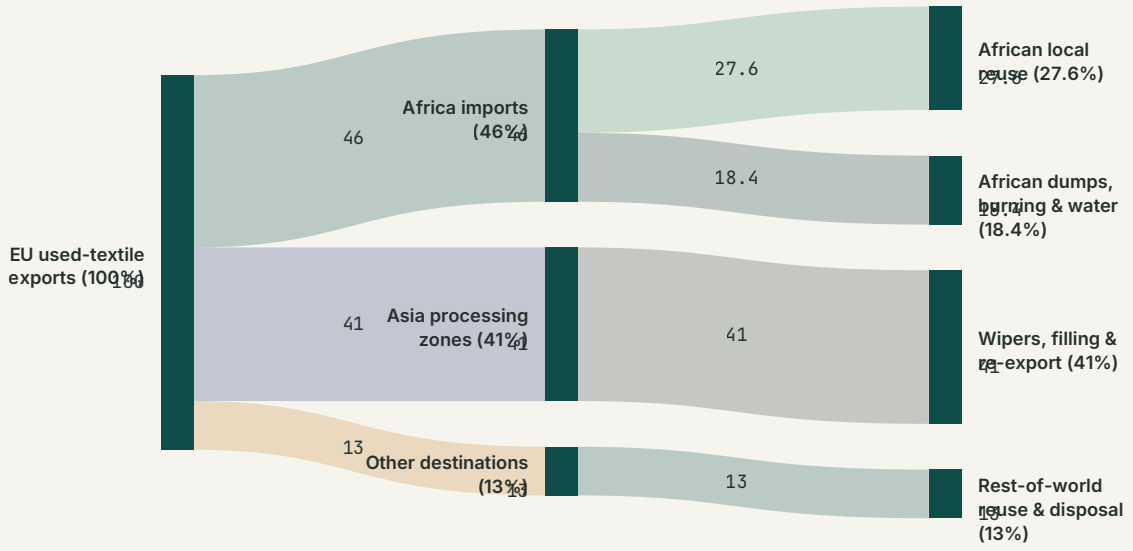
African wholesale markets in Ghana, Kenya and Cameroon absorb the physical cost of unsellable fast fashion

Once exported containers clear customs at West, East and Central African ports, the gap between European customs declarations ("sorted clothing fit for reuse") and actual garment utility becomes an immediate municipal burden. [S11] [S29] [S30] Across sub-Saharan Africa, the trade in imported used clothing supports informal retail, transport, washing and tailoring livelihoods, supplying affordable apparel to low-income households. [S30] [S0802] Yet the rising fraction of damaged, stained and synthetic fast-fashion items inside sealed wholesale bales forces local traders and municipal sanitation budgets to underwrite the disposal of Northern overproduction. [S31] [S0801] [S0805]

The material bifurcation of European used-textile exports across destination regions and end-of-life sinks in Africa is mapped in **Exhibit 36**, p. 131.

EXHIBIT 36 / PERCENT OF EU USED-TEXTILE EXPORT MASS

Nearly half of European Union used-textile exports go to Africa, where up to 40 percent of arriving bale volume enters waste sinks



DERIVED [S11] [S30] [S0802] Derived mass-balance Sankey per 100 units of EU used-textile exports. Stage 1 regional split is sourced from EEA (2019 data, S11): Africa 46%, Asia 41%, Other regions 13% (100 - 46 - 41). Stage 2 split for Africa applies the 40% non-reusable fraction reported by Wuppertal Institute at Kantamanto (S30, consistent with the 20-50% flawed bale share in Kenya, S0802): 46% *0.60 = 27.6% local reuse/upcycling and 46%* 0.40 = 18.4% immediate landfill, open burning or waterway waste.

As shown in **Exhibit 36**, p. 131, even before accounting for secondary re-exports routed from Asian sorting zones back into African ports, applying the Wuppertal Institute's observed 40 percent non-reusable threshold to Africa's 46 percent direct share means that 18.4 percent of all European used-textile exports transfer directly into African open dumpsites, hearths and coastal drainage systems upon opening the bales. [S11] [S30] Furthermore, **Exhibit 36**, p. 131 captures only immediate point-of-arrival rejection; the remaining 27.6 percent that enters local reuse still reaches end of life inside African municipalities within months or years, where no industrial fibre-to-fibre recycling plants exist to recover it. [S11] [S29]

8.5 FIELD EVIDENCE FROM ACCRA AND NAIROBI QUANTIFIES THE UNSELLABLE FRACTION

Empirical field studies conducted between 2023 and 2025 in West and East Africa provide verification of how this waste transfer operates on the ground: [S29] [S30] [S31]

1. **Kantamanto Market and Old Fadama in Accra, Ghana:** Wuppertal Institute researchers visiting Accra document that roughly 15 million garments arrive at Kantamanto Market every week, of which about 40 percent are not reusable and immediately become waste that overwhelms landfills, is burned openly, or washes into rivers and the ocean. [S30] In October 2024, Greenpeace Africa conducted a physical brand audit of 201 discarded garments collected across James Town Beach, Kantamanto and Agbogbloshie, identifying major European and British brands accumulating as coastal and landfill waste. [S31] In its September 2024

technical report (*Fast Fashion, Slow Poison*), Greenpeace scanned 164 discarded garments at the Old Fadama and Weija dumpsites using portable infrared spectroscopy, finding that 89 percent contained fossil-fuel synthetic fibres. [S31] [S0801]

2. **Gikomba and the Kenyan *mitumba* trade:** Pan African Climate Justice Alliance (PACJA) and Greenpeace Africa assessments of Kenya's second-hand clothing sector reveal an identical breakdown. [S29] [S0802] In 2021 alone, the European Union shipped 22.5 million kilograms of used clothing (more than 112 million individual garments) to Kenya. [S29] Across Kenya's total 2021 used-clothing imports of roughly 900 million garments from all global origins, about 458 million items (50.9 percent by piece count) were worthless, with market surveys confirming that Kenyan *mitumba* traders discard 20 to 50 percent of garments in bales due to flawed conditions. [S0802]
3. **Cameroon and the CEMAC *friperie* corridor:** Customs records reported by Business in Cameroon confirm that in 2023, Cameroon imported 61,221 tonnes of used clothing valued at 30.2 billion CFA francs (XAF), representing nearly 35 percent of all second-hand clothing imports entering the CEMAC zone. [S0803] Flowing through the Port of Douala into markets in Douala, Yaounde, Bafoussam and Garoua, these 61,221 tonnes of imported *friperie* carry the same 20 to 40 percent unsellable fast-fashion fraction documented across West and East African ports. [S30] [S0802] [S0803]

8.6 OPEN COMBUSTION OF SYNTHETIC TEXTILE WASTE CREATES ACUTE CHEMICAL AND MICROPLASTIC HAZARDS

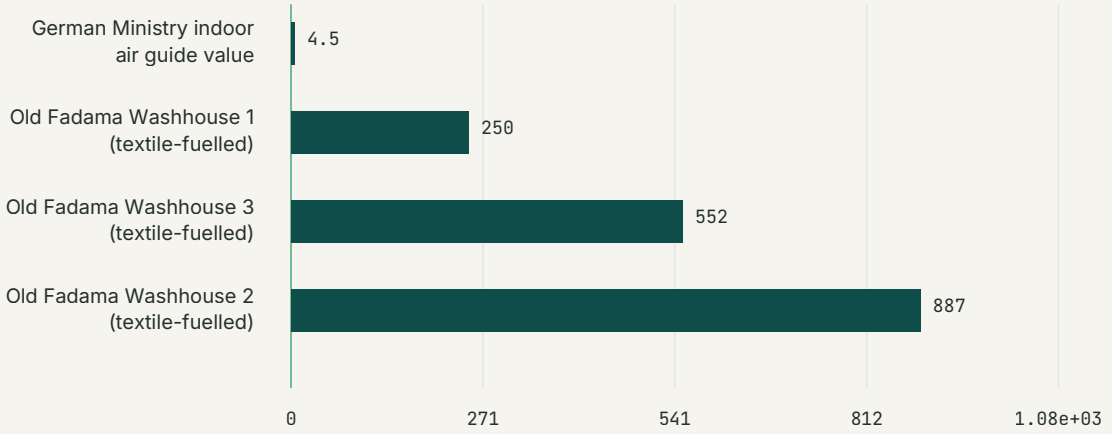
When unsellable synthetic and polycotton garments exit African wholesale markets, they do not remain inert. [S29] [S0801] Because municipal solid-waste collection in rapidly growing African cities struggles to finance engineered sanitary landfills, rejected clothing accumulates in informal dumpsites, clogs urban storm-water drains, and washes into lagoons and beaches where ultraviolet radiation and wave abrasion fragment polyester and nylon fabrics into microplastics. [S29] [S31] [S0801] Synthetic textiles also carry residual manufacturing chemicals, including disperse dyes, per- and polyfluoroalkyl substances (PFAS) from water-repellent finishes, antimony catalysts from polyester polymerisation, and bisphenol A. [S0801]

Even more severe is the public-health exposure caused by burning unmarketable synthetic clothing as fuel. [S31] [S0801] In Old Fadama, an informal settlement of more than 80,000 residents adjacent to Accra's Kantamanto Market, Greenpeace researchers documented that public washhouses collect unsellable waste garments from Kantamanto and burn them in open hearths beneath water barrels to heat bathing water. [S0801] Ambient air sampling across three Old Fadama washhouses revealed severe contamination by carcinogenic, mutagenic and reprotoxic (CMR) compounds generated by incomplete combustion of synthetic plastics, including styrene, phenol, polycyclic aromatic hydrocarbons (PAHs, with wall soot wipes reaching up to 2,160 micrograms per square metre) and benzene. [S0801]

The measured ambient air concentrations of carcinogenic benzene in those three textile-fuelled washhouses relative to the German Ministry of Environment indoor air guide value are presented in **Exhibit 37**, p. 133.

EXHIBIT 37 / MICROGRAMS OF BENZENE PER CUBIC METRE OF AIR

Burning unsellable imported clothing in Accra washhouses elevates ambient benzene to between 55 and 197 times the European reference guide value



SOURCED [S31] [S0801] Sourced from Greenpeace Africa air-quality investigation in Old Fadama, Accra (September 2024, S0801; cited in S31). Public washhouses burn unsellable waste clothing from Kantamanto Market to heat water. Benzene concentrations measured 250, 552 and 887 micrograms per cubic metre against the German Ministry of Environment indoor air guide value of 4.5 micrograms per cubic metre for carcinogenic substances.

The measurements in **Exhibit 37**, p. 133 show ambient benzene concentrations of 250 micrograms per cubic metre at Washhouse 1 (55.6 times the 4.5 microgram per cubic metre guide value), 552 micrograms per cubic metre at Washhouse 3 (122.7 times the guide value), and 887 micrograms per cubic metre at Washhouse 2 (197.1 times the guide value), alongside total volatile organic compounds (VOCs) between 2,510 and 3,760 micrograms per cubic metre. [S0801] While **Exhibit 37**, p. 133 reflects site-specific air sampling in Old Fadama rather than a continental inventory, it proves that exporting unrecyclable synthetic fast fashion to jurisdictions without flue-gas scrubbing converts Northern apparel overproduction into toxic air and water emissions in African cities. [S29] [S0801]

8.7

The import and contraband tide hollowed out Cameroon's domestic textile incumbent

In Cameroon, the macro-economic consequence of the second-hand clothing trade and parallel Asian textile smuggling is visible in the contraction of domestic industrial processing. [R11] [S0803] Upstream, Cameroon possesses an organised cotton agricultural base: supported by the *Societe de Developpement du Coton* (SODECOTON), more than 220,000 smallholder producers across northern Cameroon harvested 330,000 tonnes of seed cotton in 2022, 314,455 tonnes in 2023 and roughly 340,000 tonnes in 2024, with 2025 projections exceeding 350,000 tonnes inside a wider CFA-franc zone output of 2.3 million tonnes in 2024/25. [R01] [R02] [R03] [R05] SODECOTON operates nine ginning plants and two oil mills, injecting roughly US$100 million a year into rural communities. [R03] [R04] Yet approximately 95 percent of

Cameroon's ginned cotton lint is exported raw and only about 5 percent is processed locally, against a national target of 50 percent by 2030 under the *Strategie Nationale de Developpement 2020-2030* (SND30). [R06] [R07]

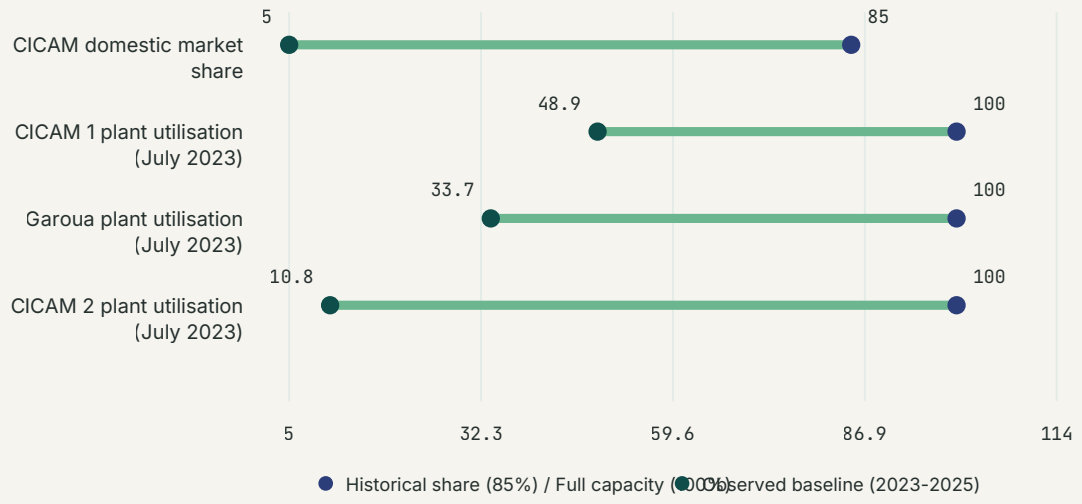
8.8 SMUGGLED FABRICS AND SURGING FRIPERIE IMPORTS ERODED CICAM TO A SINGLE-DIGIT MARKET SHARE

Downstream, cheap imported second-hand clothing and unrecorded contraband textiles hollowed out the national textile incumbent, *Cotonniere Industrielle du Cameroun* (CICAM). [R11] [S0803] [S0804] Three decades ago, CICAM commanded approximately 85 percent of Cameroon's domestic textile market (with African Development Bank historical baselines citing 80 to 85 percent). [R11] [S0804] By 2023 to 2025, undermined by 61,221 tonnes a year of used-clothing imports (worth XAF 30.2 billion in 2023) and low-cost Chinese and West African fabrics (with Chinese imports controlling nearly 80 percent of the Cameroonian textile market, much of it smuggled), CICAM's domestic market share had collapsed to about 5 percent. [R11] [S0803] [S0804]

The severity of this contraction across market share and plant-level capacity utilisation is shown in **Exhibit 38**, p. 134.

EXHIBIT 38 / PERCENT

CICAM's domestic market share fell from 85 percent to 5 percent while plant utilisation dropped to between 10.8 and 48.9 percent



SOURCED [R11] [R12] [S0803] [S0804] Sourced from Business in Cameroon and MMI News (R11, R12, S0803, S0804). Domestic market share compares historical peak (~85%, R11) against current share (~5%, R11, S0803). Plant capacity utilisation compares 100% nameplate benchmark against the July 2023 Bureau de Mise a Niveau (BMN) / Mazars diagnostic report (R12, S0804): CICAM 1 at 48.9%, Garoua at 33.7% and CICAM 2 at 10.83%.

As **Exhibit 38**, p. 134 illustrates, losing domestic retail demand to contraband and *friperie* starved CICAM's mills of volume. [R11] [R12] According to the July 2023 diagnostic by the *Bureau de Mise a Niveau* (BMN) and Mazars, capacity utilisation stood at 48.9 percent at CICAM 1, 33.7 percent at Garoua, and 10.83 percent at CICAM 2. [R12] [S0804] Underutilisation cost CICAM about XAF 2 billion in 2020, while restructuring estimates reached XAF 30.7 billion to XAF 48.2 billion in the 2023 BMN audit and XAF 70.2 billion in the African Development Bank's 2025 country report, alongside negotiations for a XAF 200 billion modernisation plan with Arise IIP and XAF 24 to

30 billion in annual public uniform orders. [R12] [R13] [S0803] [S0804] While **Exhibit 38**, p. 134 reflects legacy state-mill constraints, it confirms a core finding of GFT's Feasibility Study: no Cameroon garment venture can survive by competing on price against untaxed contraband or dumped second-hand bales. [R11] [R12]

WORKED EXAMPLE: QUANTIFYING CAMEROON'S MUNICIPAL WASTE BURDEN AND FISCAL LEAKAGE FROM 2023 SECOND-HAND IMPORTS

To make the municipal and fiscal asymmetry concrete, we construct an engineering calculation from Cameroon's sourced 2023 used-clothing import volume of 61,221 tonnes valued at XAF 30.2 billion. [S0803]

1. **Customs valuation per kilogram and per garment:** Dividing XAF 30.2 billion by 61,221,000 kilograms yields an average declared customs value of **XAF 493.29 per kilogram** (about **US$0.82 per kilogram** at an illustrative rate of XAF 600 per US dollar under the 655.957 euro peg). [R32] [S0803] At an illustrative average garment weight of 250 grams (four pieces per kilogram), 61,221 tonnes equals **244.88 million imported garments** at a declared value of **XAF 123.32 (about US$0.21) per garment**. [R32] [S0803]
2. **Immediate unsellable municipal waste mass:** Applying the documented 20 percent (Kenyan lower bound) to 40 percent (Wuppertal Institute Kantamanto audit) immediate unsellable rate across 61,221 tonnes yields **12,244 to 24,488 tonnes of immediate unsellable textile waste** entering Cameroonian municipalities in 2023. [S30] [S0802] [S0803]
3. **Synthetic plastic loading in municipal dumps:** Applying Greenpeace Africa's infrared finding that 89 percent of discarded fast-fashion waste contains synthetic fibres (0.89 share), the immediate unsellable fraction deposits an estimated **10,897 to 21,794 tonnes of non-biodegradable plastic fibres** into Cameroonian dumpsites and waterways annually. [S0801] [S0803]
4. **Uncompensated municipal hauling and disposal cost:** At an illustrative municipal collection and landfill cost of US$45 to US$75 per tonne (XAF 27,000 to XAF 45,000 per tonne), managing just the 12,244 to 24,488 tonnes of immediate rejects imposes an uncompensated cost of **US$550,980 to US$1,836,600 (XAF 330.6 million to XAF 1.10 billion)** a year on Cameroonian cities, while end-of-life disposal of the full 61,221 tonnes represents an illustrative **US$2.75 million to US$4.59 million (XAF 1.65 billion to XAF 2.75 billion)** in local waste liability, for which European EPR schemes remit **zero XAF**. [R32] [S0803] [S0805]

8.9

Post-consumer municipal waste in Cameroon is an unviable feedstock for Phase 1 fibre-to-fibre recycling

Well-intentioned circularity proposals often suggest that a new African textile venture should collect post-consumer discarded clothing from local markets to spin recycled yarn. [S20] [S29] In GFT's engineering analysis, that approach is unviable for Phase 1 and Phase 2 because it confuses municipal waste management with industrial fibre specification. [S20] [S26] [S35]

8.10 FIVE PHYSICAL AND CHEMICAL BARRIERS DISQUALIFY POST-CONSUMER FRIPERIE DISCARDS FROM GREENFIELD SPINNING

Materials engineering identifies five barriers that disqualify post-consumer street waste as a greenfield spinning feedstock: [S20] [S26] [S35]

1. **89 percent synthetic and blend dominance:** Cotton spinning and cellulosic pulping require pure cellulose, yet infrared scans of dumped second-hand apparel in West Africa show that 89 percent of items contain synthetic fibres. [S34] [S35] [S0801] As VTT's July 2026 review confirms, chemically fractionating intimate polycotton blends demands high chemical and energy inputs and suffers from incomplete fraction purity and cellulose degree-of-polymerisation (DP) loss. [S35]
2. **Elastane and hardware contamination:** Post-consumer clothes contain polyurethane elastane, metal zippers, rivets, polyester sewing threads and plastisol prints. [S20] [S26] Even 1 to 3 percent elastane wraps carding wire and forms gels in chemical reactors, requiring automated Near-Infrared (NIR) sorting (900 to 1,700 nanometres) with machine-learning classifiers (91.7 percent KNN composition accuracy and 92.6 percent 1D-CNN elastane accuracy) plus mechanical de-trimming. [S26] [S35]
3. **Restricted chemical finishes:** Imported bales mix garments from global origins containing undocumented PFAS treatments, heavy metals and azo dyes that violate Zero Discharge of Hazardous Chemicals (ZDHC) and Global Recycled Standard (GRS v4) limits. [S28] [S0801]
4. **Degraded cellulose staple length:** Repeated wear, alkaline washing and tropical UV exposure cleave cellulose chains in worn cotton; mechanical tearing reduces post-consumer staple length below 12 to 15 millimetres, too short for quality apparel yarn. [S20] [S24]
5. **Prohibitive collection and washing cost:** Aggregating scattered street rags requires reverse logistics, industrial sanitisation (30 to 60 litres of water per kilogram, illustrative basis), NIR sorting capex and reject disposal fees. [S20] [S26]

By contrast, pre-consumer cutting clips from GFT's cut-make-trim (CMT) floor (135 to 210 tonnes a year at the illustrative 3.0 million garment scale) and spinning waste from Camtext SA (960 to 2,160 tonnes a year from 12,000 tonnes of lint capacity) or the SODECOTON-CICAM pole are 100 percent traceable Cameroon cotton, unsoiled and pre-sorted at zero collection cost. [R08] [R09] [R10] [S24]

GFT NOTE: WHY GFT'S CAMEROON TEXTILE PROGRAMME QUARANTINES POST-CONSUMER WASTE OUTSIDE THE PHASE 1 FACTORY BOUNDARY

In GFT's Cameroon textile programme, Phase 1 circularity is restricted to clean pre-consumer cotton waste from the CMT cutting room and partnered domestic spinning mills. [R08] [R10] [S24] GFT recommends that sponsors **never mix post-consumer municipal clothing discards into factory cutting-clip bales**. [S10] [S28] Mixing even one bale of post-consumer *friperie* into pre-consumer cotton invalidates batch provenance under GRS v4, introduces elastane and PFAS contamination, and destroys the 3.0x to 4.5x price premium of colour-sorted 100 percent SODECOTON cotton clips. [R03] [S24] [S28] Post-consumer textile recovery in Cameroon belongs in a separate municipal non-woven insulation workstream funded by import levies and EPR transfers. [S24] [S30]

8.11

Grassroots African upcycling and downcycling fill local gaps but cannot match industrial import volumes

Rejecting post-consumer *friperie* as a Phase 1 apparel spinning feedstock does not diminish the value of African informal upcycling or the livelihood needs of subsistence waste workers. [S21] [S30] Across West, East and Central Africa, market tailors and social enterprises extend the life of imported textiles and indigenous fabrics alike. [S29] [S30]

8.12 INDIGENOUS AFRICAN CIRCULARITY AND MARKET UPCYCLING DEMONSTRATE HIGH CRAFT VALUE AT ARTISANAL SCALE

As documented by PACJA, circularity is foundational to African textile traditions: Ghana's woven *kente*, Mali's mud-dyed *bogolanfini*, East Africa's *Maasai shuka*, and Uganda's chemical-free *Mutuba* barkcloth were engineered for multi-generational durability and repair with zero waste. [S29] In contemporary markets such as Accra's Kantamanto and Nairobi's Gikomba, Wuppertal Institute and Greenpeace researchers document how tailors and collectives (*The Revival Earth* and *The Or Foundation*) transform damaged trousers and pyjamas into boxer shorts, reconstruct faded T-shirts into streetwear jerseys, and shred unwearable remnants into mattress stuffing, wiping rags, or acoustic and thermal building panels (mirroring UNIDO SwitchMed's industrial non-woven insulation pilot with Novimat in Morocco). [S24] [S30] [S31]

8.13 A THREE-ORDER-OF-MAGNITUDE SCALE MISMATCH SEPARATES ARTISANAL UPCYCLING FROM INDUSTRIAL IMPORT VOLUMES

Despite their craft vitality, artisanal upcycling and manual stuffing operate at a scale of tens or hundreds of tonnes a year (illustrative workshop basis), whereas the European Union exports 1.44 million tonnes of used textiles annually, Ghana receives 15 million items a week at Kantamanto, and Cameroon imports 61,221 tonnes a year. [S13] [S30] [S0803] As Wuppertal Institute researchers concluded in Ghana, local artisanal measures alone cannot absorb an industrial flood of low-quality fast fashion generated in the Global North. [S30]

8.14 ISO 59014:2024 GOVERNS THE SAFE INCLUSION OF INFORMAL AND SUBSISTENCE WASTE WORKERS

Where regional clusters establish non-woven or secondary recovery lines, they must protect the informal waste pickers and market porters who handle discarded textiles. [S21] [S31] In Cameroon, where informal employment represents about 90 percent of the workforce alongside a formal minimum wage (SMIG) of XAF 43,969 a month from 23 February 2024 (about US$76), waste sorting is largely a subsistence livelihood. [R14] [R16] Published in November 2024, **ISO 59014:2024** (*Sustainability and traceability of secondary materials recovery*) sets global requirements combining mass-balance traceability with safe working conditions, fair pay and formalisation for subsistence waste workers, complementing ISO 59004:2024 and ISO 59020:2024. [S21] [S39] [S40] Any Phase 2 or Phase 3 aggregation of external tailor scraps in Cameroon must audit collection points against ISO 59014:2024 health, safety and transparent weighing rules. [R14] [S21]

8.15

Geographic blind spots in European EPR schemes keep producer fees inside Europe while waste travels south

The fiscal failure of the second-hand textile trade stems from a territorial cutoff in European Extended Producer Responsibility (EPR) law. [S11] [S31] [S0805] Under the revised EU Waste Framework Directive (Directive (EU) 2025/1892, in force 16 October 2025 after mandatory separate collection on 1 January 2025), brands placing apparel on the EU market pay eco-modulated fees to Producer Responsibility Organisations (PROs) such as Refashion in France. [S04] [S05] [S06] [S22]

8.16 HOW THE CUSTOMS CLASSIFICATION OF "FIT FOR REUSE" SEVERS FINANCIAL PRODUCER RESPONSIBILITY AT THE EUROPEAN PORT

While EPR fees are intended to fund full end-of-life management, current national schemes stop at the European border: [S05] [S06] [S0805]

- **Fee collection inside Europe:** Brands pay per-garment EPR fees to European PROs when selling into EU domestic markets. [S05] [S22]
- **Domestic European disbursement:** PROs spend those funds exclusively on European collection containers, European sorting centres and European recycling pilots. [S06] [S22] [S0805]
- **The HS 6309 export exit and Basel Annex IX gap:** Once a European sorter bales lower-grade garments as "fit for reuse" under customs code HS 6309 and ships them to Africa, the shipment exits the EU waste regime as a product export, while transboundary movements of textile wastes listed under Annex IX entry B3030 of the Basel Convention are not subject to prior informed consent (PIC) procedures. [S11] [S0801] [S0805] [S0807]
- **Bypassing Cameroon's statutory waste-import ban onto municipal councils:** Under Cameroon's environmental framework statute (Law No. 96/12 of 5 August 1996 relating to environmental management), Article 44 formally prohibits the introduction, discharge, storage or transit of foreign-produced waste on national territory, while Article 46 assigns household waste and midnight-dump elimination to decentralized territorial councils (subject to current implementing regulations). [S0806] Declaring mixed bales containing 20 to 50 percent unsellable fast fashion as reusable goods under HS 6309 circumvents Article 44 at the port and transfers the uncompensated cleanup obligation onto municipal councils under Article 46, with zero cross-border funding from European PROs. [S29] [S31] [S0802] [S0805] [S0806]

As the Secretariat of the Basel Convention (May 2025), the European Environmental Bureau (EEB), ECOS, Greenpeace Africa, the Wuppertal Institute and PACJA emphasize, this regulatory gap allows Northern sorting hubs to report nominal "reuse" (with global second-hand textile trade increasing almost sevenfold over three decades and the EU holding a 30.5 percent global export value share in 2017 to 2021) while externalising landfill and open-burning costs onto African cities. [S15] [S29] [S30] [S31] [S0805] [S0807]

DESIGNING A DESTINATION-COUNTRY EPR IMPORT LEVY AND CROSS-BORDER PRO TRANSFER MECHANISM FOR CEMAC

To close this accountability gap without disrupting low-income clothing access, policy bodies (UNEP, EEB/ECOS and PACJA) outline a two-limb mechanism for CEMAC and EU regulators: [S15] [S29] [S0805]

1. **Pre-export sorting and NIR manifest verification:** Exporters must certify item-by-item sorting, durability thresholds and NIR-verified polymer manifests (<5 percent unsellable tolerance) before shipping outside the EU, reclassifying unsorted bales as regulated waste. [S04] [S26] [S0805]
2. **Destination-country environmental levy at CEMAC ports:** Applying an illustrative circular-textile port levy of **XAF 150 per kilogram (about US$0.25/kg, or XAF 37.5 per 250 g garment)** across Cameroon's 61,221 tonnes of 2023 used-clothing imports generates **XAF 9.18 billion (about US$15.3 million) a year** in dedicated municipal and recycling revenue. [R32] [S0803]
3. **Cross-border European PRO fee transfers:** Reforming EU EPR rules requires European PROs to transfer a pro-rata share of collected brand fees (illustrative EUR 0.08 to EUR 0.15 per exported garment) to destination-country waste and recycling funds. [S31] [S0805]
4. **Ring-fenced industrial deployment:** Funds finance ISO 59014-compliant market sorting hubs, non-woven building insulation lines, and mechanical tearing modules at Dibamba and Garoua. [R10] [S21] [S24]

8.17

Regional trade policy and local provenance allow a greenfield maker to out-position anonymous imports

For an industrial sponsor evaluating GFT's Cameroon textile programme, the analysis of *friperie* and contraband governs commercial positioning. [R11] [S0803] As Sections 4 and 7 of GFT's Feasibility Study establish, a greenfield Cameroon maker cannot win a race to the bottom on unit price against smuggled synthetics or XAF 123-per-piece second-hand bales, and should not try. [R11] [S0803]

8.18 FOUR COMPETITIVE FORCES DEFINE CAMEROON'S TEXTILE MARKET STRUCTURE

GFT positions the venture across four market forces to capture the upper-right quadrant of verified provenance and design agility: [R08] [R09] [R11] [R26]

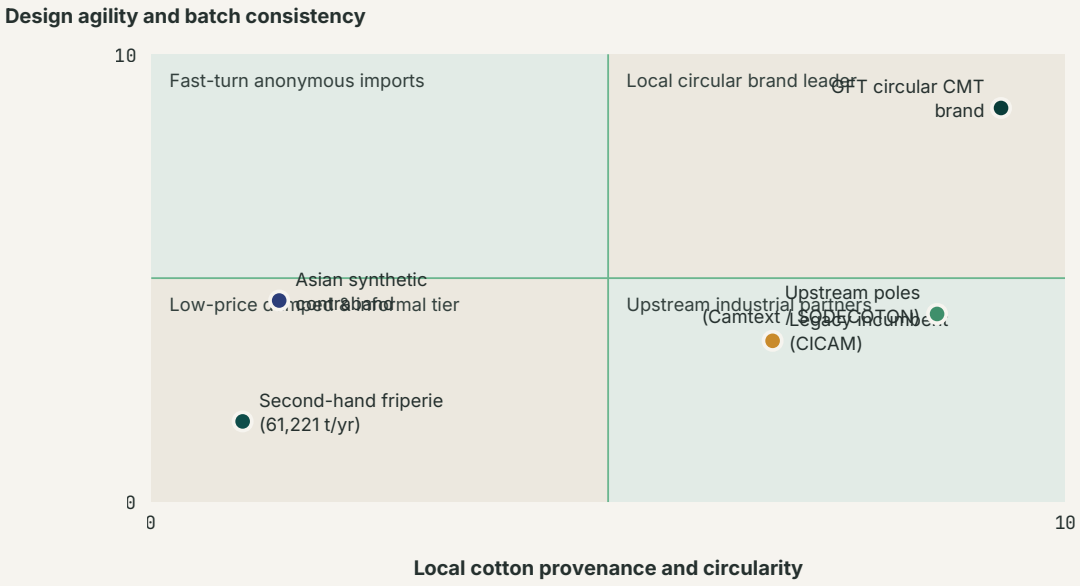
1. **Force 1: Imported second-hand *friperie* (61,221 tonnes/year, XAF 30.2 billion in 2023):** Competes on rock-bottom price, but offers random single items unsuitable for institutional uniforms, 20 to 50 percent defect rates, and zero provenance. [S30] [S0802] [S0803]
2. **Force 2: Asian synthetic contraband (~80 percent Chinese import share):** Competes on low-price uniformity, but suffers from six-month ocean lead times, foreign-exchange friction, poor tropical breathability, and zero African traceability. [R27] [S0803] [S0804]

3. **Force 3: Legacy incumbent CICAM (~5 percent market share, 10.83 to 48.9 percent utilisation):** Holds heritage recognition, but carries a XAF 30.7 billion to XAF 70.2 billion restructuring burden and multi-year turnaround timelines. [R11] [R12] [R13] [S0804]
4. **Force 4: Emerging public spinning/weaving poles (SODECOTON-CICAM 2030 merger and US$300 million / XAF 180 billion Camtext SA processing 12,000 tonnes/year at Dibamba and Garoua):** Sit upstream of a private CMT factory, serving as domestic yarn suppliers and mechanical clip-recycling partners rather than downstream rivals. [R08] [R09] [R10]

This four-force positioning is mapped in **Exhibit 39**, p. 140.

EXHIBIT 39 / STRATEGIC POSITIONING SCORE (0 TO 10 SCALE)

Competitive positioning maps GFT's local circular brand against CICAM, Asian contraband, second-hand friperie and public spinning poles



DERIVED [R08] [R09] [R11] [R26] [S0803] Derived positioning matrix synthesising GFT Feasibility Study Section 4 (Competitive Field) and Section 7 (Go-to-Market) with sourced market baselines (R08-R13, R26, S0803). X-axis scores verified Cameroon cotton provenance and closed-loop circularity (0 to 10); Y-axis scores finished garment design agility, batch consistency and brand value (0 to 10).

As **Exhibit 39**, p. 140 shows, GFT's CMT brand occupies the high-provenance, high-agility quadrant ($x = 9.3$, $y = 8.8$) by partnering with upstream poles ($x = 8.6$, $y = 4.2$) while leaving the bottom-left price tier ($x < 2$, $y < 5$) to *friperie* and contraband. [R08] [R09] [S0803] Because matrix scores are analytical syntheses rather than cash flows, they must rest on measured demand baselines. [R24] [R26]

8.19 DOMESTIC SPENDING, INSTITUTIONAL UNIFORM TENDERS AND REGIONAL TRADE BLOCS ANCHOR BANKABLE DEMAND

Although Cameroon's United States AGOA eligibility was terminated effective 1 January 2020 and remained ineligible through 2025, domestic and African demand provides a bankable market. [R18] [R24] The African textile market is valued at US$37.3 billion in 2025, projected to reach US$49.41 billion by 2030 at 4.73 percent a year and US$72.7 billion by 2035 at 6.9 percent a year (with fashion and apparel holding

48.1 percent in 2024). [R24] [R25] Under AfCFTA, 92.3 percent of tariff lines are agreed, and garments made from 100 percent local SODECOTON lint and locally recycled clips will satisfy strict origin rules once textile schedules conclude. [R06] [R23]

In Cameroon, Statista records clothing and footwear spend at US$94.70 per person in 2024 across 8.0 pieces (about US$11.84 per piece), while apparel e-commerce grows at 13.41 percent a year from US$20.32 million (2023) to US$33.61 million (2027) as penetration rises from 18.0 to 22.7 percent. [R26] Moreover, the state's plan under SND30 to reserve XAF 24 billion to XAF 30 billion a year in public school, hospital and police uniform orders for local production using at least 60 percent Cameroonian cotton creates a captive institutional market where *friperie* cannot compete. [R07] [S0803] [S0804]

To synthesise how these variables compare across Cameroon's three apparel supply channels, **Exhibit 40**, p. 141 contrasts imported *friperie*, Asian contraband and GFT's circular CMT model.

EXHIBIT 40 / COMPARATIVE CHANNEL SPECIFICATION

GFT's domestic circular cotton model outperforms imported friperie and Asian contraband across provenance, durability and municipal waste impact

Evaluation criterion	Imported second-hand friperie	Asian synthetic contraband	GFT domestic circular CMT
Cameroon annual volume / scale	61,221 tonnes in 2023 (XAF 30.2bn)	Dominates ~80% Chinese import share	3.0M garments/yr illustrative baseline
Primary fibre composition	Mixed blends (89% synthetic in dumps)	Virgin fossil polyester & polycotton	70-80% SODECOTON + 20-30% recycled cotton
Immediate defect / unsellable rate	20% to 50% of bale items flawed/waste	Uninspected; high seam & shrinkage faults	<1.5% defects after >90% vision inspection
Institutional uniform eligibility	Zero (single random items, worn)	Disqualified under 60% local cotton rule	100% eligible (traceable Cameroon cotton)
End-of-life & factory waste fate	Unfunded municipal landfill & open burning	Unfunded municipal plastic pollution	135-210 t/yr clips baled into rotor yarn
EPR & chain-of-custody status	Zero EU EPR transfer; untraceable HS 6309	Evades customs & EPR eco-contributions	GRS v4 & ISO 59020 mass-balance verified

DERIVED [R06] [R26] [S28] [S30] [S0801] [S0803] Derived engineering and commercial comparison across Cameroon's three primary apparel supply channels, combining sourced baselines (R06, R26, S30, S0801, S0803) with GFT's 3.0 million garment a year CMT operating model and GRS v4 chain-of-custody specifications (S28).

As **Exhibit 40**, p. 141 confirms, the liabilities of imported *friperie* and synthetic contraband become competitive strengths for a measured domestic maker. [R06] [S28] [S0803] By targeting Priority 1 segments (breathable Cameroon cotton traditional and urban ready-to-wear on two-to-four-week replenishment) and Priority 2 segments (institutional, school and corporate uniforms requiring durable, locally sourced batches), GFT insulates the plant from informal price wars. [R26] [S0803] Every garment carries a verified Warp and Signal record: grown by SODECOTON farmers, inspected by com-

puter vision on the cutting table, sewn by formal workers above the statutory wage floor, and backed by a cutting-room mass balance that sends zero textile waste to Cameroon's municipal dumps. [R03] [R14] [R29] [S28]

A circular economy cannot be built by sorting another continent's discarded fast fashion at the municipal dump; it is built by measuring and retaining every gram of virgin and recycled cotton inside the factory that makes the cloth.

CHAPTER SOURCE NOTES

S11 European Environment Agency (EEA). 2023-02-27.

S13 European Environment Agency (EEA Circularity Metrics Lab). 2026-04-14.

S0801 Greenpeace Africa. 2024-09.

S30 Wuppertal Institute for Climate, Environment and Energy. 2024-11.

S0802 Greenpeace Africa. 2023-11-21.

S0805 European Environmental Bureau (EEB) and Environmental Coalition on Standards (ECOS). 2025-05-28.

R06 Cameroon Trade Hub. Publication date unrecorded; inherited source-text check.

S0803 Business in Cameroon. 2025-09-22.

S12 European Environment Agency (EEA). 2024-04-15.

S14 European Environment Agency (via European Circular Economy Stakeholder Platform). 2024-05.

S04 European Commission Directorate-General for Environment. 2025-10-16.

S01 Textile Exchange (via USB Certification). 2024-10-24.

S02 United States Fashion Industry Association (citing Textile Exchange). 2024-10-10.

S29 Pan African Climate Justice Alliance (PACJA). 2025-03-30.

S31 Greenpeace Africa. 2024-10-07.

R11 Business in Cameroon; MMI News. Publication date unrecorded; inherited source-text check.

R01 Business in Cameroon. Publication date unrecorded; inherited source-text check.

R02 Fibre2Fashion; Business in Cameroon. Publication date unrecorded; inherited source-text check.

R03 SODECOTON. Publication date unrecorded; inherited source-text check.

R05 Ecofin Agency. Publication date unrecorded; inherited source-text check.

R04 Financial Fortune Media. Publication date unrecorded; inherited source-text check.

R07 Ecofin Agency. Publication date unrecorded; inherited source-text check.

S0804 Business in Cameroon. 2025-07-31.

R12 Business in Cameroon. Publication date unrecorded; inherited source-text check.

R13 Business in Cameroon; MMI News. Publication date unrecorded; inherited source-text check.

R32 Wise; XE. Publication date unrecorded; inherited source-text check.

S20 European Commission and Refashion. 2021-11.

S26 University of Groningen. 2026-04-22.

S35 VTT Technical Research Centre of Finland and MDPI Textiles. 2026-07-31.

S34 National Library of Medicine (PubMed). 2026.

S28 TraceWeave. 2026-07-27.

S24 United Nations Industrial Development Organization (UNIDO). 2023-11.

R08 Business in Cameroon. Publication date unrecorded; inherited source-text check.

R09 Ecofin Agency. Publication date unrecorded; inherited source-text check.

R10 Ecofin Agency. Publication date unrecorded; inherited source-text check.

S10 Fashion for Good and Reverse Resources. 2024-06.

S21 World Resources Forum. 2024-11.

R14 WageIndicator. Publication date unrecorded; inherited source-text check.

R16 WageIndicator. Publication date unrecorded; inherited source-text check.

S39 International Organization for Standardization (ISO). 2024-05.

S40 International Organization for Standardization (ISO). 2024-05.

S05 European Parliament. 2025-10.

S06 EURATEX (European Apparel and Textile Confederation). 2025-01.

S22 Refashion. 2026-01.

S0807 Secretariat of the Basel Convention. 2025-05.

S0806 Republic of Cameroon (via FAOLEX). 1996-08-05.

S15 United Nations Environment Programme (via World Trade Organization TESSD). 2023-06.

R26 Statista. Publication date unrecorded; inherited source-text check.

R27 McKinsey, The State of Fashion 2025. Publication date unrecorded; inherited source-text check.

R24 Mordor Intelligence. Publication date unrecorded; inherited source-text check.

R18 Congressional Research Service IF10149; AGOA (Wikipedia). Publication date unrecorded; inherited source-text check.

R25 Market.us. Publication date unrecorded; inherited source-text check.

R23 MacMap; AfCFTA. Publication date unrecorded; inherited source-text check.

R29 MDPI; industry inspection literature. Publication date unrecorded; inherited source-text check.

GREEN FUTURE TECH
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09

European Extended Producer Responsibility and eco-modulated fees rewrite export specifications

Separate textile collection has been mandatory since January 2025, the revised Waste Framework Directive has been in force since October 2025, and Member States must establish textile EPR schemes by April 2028. Eco-modulated fees turn garment durability, recyclability and evidence into direct financial variables. [S04] [S12] [S0901]

CHAPTER 09
DECISION TEST

Separate textile collection has been mandatory since January 2025, the revised Waste Framework Directive has been in force since October 2025, and Member States must establish textile EPR schemes by April 2028. Eco-modulated fees turn garment durability, recyclability and evidence into direct financial variables. [S04] [S12] [S0901]

European Extended Producer Responsibility (EPR) changes the export specification, not by taxing every African factory directly, but by making the producer finance collection, sorting, reuse preparation, recycling and disposal for products first placed on the European Union market. [S0901] The revised Waste Framework Directive entered into force on 16 October 2025 and requires national schemes by 17 April 2028, with a later application date for micro-enterprises. [S04] [S0901] Fees must reflect product weight and, where appropriate, quantity, and must be modulated against relevant ecodesign criteria. [S0901] For a Cameroon cotton-to-garment supplier, the practical answer is therefore precise: engineer each product reference for durability and recycling, retain evidence at batch level, and identify who is legally the producer in each sales channel. Do not assume that recycled content automatically earns a rebate. France's current Refashion rules explicitly exclude production offcuts from their recycled-material bonus, and the Global Recycled Standard (GRS) is not on their environmental-certification bonus list. [S0902] Circular factory economics and EPR eligibility must be calculated separately.

9.1

Europe's waste baseline explains why collection alone cannot carry the system

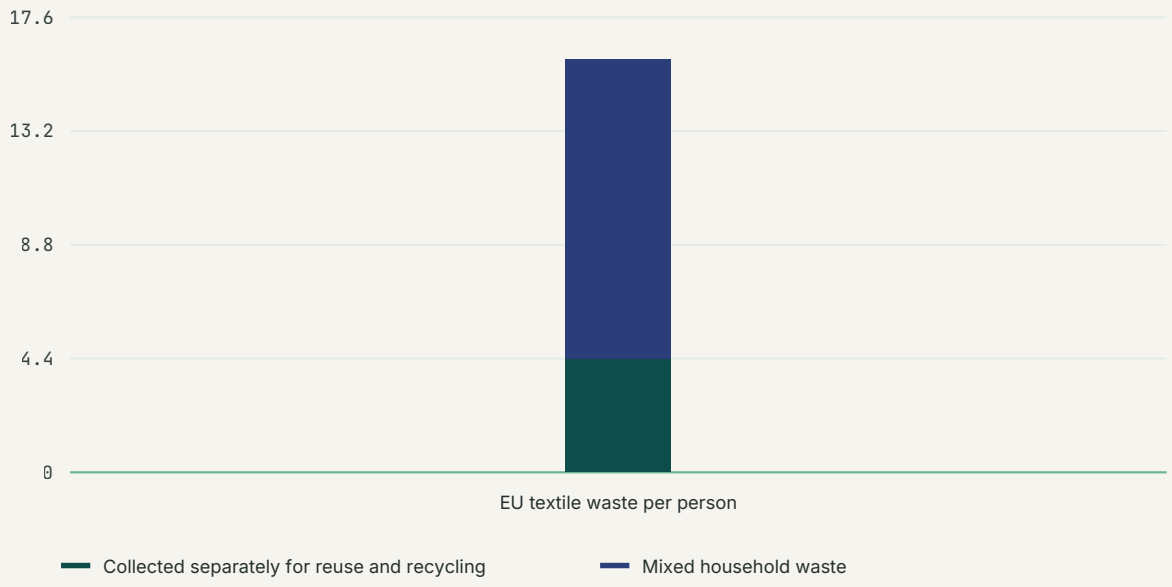
The European Environment Agency (EEA) estimates that the European Union generated 6.95 million tonnes of textile waste in 2020, approximately 16 kilograms per person. [S12] Of that per-capita total, 4.4 kilograms were collected separately for reuse and recycling, while 11.6 kilograms entered mixed household waste. [S12] GFT's arithmetic gives a separately collected share of 27.5 percent (`4.4 / 16 x 100`) and a mixed-waste share of 72.5 percent (`11.6 / 16 x 100`). [S12] Post-consumer clothing and household textiles represented 82 percent of the total, with the remainder arising from manufacturing and unsold products. [S12]

These figures describe a 2020 baseline, not a current recycling-rate claim for 2026. The EEA warns that Member States used different collection systems and interpretations of waste categories, while voluntary reporting for reusable textiles created gaps. [S12] The total is therefore useful for sizing the policy problem, but not for pretending that every tonne was measured on a common boundary. An exporter should use it to understand why Europe is funding a new collection and treatment system, not as a benchmark for its own factory performance.

The composition of that baseline is shown in **Exhibit 41**, p. 146.

EXHIBIT 41 / KILOGRAMS PER PERSON IN 2020

Mixed household rubbish received 11.6 of every 16 kilograms of EU textile waste per person in 2020



SOURCED [S12] Sourced EEA 2020 baseline. Separately collected 4.4 kg plus mixed household waste 11.6 kg equals approximately 16 kg per person. GFT arithmetic: separate share 4.4/16 = 27.5%; mixed share 11.6/16 = 72.5%. The 6.95 million tonne EU total and the 82% post-consumer share are contextual and are not plotted.

The policy problem is not simply low collection. In 2020, 1.95 million tonnes were collected in the EU while 1.41 million tonnes were treated there, excluding textiles in mixed waste in both cases. [S12] The EEA identifies exports as the likely explanation for much of the difference and cautions that collection can rise without a corresponding increase in European reuse or fibre-to-fibre recycling. [S12] This distinction matters commercially. A collection container creates a supply obligation; it does not create a recycling plant, a durable garment or a verified secondary raw material.

9.2 MANDATORY COLLECTION INCREASES THE NEED FOR SORTING DISCIPLINE AND FINANCE

Since 1 January 2025, the Waste Framework Directive has required Member States to establish separate collection systems for used textiles. [S12] The EEA expected capture rates to rise but warned that the average quality of collected items could fall, reducing reuse opportunities and potentially increasing exports, incineration or landfill if capacity did not expand. [S12] EPR supplies the funding mechanism for the missing operating system. Producers must cover collection, transport, sorting, preparation for reuse, recycling, other recovery and disposal, together with specified surveys, information, reporting and research costs. [S0901]

The revised directive also closes an important classification gap. Separately collected textiles are generally waste upon collection, apart from items handed directly to a reuse operator or social economy entity and professionally assessed as fit for reuse at the collection point. [S0901] Professional shipments declared fit for direct reuse must carry evidence of prior sorting or assessment, bale records and a declaration that

none of the consignment is waste. [S0901] Collection policy thus reaches beyond European bins into the documentary quality of exported bales discussed in the preceding chapter.

9.3

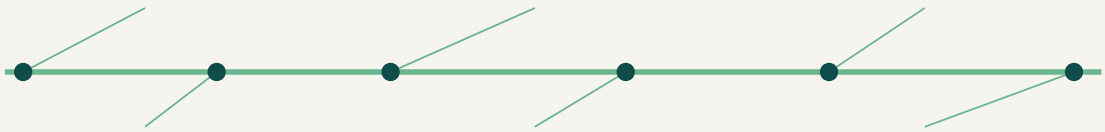
The directive establishes a dated compliance sequence, not one uniform European tariff

Directive (EU) 2025/1892 entered into force on 16 October 2025. [S04] Member States have 20 months to transpose it and 30 months to establish textile and footwear EPR schemes, producing deadlines of 17 June 2027 and 17 April 2028 respectively. [S04] [S0901] Micro-enterprises receive an additional year, to 17 April 2029, while enterprises employing fewer than 10 people and remaining within the Directive's EUR 2 million turnover and balance-sheet thresholds receive a reduced annual reporting request through their producer responsibility organisation. [S0901] These are distinct legal events. Entry into force did not instantly create an identical fee in every Member State.

The sequence is set out in **Exhibit 42**, p. 147.

EXHIBIT 42 / CALENDAR YEAR, FRACTIONAL POSITIONS FOR VISUAL SEQUENCE

Textile EPR moves from collection in 2025 to universal Member State schemes by April 2028



2,025
1 Jan 2025
Separate textile collection required across Member States.

2.03e+03
16 Oct 2025
Revised Waste Framework Directive enters into force.

2.03e+03
1 Jul 2026
Refashion recyclability penalty rates double for second-half declarations.

2.03e+03
17 Jun 2027
National transposition deadline.

2.03e+03
17 Apr 2028
Textile and footwear EPR schemes established in every Member State.

2.03e+03
17 Apr 2029
Rules extend to micro-enterprises after the additional year.

DERIVED [S04] [S12] [S0901] [S0902] Exact dates in labels govern. Derived plotting coordinates use year + day-of-year/days-in-year, rounded to two decimals, with 1 January at the year origin: 1 January 2025 = 2025.00; 16 October 2025 = 2025.79; 1 July 2026 = 2026.50; 17 June 2027 = 2027.46; 17 April 2028 = 2028.29; 17 April 2029 = 2029.29. The Refashion penalty change is national, not an EU-wide fee event.

The timeline also shows why a supplier must read national rules rather than treat France as a preview of every European fee. Where a scheme already existed on 16 October 2025, the Directive attaches cost responsibility to covered products first made available from that date. [S0901] Elsewhere, the starting point is national implementation or, at the latest, 17 April 2028. [S0901] France's second-half 2026 penalty increase belongs to Refashion's national schedule; it is not a European Commission rate change. [S0902]

9.4 THE OBLIGATED ACTOR IS DETERMINED BY THE ROUTE TO MARKET

Article 22a attaches responsibility to producers making Annex IVc textile, textile-related or footwear products available on a Member State market for the first time. [S0901] Producers must entrust a producer responsibility organisation, register in each Member State where they first make covered products available, and may place those products on that market only when the producer or its authorised representative is registered. [S0901] The application includes product Combined Nomenclature codes, organisational identifiers and the producer responsibility mandate. [S0901]

This does not mean that every Cameroon cut-make-trim factory automatically becomes the EPR producer for a European brand's order. The sales structure determines who first places the product on the relevant market. A brand importing and selling under its own name may carry the obligation, while a non-European seller offering directly to European end users can be brought into scope. [S0901] The Directive expressly addresses producers outside the EU, distance sales and online platforms. [S0901] Platforms must obtain the seller's registration number in the consumer's Member State and a self-certification of compliance before allowing the relevant distance contracts. [S0901]

Authorised-representative rules require equal care. A producer established in another Member State must appoint a representative in the destination Member State; a Member State may impose the same requirement on a third-country producer. [S0901] A producer responsibility organisation may perform that role by written mandate where permitted. [S0901] The contractual checklist for a Cameroon exporter must therefore record the importer of record, brand owner, seller to the end user, country of first placement and party responsible for registration. An FOB description alone does not answer that legal question.

9.5 FEES FUND SPECIFIED SERVICES UNDER COMMON DESIGN PRINCIPLES

The Directive requires contributions to be based on weight and, where appropriate, quantity. [S0901] They must account for producer responsibility organisation revenues from reuse, preparation for reuse and secondary raw materials, treat producers equally regardless of origin or size, and avoid disproportionate burdens on small volumes. [S0901] Covered costs cannot exceed what is necessary to provide the specified services efficiently and must be set transparently. [S0901]

Eco-modulation must use the ecodesign requirements and measurement methods adopted under Regulation (EU) 2024/1781 that are most relevant to waste prevention and treatment in line with the waste hierarchy, or other harmonised Union sustainability criteria where adopted. [S0901] Member States may additionally address fast-fashion and ultra-fast-fashion practices through producer-level criteria, includ-

ing product life span, useful life beyond the first user and contribution to closing material loops. [S0901] The Commission may harmonise modulation criteria through implementing acts, but those acts do not determine precise contribution levels. [S0901]

The result is a common direction with national price schedules. A supplier can prepare common physical and documentary attributes, but it cannot quote one universal European EPR fee per garment. It must maintain a country-and-scheme rate table, date every rate, and separate legal obligations from commercial assumptions about who ultimately bears the cost.

9.6

Eco-modulation moves circular design from a claim into a cash calculation

A conventional purchase specification defines dimensions, appearance, composition, workmanship, packing and delivery. EPR adds a second financial reading of the same bill of materials. Fibre and trim choices can alter recyclability. Seam, fabric and colour performance can substantiate durability. Product weight and units placed on the market establish the declaration base. Evidence determines whether a producer can claim a bonus or must accept a penalty. [S0901] [S0902]

This mechanism does not make every durable or recycled garment cheaper to produce. Testing, certification, data administration and sometimes more demanding materials have their own costs. The producer's decision equation is therefore wider than the eco-fee: compare base contributions, penalties, testing and certification expenditure, administrative effort and validated bonuses, then assess who shares any benefit under the supply contract. A factory should not promise a buyer a net saving before those entries are measured.

Three distinctions prevent common errors:

1. **A fee is not a tax on factory turnover.** It attaches to covered products placed on a particular market under the applicable scheme, with national rules determining the schedule. [S0901]
2. **A bonus is not automatic proof of commercial profit.** Refashion pays some bonuses per item or per tonne of eligible recycled input, and eligibility depends on documents and subsequent volume declarations. [S22] [S0902]
3. **A recycling claim is not the same as EPR eligibility.** GRS can certify recycled content and chain of custody for qualifying pre-consumer material, while a national EPR scheme can apply a narrower bonus definition. [S0902] [S0905]

For the export specification, the useful response is a controlled evidence record per product reference. It should connect style, colour and size identifiers to garment weight, composition, trims, test reports, certification documents, production batches and market declarations. The physical garment remains the warp; the evidence record is the weft that allows a buyer to calculate the financial consequence.

9.7

Refashion rewards tested durability and eligible inputs, but penalties cancel every bonus

France provides the clearest operating example because Refashion publishes both the base declaration scale and the eco-modulation method. Its 2026 system contains three optional bonuses, for physical durability, environmental certification and incorporation of recycled raw materials, plus mandatory recyclability penalties. [S22] [S0902] Bonuses can be combined when separate registrations and supporting documents establish eligibility. A product subject to a penalty cannot receive any bonus, and the two penalty types can accumulate on the same product. [S0902]

9.8 DURABILITY REQUIRES A PASSED TEST PROTOCOL, NOT A MARKETING ADJECTIVE

The durability bonus uses a reference amount of EUR 0.70 or EUR 0.07 per item, depending on volumes placed on the market, multiplied by a factor for one of 11 product categories. [S22] [S0902] This is not a flat EUR 0.70 payment for every garment. The category factor, validated reference and eligible volume all matter. Refashion's worked example applies the schedule to 215,000 qualifying women's tops and calculates EUR 78,050: `100,000 x EUR 0.70 + 115,000 x EUR 0.07`. [S0902]

The evidence threshold is more important than the arithmetic. Products must meet every applicable threshold in the product-specific test protocol. Tests must be conducted by an ISO 17025 accredited laboratory, with a 2026 exception accepting at least 60 percent accredited test coverage across the required tests for a product family. [S0902] Where raw-material tests are permitted, those samples and the finished product must go to the same laboratory at the same time and produce a single report. [S0902] For 2026 declarations, newly submitted supporting documents must be dated 2025 or 2026 and are valid only for products placed on the market in 2026. [S0902]

A factory quality plan should therefore begin with Refashion's current product-specific test matrix, not a generic internal durability score. Dimensional stability, pilling, strength, seam performance or colourfastness matter only insofar as the exact required methods and thresholds are met. The quality lead should preserve the tested reference, colour set, batch relationship, laboratory scope and report date. A later bulk order cannot borrow credibility from an unrelated sample.

9.9 ENVIRONMENTAL CERTIFICATION APPLIES TO THE FINISHED PRODUCT AND ONLY TO LISTED LABELS

Refashion's environmental-certification bonus is EUR 0.30 or EUR 0.03 per item, depending on product category and volume. [S22] [S0902] The current guide lists eight eligible labels, including GOTS, the European Ecolabel, Fairtrade Textile and Oeko-tex Made in Green. [S0902] Multiple eligible labels on one reference do not multiply the bonus. [S0902] Certification of a raw material alone is insufficient: the finished product must be certified, carry the required label and have documents naming the exact references concerned. [S0902]

GRS is absent from that list. This does not diminish GRS's function as a chain-of-custody standard. It means a supplier must not describe GRS certification as though it automatically generates Refashion's environmental-certification bonus. [S0902] [S0905] GOTS and GRS answer different questions, use different criteria and require separate commercial and technical assessment.

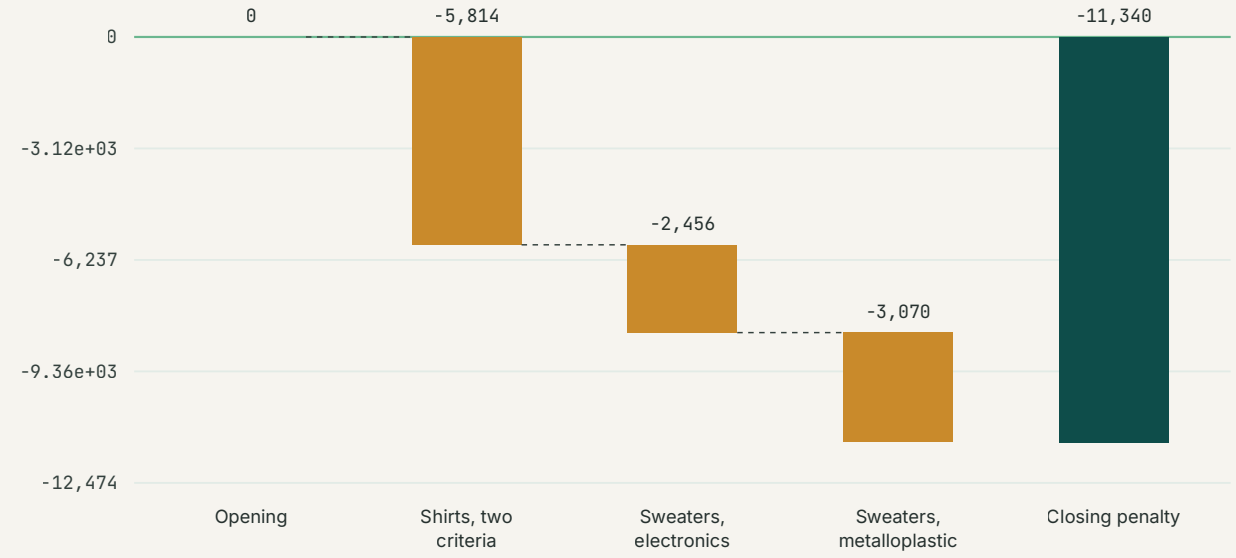
9.10 RECYCLABILITY PENALTIES CREATE A DESIGN VETO BEFORE BONUSES ARE CONSIDERED

The two current penalty triggers are metalloplastic fibres or wires and electrical or electronic components, subject to specified exclusions. [S22] [S0902] Battery-free components used only to communicate traceability or composition information, including an RFID example, are excluded from the electronic-component penalty. [S0902] For metalloplastic content there is no minimum percentage threshold, and internal disruptors such as all-over embroidery or knitting threads can trigger the penalty even when external accessories do not. [S0902]

The June 2026 guide distinguishes two pricing periods. Penalty rates rise in proportion to eco-fees for January to June, then double for July to December 2026. [S0902] **Exhibit 43**, p. 151 applies the published second-half unit rates to an illustrative set of references. The volumes are assumptions, not an observed Refashion invoice.

EXHIBIT 43 / EUR, ILLUSTRATIVE SECOND-HALF 2026 PENALTY MODEL

Three illustrative penalised references generate EUR 11,340 before counting lost bonuses



ILLUSTRATIVE [S0902] Illustrative arithmetic using Refashion's published July to December 2026 rates. Assumptions: 90,000 shirts at EUR 0.0323 per item per criterion with two criteria; 40,000 sweaters with electronics at EUR 0.0614; 50,000 sweaters with metalloplastic fibres at EUR 0.0614. Calculation: 90,000 × 0.0323 × 2 = 5,814; 40,000 × 0.0614 = 2,456; 50,000 × 0.0614 = 3,070; total = 11,340. Base eco-fees, administration and the additional loss of all bonuses are excluded.

The waterfall shows why penalty avoidance belongs at design freeze. Removing an electronic novelty or metalloplastic thread after bulk production cannot recover the development cost already incurred, while the same reference remains ineligible for

every bonus. [S0902] The illustration also understates the full commercial effect because it excludes the value of forfeited durability or certification bonuses and the base eco-fee itself.

9.11 THE DECLARATION CALENDAR MAKES EVIDENCE A PRODUCTION ROUTINE

Refashion's June 2026 procedure starts with registration of references and supporting documents during 2026, continues with declarations and checks of 2026 quantities in early 2027, and ends with bonus payments or penalty invoices from the second quarter of 2027. [S0902] Registrations allowing corrections run to 30 November 2026, with a narrower correction and documentation window to 31 December and a specific exception for late GOTS Transaction Certificates. [S0902] Refashion may examine the last five declarations during targeted checks or independent audit. [S0902]

The base declaration has its own classification discipline. A detailed declaration is mandatory for marketers declaring products eligible for eco-modulation and is available at any volume. [S0903] The simplified scale is limited to marketers declaring no eco-modulated products and fewer than 5,000 items a year. [S0903] [S0904] Its higher per-item rate explicitly covers the absence of eco-modulation declarations and traceability. [S0904] The administrative lesson is direct: product classification and evidence are not optional back-office polish. They influence the declaration route and the amount paid.

9.12

France's recycled-material bonus does not reward factory offcuts

The most consequential eligibility rule for this paper is a negative one. Refashion states that its bonus for incorporating recycled raw materials will not be granted when the material comes from production offcuts or unsold items. [S0902] A garment containing mechanically recycled cotton from a Cameroon cutting room can have a genuine resource-efficiency benefit and may qualify for GRS certification, yet still fail this particular French bonus test. [S0902] [S0905] The two assessments must never be conflated.

The positive route is also tightly bounded. The 2026 schedule offers EUR 1,000 per tonne for eligible recycled material from post-consumer clothing, household linen and footwear waste collected or funded by an approved eco-organisation, and EUR 500 per tonne for qualifying open-loop recycled material, excluding food-grade plastic resin. [S22] Sorting, preparation, recycling and incorporation must meet traceability and local-proximity rules. The relevant stages generally fall within 1,500 kilometres of the collection point, or within 1,000 kilometres of a French sorting centre or the specified French barycentre when collection-point traceability is unavailable. [S0902] Facilities must also apply measures equivalent to French ICPE environmental requirements. [S0902]

For the factory-offcut loop in this paper, the production-offcut exclusion is decisive. A different Cameroon waste stream would still need approved collection or funding, traceability, proximity measured from its actual collection point or the relevant French reference point, and ICPE-equivalent measures. [S0902] Cameroon origin alone neither

passes nor fails every part of that test. The commercial recommendation is not to abandon the loop. It is to value it for avoided virgin input, waste recovery, product demand and chain-of-custody evidence, while booking zero Refashion recycled-material bonus unless the competent scheme confirms otherwise.

GRS uses a different boundary. Version 4.0 applies to products with at least 20 per-cent recycled content, requires certification at each production stage from recycling to the last business-to-business seller, and requires valid Transaction Certificates for recycled materials entering the supply chain. [S0905] It records pre-consumer and post-consumer shares separately by batch and requires mass-balance treatment where recycled and virgin inputs can have different process losses. [S0905] These are valuable controls for a Cameroon clip-to-yarn loop. They do not override Refashion's narrower eligibility rules or create a legal entitlement to a payment.

WARNING

Do not write “GRS certified, therefore EPR bonus eligible” into a buyer quotation. Record two fields instead: **recycled-content verification status** and **scheme-specific fee eligibility**. The first can be supported by GRS evidence; the second requires the dated rules of the relevant producer responsibility organisation. [S0902] [S0905]

WORKED EXAMPLE: DECLARATION CLASSIFICATION AND RECYCLED-INPUT ARITHMETIC

This illustrative case separates three calculations that are often compressed into one unsupported “EPR saving”.

Base declaration route. Assume a marketer places 4,000 men's T-shirts on the French market in 2026 and claims no eco-modulation, so the simplified route is available because volume is below 5,000 items. [S0903] [S0904] At the detailed rate of EUR 0.0396 per item, the product contribution is `4,000 x 0.0396 = EUR 158.40`. [S0904] At the simplified clothing rate of EUR 0.5799, it is `4,000 x 0.5799 = EUR 2,319.60`. [S0904] The illustrative difference is EUR 2,161.20, before administrative charges and other levies. This is not a bonus; it shows the cost of weak classification and traceability under Refashion's published schedules.

Eligible recycled input. Reproduce Refashion's documented example as a check on units. For 60,000 garments weighing 0.15 kilograms each with 50 percent eligible clothing, household linen and footwear waste input, recycled mass is `60,000 x 0.00015 tonnes x 50 percent = 4.5 tonnes`, producing `4.5 x EUR 1,000 = EUR 4,500`. [S0902] For another 40,000 garments of the same weight with 30 percent qualifying open-loop input, mass is `40,000 x 0.00015 x 30 percent = 1.8 tonnes`, producing `1.8 x EUR 500 = EUR 900`. [S0902] Total illustrative bonus: EUR 5,400. These inputs satisfy the scheme's waste-origin conditions; factory offcuts would not. [S0902]

Supplier benefit. No supplier saving is recognised until the buyer contract states whether and how a validated bonus or avoided penalty is shared. The producer's invoice and the factory's conversion price are separate ledgers. A supplier can offer evidence and design work, but cannot unilaterally book the producer's EPR cash effect as its own margin.

9.13

African suppliers capture value through evidence, not an assumed fee transfer

European EPR reaches a Cameroon manufacturer through two distinct channels. The first is contractual: a European producer asks its supplier for tested durability, controlled composition, recycled-content custody and reference-level data so that it can make its own declaration. The second is direct: the African business itself sells covered products to European end users and becomes responsible under the applicable market and national rules. [S0901] The first channel changes the purchase specification. The second can create a legal obligation for the exporter itself.

GFT's Cameroon textile programme begins with domestic and CEMAC commercial discipline, so European readiness should be built as an option rather than presented as current export revenue. The lowest-cost preparation is common to both channels: a stable product-reference system, an approved bill of materials, batch-level quality records and a controlled evidence library. These are also ordinary good manufacturing records. They do not require a claim that GFT or any supplier already holds a certification.

9.14 PURCHASE-ORDER CLAUSES MUST ALLOCATE THE WORK BEFORE THE FEE OUTCOME IS KNOWN

An export-ready purchase order should identify the producer-responsibility party and the destination scheme before materials are approved. It should then state which party selects the test protocol, commissions the laboratory, pays for certification, registers product references and submits market volumes. Without those assignments, a supplier can complete useful work and still fail to produce a declaration accepted by the buyer's producer responsibility organisation. [S0902]

The commercial clause should address five separate outcomes:

- **Base contributions:** identify whether they sit inside the product price, are charged separately, or are absorbed by the producer.
- **Evidence expenditure:** assign laboratory, certification, translation, registration and data-preparation costs, including retesting when a reference changes.
- **Validated bonuses:** state whether the producer retains them, shares them through a price adjustment, or uses them to fund a wider circular-supply programme.
- **Penalties and rejected evidence:** allocate responsibility according to cause, distinguishing an unauthorised supplier material substitution from an incorrect buyer declaration.
- **Rule changes:** require the parties to refresh the applicable national schedule and agree a change-control process rather than freezing an old rate into a long-term price.

This allocation prevents a subtle quotation error. A factory may offer a lower conversion price in expectation of an EPR bonus that belongs legally to its buyer, while also paying for the tests needed to obtain it. Conversely, a buyer may demand premium

evidence without accepting any of its cost. Neither arrangement is necessarily unfair, but both must be explicit. The purchase order should value the evidence service separately from the garment so that both parties can inspect the transaction.

9.15 REFERENCE-LEVEL ECONOMICS REPLACE GENERIC CLAIMS ABOUT APPAREL MARGINS

A meaningful EPR business case is calculated per product reference and destination market. The same cotton garment can have different outcomes if its weight, target customer category, test eligibility, material origin or declaration route changes. [S0902] [S0904] A single percentage supposedly representing “the EPR benefit” across a whole collection would hide those differences and could overstate the value of a small bonus on a low-volume style.

The reference model should begin with actual units and garment weight, apply the current scheme schedule, and retain a zero where eligibility is absent. It should then show sensitivity to variables that management can genuinely change: passing or failing a durability threshold, removing a penalty trigger, improving document completeness, or changing the volume eligible for a validated bonus. Costs should include sample destruction during testing, laboratory lead time, certificate administration and the personnel time needed to reconcile references. These are operational inputs to be measured by the venture, not universal benchmarks.

For a Cameroon supplier serving domestic and CEMAC customers first, the same model has a second use. It reveals which European-readiness expenditures also improve the core business. Better seam and fabric testing can reduce returns; disciplined bills of materials can prevent unauthorised substitutions; batch reconciliation can expose stock errors. Those benefits should be evaluated independently of any future European order. European EPR readiness then becomes a controlled extension of factory discipline rather than a speculative certification programme.

9.16 DATA OWNERSHIP MUST SURVIVE SUPPLIER AND PERSONNEL CHANGES

Evidence should reside in a controlled repository with immutable originals, dated revisions and a link to every affected product reference. A revised laboratory report must not silently overwrite the earlier version. A replacement sewing thread, label or electronic component must trigger a new eligibility review. A change of recycling or preparation location must trigger a fresh proximity assessment where the French recycled-material route is being considered. [S0902]

Access control matters as much as preservation. Suppliers should share the documents required by the buyer and auditor without exposing unrelated formulations, commercially sensitive costing or confidential customer information. The Directive itself requires producer responsibility organisations to protect proprietary information and information attributable to individual producers. [S0901] A clean evidence architecture therefore supports both auditability and commercial confidentiality.

GFT NOTE

Create one EPR evidence pack per product reference before bulk production. Include style, colour and size identifiers; garment weight; fibre, thread, label and trim composition; the durability test plan and ISO 17025 report; applicable Scope and Transaction Certificates; recycled-material origin and process locations; and a country-specific fee-eligibility assessment. [S0902] [S0905] Mark production-offcut input as **ineligible for Refashion's 2026 recycled-material bonus** unless the rule changes. Screen metalloplastic fibres and electronic components at design review, because one penalty removes every bonus. [S0902] This is a specification-control recommendation, not a claim of completed certification.

The pack should also distinguish evidence ownership. The quality lead owns test reports and batch relationships. Materials control owns composition and supplier certificates. The commercial lead owns market volumes and the producer-responsibility clause. Finance owns rate dates and calculations. A certificate without the matching product reference, or a test report without the relevant batch relationship, does not make a usable declaration pack. [S0902]

9.17

A controlled record turns regulatory complexity into a repeatable export routine

The operational mapping in **Exhibit 44**, p. 157 separates legal and scheme requirements from GFT's recommended factory controls. It is an implementation synthesis, not a statement that every record is mandated in the same form by every Member State.

EXHIBIT 44 / GFT OPERATIONAL SYNTHESIS

One controlled evidence map connects EPR criteria to factory records and commercial decisions

Decision criterion	Controlled record	Factory control	Error prevented
Market and producer	Country, channel, importer and registration mandate	Name the obligated party in the contract	Assuming every supplier is the producer
Declaration base	Product code, weight and units by reference	Reconcile dispatch to market declaration	Wrong volume or classification
Durability bonus	Current protocol and laboratory report	Test the relevant product and retain batch links	Using a generic durability claim
Environmental bonus	Finished-product certificate and exact references	Verify label eligibility and document validity	Treating GRS as a listed Refashion label
Recycled-material bonus	Waste origin, process locations, mass and custody	Test scheme eligibility before valuation	Claiming a bonus for production offcuts
Recyclability penalty	Metalloplastic and electronic component review	Screen internal disruptors at design freeze	Losing every bonus and paying a penalty

DERIVED [S0901] [S0902] [S0903] [S0905] Derived operational mapping from the Directive, Refashion's 2026 procedures and GRS v4.0. Record formats and role assignments are GFT recommendations, not prescribed EU forms. National scheme confirmation remains necessary before declaration or quotation.

The mapping makes the management cadence clear. At product-development gate, engineering confirms composition and test requirements. Before bulk cutting, quality confirms that samples, reports and references agree. At shipment, materials control reconciles weights and custody documents. Before the buyer's declaration, commercial and finance teams verify the applicable national schedule and the contractual treatment of any bonus or penalty. The record is reviewed when a material, reference, process location or scheme rule changes, not merely once a year.

> **METHOD**
>
> Use a five-line calculation sheet for each market and reference: **base contribution + recyclability penalty + testing and certification cost + administration - validated bonus = net producer EPR cost**. Then add a separate supplier line: **buyer-shared benefit - supplier evidence and design cost = supplier commercial effect**. Keep both sheets dated and sourced. Never substitute a sector-average fee or an assumed buyer pass-through for these entries.

Nothing in this chapter is legal, investment or tax advice. National transposition, scheme rules and product classifications must be checked for the actual transaction, and the current French documents themselves reserve the possibility of later public-

authority changes. [S0902] The durable operating principle survives those changes: design the product so its afterlife is manageable, and preserve the evidence so its financial treatment can be verified.

The export specification now includes the garment's afterlife, but only eligible evidence earns the fee advantage.

CHAPTER SOURCE NOTES

S04 European Commission Directorate-General for Environment. 2025-10-16.

S12 European Environment Agency (EEA). 2024-05-21.

S0901 European Union, EUR-Lex. 2025-09-10.

S0902 Refashion. 2026-06-03.

S22 Refashion. 2026-06-03.

S0905 Textile Exchange. 2017-07-01.

S0903 Refashion. 2026-01.

S0904 Refashion. 2025-11.

10

Bans on destroying unsold apparel convert demand-forecasting accuracy into a compliance mandate

Regulation (EU) 2024/1781 bans the destruction of unsold apparel and mandates public disclosure of discarded stock, making machine-learning demand forecasting and computer-vision quality control the primary defences against overproduction waste. [S03] [R27] [R29]

CHAPTER 10
DECISION TEST

Regulation (EU) 2024/1781 bans the destruction of unsold apparel and mandates public disclosure of discarded stock, making machine-learning demand forecasting and computer-vision quality control the primary defences against overproduction waste. [S03] [R27] [R29]

Circularity in the apparel sector fails when a factory sorts its cutting-room offcuts with discipline only to manufacture thousands of finished garments that no customer buys and that law now forbids destroying. [S03] [S1002] Under the European Union Ecodesign for Sustainable Products Regulation, Regulation (EU) 2024/1781, published on 28 June 2024, the destruction of unsold consumer apparel, clothing accessories and footwear is directly prohibited for large enterprises from 19 July 2026 and for medium-sized enterprises from 19 July 2030, reinforced by mandatory annual public disclosures of discarded stock volumes and waste-treatment routes. [S03] [S1002] [S1003] For a greenfield cotton-to-garment manufacturer in Cameroon sized at an illustrative nameplate capacity of 3.0 million garments a year, this regulatory shift converts demand forecasting, near-market production scheduling, computer-vision defect interception and digital 3D sampling from optional merchandising tools into statutory compliance defences. [R27] [R29] [R31] Because destroying a finished garment squanders 100 percent of the agricultural water, ginning power, spinning energy, dyehouse chemicals and sewing labour already invested in the cloth, preventing overproduction and whole-batch quality rejections preserves roughly five times more embodied carbon and water per unit than shredding deadstock after the fact (illustrative lifecycle mass-balance estimate). [S08] [S38] This chapter shows how GFT's Cameroon textile programme unifies its three deliverables (the Feasibility Study, the Performance-Management System Design and the Digital Strategy) to stop unsold inventory at its root while routing unavoidable factory seconds through a verifiable reuse and mechanical recycling hierarchy. [R27] [R29] [S03]

10.1

Overproduction and deadstock destroy finished garments before a consumer ever wears them

Industrial circularity strategies typically focus on two endpoints: pre-consumer cutting clips on the factory floor and post-consumer worn clothing in municipal collection bins. [S10] [S12] Between those boundaries sits a third, highly destructive waste stream: brand-new finished garments, seasonal overruns, cancelled export orders and e-commerce returns that are discarded or incinerated before a single wearer ever uses them. [S14] [S1001] When global fibre output reaches 124 million tonnes in 2023 on a path toward 160 million tonnes by 2030, and when more than US$500 billion in value is lost annually to clothing underutilisation and lack of recycling, manufacturing garments for the furnace or the dump is the sharpest operational failure in the modern apparel economy. [S01] [S02] [S08]

10.2 PRE-CONSUMER MANUFACTURING AND UNSOLD STOCK FORM NEARLY A FIFTH OF EUROPEAN TEXTILE WASTE

Empirical waste accounting by the European Environment Agency (EEA) establishes the physical scale of pre-use apparel losses across European supply chains. [S12] [S14] Out of the estimated 6.95 million tonnes of total textile waste generated across EU Member States in the 2020 baseline year (roughly 16 kilograms per person per year, of which 4.4 kilograms was collected separately and 11.6 kilograms entered mixed household rubbish), post-consumer used clothing and household textiles represented 82 percent of the mass. [S12] [S14] The remaining 18 percent, or roughly

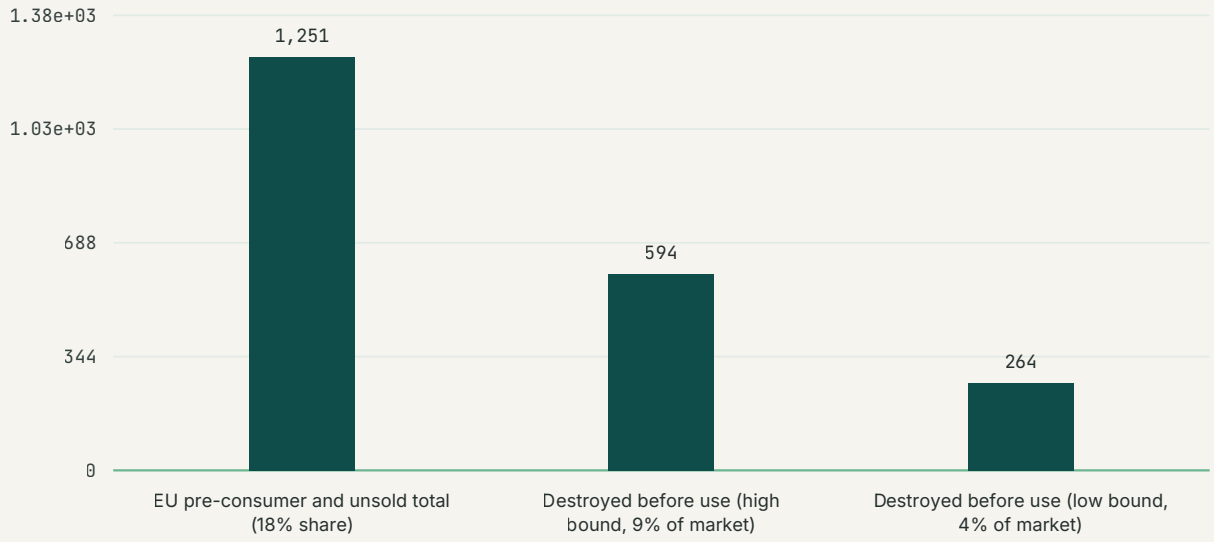
1.25 million tonnes a year by derived arithmetic from the 6.95 million tonne total, originated from pre-consumer manufacturing waste and unsold retail textiles discarded prior to consumer use. [S12] [S14]

In a March 2024 briefing on returned and unsold textiles, the EEA synthesized European research literature to isolate the fate of finished products that never complete a consumer lifecycle. [S1001] Across surveyed retail and brand inventories, an average share of 21 percent of textile products remains unsold at the end of the season, and roughly one fifth of that 21 percent unsold stock is destroyed. [S1001] Combined with destroyed e-commerce returns, the EEA estimates that between 4 and 9 percent of all textile products placed on the European market are destroyed before ever being worn, equal to between 264,000 and 594,000 tonnes of brand-new textiles destroyed every year. [S1001] [S1002] According to the European Commission, manufacturing and destroying this 4 to 9 percent share of unworn textiles generates around 5.6 million tonnes of carbon dioxide equivalent emissions annually, nearly equal to the total net national greenhouse gas emissions of Sweden in 2021. [S1002] National disclosures confirm the scale: in France alone, around EUR 630 million worth of unsold consumer products are destroyed each year, while in Germany nearly 20 million returned items are discarded annually. [S1002]

The composition of European pre-consumer and unsold textile waste is shown in **Exhibit 45**, p. 161, which compares total pre-consumer and unsold waste against the upper and lower bounds of finished textiles destroyed before use. [S12] [S14] [S1001]

EXHIBIT 45 / THOUSAND TONNES PER YEAR IN THE EUROPEAN UNION

Unsold and returned textiles destroyed before use in Europe reach up to 594,000 tonnes a year within a 1.25 million tonne pre-consumer stream



SOURCED [S12] [S14] [S1001] [S1002] Pre-consumer manufacturing and unsold stock equals 18 percent of the 6.95 million tonne EU textile waste baseline (1,251 thousand tonnes by derived arithmetic from S12, S14). Destroyed unsold and returned finished textiles represent 4 percent (264 thousand tonnes) to 9 percent (594 thousand tonnes) of textiles placed on the EU market (S1001, S1002).

While **Exhibit 45**, p. 161 captures waste recorded inside European borders, it cannot measure cancelled orders, late-delivery rejects and specification overruns stranded inside origin-country factories across Asia and Africa before export, nor does it isolate the share of the 1.4 to 1.7 million tonnes of annual European used-textile exports that consists of cleared fast-fashion deadstock shipped to African wholesale markets. [S11] [S13] [S29]

10.3 LONG-LEAD SEASONAL SPECULATION AND E-COMMERCE RETURN MECHANICS DRIVE SYSTEMIC OVERSTOCK

Two commercial mechanisms generate the bulk of unsold finished apparel: speculative long-lead ordering and high-velocity online return loops. [R27] [S1001] In traditional offshore sourcing, retail buyers commit to style, colour and size-ratio orders six to nine months before the selling season opens. [R27] Forecasting SKU-level demand six months ahead without machine-learning support produces systematic error: slow sellers pile up in warehouses as deadstock, while popular items suffer stockouts. [R27]

Simultaneously, online apparel retail has multiplied reverse-logistics waste. [S1001] In the EU, the share of textiles and clothing sold online more than doubled from 5 percent in 2009 to 11 percent in 2020, with 68 percent of internet shoppers ordering clothing, shoes or accessories in 2022. [S1001] Under the 14-day statutory right of withdrawal for distance sales and free-return policies, the average return rate for clothing bought online in Europe reaches 20 percent (one in five garments sold), up to three times higher than in physical stores. [S1001] Because inspecting, steaming, re-tagging and restocking individual returns often costs more than the wholesale margin of low-priced apparel, the EEA estimates that 22 to 43 percent (roughly one third on average) of all returned online clothing is destroyed. [S1001]

10.4 DESTROYING A FINISHED GARMENT FORFEITS ALL UPSTREAM EMBODIED WATER, ENERGY AND LABOUR

Thermodynamically, destroying an unsold finished garment is far worse than generating cutting-room marker offcuts. [S08] [S32] [S38] When a cutting knife trims 15 to 22 percent inter-piece void space around a pattern marker, the offcut has not yet consumed sewing thread, trims, assembly labour, garment washing, pressing, packaging or container freight (derived from cutting-room mass balance). [S32] [S33] By contrast, a finished garment embodies the full cumulative footprint of the textile chain, which ranks fourth highest among EU consumption categories for overall environmental and climate impact and third highest for water and land use. [S38]

Producing a single pair of cotton jeans consumes roughly 7,500 litres of water across cultivation, wet processing and finishing. [S29] Even if an unsold garment is diverted into a mechanical tearing line rather than burned, shredding a brand-new shirt back into shortened 18 to 24 millimetre staple fibres destroys the value of spinning, weaving, dyeing and sewing, recovering raw fibre worth US$0.35 to US$0.85 per kilogram while forfeiting an illustrative US$6.00 to US$15.00 FOB finished garment value (illustrative benchmark from North African secondary fibre markets). [S24] In circularity engineering, the highest-return intervention is preventing deadstock from being cut and sewn in the first place. [S03] [R27]

10.5

Regulation (EU) 2024/1781 prohibits the destruction of unsold consumer apparel and footwear

European legislators responded to the destruction of 264,000 to 594,000 tonnes of unworn textiles a year by replacing voluntary pledges with statutory prohibitions. [S03] [S1001] [S1002] On 28 June 2024, the European Union published Regulation (EU) 2024/1781 (the Ecodesign for Sustainable Products Regulation, or ESPR), establishing a framework for ecodesign requirements, Digital Product Passports, green public procurement and preventing the destruction of unsold consumer products. [S03] Complemented on 16 October 2025 by the revised EU Waste Framework Directive (Directive (EU) 2025/1892), ESPR reshapes inventory governance across all European apparel supply chains. [S03] [S04]

10.6 ARTICLES 23 TO 25 AND THE FEBRUARY 2026 SECONDARY ACTS ESTABLISH DISCLOSURE RULES AND A DIRECT DESTRUCTION BAN

Chapter VI of Regulation (EU) 2024/1781 (Articles 23, 24 and 25, plus Annex VII) sets out a three-tier legal regime for unsold consumer products, operationalised by the Commission Delegated Regulation on derogations and the Commission Implementing Regulation on disclosure formats adopted on 9 February 2026: [S03] [S1002] [S1003]

1. **General duty of prevention (Article 23):** All economic operators must take reasonable measures to prevent the need to destroy unsold consumer products, prioritising stock management, return handling, discounted resale, charitable donation and preparation for reuse. [S03] [S1002] [S1003]
2. **Mandatory public disclosure of discarded stock (Article 24):** Large enterprises (and medium-sized enterprises from 19 July 2030) must disclose annually the number and weight of unsold consumer products discarded, broken down by Combined Nomenclature customs code, the reasons for discarding them, the waste-treatment pathways used (reuse preparation, recycling, energy recovery, disposal), and prevention measures planned. [S03] [S1002] [S1003] Under the February 2026 Implementing Regulation, companies must retain verification records for five years for national inspections. [S1002] [S1003]
3. **Direct prohibition on destroying unsold apparel and footwear (Article 25 and Annex VII):** Regulation (EU) 2024/1781 writes an immediate prohibition into Article 25 and Annex VII forbidding the destruction of unsold consumer apparel, clothing accessories and footwear. [S03] [S1002] This ban entered into application for large enterprises on 19 July 2026 and extends to medium-sized enterprises on 19 July 2030, while small and micro-businesses are exempt. [S1002] [S1003]

10.7 DEROGATIONS REQUIRE DOCUMENTED PROOF OF SAFETY HAZARDS, DAMAGE OR CHARITY REJECTION

Under the Commission Delegated Regulation adopted on 9 February 2026 and applied from 19 July 2026, companies may destroy unsold clothes and shoes only under strict derogations and in accordance with the waste treatment hierarchy (giving priority to recycling over incineration or landfill): [S04] [S1002] [S1003]

- **Unsafe or non-compliant items:** products posing health or safety risks or breaching statutory chemical limits where remediation is unfeasible. [S1003]
- **Physically damaged or contaminated goods:** items damaged in transit, storage or handling beyond repair or refurbishment. [S1003]
- **Counterfeit or intellectual-property-infringing goods:** items barred from sale due to IP infringement where label removal cannot cure the breach. [S1003]
- **Items rejected by charities or donation schemes:** goods offered to vetted charities or social enterprises and formally refused. [S1003]

Operators relying on any exemption must keep documentary proof (such as laboratory test reports, damage logs or signed charity refusal notices) for five years and publish annual reports on discarded volumes, subject to national compliance inspections and fines. [S1003]

10.8 DELEGATED ECODESIGN ACTS AND DIGITAL PRODUCT PASSPORTS LINK FACTORY QUALITY TO MARKET ACCESS

Articles 4 and 5 of Regulation (EU) 2024/1781 also authorise the European Commission to adopt delegated acts setting mandatory product requirements for durability, reliability, reusability, repairability, recycled content and Digital Product Passports (DPPs), applying 18 months after adoption. [S03] [S28] Even though GFT's Phase 1 market plan anchors on Cameroon and CEMAC while Cameroon remains ineligible for US AGOA preferences (terminated 1 January 2020 and still ineligible for 2025), any European buyer or regional distributor subject to ESPR cannot source from a factory that delivers late seasonal overstocks or fails physical quality audits. [R18] [S03] [S1003] If a defective shipment fails audit at port, it must be repaired at high cost or publicly disclosed as destroyed damaged stock. [S1002] [S1003]

10.9

Machine-learning demand forecasting cuts forecast errors by 20 to 50 percent, attacking unsold stock at its root

The structural cure for unsold inventory under Regulation (EU) 2024/1781 is producing only what the market will absorb at the right size ratio, shade and delivery window. [R27] [S03] Legacy factories often produce unmeasured standard styles simply to fill line capacity, a trap illustrated by incumbent CICAM's chronic imbalances and low utilisation (33.7 percent at Garoua, 48.9 percent at CICAM 1 and 10.83 percent at CICAM 2 in July 2023, costing about CFAF 2 billion in 2020). [R12] [R27]

10.10 EMPIRICAL EVIDENCE SHOWS AI AT SCALE CUTS FORECAST ERRORS BY UP TO HALF AND LOWERS INVENTORY COSTS

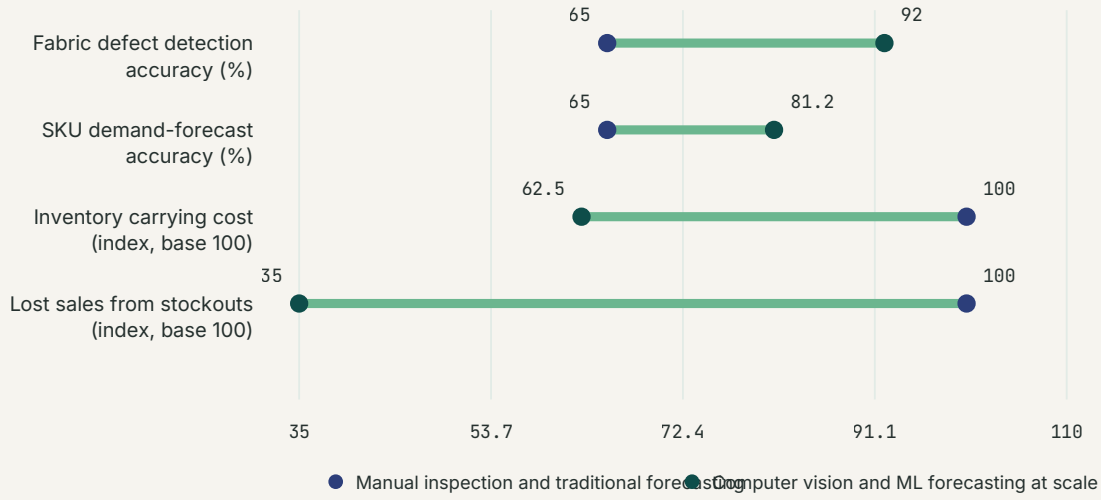
McKinsey's *The State of Fashion 2025* quantifies the operational gains when machine-learning demand forecasting replaces traditional merchandising guesswork: [R27]

- **Demand-forecast errors are cut by 20 to 50 percent**, shrinking the tail of slow-moving SKUs that become deadstock. [R27]
- **Overall forecast accuracy rises by 20 to 30 percent** across seasonal and replenishment lines. [R27]
- **Inventory carrying costs drop by 35 to 40 percent**, freeing working capital trapped in slow-moving stock. [R27]
- **Lost sales from stockouts fall by up to 65 percent**, directing capacity to proven sellers. [R27]
- **Revenue per customer increases by 15 to 25 percent**, supporting a sector operating-profit potential of US$150 billion to US$275 billion over three to five years, with 75 percent of executives prioritising AI. [R27]

The combined shift from pairing machine-learning demand forecasting with computer-vision defect inspection is shown in **Exhibit 46**, p. 165. [R27] [R29]

EXHIBIT 46 / PERCENT PERFORMANCE OR INDEX (BASE 100)

AI demand forecasting and computer-vision inspection shift garment operations from high-waste guesswork to precision production



SOURCED [R27] [R29] Sourced benchmarks from McKinsey State of Fashion 2025 (R27) and MDPI industry inspection literature (R29). Defect detection rises from 60-70% manual midpoint (65%) to >90% computer vision (92%, R29). Forecast accuracy rises 20-30% above an illustrative 65% traditional baseline to 81.25% (R27). Inventory cost index drops 35-40% (to 62.5 midpoint) and lost-sales index drops up to 65% (to 35, R27).

As **Exhibit 46**, p. 165 shows, lifting defect detection from a 65 percent manual midpoint to above 90 percent with computer vision while cutting forecast errors by 20 to 50 percent and inventory costs by 35 to 40 percent eliminates both physical rework scrap and commercial deadstock. [R27] [R29] However, **Exhibit 46**, p. 165 cannot be realised on Day 1 for forecasting without historical order records; achieving these gains requires GFT's cold-start sequencing. [R27]

10.11 GFT'S COLD-START SEQUENCING CAPTURES CLEAN ORDER HISTORY IN PHASE 1 BEFORE SWITCHING ON ML MODELS IN PHASE 2

GFT's Digital Strategy (Deliverable 3) separates AI tools by their data prerequisites. [R27] [R29] Computer-vision defect detection uses pre-trained optical models evaluating live camera feeds and therefore deploys immediately in Phase 1. [R29] Machine-learning demand forecasting requires commercial sales history and cannot run on an empty database. [R27] GFT sequences forecasting across three steps:

1. **Months 1 to 12 (Phase 1 manual data spine):** Every domestic Cameroon and CEMAC purchase order, reorder, sell-through report, style, shade and size ratio is logged in the validated Excel pack (`GFT_Production_Tracking_Templates.xlsx`) from Deliverable 2 (Performance-Management System Design). [R26] Phase 1 production focuses on firm institutional uniform contracts and small-batch replenishment. [R26]
2. **Months 13 to 24 (Phase 2 Tier-1 ML demand forecasting):** Once 12 months of clean order history accumulate in the core data store, the factory switches on Tier-1 ML demand forecasting and Tier-2 inventory optimisation. [R27]
3. **Months 25 to 36 (Phase 3 S&OP integration):** Forecasting links directly to yarn and greige fabric schedules with upstream poles (Camtext SA at Dibamba and Garoua or the SODECOTON-CICAM pole) and to domestic apparel e-commerce signals in Cameroon, where e-commerce revenue is projected to rise at 13.41 percent a year from US$20.32 million in 2023 to US$33.61 million by 2027 as user penetration grows from 18.0 percent to 22.7 percent. [R08] [R09] [R10] [R26] [R27]

> **GFT NOTE**
>
> Do not purchase or activate machine-learning demand-forecasting software in Month 1 of a greenfield garment venture when the order database is empty. [R27] Use Phase 1 (Months 1 to 12) to capture clean order, size-ratio, shade, stockout and return records in the Performance-Management System Excel pack alongside Phase 1 computer-vision fabric inspection. [R29] Switch on Tier-1 ML demand forecasting at the Phase 2 gate once 12 months of verified domestic and CEMAC sales history exist. [R27]

10.12

Near-market domestic and CEMAC production eliminates the six-month import lead-time trap

Forecast error grows with planning lead time: ordering garments from Asian mills requires locking in quantities 150 to 210 days ahead of retail delivery (illustrative import lead-time benchmark). [R26] [R27] A greenfield factory in Cameroon (sited on the Douala-Dibamba corridor or in the Garoua cotton belt near SODECOTON's nine ginning plants) serves Douala, Yaounde and CEMAC distributors on a two-to-four-week replenishment clock (illustrative planning basis, GFT Feasibility Study Sections 7 and 10). [R03] [R10] [R26]

10.13 SHORT REPLENISHMENT CYCLES REPLACE SEASONAL SPECULATION WITH REACTIVE RE-CUTTING

Lead-time compression reduces overproduction across GFT's three Go-to-Market segments:

- **Priority 1 (Traditional African wear and urban ready-to-wear):** Instead of cutting 50,000 speculative units, the plant cuts an initial batch of 1,500 to 3,000 units (illustrative batch size) and re-cuts proven sellers within 10 to 14 days based on weekly sell-through and Phase 2 ML forecasts. [R26] [R27]
- **Priority 2 (Institutional uniforms and workwear):** Produced against pre-contracted size rolls, generating near-zero commercial deadstock when first-pass quality is controlled. [R24] [R29]
- **Priority 3 (Selected export niches):** Within an African textile market valued at US$37.3 billion in 2025 and projected to reach US$49.41 billion by 2030 at 4.73 percent a year (and US$72.7 billion by 2035 at 6.9 percent a year, with fashion and apparel holding 48.1 percent share in 2024), and as AfCFTA textile rules of origin (among the remaining unresolved lines beyond the 92.3 percent agreed tariff lines) mature, quick-response regional manufacturing prevents long-lead import deadstock. [R23] [R24] [R25] [S03]

10.14 GREIGE FABRIC POSTPONEMENT DECOUPLES SPINNING UTILISATION FROM FINAL SHADE AND STYLE COMMITMENT

While garment retail requires small-batch agility, upstream spinning mills require continuous runs to maintain high utilisation. [R12] [R27] GFT bridges this gap through **greige fabric postponement**: upstream partners such as Camtext SA (the US$300 million or 180 billion XAF project announced on 12 November 2025 to process 12,000 tonnes a year of cotton across Dibamba and Garoua) or the SODECOTON-CICAM pole spin and knit or weave standard base fabrics in unbleached greige form from SODECOTON's 314,455 to 350,000-plus tonne annual seed-cotton crop. [R01] [R02] [R03] [R08] [R09] [R10]

Holding buffer stock as undyed greige rolls rather than finished garments yields three advantages:

1. **Zero style or size obsolescence:** Greige rolls can be piece-dyed or digitally printed into any colour and cut into demanded sizes on seven days' notice. [R03] [R27]
2. **Purest recycling feedstock:** Greige roll remnants require no dye-stripping before mechanical tearing or deep eutectic solvent depolymerisation (tuning waste cotton DP from 2,409 to 500 to 700 at 98.80 percent alpha-cellulose purity and 88.01 percent yield). [S24] [S34]
3. **Working-capital discipline:** Because fabric is 50 to 60 percent of garment cost and the CFA franc is pegged to the euro at 655.957, postponing dyeing and CMT assembly (above the XAF 43,969 a month SMIG wage floor from 23 February 2024, about US$76) cuts inventory carrying costs by 35 to 40 percent. [R14] [R27] [R32] [S32]

WORKED EXAMPLE: MASS, CARBON, WATER AND FINANCIAL RECONCILIATION OF DEADSTOCK PREVENTION ON A 3.0 MILLION GARMENT LINE

Consider an illustrative engineering model for GFT's CMT factory at its nameplate capacity of 3,000,000 garments a year, with an average finished weight of 250 grams (750.0 tonnes net garment mass) and an illustrative FOB price of US$7.00 per unit (XAF 4,200 at 600 XAF/US$ under the 655.957 euro peg). [R26] [R32] [S03]

Step 1: Unmeasured baseline deadstock. Without ML forecasting and with manual fabric inspection (60 to 70 percent accuracy), suppose the factory incurs an illustrative 8.0 percent seasonal unsold overrun (within the 4 to 9 percent EU destroyed band) plus a 3.0 percent whole-batch AQL rejection rate, totalling 11.0 percent deadstock: [R29] [S1001]

- Deadstock volume = 3,000,000 × 11.0 percent = 330,000 unsellable garments a year (82.5 tonnes of garments, requiring 100.6 tonnes of purchased fabric at 18.0 percent cutting loss, illustrative arithmetic). [S32] [S33]
- Stranded manufacturing value = 330,000 x US$7.00 = US$2,310,000 (XAF 1.386 billion). [R32]
- Embodied water and carbon squandered: at an illustrative 2,500 litres of water and 4.5 kg CO2e per 250-gram cotton garment (scaled from the 7,500-litre jeans benchmark and the European Commission's 5.6 million tonnes CO2e across 264,000 to 594,000 tonnes of destroyed textiles), 330,000 deadstock garments embody 825.0 million litres of water and 1,485.0 tonnes of CO2e. [S29] [S1001] [S1002]

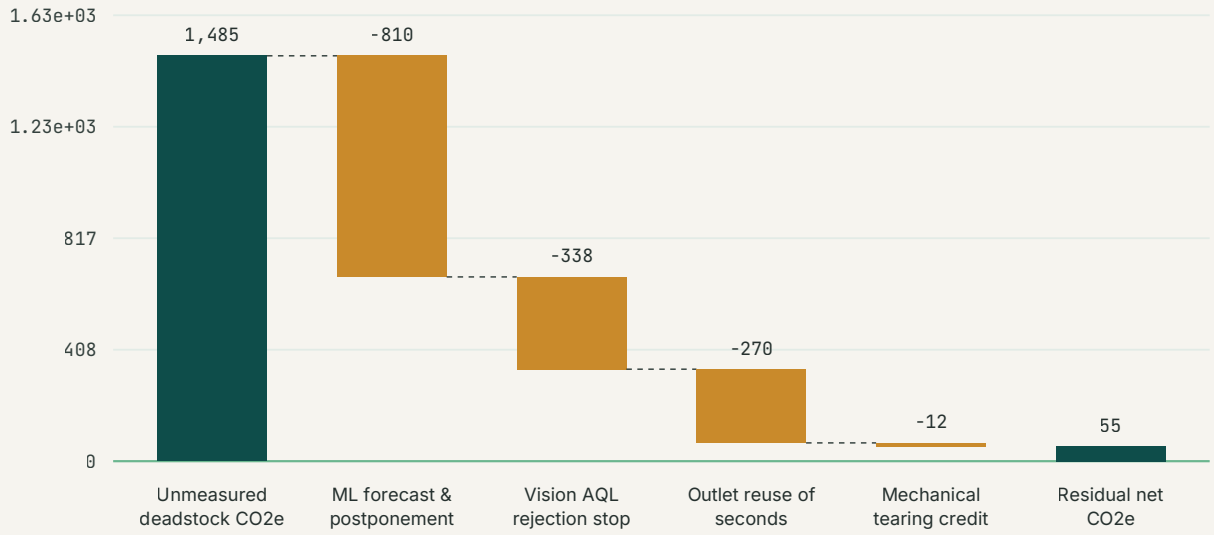
Step 2: GFT measured intervention. Computer-vision inspection (>90 percent accuracy) cuts AQL batch rejections from 3.0 percent to 0.5 percent, while Phase 2 ML forecasting (cutting forecast errors 20 to 50 percent) and greige postponement cut seasonal overruns from 8.0 percent to 2.0 percent, reducing total deadstock and seconds from 11.0 percent to 2.5 percent (75,000 garments, or 18.75 tonnes): [R27] [R29]

- Avoided deadstock = 330,000 minus 75,000 = 255,000 garments a year (63.75 tonnes of garments, saving 77.7 tonnes of purchased fabric, illustrative arithmetic). [R27] [R29] [S32]
- Preserved value = 255,000 x US$7.00 = US$1,785,000 (XAF 1.071 billion), plus US$262,500 recovered by selling 60,000 wearable cosmetic seconds through de-labelled corridor outlets at 50 percent cost recovery (US$3.50/unit), leaving only 15,000 unwearable rejects (3.75 tonnes) for mechanical tearing. [R27] [S03] [S24]
- Preserved resources = 637.5 million litres of water and 1,147.5 tonnes of CO2e saved by avoiding unneeded production, more than five times the illustrative 210.0 tonnes of CO2e credit from mechanically shredding 82.5 tonnes of deadstock after manufacture. [S08] [S24] [S1002]

The carbon reconciliation from this worked example is shown in **Exhibit 47**, p. 169. [R27] [R29] [S1002]

EXHIBIT 47 / TONNES OF CO2E PER YEAR (ILLUSTRATIVE)

Avoiding overproduction and batch rejections saves five times more embodied carbon than recycling deadstock after the fact



ILLUSTRATIVE [R27] [R29] [S08] [S1001] [S1002] Illustrative lifecycle carbon model for 330,000 baseline deadstock and rejected garments (82.5 tonnes at 18 t CO2e/tonne embodied intensity derived from EC 5.6M t CO2e over 264k-594k t destroyed textiles, S1001, S1002). Prevention via ML forecasting (R27) and computer vision (R29) eliminates 1,148 t CO2e of unneeded production, outlet reuse saves 270 t CO2e, and mechanical tearing handles the 3.75 t unwearable residual.

As **Exhibit 47**, p. 169 demonstrates, preventing 255,000 unneeded or rejected garments via ML forecasting (-810 tonnes CO2e) and computer vision (-338 tonnes CO2e) eliminates 1,148 tonnes of avoidable emissions before resources are spent, leaving a 55-tonne residual after outlet reuse and mechanical tearing. [R27] [R29] [S1002]

10.15

Computer-vision quality inspection prevents whole-order rejections that turn shipments into deadstock

When a packed garment shipment fails a statistical sampling audit (commonly Acceptable Quality Limit AQL 2.5 for major defects) due to unspotted fabric faults or shade variation, the buyer rejects the entire lot (illustrative quality benchmark). [R29] [S23] Once a shipment misses its seasonal delivery window during manual rework, order cancellation turns the entire lot into branded deadstock that cannot be sold openly without de-labelling and that wipes out both the 50 to 60 percent fabric cost share and 100 percent of sewing labour. [S32] [S1003]

10.16 MANUAL FABRIC INSPECTION MISSES UP TO A THIRD OF DEFECTS BEFORE THE CUTTING KNIFE MOVES

Published inspection studies confirm that manual human visual inspection on backlit tables is only 60 to 70 percent accurate, missing 20 to 30 percent of fabric defects due to eye fatigue and roll speed. [R29] Undetected slubs, oil stains, broken picks and dye bars pass into the cutting lay and are sewn into finished garments before discovery at final audit. [R29] [S33]

10.17 AUTOMATED LINE-SCAN VISION EXCEEDS NINETY PERCENT ACCURACY ACROSS MORE THAN FORTY DEFECT TYPES

Automated line-scan computer vision operating at speeds up to 60 metres a minute achieves above 90 percent accuracy across more than 40 defect types, driving the global AI fabric-inspection market from US$523.4 million in 2024 to US$6,522.1 million by 2033 at 33.8 percent a year (with Asia-Pacific at 46 percent in 2024). [R28] [R29]

In GFT's Cameroon operating model (Digital Strategy, Section 3), deploying computer vision in Phase 1 prevents batch deadstock through three mechanisms: [R29]

- **Pre-cut fault mapping and clean splice removal:** Defect coordinates are logged before spreading so operators splice out faulty strips as unsewn 100 percent cotton clips rather than sewing defective garments. [R29] [S24] [S33]
- **Continuous roll-width and Delta-E shade verification:** Optical sensors check width and roll-to-roll shade consistency, preventing shade-mixed bundles that trigger AQL batch rejections. [R29] [S32] [S33]
- **Empirical process-loss documentation:** Vision logs support supplier credit claims and provide empirical Process Loss Rate records for Global Recycled Standard (GRS v4) and Recycled Claim Standard (RCS v4) mass-balance audits. [R29] [S28]

10.18

Digital 3D sampling and physics-constrained design pipelines eliminate physical prototype waste

Conventional apparel development produces three to five rounds of physical strike-offs, fit samples and salesman samples per style, discarding 60 to 80 percent before bulk production begins (illustrative industry baseline). [S14]

10.19 MULTI-MODEL PHYSICS-CONSTRAINED GENERATION BRIDGES CREATIVE IDEATION AND MANUFACTURABLE TECH PACKS

Between 2023 and 2026, design AI progressed from 2D image ideation (Midjourney and Stable Diffusion in 2023 to 2024) to multi-model garment-design pipelines covering fabric construction, shade, weave and silhouette coupled with physics-constrained simulation validation in 2025 to 2026 (arXiv 2509.04705). [R30] [R31] Physics-constrained simulation maps 2D CAD pattern panels onto 3D avatars using measured cotton fabric mechanics, validating fit and drape on screen before cloth is cut. [R31] [S32]

10.20 VIRTUAL SAMPLING AND DIGITAL PRINTING COMPRESS PRE-PRODUCTION WASTE AND MARKER LOSS

In GFT's Digital Strategy (Deliverable 3, Section 3), digital sampling tools deploy across Tier 2 (Phase 2) and Tier 3 (Phase 3): [R30] [R31]

1. **Screen-approved 3D fit (Tier 2):** Institutional and retail buyers approve garment drape and trim placement on 3D avatars, cutting physical sample rounds by an illustrative 65 to 75 percent. [R30] [R31]
2. **Digital ink-jet strike-offs (Tier 2):** Short-run digital printing on SODECOTON cotton cloth replaces 300-metre rotary screen minimums for testing traditional African motifs (illustrative basis). [R03] [R30]
3. **Physics-constrained marker and BOM validation (Tier 3):** Automated pipelines verify CAD marker nesting efficiency (where saving 2 percent fabric raises profit margin by 1 percentage point) and enforce mono-material cotton bills of materials that qualify for Refashion 2026 and EU EPR eco-modulation bonuses. [R31] [S05] [S23] [S32]

The alignment of GFT's Digital Strategy tiers with waste prevention and Regulation (EU) 2024/1781 is summarised in **Exhibit 48**, p. 171. [R27] [R29] [R30] [R31] [S03]

EXHIBIT 48 / PROGRAMME TIER, PHASE AND REGULATORY MAPPING

Digital Strategy use cases across Tiers 1 to 3 directly reduce pre-consumer fabric and deadstock waste streams

Digital Strategy use case	Tier & Phase	Primary data input	Waste stream prevented	ESPR (EU) 2024/1781 link
Computer-vision defect inspection (>90% accuracy)	Tier 1 / Phase 1	Line-scan optical camera feed (up to 60 m/min)	Defective cut panels, rework scrap & AQL batch rejections	Art. 5 durability & Art. 23/25 damaged-stock prevention
ML demand forecasting (errors cut 20-50%)	Tier 1 / Phase 2	12+ months PMS order, SKU, size & sell-through logs	Unsold seasonal finished-goods deadstock & overruns	Art. 23 prevention duty & Art. 25 unsold destruction ban
Inventory optimisation & greige postponement	Tier 2 / Phase 2	Roll-level warehouse & S&OP replenishment cadence	Obsolete dyed fabric rolls & slow-moving size tails	Art. 24 annual discarded-stock disclosure minimisation
Digital printing & 3D virtual sample approval	Tier 2 / Phase 2	Colorimetric shade files & 3D avatar drape parameters	Physical proto/salesman samples & rotary strike-off waste	Art. 23 pre-commercial prototype waste reduction
Multi-model physic s-constrained design pipeline	Tier 3 / Phase 3	Fabric mechanics, CAD marker geometry & BOM rules	Cutting-room marker void loss & non-recyclable blends	Art. 4/5 ecodesign recyclability & Art. 8-13 DPP data

DERIVED [R27] [R29] [R30] [R31] [S03] [S1002] Derived operational mapping combining GFT Digital Strategy (Deliverable 3, Sections 3 and 7) with empirical benchmarks from R27, R29, R30, R31 and legal obligations under ESPR Regulation (EU) 2024/1781 (S03, S1002).

As **Exhibit 48**, p. 171 shows, Phase 1 computer vision protects physical batch quality, Phase 2 ML forecasting and postponement control commercial inventory, and Phase 2/3 virtual sampling and physics-constrained design eliminate prototype and marker waste upstream. [R27] [R29] [R31] [S03]

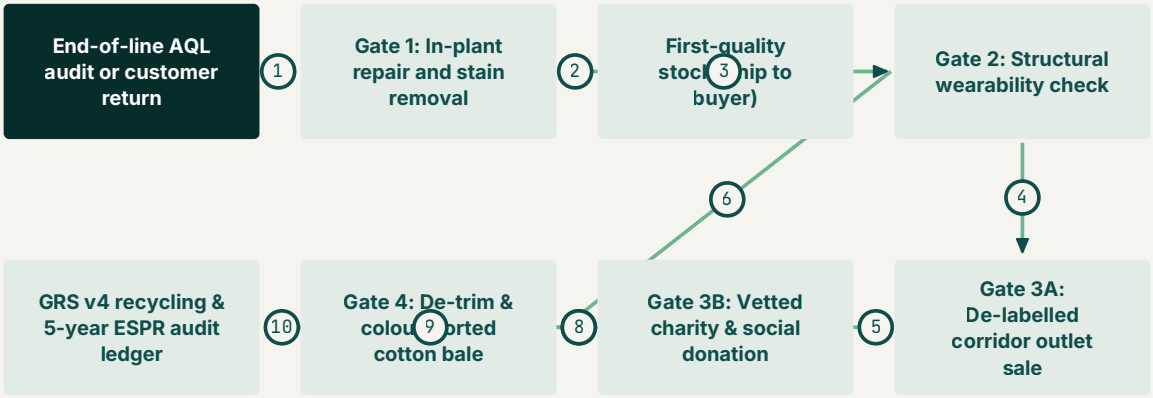
10.21

Structured circular hierarchy routes unavoidable seconds and returns to reuse before shredding

Even with >90 percent vision inspection and ML forecasting, a 3.0 million garment a year factory will generate an illustrative 1.0 to 2.0 percent rate of second-quality garments (30,000 to 60,000 pieces a year, or 7.5 to 15.0 tonnes) with minor stitching or shade deviations. [R27] [R29] To comply with Regulation (EU) 2024/1781 and Directive (EU) 2025/1892, GFT enforces a **four-gate circular disposition protocol** (0.0 percent landfill or incineration target), mapped in **Exhibit 49**, p. 173. [S03] [S04] [S1002] [S1003]

EXHIBIT 49 / OPERATIONAL DECISION SEQUENCE

GFT's four-gate ESPR compliance protocol routes unavoidable factory seconds through outlet reuse and social donation before fibre recycling



1. Defect flagged
2. Restored to spec
3. Unrestorable second
4. Wearable cosmetic second
5. Unsold after 60 days
6. Structurally unwearable
7. Signed charity refusal
8. Reuse count & weight
9. Donation receipt
10. GRS TC & 5-yr proof

ILLUSTRATIVE [S03] [S04] [S1002] [S1003] Illustrative shop-floor and warehouse disposition workflow engineered to satisfy Regulation (EU) 2024/1781 Articles 23-25 (S03, S1002, S1003) and the EU Waste Framework Directive waste hierarchy (S04).

10.22 GATE 1 AND GATE 2 SEPARATE REPAIRABLE FAULTS FROM COSMETIC SECONDS

In **Exhibit 49**, p. 173, every flagged garment enters **Gate 1 (In-plant repair)**, where repair operators fix skipped stitches, loose buttons or cleanable spots so the garment rejoins first-quality stock. [R29] [S1003] Unrestorable items pass to **Gate 2 (Structural wearability check)**, where the quality lead separates structurally durable wearable seconds from torn or unsafe rejects under Article 23 and Article 25 of Regulation (EU) 2024/1781. [S03] [S23] [S1003]

10.23 GATE 3 KEEPS WEARABLE SECONDS IN HUMAN USE THROUGH DE-LABELLED CORRIDOR OUTLETS AND VETTED DONATIONS

Structurally wearable seconds are barred from shredding. [S04] [S1003] At **Gate 3A (De-labelled corridor outlet resale)**, third-party brand labels are removed to protect intellectual property, and garments are sold at 40 to 60 percent of wholesale price through factory outlets in Douala, Yaounde or Garoua (serving households spending

an average of US$94.70 per person across 8.0 pieces a year). [R26] [S1003] Items unsold after 60 days move to **Gate 3B (Vetted social donation)** under signed transfer receipts. [S1002] [S1003]

10.24 GATE 4 ROUTES STRUCTURALLY UNWEARABLE REJECTS INTO CERTIFIED FIBRE-TO-FIBRE RECYCLING WITH FIVE-YEAR AUDIT LOGS

Only structurally unwearable rejects (or items refused in writing by charities) enter **Gate 4 (De-trimming and certified recycling)** under the February 2026 Delegated Regulation derogations. [S1002] [S1003] Operators remove non-cellulosic trims, sort cotton panels by shade alongside cutting clips, and bale them under Global Recycled Standard (GRS v4) Transaction Certificates for regional open-end rotor spinning at Camtext SA or SODECOTON-CICAM (blended at 20 to 35 percent with virgin lint) or deep eutectic solvent cellulosic pulping. [R08] [R09] [R10] [S24] [S28] [S34]

FIVE-YEAR ESPR ARTICLE 24/25 AND ISO 59020:2024 COMPLIANCE LEDGER SPECIFICATION

To satisfy the five-year inspection retention rule under Regulation (EU) 2024/1781 and ISO 59020:2024 circularity measurement, GFT's Performance-Management System records seven fields per non-first-quality lot: [S03] [S40] [S1003]

1. **Combined Nomenclature Code (`CN_Code`):** Order ID and 8-digit customs code (chapters 61, 62 or 64) per the February 2026 ESPR Implementing Regulation. [S1002] [S1003]
2. **Quantity and Net Mass (`Units_Count`, `Net_Mass_kg`):** Piece count and platform-scale mass reconciled against cutting-room roll weight. [S28] [S40]
3. **Disposition Code (`Disposition_Code`):** `REPAIRED_FIRST`, `WEARABLE_SECOND`, `DAMAGED_UNWEARABLE`, `SAFETY_NONCOMPLIANT` or `CHARITY_REFUSED`. [S1003]
4. **Derogation Proof (`Proof_Ref_ID`):** Five-year archive link to lab failure reports, damage inspection photos, de-labelling logs or signed charity refusal letters. [S1003]
5. **Treatment Pathway (`Waste_Hierarchy_Route`):** `OUTLET_REUSE`, `SOCIAL_DONATION`, `MECHANICAL_GARNETTING_GRS` or `CELLULOSIC_PULP_FEEDSTOCK` (`0.0 percent` disposal). [S04] [S24] [S34] [S1003]
6. **Chain of Custody (`GRS_TC_Number`):** Batch Transaction Certificate and spinner Scope Certificate IDs for Gate 4 bales. [S28]
7. **Embodied Resource Ledger (`Preserved_Water_L`, `Preserved_CO2e_kg`):** Water and carbon preserved via repair and reuse for ISO 59020:2024 reporting. [S40] [S1002]

OPERATIONAL AND REGULATORY BOUNDARY CONDITIONS

1. **Year 1 cold-start forecasting risk:** Because ML forecasting requires 12 months of sales history before Phase 2 activation, Phase 1 output must be restricted to pre-contracted institutional uniforms (Priority 2) and small-batch replenishment from SODECOTON greige fabric buffers. [R03] [R26] [R27]
2. **Brand IP clauses on rejected export lots:** Manufacturing contracts signed at Phase 0 must include ESPR Article 23 and Article 25 clauses permitting de-labelled domestic outlet resale or GRS v4 mechanical shredding rather than destruction. [S03] [S28] [S1003]
3. **Legal and investment notice:** Regulatory analysis of Regulation (EU) 2024/1781 and Directive (EU) 2025/1892 in this chapter is for industrial engineering design and does not constitute legal, tax or investment advice. [S03] [S04] [S1002]

By uniting Phase 1 computer-vision defect detection, Phase 2 machine-learning demand forecasting, near-market greige fabric postponement and the four-gate ESPR reuse-and-recycling protocol inside one Performance-Management System ledger, a greenfield Cameroon garment maker eliminates overproduction waste at its source. [R27] [R29] [S03]

The cleanest recycling reactor is an accurate forecast that never cuts an unwanted garment.

CHAPTER SOURCE NOTES

S03 European Union (via LSE Grantham Research Institute Climate Change Laws of the World). 2024-06-28.
R27 McKinsey, The State of Fashion 2025. Publication date unrecorded; inherited source-text check.
R29 MDPI; industry inspection literature. Publication date unrecorded; inherited source-text check.
S1002 European Commission Directorate-General for Environment. 2026-02-09.
S1003 European Commission Directorate-General for Environment. 2026-07-17.
R31 arXiv 2509.04705. Publication date unrecorded; inherited source-text check.
S08 Ellen MacArthur Foundation. 2017-11-28.
S38 European Commission Directorate-General for Environment. 2024.
S10 Fashion for Good and Reverse Resources. 2024-06.
S12 European Environment Agency (EEA). 2024-04-15.
S14 European Environment Agency (via European Circular Economy Stakeholder Platform). 2024-05.
S1001 European Environment Agency (EEA). 2024-03-04.
S01 Textile Exchange (via USB Certification). 2024-10-24.
S02 United States Fashion Industry Association (citing Textile Exchange). 2024-10-10.
S11 European Environment Agency (EEA). 2023-02-27.
S13 European Environment Agency (EEA Circularity Metrics Lab). 2026-04-14.
S29 Pan African Climate Justice Alliance (PACJA). 2025-03-30.
S32 Textile Learner. 2023-08-26.
S33 iFactory. 2025.
S24 United Nations Industrial Development Organization (UNIDO). 2023-11.
S04 European Commission Directorate-General for Environment. 2025-10-16.

S28 TraceWeave. 2026-07-27.
R18 Congressional Research Service IF10149; AGOA (Wikipedia). Publication date unrecorded; inherited source-text check.
R12 Business in Cameroon. Publication date unrecorded; inherited source-text check.
R26 Statista. Publication date unrecorded; inherited source-text check.
R08 Business in Cameroon. Publication date unrecorded; inherited source-text check.
R09 Ecofin Agency. Publication date unrecorded; inherited source-text check.
R10 Ecofin Agency. Publication date unrecorded; inherited source-text check.
R03 SODECOTON. Publication date unrecorded; inherited source-text check.
R24 Mordor Intelligence. Publication date unrecorded; inherited source-text check.
R23 MacMap; AfCFTA. Publication date unrecorded; inherited source-text check.
R25 Market.us. Publication date unrecorded; inherited source-text check.
R01 Business in Cameroon. Publication date unrecorded; inherited source-text check.
R02 Fibre2Fashion; Business in Cameroon. Publication date unrecorded; inherited source-text check.
S34 National Library of Medicine (PubMed). 2026.
R14 WageIndicator. Publication date unrecorded; inherited source-text check.
R32 Wise; XE. Publication date unrecorded; inherited source-text check.
S23 Refashion. 2026-01-27.
R28 DataIntelo. Publication date unrecorded; inherited source-text check.
R30 Design Journal (Taylor and Francis). Publication date unrecorded; inherited source-text check.
S05 European Parliament. 2025-10.
S40 International Organization for Standardization (ISO). 2024-05.

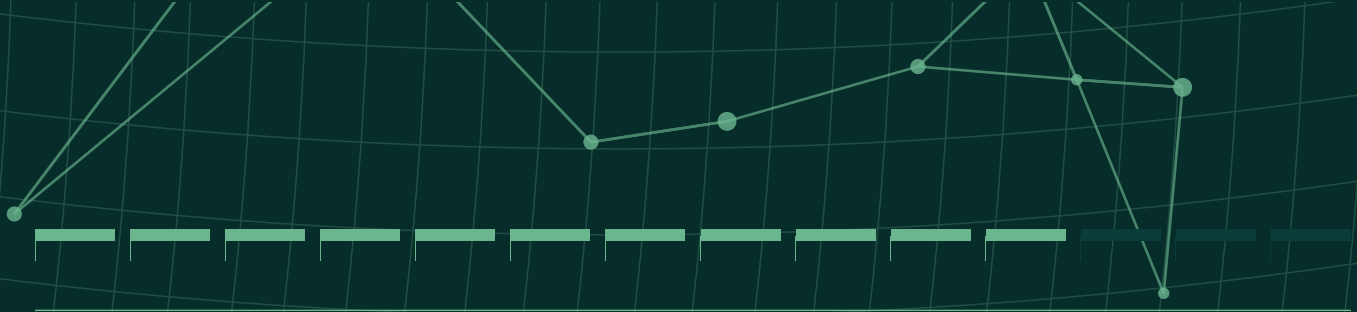
GREEN FUTURE TECH

LIMITED / HONG KONG SAR

11

Auditable chain of custody and mass-balance accounting separate verified circularity from greenwashing

A recycled-content claim is only as strong as the material identity, custody documents, process-loss arithmetic and claim approval behind it. Certificates support that evidence; they do not replace it.



CHAPTER 11
DECISION TEST

A recycled-content claim is only as strong as the material identity, custody documents, process-loss arithmetic and claim approval behind it. Certificates support that evidence; they do not replace it.

Verified circularity is an evidence state, not a visual identity. A bale of cutting clips can be clean, locally sourced and commercially valuable without yet being certified recycled input. A garment can carry a precise percentage without proving that the percentage came from a real batch. The answer is a continuous chain from material origin to product release: classify the material correctly, preserve its identity through physical handling, reconcile input with stock and output, attach the right certificates, and approve only the claim that those records support. Mass balance is one control within that chain. It is not permission to create recycled content on paper.

As of 30 October 2026, the current Textile Exchange editions are Global Recycled Standard (GRS) 5.0 and Recycled Claim Standard (RCS) 3.0. Both took effect on 1 July 2026 and become mandatory for audits on 31 December 2026. GRS 5.0 supersedes GRS 4.0 for audits after that mandatory date, while RCS 3.0 replaces the preceding RCS edition. This chapter uses the current editions rather than repeating obsolete version labels. [S1101] [S1102]

GFT's practical recommendation for its Cameroon textile programme is to build the evidence rules into the performance-management system before seeking a logo. The factory should connect each material lot to its source declaration, weighing events, process recipe, stock position, custody documents and outward claim. That is a design recommendation, not a statement that GFT, a supplier or a proposed factory already holds certification. Certification eligibility and legal claims require review by the relevant certification body and, where applicable, counsel in the destination market.

11.1

ISO standards define the system but do not certify a recycled garment

The ISO 59000 family and Textile Exchange standards answer different questions. ISO 59004:2024 provides circular-economy vocabulary, principles and implementation guidance for any type of organisation. It can help a manufacturer define resource stewardship, value creation and transition logic. It does not, from its public description, establish a recycled-content threshold or issue a product-specific cotton claim. Treating general alignment with ISO 59004 as proof of recycled fibre would confuse management guidance with product assurance. [S39]

ISO 59020:2024 addresses measurement and assessment within defined economic systems. Its public description calls for consistent data collection and calculation using mandatory and optional circularity indicators. The essential engineering consequence is boundary discipline. A factory must name the material, process, period, stock position and output covered by an indicator before comparing results. A plant-wide recovery rate, a batch recycled-content percentage and a national processing share are different measures and cannot be substituted for one another. [S40]

This distinction prevents two common errors. First, a high proportion of waste collected does not prove a high proportion of recycled content in a product. Collection is an input event; recycled content concerns the mass of qualifying recycled material in the claimed output. Second, an improvement in a circularity indicator does not by itself

demonstrate lower environmental impact. ISO 59020 can structure measurement, but the organisation still needs suitable impact methods and evidence before making a broader environmental claim. [S40]

ISO 59014:2024 covers the sustainability and traceability of secondary-material recovery. Its scope includes organisations engaging with individuals in subsistence activities, with requirements and guidance aimed at safe and healthy working conditions and continual improvement in livelihoods and professional practices. For a Cameroon recovery network, that brings worker treatment, supplier formalisation and material traceability into the same recovery review. It is especially relevant where formal factories interface with small collectors or informal transport services. [S1105]

The same public scope also sets limits. ISO 59014 does not provide quality criteria for particular secondary materials, and it excludes energy recovery and disposal. A cotton-clip specification therefore still needs its own fibre composition, contamination, moisture and acceptance tests. A document stating that material was recovered responsibly does not prove that a spinner will accept it, and dispatch to a recycler does not establish what happened after receipt. [S1105]

Exhibit 50, p. 180 places these instruments in separate layers. The operating layer records physical events. Recovery and measurement standards organise responsible recovery and circularity indicators. Textile Exchange provides commercial chain-of-custody and recycled-content assurance. Product-information law and claims rules govern what may be communicated. None of these layers can honestly substitute for the one below or above it.

EXHIBIT 50 / STANDARDS AND RECORDS BY RESPONSIBILITY

Credible circularity connects physical recovery, commercial assurance and controlled claims



DERIVED [S39] [S40] [S1101] [S1102] [S1105] [S1106] GFT synthesis of the cited public scopes. The layers cooperate but are not equivalent, and inclusion here does not imply that any GFT operation is certified.

The practical design rule is to state which question each record answers. A weighing ticket answers how much material crossed a boundary. A composition report answers what was found by a stated method. A Scope Certificate concerns an organisation's certified scope. A Transaction Certificate concerns certified products in a transaction. An ISO 59020 indicator reports a defined aspect of circularity performance. Combining them can strengthen a claim; calling any one of them complete proof would overstate its scope.

11.2

GRS and RCS set different thresholds and different depths of assurance

GRS 5.0 is a full product standard covering recycled content, chain of custody, social and environmental practices, and chemical restrictions. It applies to products containing at least 20 percent recycled material, while only products with at least 50 percent recycled content qualify for product-specific GRS labelling. The 20 percent certification threshold and the 50 percent consumer-facing label threshold must therefore not be collapsed into one number. A batch may be eligible for business-to-business GRS certification without qualifying for a GRS product label. [S1101] [S1104]

RCS 3.0 has a narrower purpose. It covers third-party certification of recycled input and chain of custody for products containing at least 5 percent recycled material. It does not address social or environmental aspects of processing and manufacturing, product quality, or legal compliance. RCS can support a recycled-content claim, but it cannot carry the wider processing assurances associated with GRS. [S1102]

Both standards require production stages to be certified from the recycling stage through the last seller in the final business-to-business transaction, subject to their detailed rules and exceptions. Both also address reclaimed material before recycling and recycled material during and after recycling. Their 2026 revisions strengthen structured source data through the revised Reclaimed Material Declaration Form. The change is directly relevant to greenwashing control: better source information makes it harder to relabel ordinary virgin material or same-process rework as recycled input. [S1101] [S1102]

Edition control is itself an assurance control. GRS 5.0 and RCS 3.0 are effective now and mandatory for audits from 31 December 2026. A readiness plan written against GRS 4.0 or an assumed RCS 4.0 would be unreliable. The factory should record the standard name, edition, effective date and applicable certification procedure in its compliance register, then have the certification body confirm the edition and transition arrangements that apply to its audit. [S1101] [S1102]

Exhibit 51, p. 181 summarises the division of labour. The thresholds are entry conditions, not guarantees. Meeting a percentage does not prove material eligibility, complete custody, acceptable processing or permission to use a consumer label.

EXHIBIT 51 / REQUIREMENTS AND PUBLIC SCOPES AS OF 2026-10-30

Recycled-content thresholds sit inside wider and narrower assurance scopes

Instrument	Content threshold	Primary assurance	Limit to retain
GRS 5.0	20% certification; 50% product label	Content, custody, social, environment, chemicals	Not quality or legal compliance
RCS 3.0	5% recycled material	Recycled input and custody	No added social or environmental assurance
CCS 3.1	Set by primary standard	Handling, volume reconciliation, records and sale	Not a consumer-facing claim
ISO 59014	No product-content threshold	Responsible secondary-material recovery	No material-specific quality criteria
ISO 59020	No product-content threshold	Circularity measurement within defined systems	Not proof of recycled content

DERIVED [S1101] [S1102] [S1103] [S1104] [S1105] [S39] [S40] GRS and RCS thresholds come from the current 2026 standards. The 50 percent GRS threshold concerns product-specific labelling. CCS, ISO 59014 and ISO 59020 do not supply alternative recycled-content labels. This is a decision aid, not a substitute for the full normative documents.

A sourcing team should select the assurance depth before writing the purchase specification. If the buyer needs only verified recycled input and custody, RCS may be relevant. If the buyer also requires the GRS social, environmental and chemical criteria, RCS alone cannot satisfy that requirement. If the intended label is consumer-facing GRS, a recipe below 50 percent recycled content fails that labelling threshold even if it exceeds the 20 percent certification threshold. These are separate release tests in the data model, not nuances for a later marketing review. [S1101] [S1102] [S1104]

11.3

Scope Certificates, Transaction Certificates and source declarations perform different jobs

The Content Claim Standard (CCS) supplies the chain-of-custody foundation used across Textile Exchange standards. It covers sites that own or take physical possession of claimed material, subject to stated exceptions. A Scope Certificate establishes that an organisation has been assessed for a defined standard, product and process scope. It is not a batch of material and it does not prove that every product made by that organisation is certified. A certificate held by a spinner cannot automatically cover a garment factory, a subcontractor or a different process at the same address. [S1103]

A Transaction Certificate connects certified products to a transaction. The CCS requires a seller to apply for one when products sold to another business reference the standard, carry its logo or are identified as certified in marketing. The application can require purchase and sales records, shipping documents, input Transaction Certificates, composition calculations, a balanced volume reconciliation and subcontractor identities. Only products issued a valid Transaction Certificate are considered certified under the cited CCS rule. The factory should therefore treat a certificate number copied onto an invoice as an unverified reference until its authenticity, product scope, quantity, dates and parties have been checked. [S1103]

The revised GRS and RCS source controls add another distinct record. The first certified entity in a recycling supply chain must verify relevant legal authorisation, hold supplier agreements, collect Reclaimed Material Declaration Forms for reclaimed inputs, inspect incoming shipments and retain inspection records. A recycler using reclaimed material from its own processing must retain records of inputs, the reclaimed-material description and collection stage, and relevant transfer notes. These records establish origin before a recycled output claim exists. [S1101] [S1102]

This division matters at the cutting-room boundary. A clean bale and a supplier invoice can document a commercial dispatch, but they do not answer every certification question. The receiver still needs to establish whether the input qualifies as reclaimed material, whether it came from a distinct recycling route rather than same-process reuse, and which entity must hold which certificate. GFT recommends keeping source eligibility, physical acceptance and certification review as three separate status fields. A bale can pass one and fail another.

Exhibit 52, p. 183 shows the intended evidence chain. The arrows represent linked controls, not an assumption that every organisation follows an identical certification path. Multi-site organisations, traders, subcontractors and other exceptions require the detailed CCS and primary-standard rules. The certification body should confirm the applicable route before the first certified shipment. [S1103]

EXHIBIT 52 / ILLUSTRATIVE CUSTODY SEQUENCE UNDER CITED STANDARDS

A certified output depends on an unbroken chain of source, site and transaction evidence



1. Declaration and agreement
2. Source and input checks
3. Input TC and batch identity
4. Volume balance and output TC
5. Scope and label review

DERIVED [S1101] [S1102] [S1103] GFT synthesis of GRS 5.0, RCS 3.0 and CCS 3.1 controls. Roles and exceptions must be confirmed with the certification body. This is not evidence of an existing Cameroon certified chain.

CCS also requires documented procedures, training, internal inspection and access for the certification body. Sites subject to certification are generally audited on site at least annually unless an exception applies, and records used to implement or verify the CCS must be retained for at least five years. A spreadsheet can support these duties, but only if it preserves original evidence, corrections and responsible review. An annual tidy-up cannot reconstruct reliable custody from missing daily events. [S1103]

Outsourcing needs particular care because material can leave the certified site's physical control without leaving the claim chain. The CCS distinguishes associated subcontractors from independently certified subcontractors, assigns continuing responsibility to the contracting organisation, and requires records and certification-body controls. Before using an outside sorter, baler, recycler or warehouse, the factory should establish which entity owns the material, who takes possession, what process occurs and which certificate covers it. A transport document alone does not resolve those questions. [S1103]

11.4

Mass balance must reconcile physical material rather than manufacture a claim

CCS volume reconciliation starts with a simple prohibition: an organisation must not sell more certified product than it could produce from its available claimed inputs. The organisation must quantify claimed inputs and outputs, keep their origins and destinations, hold incoming Transaction Certificates, and reconcile purchases, stock and sales on an ongoing lot or batch basis. Calculations normally use standardised weight. Inventory, waste, rejected products and claimed material sold without certification all belong in the reconciliation. [S1103]

For a defined site and period, GFT recommends expressing the control as an identity: opening claimed stock plus claimed receipts equals claimed outputs plus closing claimed stock plus measured waste and rejects plus claimed material sold without a claim plus a signed unresolved difference. The precise classification of each term must follow the applicable standard and the material's actual state. The identity is useful because it prevents unexplained stock from becoming free claim volume. It is not a substitute for the CCS equations that the organisation must document and exemplify. [S1103]

Expected waste factors need a stated basis for each processing step. CCS requires actual waste factors to be compared with expectations during at least an annual review, physical inventory to be taken, and deviations of more than 5 percent from expected waste factors to be investigated. That review requirement does not make a smaller daily discrepancy meaningless, nor does it make an unexplained variance acceptable. It sets a specific investigation trigger inside a wider control system. [S1103]

The word mass balance can mislead if it is understood as a credit system. CCS material handling is based on segregation and controlled blending. Claimed material must remain identified, with procedures against commingling and substitution. Where claimed and non-claimed inputs are blended, the organisation must calculate composition from input weights and claim percentages, consider loss factors, and show that the result represents the claimed material actually present. A certificate generated elsewhere cannot be assigned to an unrelated garment simply because total site volumes appear to match. [S1103]

GRS 5.0 and RCS 3.0 add a direct cotton-relevant rule: where recycled and virgin inputs may suffer different production-loss rates, the mass-balance formula for each material must account for the difference. Mechanically recycled cotton can lose a different share during opening, carding or combing from virgin cotton. The input recipe therefore cannot automatically become the output claim. The calculation must follow each material through the process and remain open to verification. [S1101] [S1102]

METHOD

For each batch, retain input mass by material and claim status, expected and actual loss by material, output mass, rejected output, closing work in progress and any sale made without a claim. Calculate recycled share from qualifying recycled output mass divided by total output mass, multiplied by 100. Treat that result as provisional until the records demonstrate that it represents the actual batch. Preserve original weights and the conversion to any standardised weight. The formula and its worked example are part of the evidence, not an undocumented back-office adjustment. [S1103]

WORKED EXAMPLE: DIFFERENTIAL LOSS CHANGES THE OUTPUT PERCENTAGE

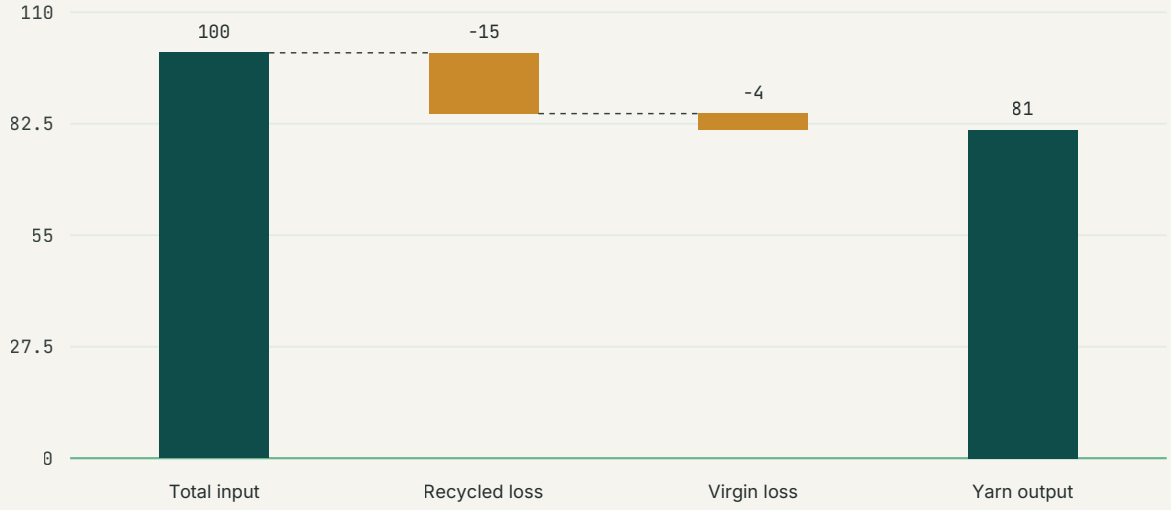
Assume an illustrative yarn batch containing 60 kg of eligible recycled cotton and 40 kg of virgin cotton. The input recipe is therefore 60 percent recycled cotton by mass. During processing, assume that 15 kg of the recycled fraction is lost and 4 kg of the virgin fraction is lost. These are constructed inputs used only to demonstrate the required arithmetic, not measured losses from a GFT facility or a recommended allowance. [S1101]

Recycled output is 60 - 15 = 45 kg. Virgin output is 40 - 4 = 36 kg. Total yarn output is 45 + 36 = 81 kg. The illustrative recycled share is therefore 45 / 81 × 100 = 55.56 percent, rounded to two decimal places. Reporting the original 60 percent input recipe would overstate the output share by 4.44 percentage points. The result exceeds the GRS product-labelling content threshold, but that alone would not establish eligibility for the label or certification. [S1101] [S1104]

Exhibit 53, p. 186 shows why total output reconciliation is insufficient on its own. In this illustrative case, total loss is 19 kg, but the two input fractions do not shrink at the same rate. A sound claim calculation preserves both contributions instead of allocating total loss proportionally after the event. If the actual loss assignment is unknown, the honest result is an unresolved claim calculation, not a convenient assumption.

EXHIBIT 53 / KG OF ILLUSTRATIVE COTTON INPUT AND OUTPUT

Differential process losses change an illustrative recycled share from 60.00 to 55.56 percent



ILLUSTRATIVE [S1101] [S1103] Illustrative arithmetic, not observed factory performance. Inputs: recycled 60 kg and virgin 40 kg. Losses: recycled 15 kg and virgin 4 kg. Outputs: recycled 45 kg and virgin 36 kg, total 81 kg. Recycled output share = 45 / 81 × 100 = 55.56 percent.

Rejected output and downgraded sales also need explicit treatment. A failed yarn lot cannot disappear from the batch merely because it will not be sold as certified. CCS requires rejected products and claimed material sold without certification to enter volume reconciliation. If a customer accepts the physical yarn without a certified claim, the records should show that disposition. Otherwise the same quantity could remain available in the system for a later certified sale, creating duplicate claim capacity. [S1103]

Timing differences require equal discipline. Material received near a period close may remain in stock, while output may include material received earlier. A calendar-period balance that ignores opening and closing inventory will produce artificial gains and losses. Work in progress must have a defensible quantity and claim status. Where batch-level segregation is impossible in continuous production, the organisation should use the applicable alternative reconciliation rules rather than inventing a looser internal method. [S1103]

Finally, measurement uncertainty is not a licence to inflate content. Moisture adjustment, tare, scale calibration and receiver-versus-sender weights can change a balance. Preserve the original observation and the standardised-weight conversion. Investigate systematic residuals by material and process. A small unresolved difference repeated in one direction can indicate a weak boundary or an unrecorded flow. The claim owner should hold release when the available evidence cannot distinguish real output from arithmetic error.

11.5

Claim approval must stop evidence from becoming exaggeration

The claim is a separate release decision, not an automatic consequence of production. Textile Exchange's Standards Claims Policy requires RCS, GRS and OCS product-related claims to state the percentage of certified content, calculated by weight for the full product or applicable component. Transaction Certificates carry the exact percentage for the specific batch. The policy also requires relevant certification information and claim approval. A general statement that a company is certified must not imply that all of its products are certified. [S1104]

The claim review should compare four objects: the physical product, its approved composition calculation, the Transaction Certificate and the exact words or artwork proposed for sale. Differences in material name, component, percentage, licence identifier or certification body can change the claim's meaning. A lower percentage may sometimes be used under the claims rules, but an unsupported higher percentage cannot be justified by a favourable batch average. The final claim maker remains responsible for accurate communication and applicable law. [S1104]

European consumer rules add a legal communication boundary. The European Commission states that Directive (EU) 2024/825 applies from 27 September 2026 to business-to-consumer environmental claims and sustainability labels, including claims for existing products. Sustainability labels must be based on a certification scheme or established by public authorities, while national authorities enforce the rules. This does not mean that holding any voluntary certificate automatically makes every environmental statement lawful. The claim must still match the product, the evidence and the applicable national implementation. [S1107]

The Ecodesign for Sustainable Products Regulation establishes a framework that can require a Digital Product Passport through product-specific information requirements. Its recitals call for model, batch or item granularity to be considered when delegated acts are prepared. It would therefore be wrong to state that every textile already has an identical passport obligation. The manufacturer should track the applicable textile delegated act, its data fields, its identifier level and its commencement date rather than buying a generic passport badge. [S1106]

A future passport can point to reliable source evidence, but it cannot make weak evidence true. Useful links include the product and batch identifier, material composition, recycled percentage by pre-consumer and post-consumer class, manufacturing site, supporting certificate references, claim status and correction history. Public access should be limited to information required for the relevant audience. Commercially sensitive recipes and supplier records can remain in controlled evidence storage where the applicable rules permit.

GFT NOTE

Create a claim-release gate outside production. The cutting or sewing team may confirm physical completion, but an authorised claim reviewer should release the recycled percentage only after checking material eligibility, batch arithmetic, certificate scope, transaction evidence and proposed wording. If evidence is incomplete, hold the claim rather than the ordinary product. Never solve a documentary gap by choosing a broader sustainability adjective.

11.6

Cotton provenance and recycled content need parallel evidence chains

A garment made partly from Cameroon virgin cotton and partly from recycled cutting clips carries two different attributes. Provenance concerns where and how the virgin fibre entered the chain. Recycled content concerns the proportion of qualifying reclaimed material that was reprocessed and carried into the product. One attribute cannot prove the other. A local farm or gin record does not turn virgin lint into recycled material, and a recycled-content certificate does not establish the origin of the remaining virgin fibre.

Consider an illustrative garment containing 75 percent virgin cotton and 25 percent eligible pre-consumer recycled cotton by weight. The recycled share exceeds the 20 percent GRS certification threshold and the 5 percent RCS threshold, but falls below the 50 percent threshold for product-specific GRS labelling. It could therefore be considered for business-to-business GRS certification only if all other requirements are met, while the consumer-facing GRS label would not be available on content grounds. These arithmetic outcomes describe thresholds only, not eligibility of this constructed garment. [S1101] [S1102] [S1104]

Material classification comes before that calculation. GRS and RCS define pre-consumer material as material diverted from the waste stream during manufacturing, but exclude rework, regrind or scrap generated in a process and capable of being reclaimed within the same process. Returning a usable remnant to the same cutting or production process can be excellent resource efficiency without qualifying as recycled content. Sending material into a distinct recycling process may support a recycled claim, subject to inspection and certification-body acceptance. [S1101] [S1102]

This distinction belongs in product and process design. Same-process reuse should be recorded as reused internal material, with its own mass and destination. External pre-consumer recycling should carry source declarations, collection records and the required custody evidence. Post-consumer material should remain separately identified because GRS and RCS require pre-consumer and post-consumer percentages to be recorded separately by batch at certified sites. Mixing those categories destroys information that the Transaction Certificate needs. [S1101] [S1102]

For a proposed Cameroon loop, the garment factory may therefore operate two evidence chains at once. The first follows virgin cotton into fabric and garment production. The second follows cutting clips out of the factory, through an independent recycling route, back into recycled fibre or yarn, and finally into a new garment batch. GFT

recommends no assumption of certification or partnership for any named regional organisation. Each actual collector, recycler, spinner and fabric supplier must be contracted and assessed on its own role, scope and evidence.

The resulting product record should show both chains without adding their percentages into a vague sustainability score. A buyer needs to know what is virgin, what is recycled, what is pre-consumer, what is post-consumer and which evidence covers each statement. That precision is more useful than a broad claim of circular origin.

11.7

Lightweight governance can make verification affordable from the first batch

A cold-start factory does not need an expensive platform before it can preserve evidence. It needs stable identifiers, controlled records and people with authority to stop an unsupported claim. GFT's performance-management design supplies the operating context for daily capture and later migration. The circularity extension should begin with a lot register, an evidence register, a batch calculation and a claim-release log. Each record should identify its owner, observation time, source document, review status and correction history.

The lot register connects source material to containers and process batches. Minimum fields include source and receiver, material description, pre-consumer or post-consumer class, gross weight, tare, net or standardised weight, container identifier, process destination and stock status. The evidence register holds supplier agreements, Reclaimed Material Declaration Forms, incoming and outgoing Transaction Certificates, Scope Certificates, inspection results and shipping records. A document reference without a reviewed file and validity state is not enough.

The batch calculation retains input composition, loss factors by material, outputs, rejects, stock, non-certified dispositions and unresolved differences. The claim-release log records the exact product, component, percentage, wording, certification information, approver and date. These four records make the arithmetic traceable without pretending that a workbook is a certification decision. When the operation migrates to a central data store, the same states and identifiers should survive unchanged.

GFT recommends four system states: physically received, technically accepted, certification reviewed and claim released. Physical receipt confirms that material arrived. Technical acceptance confirms composition and quality against the receiver's specification. Certification review confirms the required source and custody evidence. Claim release authorises particular wording for a defined product. Keeping these states separate prevents a usable bale from being rejected unnecessarily while also preventing its early use in an assured claim.

Supplier certificate changes require a controlled response. Before certified purchase or dispatch, the system should check certificate scope, validity and process coverage. If a certificate expires, is suspended or no longer covers the relevant product, the recommended control is to stop new certified claims and affected certified orders until

the certification body resolves the position. Ordinary production may continue only under an authorised non-claim disposition. This is a governance recommendation, not a claim that software alone proves fraud or conformity.

A practical exception test should include the following cases:

- **Missing input Transaction Certificate:** hold the affected material's certified status, preserve the physical lot and request evidence. Do not reconstruct a certificate from an invoice.
- **Different recycled and virgin losses:** calculate each fraction separately and hold the output percentage until representative batch evidence supports it. [S1101]
- **Same-process return:** classify the material as internal reuse unless the certification body accepts another treatment. Do not count it automatically as pre-consumer recycled content. [S1101]
- **Certificate scope mismatch:** stop the affected claim even when the supplier holds a valid certificate for another site, product or process. [S1103]
- **Unresolved stock difference:** investigate before closing the period. Do not allocate the difference to certified output because that would make the report balance.

Before an external audit, the plant should perform a vertical trace and a horizontal reconciliation. The vertical trace selects one claimed garment batch and follows it backwards through output documents, production records, input certificates and reclaimed-material origin. The horizontal reconciliation selects one period and tests whether total claimed inputs, stock, outputs, waste, rejects and non-certified sales reconcile. One tests depth; the other tests completeness. Both should include a deliberate correction so that the history of who changed what remains visible.

The final test is whether an independent reviewer can reach the same conclusion without oral explanation from the original operator. If the evidence requires a remembered supplier nickname, an undocumented moisture adjustment or a private spreadsheet formula, the control is not ready. GFT's recommendation is deliberately modest: record the material event once, preserve its source, calculate openly, and release only the claim that survives inspection. That gives a small factory an affordable path to assurance and gives its buyers a claim they can test.

Circularity becomes credible when every claimed kilogram has a history and every lost kilogram has an explanation.

CHAPTER SOURCE NOTES

S1101 Textile Exchange. 2026-07-01.

S1102 Textile Exchange. 2026-07-01.

S39 International Organization for Standardization (ISO). 2024-05.

S40 International Organization for Standardization (ISO). 2024-05.

S1105 International Organization for Standardization (ISO). 2024-10.

S1106 European Union. 2024-06-13.

S1104 Textile Exchange. 2025-10-08.

S1103 Textile Exchange. 2022-06-09.

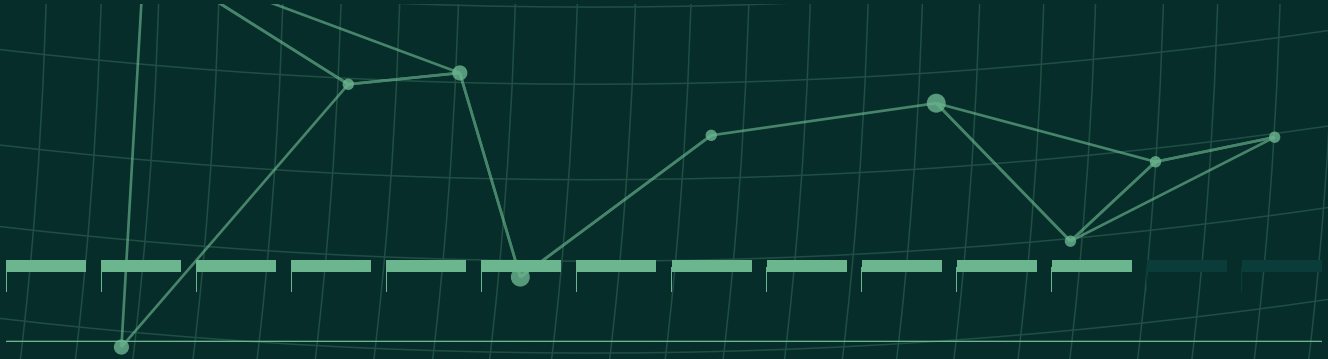
S1107 European Commission. 2026-09.

12

OPERATIONALISING THE CIRCULAR FACTORY / SHOP-FLOOR MEASUREMENT

Line-level waste logs in the performance-management system build the factory's circular data spine

Weigh material where it changes hands, preserve its identity, and make each unresolved difference a management decision. Circularity then becomes an operating discipline with inspectable limits.



CHAPTER 12
DECISION TEST

Weigh material where it changes hands, preserve its identity, and make each unresolved difference a management decision. Circularity then becomes an operating discipline with inspectable limits.

A factory's circular data spine should begin with a reconciled material event, then connect that event to quality, inventory and corrective action. A waste total alone cannot explain where material disappeared, whether a clean stream stayed separate, or whether a recycler accepted it. This chapter proposes a practical extension to GFT's performance-management system: weigh at defined boundaries, retain the original observation, link transfers through stable identifiers, and review exceptions before claiming improvement. The design is a recommendation for a greenfield operation, not evidence of an installed GFT factory or achieved recycling outcome.

The documentary starting point is GFT's Garment Production Performance-Management System Design, prepared for its Cameroon textile programme. Its KPI Architecture, Data Capture and Governance, Management Cadence, Incentives, Maturity Model, and Roles sections establish the operating framework used here. The companion workbook is described by that design; its actual cells have not been inspected for this chapter. Proposed waste fields, alert formulas and device connections below therefore remain extensions to specify and test, rather than features asserted to exist already.

12.1

The Sustainability KPI family needs the same production boundary as the factory decision

GFT's programme design groups measures into production, quality, delivery, cost, people and sustainability. Its Sustainability family covers water, energy and waste per unit. The proposed circularity extension should preserve that architecture. It should not introduce a separate sustainability spreadsheet with a different output count, reporting calendar or definition of a good garment. Each numerator must travel with its denominator and the boundary over which both were collected. Otherwise an apparent reduction in waste intensity may describe a change in reporting rather than a change in production.

The public description of ISO's circularity measurement standard emphasises defined economic systems and consistent data collection. That supports a boundary-first approach, but does not prescribe this chapter's factory dashboard. GFT recommends recording the physical area, material class, reporting interval, unit, allocation rule and approval status beside each measure. Plant totals and line-level estimates should remain visibly different. A total plant electricity meter, for example, should not be presented as a direct reading from an individual cutting table. [S40]

Define cutting waste as material removed at the cutting operation and classified for a stated destination. Keep reusable remnants, work in progress and unverified losses separate. Define sewing scrap over the sewing boundary without counting the cutting clips again. Define plant waste generation over the outer factory boundary, eliminating internal transfers. A transfer from cutting to a central scrap store changes location but does not create more waste. A subsequent bale dispatch changes custody but does not prove that recycling occurred.

For the proposed dashboard, pair absolute waste mass with intensity per accepted garment. Also retain waste relative to fabric consumed at the relevant operation. The garment denominator supports commercial planning; the fabric denominator helps compare material conversion. Product mix must remain available because a heavier garment can increase scrap per garment even when conversion improves. Aggregate by adding compatible numerators and denominators, then dividing. Do not average line percentages where their underlying material volumes differ.

Water and energy require equivalent care. GFT recommends separating directly metered consumption from allocated consumption and naming the allocation basis. Where shared services cannot be submetered, label their allocation as an estimate. Record idle consumption separately when possible so that low output does not hide the plant's standing demand. A waste intervention should be reviewed alongside quality, output and resource use; moving work into repeated reprocessing may reduce discarded panels while increasing another burden.

There is also a timing boundary between cutting and garment acceptance. Panels cut today may become accepted garments in a later period. GFT recommends maintaining a production-cohort view for conversion analysis and a calendar-period view for resource planning. Give each a clear title. Where the cohort is incomplete, leave its final intensity provisional. A calendar ratio can still help plan utilities and handling, but should not be interpreted as the completed material yield of that day's cutting work.

Cameroon's inherited sector register reports about 95 percent of cotton fibre exported raw and about 5 percent processed locally. The original publication date is not recorded and this chapter has not independently refreshed that baseline. It supplies context for measuring domestic conversion, not a factory yield target or a claim about GFT output. The chapter's operating examples deliberately use assumed factory inputs instead of treating a national fibre share as plant evidence. [R06]

> **GFT NOTE**
>
> Use the existing management dashboard as the receiving surface. Add a waste view only when its owner can identify the source observations, reconcile the material boundary and name the next decision. Keep unresolved mass visible. Do not make a plant's circularity story depend on a cleaner-looking total produced by excluding inconvenient material.

12.2

The cutting-table balance must include stock, returns and unresolved differences

The proposed lay record starts when fabric is issued to the cutting operation and ends when the lay is closed. Record the roll and batch identity, order, marker revision, operator role, scale identity and event time. Gross weight and tare should be separate observations. Packaging and cores should not enter a fabric-only balance. A partially used roll returned to stores must retain its identity and measured remainder; it cannot disappear because the original issue was entered as full consumption.

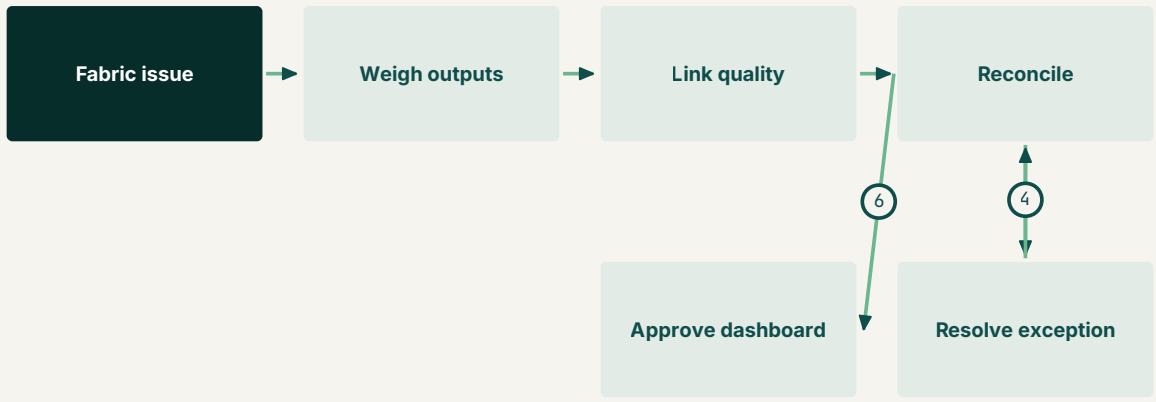
For a defined period, use the following recommended equation: opening fabric stock plus net receipts equals accepted panel transfers plus sorted clips plus other scrap plus reusable returns plus closing fabric stock plus signed unresolved difference. Internal receipts and transfers should use the same identifiers on both sides. The equation is an accounting identity, not a promise of perfect measurement. It requires a common material basis and sufficiently aligned observations before its residual has operational meaning.

Moisture change, timing differences, scale resolution, unrecorded packaging and incomplete work can all complicate interpretation. Treat these as hypotheses to investigate, rather than automatic explanations. Record the weighing condition and repeat a suspect observation where practicable. If conditioned or standardised weights are needed for a later claim, keep that conversion separate from the original shop-floor reading. Textile Exchange's cited Content Claim Standard describes standardised-weight reconciliation, expected waste factors and inventory treatment; its requirements should not be replaced by an unexplained cutting-room tolerance. [S1201]

Exhibit 54, p. 195 shows the proposed event path. The physical record should reach the exception queue before the dashboard publishes a closed period. Linking quality at this point allows a disputed result to remain reviewable without pretending that every defect caused a measured mass loss.

EXHIBIT 54 / ILLUSTRATIVE EVENT SEQUENCE

A material event reaches the dashboard through a reconciliation decision



4. Open

6. Approved

ILLUSTRATIVE GFT proposed control design, not an implemented system. Physical movements retain their event identifiers; quality links inform classification and do not manufacture additional mass.

The diagram is intentionally a control flow rather than a material-flow chart. Its arrows do not represent kilograms. At the actual factory boundary, a bag transfer and the later bale containing that bag must be linked so the system can eliminate duplicate

counting. If bags from different lays are combined, store their contributions to the bale. Where attribution was lost, mark the origin unresolved and keep the material out of origin-specific claims until evidence resolves it.

WORKED EXAMPLE: A BALANCED PERIOD STILL CONTAINS AN UNRESOLVED DIFFERENCE

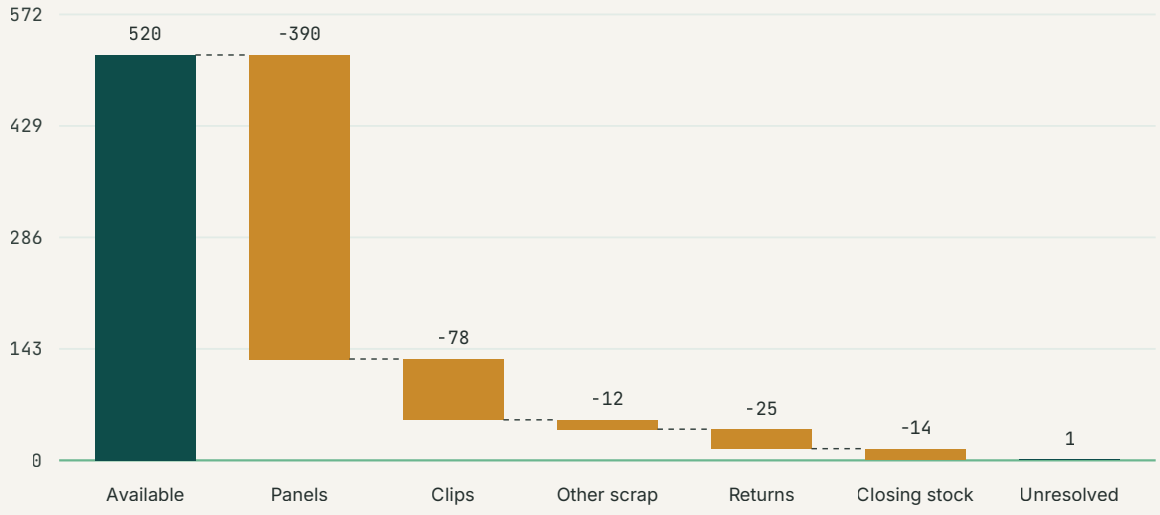
Assume an illustrative cutting period with 500 kg of net fabric receipts and 20 kg of opening stock. Observed destinations are assumed to be 390 kg of accepted panels, 78 kg of sorted clips, 12 kg of other scrap, 25 kg of reusable returns and 14 kg of closing stock. Available fabric is 500 + 20 = 520 kg. Recorded destinations total 390 + 78 + 12 + 25 + 14 = 519 kg. The signed unresolved difference is therefore 1 kg, or 1 / 520 × 100 = 0.192 percent, rounded to three decimal places. These inputs are constructed to demonstrate the method, not measured factory performance.

For this illustrative period, total generated scrap is 78 + 12 = 90 kg. Its share of available fabric is 90 / 520 × 100 = 17.31 percent, rounded to two decimal places. This is a period availability measure, not a marker-efficiency result. The returns and closing stock remain usable material. The 1 kg difference remains unresolved; it is not silently added to saleable clips or explained as evaporation.

Exhibit 55, p. 196 preserves that residual explicitly. An apparently small percentage can still require review when it repeats systematically or follows a particular weighing device. The illustration does not establish an acceptable commercial or certification tolerance.

EXHIBIT 55 / KG, ILLUSTRATIVE CUTTING PERIOD

Recorded destinations leave an unresolved mass that remains visible



ILLUSTRATIVE Assumed inputs: opening stock 20 plus receipts 500 = 520. Subtract panels 390, clips 78, other scrap 12, reusable returns 25 and closing stock 14. Residual = 1 kg. This is a demonstration, not an observed loss rate.

A proposed alert could compare the absolute residual with available mass, but its threshold needs pilot evidence. An illustrative 0.5 percent alert would correspond to 2.6 kg on the assumed 520 kg availability. That is a design test value, not an existing workbook rule, a theft test or a standard's allowance. Before adopting it, establish scale repeatability, tare discipline, typical transfer timing and the smallest operationally important discrepancy. Review signed residuals as well as absolute values, because alternating errors and persistent bias require different responses.

Distinguish a control threshold from measurement uncertainty. A scale's displayed resolution is not, by itself, the uncertainty of an entire period balance. Several readings, variable tare and different weighing conditions can contribute. Recommend a documented weighing study using repeat observations, reference loads and the actual containers. Its result should determine whether the proposed alert can distinguish an operational difference from ordinary measurement variation. If it cannot, improve the weighing method or aggregate at a more suitable boundary before tightening the threshold.

12.3

Quality-linked waste events separate observed loss from assumed cause

GFT's programme design assigns defect type and count to a Quality Log and resource quantities to a Sustainability Log. The proposed extension joins them through material and process identifiers. A defect event should record where the problem was detected, the affected roll or panel bundle, the inspection method, the defect code and the disposition decision. A waste event should record the material actually removed. Their relationship may be absent, disputed or shared across several observations.

Do not convert a defect count into a scrap weight using an average garment mass unless the result is explicitly an estimate with its basis. A defect can be repaired without discarding the panel; an imperfect panel can carry several defects; a single roll fault can affect several bundles. A simple unrestricted join would multiply the waste mass across matching defect rows. Preserve a unique material-event record and use a separate link record for causation or allocation. Test totals before and after any cross-tabulation.

Recommended cause classes distinguish marker-related clips, fabric faults, spreading or splice losses, cutting errors, sewing trimming and rejected work. Preserve unknown cause as an allowable state. Mark classifications as provisional until an authorised reviewer accepts them. The weekly review can then ask whether loss concentrates by supplier lot, marker revision, fabric width, machine or training need. Supplier chargebacks require agreed terms and evidence; a dashboard correlation alone should not create a debit or assign blame.

For the proposed output measures, define defects per hundred inspected units as defect count divided by inspected units, multiplied by the percentage scale. Define first-pass yield as units accepted on their first completed inspection divided by units first inspected. Keep repaired units in a separate disposition field. Declare the inspec-

tion boundary and sampling coverage. An empty inspection denominator produces an unavailable rate, not perfect yield. Repeat inspections must not inflate the denominator or conceal the original first-pass failure.

Composition and shade need their own evidence states. NIST explains that reference data are needed to train textile-sorting algorithms and describes near-infrared measurements as a way of distinguishing fabric types. This supports retaining test methods and references; it does not establish local classifier performance or prove that a bin is pure. Record supplier declarations, visual segregation and instrumental checks separately. A scanned roll label identifies a record, while a verified composition result supports a material classification. [S27]

The field proposal in **Exhibit 56**, p. 198 extends the programme's log concept without claiming that these columns already exist. Its concise presentation is not a complete database schema. The underlying event header must also carry time, location, units, weighing device, tare, editor, approval state and correction history.

EXHIBIT 56 / ILLUSTRATIVE FIELD SPECIFICATION

Circularity fields connect material identity to a controlled disposition

Field	Validation purpose
Roll / batch ID	Resolve material origin
Fibre / shade code	Retain evidence status
Marker plan ID	Preserve approved revision
Actual consumption	Retain mass and unit count
Sorted clip mass	Link event and container
Other scrap mass	Classify without duplication
Custody reference	Distinguish pending evidence

ILLUSTRATIVE GFT proposed extension to the programme's log concept. These fields have not been verified in the companion workbook. Optional certification references stay empty with a reason until relevant evidence exists.

A custody reference should point to a document and its review state, rather than a typed assertion that material is certified. Keep physical dispatch, buyer receipt, accepted net mass, claim eligibility and payment as separate states. An outgoing bale can be physically present and commercially saleable while its claim evidence remains incomplete. The recovery standard's public scope explicitly excludes material-specific quality criteria, so a buyer's composition and contamination specification still needs its own agreement and verification method. [S1202]

Treat container splits and merges as explicit events. When a damaged bale is reopened, retain its original identifier and link the replacement containers to the material removed from it. Do not allocate their combined mass back to every contributing lay. When a remnant re-enters production, record its issue from stock rather

than a new external fabric purchase. These controls let the record explain physical movements without creating fictitious receipts, repeated waste generation or recycled input simply because the same material crossed an internal door.

12.4

Daily, weekly and monthly reviews must produce different decisions

The Management Cadence section of GFT's programme design establishes a daily line huddle, a weekly plant review and a monthly sales-and-operations meeting. Apply those rhythms to circularity without creating a parallel governance structure. Daily review should address material still close enough to inspect. Weekly review should investigate patterns and reconcile stores. Monthly planning should adjust future production and material requirements using approved histories and clearly identified unresolved quantities.

At the daily huddle, recommend displaying waste mass, accepted output, first-pass yield, open reconciliation exceptions and sorting exceptions for the affected operation. Begin with the exception that needs a physical decision: an unidentified bag, an incomplete lay, a disputed tare or a rejected bundle. Allocate an owner and a deadline. Keep provisional figures visibly provisional. If the source observation cannot be checked immediately, carry the issue forward rather than replacing it with yesterday's average.

At the weekly review, reconcile the scrap store as carefully as the cutting table. Opening stock plus receipts should equal dispatches plus closing stock plus unresolved difference. Confirm whether dispatched mass came from the current production period or earlier inventory. Check dispatch weight against receiver acceptance without overwriting either reading. A disagreement may arise at a different boundary or weighing condition. GFT recommends a documented resolution that preserves both observations and identifies the quantity used for operational and commercial reporting.

The weekly review should also close corrective actions with evidence. A proposed marker change needs a comparable product and fabric basis. A training intervention needs a defined defect category and inspection coverage. Reweighing an ambiguous container resolves a measurement issue, but does not establish a process improvement. The action register should therefore distinguish data correction, containment, cause investigation and verified operating change. Each has a different completion test and may belong to a different role.

Monthly sales-and-operations planning should use the approved material history to estimate fabric needs and recoverable streams under the chosen product mix. Keep these forecasts distinct from observed stock and accepted sales. Do not net expected scrap revenue against fabric requirements or present an unconfirmed recycler destination as dependable demand. The chapter does not evaluate recycling-route economics; its task is to make the quantities, dates and evidence states available for that later decision.

The limited dashboard in **Exhibit 57**, p. 200 deliberately avoids universal target percentages. Targets require a baseline, product scope, measuring method and owner approval. The proposed cards combine mass, quality and evidence completion, so a smaller waste number cannot automatically erase an unresolved stock movement.

EXHIBIT 57 / ILLUSTRATIVE MEASURE DEFINITIONS

A short dashboard keeps material, quality and evidence in view

g / good unit **Waste intensity** Pair with absolute kg	Actual / plan **Consumption** Same product basis	Good / inspected **First-pass yield** First inspection only
Accepted / checked **Sorting** Disclose check coverage	Signed kg **Mass difference** Retain open exceptions	Reviewed / due **Custody evidence** No certification implied

ILLUSTRATIVE Recommended dashboard design, not operating results or targets. Each measure requires a period, boundary and owner; unavailable denominators remain unavailable.

Where a decision depends on a missing quantity, display the decision constraint beside the measure. An open bale reconciliation can block a recycled-content claim while allowing ordinary production to continue under an authorised disposition. A safety concern may require a different response. Define these authorities before launch. The review must end with a decision, an owner and evidence needed for closure, rather than a dashboard colour that nobody is responsible for interpreting.

For comparable performance reviews, keep both the approved snapshot and the latest corrected record. A late receiver acknowledgement may close a custody exception without changing the original dispatch observation. A corrected tare may change net mass and require a restated total. The action log should distinguish these cases.

Recommend displaying the reason for a restatement beside the revised period, with a route back to the original approved view. This makes a management decision inspectable without freezing a known error indefinitely.

12.5

Incentives should reward verified good output and protect honest reporting

The Incentives and Improvement Engine section of GFT's programme design links rewards to productivity and quality within the applicable wage rules. It explicitly favours first-pass yield and reliable output over raw speed. The proposed waste extension should follow that principle: reward controllable improvements while preserving the ability to report a supplier defect, a failed sort or an unexplained mass difference. This chapter does not set wages, determine statutory compliance or recommend deductions from pay.

A proposed team reward should require an agreed quality result, a reconciled material record and satisfactory verification of segregation. Explain the eligibility rules before the measurement period starts. Exclude unresolved data from reward calculations without treating honest reporting itself as misconduct. Provide a way to challenge a classification. If incoming material fails, log it before production and separate the supplier issue from the team's controlled performance. The point is to reveal the constraint early enough to act on it.

Guard against a poorly chosen waste target by reviewing possible substitutions. Teams might reclassify scrap as reusable stock indefinitely, move containers across reporting periods, or delay reject recording until after a reward is calculated. These are design risks to test, not claims that a particular workforce has behaved this way. Age reusable remnants and require a disposition decision when they cease to have a credible use. Preserve the original event date when a correction is entered later.

Sorting compliance also needs an honest denominator. A checked-bag acceptance rate describes the inspected population, not every bag produced. Record how bags were chosen, what was checked and which streams were excluded. If composition testing is expensive, use a risk-based sampling proposal and state its limits. Do not attach a purity percentage to shade labels alone. GFT recommends changing the checking plan when a new fabric blend, finish, supplier or destination introduces an untested classification problem.

Use small supervised trials before changing reward policy. Compare record completeness, unclassified mass, quality dispositions and total good output under similar operating conditions. A fall in reported scrap accompanied by growing unknown stock is a signal to investigate the measure. Keep evidence of the trial and employee communication with the approved policy. Any compensation arrangement needs separate local review; this operational design is not legal, tax or investment advice.

12.6

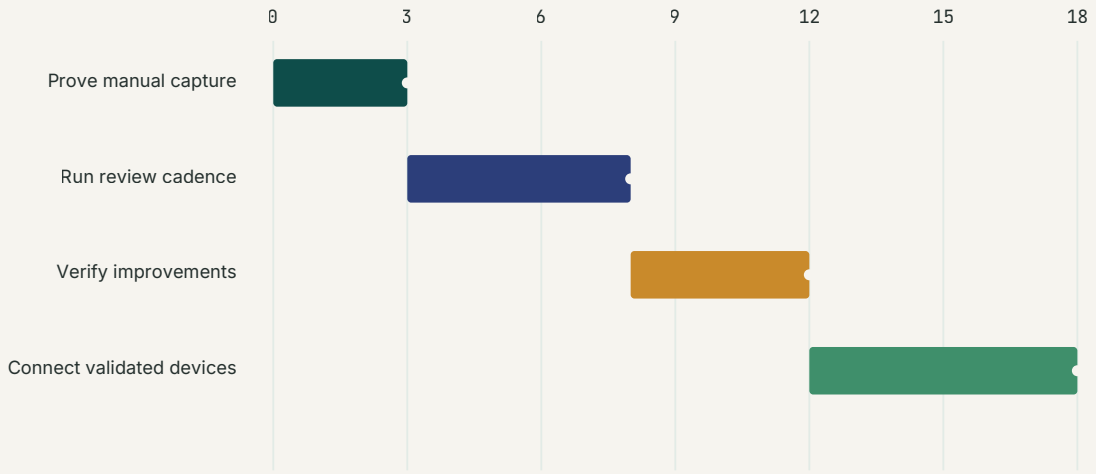
Manual capture must prove its definitions before connected scales automate them

The Maturity Model section of GFT's programme design specifies an eighteen-month sequence. Its illustrative planning windows are months 1 to 3 for clean capture, months 4 to 8 for active management, months 9 to 12 for improvement, and months 13 to 18 for connecting the digital layer. Those are the source design's planning stages, not achieved milestones. The circularity overlay below preserves that sequence instead of assigning connected scales to a calendar date without an operating gate.

Exhibit 58, p. 202 uses elapsed months from an assumed start. It is an illustrative planning aid. Procurement, staffing, production readiness and a workable weighing method would determine the real start and stage transitions.

EXHIBIT 58 / ILLUSTRATIVE ELAPSED MONTHS FROM AUTHORISED START

The proposed rollout connects devices after capture and management work



ILLUSTRATIVE Circularity overlay on GFT's PMS maturity design. Intervals 0 to 3, 3 to 8, 8 to 12 and 12 to 18 correspond to planning months 1 to 3, 4 to 8, 9 to 12 and 13 to 18. These are proposed windows, not commitments or achieved gates.

For clean capture, recommend proving container identity, tare handling, units, incomplete-lay treatment and the period close. Staff should be able to reconstruct a selected movement from the original weighing evidence to its dashboard contribution. Include a power interruption and an absent supervisor in the exercise. Paper contingency records should carry unique references and later be entered as transcriptions with their original observation times. The gate is recoverable evidence, not merely a workbook populated with plausible values.

For active management, prove that exceptions reach a responsible person and remain open until resolved. Test an unidentified bag, a duplicated entry, a negative net weight, an implausible unit conversion and a material movement entered after close.

The dashboard should distinguish invalid input from a valid but unusual reading. Do not delete an observation merely because it falls outside a normal range. Require a reason, reviewer and replacement link when correction is appropriate.

For improvement, recommend comparing measures under controlled definitions and preserving the old baseline when the product mix or inspection method changes. Demonstrate that an intervention reduced a specific loss mechanism without shifting it into rejects, inventory or a different reporting period. ISO's foundational circular-economy guidance supplies a vocabulary and implementation context; it does not certify the effect of a local trial. Keep the trial's evidence and decision record available for review. [S39]

Only then test connected weighing devices. Automatic transfer can reduce retyping, but it can also repeatedly transmit a wrong tare, stale reading or incorrect container identity. Require stable-weight logic, device identification, unit checks, duplicate-event handling and an offline queue with explicit synchronisation status. Test a disconnected network and a restarted device. Compare physical observations with stored events and published totals before authorising unattended capture. No particular connection protocol is assumed to solve these controls by itself.

The reviewed GS1 EPCIS specification describes event data and interfaces for sharing visibility information. It offers a useful reference when the plant later exchanges material events with other systems. GFT recommends preserving the identity, time, place, business context and provenance of an observation even in a manual design. This recommendation does not mean the proposed workbook implements EPCIS or that acquiring an interface produces verified custody. [S1203]

Before migration, agree an acceptance dataset containing ordinary movements and deliberate exceptions. Include a reopened lay, a split container, a corrected weighing, an incomplete inspection and a dispatch disputed by its receiver. Reconcile event counts, mass totals and exception states across the manual and replacement systems. Require differences to be explained and approved before the replacement becomes authoritative. Preserve the original record export and the transformation rules so that historical classifications remain intelligible even after software and staff change.

12.7

Role ownership and preserved history make the data spine transferable

GFT's Roles and System of Record section assigns the line logs to supervisors, the Quality Log to the quality lead, the dashboard to the plant manager and the monthly plan to leadership. It describes the manual Excel pack as the initial record and the specification for a later platform. Apply that continuity principle to circularity. Responsibility should attach to an operating role and a documented handover, rather than depend on an individual's undocumented knowledge.

The proposed cutting-room owner checks issues, reusable returns and lay closure. Sewing supervisors check accepted transfers, rework and sewing scrap. The quality lead approves defect classifications and disputed segregation evidence. Stores personnel control bag-to-bale aggregation and physical stock. The plant manager

approves period closure and resolves cross-functional exceptions. A separate authorised reviewer should approve outward claims after checking the relevant evidence. These are recommended responsibilities, not a representation of GFT staffing or certification.

Preserve a versioned definition register alongside the operational records. It should state each measure's formula, unit, scope, exclusions, owner and effective date. Treat a formula change as a controlled change, with a comparison against the preceding method. Historical reports should retain the definition used when approved. If history is restated, identify the restatement and its reason. A future platform must reproduce selected historical totals before it replaces the manual system as the authoritative record.

The cited Textile Exchange standard provides a useful benchmark for the distinction between inputs, stock, waste and claimed outputs. It calls for documented equations and waste-factor bases within its stated scope. The proposed PMS should make those records available, while leaving certification eligibility and scheme-version applicability to a separate review. Physical reconciliation is necessary evidence; it is not a substitute for the full requirements governing a commercial content claim. [S1201]

Finish the handover with an exception exercise rather than a presentation. Ask the incoming owner to trace a returned roll, locate an unclosed lay, explain a corrected tare and reconcile a selected bale to its contributing material events. Require the person to identify what remains unknown and who may authorise the next action. Successful completion demonstrates usable continuity. It does not establish production performance, recycler acceptance or an independently verified circularity claim.

The result is a modest but consequential operating discipline: production creates material movements, measurement preserves their identity, and management decides what unresolved evidence permits. A future recycling agreement can use those quantities without asking the factory to reconstruct its past. The circular data spine earns its place by making the next shift easier to control and the next claim easier to inspect.

Keep the unresolved kilogram in the record until the evidence gives it a destination.

CHAPTER SOURCE NOTES

S40 International Organization for Standardization (ISO). 2024-05.

R06 Cameroon Trade Hub. Publication date unrecorded; inherited source-text check.

S1201 Textile Exchange. 2022-06-09.

S27 National Institute of Standards and Technology (NIST). 2025-01-07.

S1202 International Organization for Standardization (ISO). 2024-10.

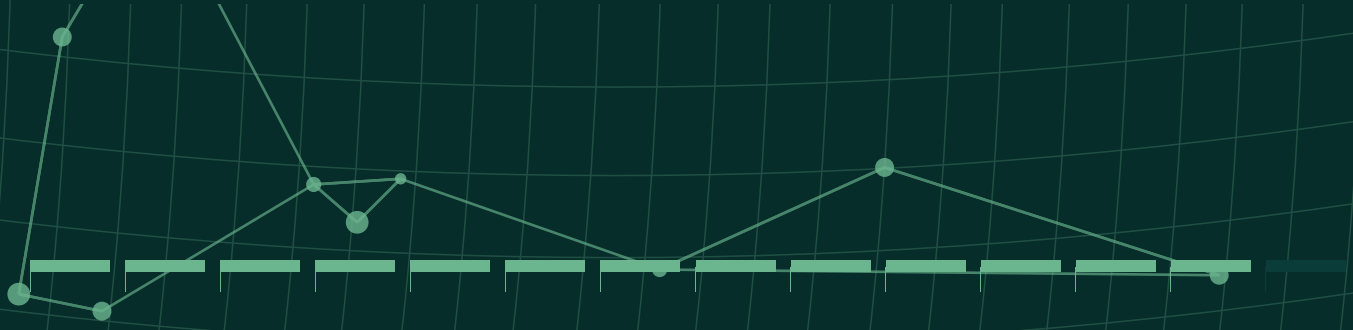
S39 International Organization for Standardization (ISO). 2024-05.

S1203 GS1. 2022-06.

13

Industrial symbiosis between cut-make-trim plants and integrated spinning poles closes the regional loop

By partnering a lean cut-make-trim garment factory with Cameroon's emerging integrated spinning poles at Dibamba and Garoua, pre-consumer cotton clips cycle back into local yarn without greenfield spinning capex.



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By partnering a lean cut-make-trim garment factory with Cameroon's emerging integrated spinning poles at Dibamba and Garoua, pre-consumer cotton clips cycle back into local yarn without greenfield spinning capex.

A greenfield garment manufacturer in Cameroon does not need to finance a spinning or chemical pulping mill in Phase 1 to close the textile loop, provided it signs a two-way industrial symbiosis contract with the country's upstream spinning poles. [R08] Under Green Future Tech Limited's (GFT) partnered-spinning model, defined in the Cameroon programme prepared on 31 January 2024 with source refreshes retained in 2026, a cut-make-trim (CMT) factory sized at an illustrative 3.0 million garments a year buys traceable cotton fabric from domestic hubs and returns 135 to 210 tonnes a year of colour-sorted, 100 percent cotton cutting clips. [R09] When those pre-consumer clips are mechanically torn and blended at 20 to 30 percent with virgin SODECOTON lint on open-end rotor frames at hubs such as Camtext SA (12,000 tonnes a year across Dibamba and Garoua) or the announced SODECOTON and CICAM pole, the loop stays inside the Central African CFA franc (XAF) zone. [R10] Sorting and baling clips at the cutting table while incorporating 25 percent recycled yarn into uniforms and basics generates an illustrative net value of US$110,000 to US$260,000 a year, cuts unit fabric cost by 4 to 7 percent, and meets Global Recycled Standard (GRS v4) rules without spinning debt. [S24] Nothing in this chapter is investment, legal or tax advice; all figures and terms are derived from cited benchmarks or labelled illustrative models requiring project-specific validation.

13.1

GFT's partnered-spinning operating model creates a natural two-way material loop with public poles

GFT's Cameroon feasibility study separates capital-light garment assembly from capital-heavy yarn and fabric manufacturing in Phase 1. [R06] Rather than building an isolated vertical complex from ginning to retail at launch, the private CMT venture focuses capital on pattern engineering, spreading, cutting, sewing, quality assurance and shop-floor measurement, while treating national and mixed-capital textile projects as upstream fabric suppliers and circular reprocessing partners. [R08]

Cameroon's National Development Strategy 2020 to 2030 (SND30) targets raising domestic cotton processing from 5 percent of lint output to 50 percent by 2030, alongside a 600,000-tonne seed-cotton goal. [R07] Two upstream projects anchor this shift. [S1301] First, Camtext SA, unveiled in November 2025 at US$300 million (180 billion XAF) by Panafritex and Arise with SODECOTON, CNPS and Marlo Properties Fincorp, will process 12,000 tonnes a year of SODECOTON lint. [R09] Modelled on Arise's Benin platforms, Camtext SA splits operations between a Dibamba port-zone hub near Douala (spinning, weaving, knitting and finishing creating 12,000 jobs) and a Garoua pole (training and garment assembly creating 3,000 jobs), opening preparation in the first half of 2026 and ramping over four years toward optimal capacity around 2033 with return on investment near 11 years. [S1301] Second, the state announced the merger of SODECOTON and CICAM to form a national cotton-textile pole by 2030, alongside CICAM site modernisation. [R08]

13.2 UPSTREAM SCALE REQUIRES DOWNSTREAM CUTTING ROOMS, AND CUTTING ROOMS REQUIRE UPSTREAM ROTORS

Viewing Camtext SA or a merged SODECOTON-CICAM pole solely as a garment rival misreads plant economics. [R10] A mill processing 12,000 tonnes of lint a year carries high fixed utility, depreciation and effluent costs. [S1301] As CICAM's July 2023 report showed, with utilisation at 33.7 percent in Garoua, 48.9 percent at CICAM 1 and 10.83 percent at CICAM 2 and underutilisation costing CFAF 2 billion in 2020, running heavy textile equipment below capacity erodes solvency. [R12] Upstream poles need solvent domestic CMT buyers placing predictable fabric orders. [R09]

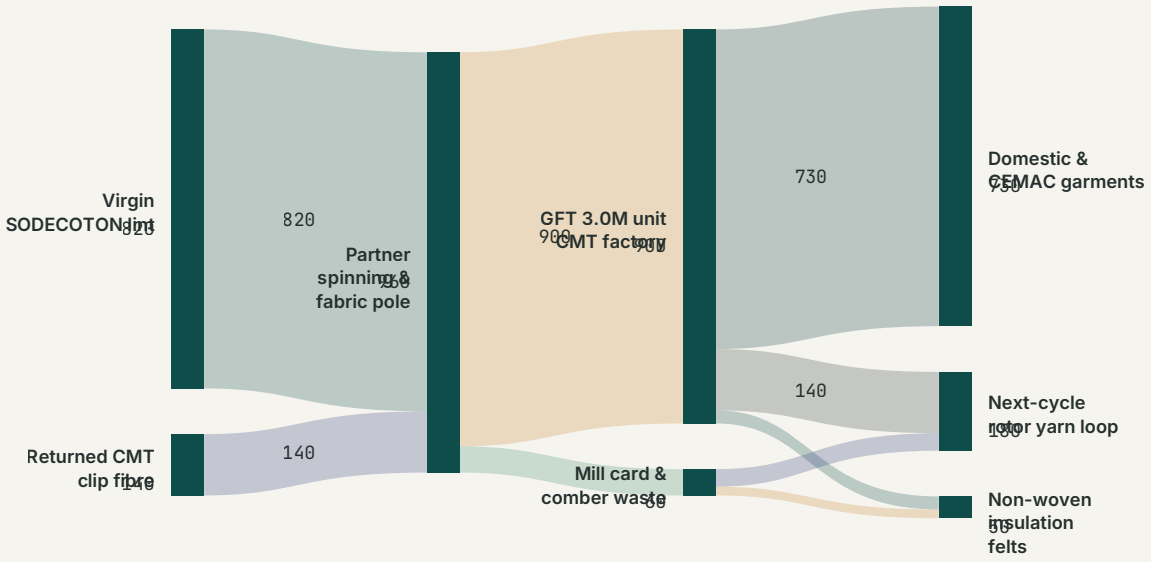
Conversely, a CMT plant at an illustrative 3.0 million garments a year generates 135 to 210 tonnes of pre-consumer waste annually (105 to 155 tonnes of pure clips, 15 to 25 tonnes of remnants, and 15 to 30 tonnes of overlock trims, derived in Chapter 3 from 15 to 22 percent loss rates). [S32] At 105 to 155 tonnes a year, one CMT factory cannot justify a US$600,000 to US$1.5 million 5-cylinder tearing line needing 1,500 to 3,000 tonnes a year. [S24] Inside a 12,000-tonne spinning pole, however, internal blowroom droppings, card strips and comber noils already yield 960 to 2,160 tonnes a year of cotton waste at an illustrative 8 to 18 percent loss rate. [R10] Adding 105 to 155 tonnes of colour-sorted clips from GFT's CMT plant and peer workshops brings a EUR 1 million tearing module at the pole to full utilisation. [S1302]

13.3 PHYSICAL AND DOCUMENTARY RECIPROCITY GOVERNS THE CLOSED-LOOP FLOW

Exhibit 59, p. 208 maps the conserved annual mass balance across four stages for an illustrative CMT contract of 900 tonnes of cotton fabric a year. [R10] In Stage 0, the spinning pole blends 820 tonnes of virgin lint from SODECOTON's nine gins with 140 tonnes of torn fibre from prior CMT clips. [R03] In Stage 1, the pole processes those 960 tonnes, delivering 900 tonnes of cloth to GFT's cutting room and capturing 60 tonnes of card and comber waste. [S24] In Stage 2, the CMT plant turns the 900 tonnes of cloth into 730 tonnes of garments, bales 140 tonnes of shade-sorted clips for rotor re-spinning, and routes 30 tonnes of overlock trims (plus 20 tonnes of short mill droppings) into non-woven insulation felts. [S28]

EXHIBIT 59 / TONNES OF COTTON MATERIAL PER YEAR

Regional industrial symbiosis loops SODECOTON lint, Camtext spinning and GFT cut-make-trim clips inside Cameroon



ILLUSTRATIVE [R03] [R09] [R10] [S24] [S28] Illustrative conserved mass balance for a 3.0 million garment a year CMT plant purchasing 900 t/yr of fabric from a partner spinning pole (such as Camtext SA at 12,000 t/yr total capacity, R10). Internal nodes conserve mass exactly (960 t total input = 730 t garments + 180 t rotor yarn loop + 50 t non-woven insulation). This is a planning model, not a recorded operating result.

As shown in **Exhibit 59**, p. 208, out of 960 tonnes of total fibre entering the boundary, 730 tonnes exit as apparel, 180 tonnes (140 tonnes of CMT clips plus 40 tonnes of comber noils) cycle back into open-end rotor yarn, and 50 tonnes of short droppings and seam trims enter construction non-wovens. [S24] What **Exhibit 59**, p. 208 cannot establish on its own is the construction schedule of the upstream poles: both Camtext SA (optimal capacity around 2033) and the SODECOTON-CICAM merger (targeted by 2030) depend on financing and grid energy delivery. [R08] Until domestic tearing capacity is commissioned at Dibamba or Garoua, the CMT factory executes the same sorting and baling protocol and sells graded bales to regional or Mediterranean mechanical recyclers under export backhaul contracts. [S25]

GFT NOTE

Treat public and mixed-capital spinning poles as bilateral industrial partners from Phase 0. A private CMT sponsor should not compete head-on against state-backed mills in commodity yarn spinning; instead, sign a reciprocal supply and waste-return memorandum where the CMT plant guarantees fabric offtake and returns pre-sorted, zero-elastane cutting clips to the spinner's blowroom under a transparent XAF credit formula. [R09]

13.4

Location trade-offs between the Douala-Dibamba corridor and Garoua shape reverse-logistics costs

GFT's feasibility study compares two Cameroonian siting geographies: the southern Douala-Dibamba port-industrial corridor in the Littoral region, and the northern cotton-basin hub of Garoua. [S1301] Adding reverse logistics highlights distinct transport distances, utilities and co-product links. [R10]

North African circular pilots show why distance between the cutting room and the tearing line governs recycling cost. [S1302] In UNIDO's SwitchMed pilot with Moroccan denim producer EVLOX in Casablanca-Settat, researchers tracked 160 tonnes of pre-consumer cotton waste (50 tonnes white, 110 tonnes denim) from five garment makers over four months. [S1302] UNIDO proved that warehouse re-sorting is far costlier than in-factory table segregation and that transport accounts for 30 to 40 percent of recycling cost when loose scraps travel long distances. [S1302] EVLOX therefore limited collection to five plants within 70 kilometres of its Settat mill (500 tonnes a year of potential waste). [S1302]

13.5 SITING ON THE DOUALA-DIBAMBA CORRIDOR MINIMISES SPINNING-HUB BACKHAUL AND MARKET DELIVERY LEGS

Locating the CMT factory on the Douala-Dibamba corridor places the cutting room within 15 to 40 kilometres (illustrative industrial radius) of the Camtext SA Dibamba hub, which houses spinning, weaving, knitting and finishing units and 12,000 projected jobs. [S1301] Like the 70-kilometre Settat cluster, co-location on the Douala-Dibamba axis reduces clip return to a local flatbed shuttle next to Douala and Yaounde markets, Douala port, and the southern hydroelectric grid, balanced against higher urban wage competition and land lease rates than in the north. [R14]

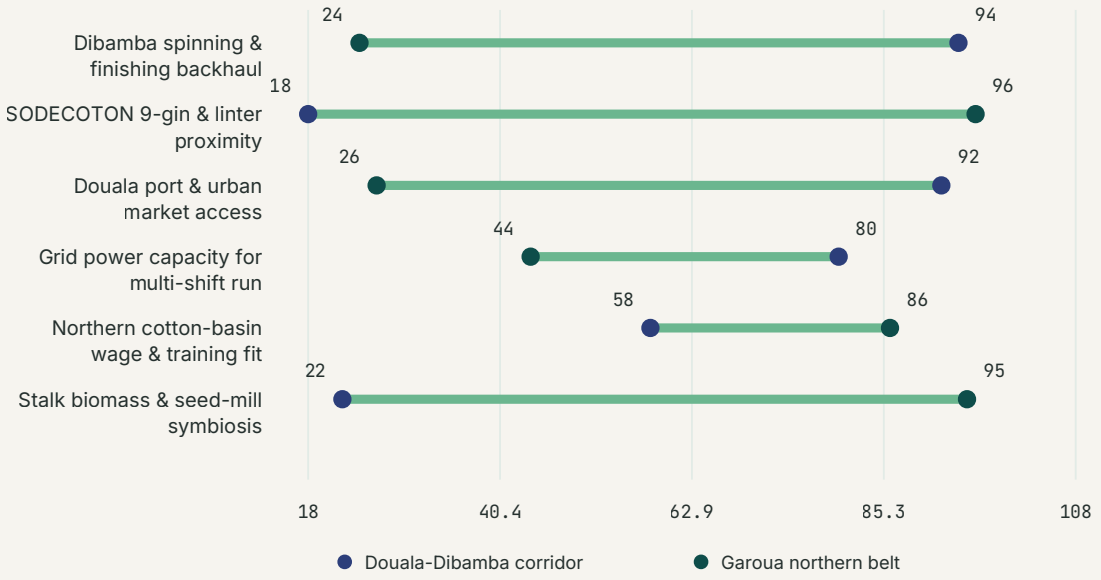
13.6 SITING AT GAROUA PLACES THE FACTORY INSIDE THE COTTON HARVEST AND GINNING BASIN

Conversely, siting in Garoua places assembly inside the cotton basin, where SODECOTON supports 220,000-plus farmers across nine gins and two oil mills, harvesting 314,455 tonnes of seed cotton in 2023, about 340,000 tonnes in 2024, and a projected 350,000-plus tonnes in 2025. [R01] Garoua hosts CICAM's northern plant (33.7 percent utilisation in July 2023) and Camtext SA's planned 3,000-job training centre and garment plant, whose recruitment opens in the first half of 2026. [R12] A Garoua CMT plant sits beside ginning co-products (linters, motes, seed-oil mills and stalks) and lower northern living costs near the statutory wage floor, though until full spinning operates in Garoua it faces an 800-to-1,000-kilometre haul (illustrative transit distance) to ship garments south or exchange bales with Dibamba. [S1301]

Exhibit 60, p. 210 compares the Douala-Dibamba corridor and Garoua across six derived circularity and operational criteria on a 0 to 100 suitability scale. [S1301]

EXHIBIT 60 / DERIVED SITE-SUITABILITY SCORE (0 TO 100 SCALE)

Douala-Dibamba corridor siting minimises spinning-partner backhaul distance while Garoua siting minimises ginning distance



DERIVED [R03] [R09] [R10] [R12] [S1301] [S1302] Derived multi-criteria evaluation (0 = severe friction, 100 = optimal co-location) comparing the Douala-Dibamba corridor and Garoua across six operational factors from GFT's Feasibility Study (Sections 5 and 10), Camtext SA's dual-pole design (R10, S1301) and UNIDO's 70 km waste-transport threshold (S1302). Scores are analytical planning indices, not physical measurements.

The paired scores in **Exhibit 60**, p. 210 explain why Cameroon's textile build-out uses a bi-polar corridor architecture. [S1301] On the Douala-Dibamba corridor, spinning-partner backhaul (94 versus 24), port and southern urban market access (92 versus 26) and southern grid power (80 versus 44) favour Phase 1 CMT launch and short-loop clip return to Dibamba mills. [R10] In Garoua, proximity to SODECOTON's nine gins (96 versus 18), northern workforce and training fit (86 versus 58) and biomass symbiosis (95 versus 22) favour upstream co-product processing and basic workwear assembly. [R03] What **Exhibit 60**, p. 210 cannot decide alone is plot-specific cost: sponsors must price actual XAF per tonne-kilometre trucking tariffs, land concessions and backup diesel hours at the selected site. [S1302]

13.7 HIGH-DENSITY HYDRAULIC BALING NEUTRALISES THE FREIGHT PENALTY THROUGH BACKHAUL CONTAINER LOADING

Whether the CMT plant sits in Dibamba or Garoua, bale density determines whether transport consumes 30 to 40 percent of recovery value or drops below 8 percent (illustrative logistics share). [S1302] Loose cutting clips in polythene sacks have a bulk density of 40 to 60 kilograms per cubic metre (illustrative bulk density), so a 40-foot container cubes out at under 3.5 tonnes. Pressing 250 to 400 kilogram bales on a vertical hydraulic baler raises density above 350 to 450 kilograms per cubic metre (illustrative bale density), letting a 20-tonne truck haul 50 to 70 bales on discounted Garoua-to-Douala backhaul legs in 5.0-tonne to 10.0-tonne minimum lots. [S24]

13.8

Unit economics of pre-consumer waste valorisation turn a disposal cost into a gross-margin buffer

In an unmeasured garment plant, the 135 to 210 tonnes of annual cutting clips, remnants and sewing rejects from a 3.0 million garment a year factory are treated as rubbish. [S10] Mixed with polyester thread, oil and dust, unsorted waste incurs landfill tipping fees of US$30 to US$60 a tonne (illustrative hauling cost) or sells to brokers for pennies per kilogram. [S24] Enforcing cutting-table segregation by shade and composition from Shift 1 reverses that loss: because GFT's core clips are 100 percent traceable SODECOTON cotton, unsoiled, elastane-free, and separated into greige, white, pastel and dark/indigo shade lots, they bypass post-collection sorting and dye stripping. [S25]

13.9 LABOUR AND EQUIPMENT ECONOMICS IN CAMEROON STRONGLY FAVOUR IN-FACTORY TABLE SEGREGATION

Cameroon's wage structure makes in-factory bale preparation cost-effective relative to global secondary fibre prices. [R14] The statutory minimum wage (SMIG) rose 5 percent from XAF 41,875 a month in 2023 to XAF 43,969 a month from 23 February 2024 (about US$76), while the average cross-sector salary is US$359 a month and informal employment sits near 90 percent under a 40-hour week (48-hour maximum, overtime at 1.2 times). [R15] Compared with Cambodia's 2024 garment minimum wage of US$204 a month, Cameroon's wage base keeps formal material handling affordable. [R17]

Initial shade separation at the cutting table takes zero extra labour minutes when barcoded gaylord bins sit at each table. [S33] Weighing, scanning and pressing 135 to 210 tonnes a year (450 to 700 kilograms a day across an illustrative 300-day year) requires two handlers per shift on a vertical baler. [R14] Paying two handlers XAF 85,000 to XAF 110,000 a month including social charges and purity bonuses (double the XAF 43,969 SMIG floor, R14) costs XAF 2.04 million to XAF 2.64 million a year (US$3,400 to US$4,600 at 563 to 610 XAF per US dollar). [R32] Adding depreciation on a US$10,000 baler (US$1,500 a year, illustrative equipment estimate) brings total baling cost to about US$5,000 a year. [R14]

13.10 BENCHMARKING VIRGIN CFA-ZONE COTTON LINT AGAINST GRADED PRE-CONSUMER CLIP PRICES

Both partners price baled clips against virgin CFA-zone cotton lint. [R05] In 2024/2025, CFA-zone cotton output fell 11.5 percent to 2.3 million tonnes amid climate and pest pressures, with lint trading around 890 to 900 XAF per kilogram (US$1.48 to US$1.58 per kilogram at 570 to 600 XAF per US dollar). [S1301] Across Mediterranean markets mapped by UNIDO SwitchMed and Reverse Resources, clean colour-sorted 100 percent cotton clips trade at 30 to 55 percent of virgin lint: US$0.45 to US$0.85 per kilogram (XAF 260 to XAF 500) for white/greige clips, and US$0.30 to US$0.55 per kilogram (XAF 175 to XAF 325) for dyed clips (derived from S1301, S10, S24, S25). [S24] Roll-end remnants (>0.5 metres) reused internally save US$0.75 to US$1.20 per kilogram in fabric purchases, while mixed overlock trims sold for non-woven felts fetch an illustrative US$0.12 to US$0.20 per kilogram. [S25]

WORKED EXAMPLE: ANNUAL CIRCULAR VALUE RECONCILIATION FOR A 3.0 MILLION GARMENT CMT FACTORY

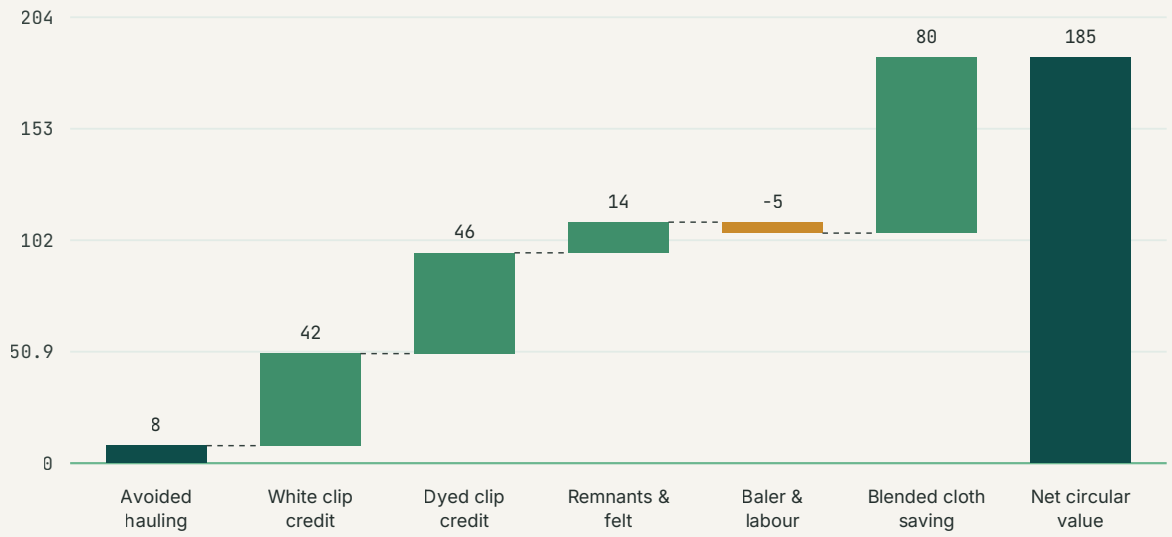
Consider an illustrative CMT plant in Cameroon producing 3,000,000 cotton garments a year at 250 grams average weight (750 tonnes net apparel). [S32] At a 19.35 percent total loss rate, the plant buys 930 tonnes of fabric and generates 180 tonnes of pre-consumer waste (illustrative mass balance from S32, S33). [S33]

1. **Stream A, white/greige clips (60 tonnes of the 180 tonnes illustrative total):** Baled at >99.5 percent purity and credited at XAF 410 per kilogram (US$0.70 per kilogram at 585 XAF/US$ from R32), yielding **US$42,000** (XAF 24.60 million) a year. [R32]
2. **Stream B, colour-sorted dyed clips (85 tonnes of the 180 tonnes illustrative total):** Segregated by shade to skip re-dyeing and credited at an illustrative XAF 315 per kilogram (US$0.54 per kilogram), yielding **US$45,900** (rounded to **US$46,000**, or XAF 26.78 million) a year. [S24]
3. **Stream C, remnants and overlock scrap (35 tonnes of the 180 tonnes illustrative total):** 15 tonnes of remnants reused internally at US$0.75 per kilogram (US$11,250) plus 20 tonnes of overlock trims sold for insulation at US$0.14 per kilogram (US$2,800), yielding **US$14,050** (rounded to **US$14,000**, or XAF 8.22 million) a year. [S24]
4. **Avoided landfill hauling fees:** Diverting 180 tonnes of illustrative waste saves an estimated **US$8,000** a year (US$44.44 per tonne avoided hauling cost). [S10]
5. **Direct baling cost:** Two handlers paid double the XAF 43,969 SMIG floor (R14) plus baler depreciation cost an estimated **-US$5,000** a year, leaving a net waste subtotal of $\text{US\$8,000} + \text{US\$42,000} + \text{US\$46,000} + \text{US\$14,000} - \text{US\$5,000} = \text{US\$105,000}$ a year (XAF 61.43 million). [R14]
6. **Blended fabric rebate:** Specifying a 25 percent recycled / 75 percent virgin SODECOTON rotor blend across 40 percent of fabric orders (372 tonnes out of 930 tonnes, illustrative) substitutes clips at XAF 315 to 410 per kilogram for virgin lint at 890 to 900 XAF (S1301) and skips re-dyeing, earning a US$0.215 per kilogram rebate worth **US$80,000** a year (XAF 46.80 million). [S1302]
7. **Total net annual circular value:** Combining the **US$105,000** waste subtotal and **US$80,000** fabric rebate yields **US$185,000** a year (XAF 108.23 million) in illustrative net value, inside the **US$110,000 to US$260,000** sensitivity band. [S32]

Exhibit 61, p. 213 charts this central illustrative US$185,000 annual value bridge. [R14]

EXHIBIT 61 / US$ THOUSAND PER YEAR (3.0M GARMENT PLANT)

Sorting and baling pre-consumer cotton clips plus 25 percent recycled yarn blending adds US$110,000 to US$260,000 in annual factory value



ILLUSTRATIVE [R14] [R32] [S10] [S24] [S32] [S1301] Central illustrative scenario reconciling to US$185,000/yr (within the US$110k to US$260k sensitivity band) for a 3.0 million garment/yr CMT factory generating 180 t/yr of pre-consumer waste: +8k avoided hauling, +42k white/greige clip credit, +46k dyed clip credit, +14k remnant/non-woven recovery, -5k baler labour/capex at Cameroon wage rates (R14, R32), and +80k blended fabric rebate from substituting clips for 890-900 XAF/kg virgin lint (S1301). Illustrative model, not realized GFT financial performance.

As **Exhibit 61**, p. 213 shows, avoiding hauling fees (+US$8,000), selling 60 tonnes of white clips (+US$42,000) and 85 tonnes of dyed clips (+US$46,000), recovering 35 tonnes of remnants and trims (+US$14,000), deducting baling cost (-US$5,000), and earning the fabric rebate (+US$80,000) total US$185,000 a year. [S24] Because fabric is 50 to 60 percent of garment cost and a 2 percent fabric saving raises operating margin by 1 percentage point, this loop adds a 1.5 to 2.2 percentage point margin buffer. [S32] What **Exhibit 61**, p. 213 cannot guarantee is fixed commodity pricing: if lint falls below 700 XAF per kilogram or elastane contaminates bins, credits drop toward the lower bound. [S26]

13.11

Substituting 20 to 30 percent recycled cotton in domestic and regional collections lowers fabric cost per garment

Closing the regional loop requires specifying mechanically recycled cotton yarns into commercial collections. [S24] Industrial proof of a 20 to 30 percent pre-consumer blend comes from UNIDO's SwitchMed pilot with EVLOX in Morocco, where 160 tonnes of sorted cotton waste (50 tonnes white, 110 tonnes denim) supplied the 20 percent recycled fibre fraction for 1,204,364 metres of denim at 0.55 kilograms per metre (662.4 tonnes of cloth, or 132.48 tonnes net recycled fibre at an 82.8 percent tearing/carding yield), producing 926,434 pairs of jeans (0.715 kilograms per pair). [S1302]

13.12 MATCHING RECYCLED ROTOR-SPUN YARN COUNTS TO CAMEROON'S PRIORITY PRODUCT SEGMENTS

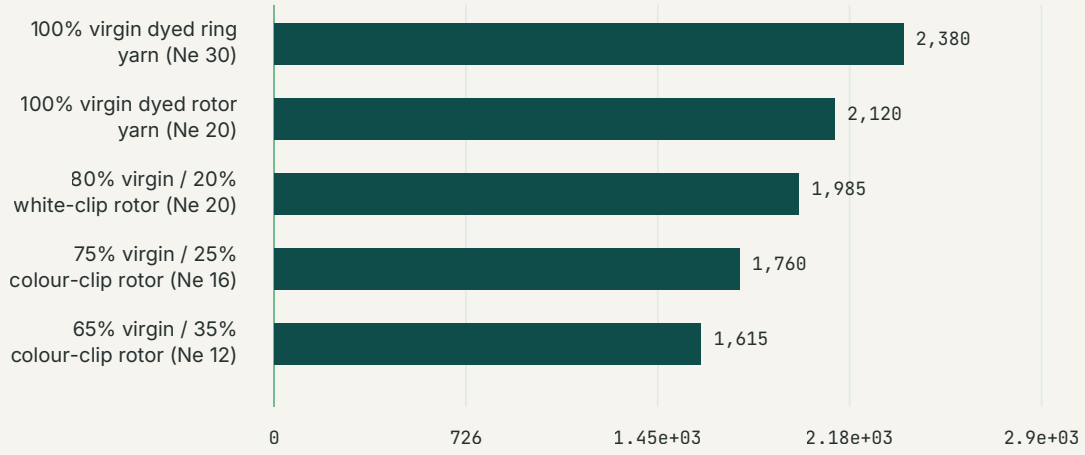
This spinning physics fits GFT's Go-to-Market segments and Camtext SA's roadmap, which targets defence, security and public-service uniforms (at least 60 percent local cotton) and sportswear/jerseys (at least 50 percent of domestic demand), alongside GFT's Priority 1 traditional/urban wear and Priority 2 uniform lines. [S1301] Because torn clips have an 18 to 24 millimetre staple length versus 27 to 30 millimetres for virgin SODECOTON lint (Chapter 5), they suit open-end rotor yarns (Ne 10 to Ne 24): [S20]

- **Heavy workwear, school uniforms, twills and denim (Ne 10 to Ne 16, 240 to 320 grams per square metre):** Blends 25 to 35 percent recycled cotton with 65 to 75 percent virgin SODECOTON lint while meeting tear and seam-slippage standards. [S23]
- **Pique polos, single jersey and sportswear fleece (Ne 18 to Ne 24, 180 to 240 grams per square metre):** Blends 20 to 25 percent torn knit clips with 75 to 80 percent virgin lint, meeting the 20 percent Global Recycled Standard (GRS v4) threshold. [S28]
- **Fine shirting poplin and ceremonial prints (Ne 30 to Ne 40, 110 to 145 grams per square metre):** Kept at 100 percent virgin combed SODECOTON ring-spun yarn, while its cutting offcuts feed the rotor uniform lines. [R03]

Exhibit 62, p. 214 compares derived mill-gate yarn costs in XAF per kilogram using the 895 XAF per kilogram CFA-zone lint midpoint. [S1301]

EXHIBIT 62 / XAF PER KILOGRAM OF FINISHED YARN

Blending 25 to 35 percent colour-sorted pre-consumer clips cuts rotor yarn cost by 14 to 24 percent in CFA francs



DERIVED [R32] [S24] [S28] [S32] [S1301] [S1302] Derived mill-gate yarn cost per kg in XAF based on virgin CFA-zone cotton lint at 895 XAF/kg midpoint (890-900 XAF/kg, S1301), sorted white clips at 410 XAF/kg, colour-sorted dyed clips at 315 XAF/kg, 82.8% mechanical tearing/carding yield (S1302), rotor spinning conversion of 650 XAF/kg, and reactive dyeing of 480 XAF/kg (avoided on colour-sorted melange lots, S24). Analytical cost comparison, not a quoted supplier tariff.

In **Exhibit 62**, p. 214, virgin lint at 895 XAF per kilogram (S1301) with 10 percent carding waste gives 994 XAF per kilogram net fibre cost; adding 646 XAF rotor conversion and 480 XAF dyeing yields **2,120 XAF per kilogram** for virgin dyed Ne 20 rotor yarn (**2,380 XAF** for combed Ne 30 ring yarn). [S24] Blending 20 percent white clips (410 XAF per kilogram, or 495 XAF net after 82.8 percent tearing yield from S1302) lowers dyed Ne 20 rotor yarn by 6.4 percent to **1,985 XAF per kilogram**. [S28] Using 25 percent colour-sorted dyed clips (315 XAF per kilogram, 380 XAF net) in melange Ne 16 yarn that skips re-dyeing on the recycled share cuts cost by 17.0 percent to **1,760 XAF per kilogram**, and at 35 percent in Ne 12 workwear yarn by 23.8 percent to **1,615 XAF per kilogram**. [S24] What **Exhibit 62**, p. 214 cannot claim is universal shade applicability: melange savings apply to pre-dyed recipes (navy, grey marl, indigo), whereas solid shades still require piece dyeing. [S20]

13.13 RETAIL PRICE SENSITIVITY IN CAMEROON REWARDS EVERY PERCENTAGE POINT OF FABRIC COST REDUCTION

Passing half of that 14 to 24 percent yarn saving into fabric pricing trims unit garment cost by 4 to 7 percent. [S32] Statista places Cameroon's clothing and footwear spend at US$94.70 per person in 2024 across 8.0 pieces a year (US$11.84 or XAF 7,000 per piece), while apparel e-commerce grows at 13.41 percent a year from US$20.32 million (2023) to US$33.61 million (2027) as user penetration rises from 18.0 to 22.7 percent. [R26] Against an US$11.84 average retail price, a 4 to 7 percent manufacturing cost reduction widens margin on basics and school uniforms without sacrificing durability. [R26]

13.14

Regional trade policy under CEMAC and AfCFTA shapes cross-border circular textile flows

Trade planning must rest on verified eligibility. [R18] Cameroon's duty-free access to the United States under AGOA was terminated effective 1 January 2020 and remained ineligible through 2025. [R18] GFT's market plan therefore anchors on domestic Cameroon first, expands into CEMAC in Phase 2, and positions for AfCFTA and European Union channels as capacity scales. [R23] Across Africa, Mordor Intelligence values the textile market at US$37.3 billion in 2025, rising to US$49.41 billion by 2030 at 4.73 percent a year, while Market.us projects US$72.7 billion by 2035 at 6.9 percent a year, with fashion and apparel holding 48.1 percent in 2024. [R24] Capturing regional share requires navigating rules of origin and waste customs codes. [R25]

13.15 WHOLLY OBTAINED DOMESTIC WASTE AND LINT SATISFY STRICT AFCFTA DOUBLE-TRANSFORMATION RULES OF ORIGIN

Under AfCFTA, 92.3 percent of tariff lines are agreed, but textiles and clothing remain unresolved pending product-specific rules of origin, where cotton nations favour 'double transformation' (yarn-forward) rules. [R23] Importing extra-continental recycled yarn (as EVLOX did from Spain before opening its Settat line, S1302) can complicate origin cumulation. [S1302] Under GFT's Cameroon loop, 100 percent of virgin lint comes from SODECOTON, 100 percent of clips originate on GFT's domestic tables, and tearing, spinning, weaving and sewing occur inside Cameroon, satisfying any CEMAC, AfCFTA or EU origin threshold. [R06]

13.16 DISTINGUISHING CLEAN PRE-CONSUMER INDUSTRIAL CLIPS FROM PROHIBITED MUNICIPAL WASTE IN REGIONAL CUSTOMS

Customs rules must separate clean industrial offcuts (HS 5202 cotton waste, illustrative HS code) from worn clothing (HS 6309), so bans on dumped post-consumer rags do not block cross-border pre-consumer clip shipments inside CEMAC. [S24] Applying ISO 59004:2024 and ISO 59014:2024 establishes that baled, unsoiled pre-consumer clips carrying a GRS v4 Transaction Certificate and an NIR purity report (91.7 percent composition and 92.6 percent elastane accuracy, S26) are verified secondary raw materials. [S21]

CONTRACTUAL ARCHITECTURE FOR A BILATERAL CMT-TO-SPINNER SYMBIOSIS AGREEMENT

GFT structures the CMT-to-spinner partnership as a Master Supply and Secondary Feedstock Offtake Agreement with five controls: [R09]

1. **System boundary and bale tagging:** Every cutting-table bin carries a barcode in `GFT_Production_Tracking_Templates.xlsx` linked to incoming roll batch ID, composition and Pantone shade; overlock trims with thread or elastane are quarantined separately. [S33]
2. **Hub intake NIR and weight gate:** Bales arriving at Dibamba or Garoua in minimum 5.0-tonne backhaul lots are weighed on calibrated scales and scanned via 900 to 1,700 nanometre NIR spectroscopy to confirm zero elastane and ≤ 8.5 percent moisture. [S26]
3. **Formulaic XAF transfer credit:** Grade-A white/greige clips earn 45 percent and Grade-B colour-sorted dyed clips earn 35 percent of the quarterly CFA-zone virgin lint benchmark (890 to 900 XAF per kilogram in 2024/2025, S1301), netted in XAF against monthly fabric invoices. [S1301]
4. **Reciprocal GRS v4 custody loop:** Both sites hold GRS v4 Scope Certificates and exchange per-shipment Transaction Certificates reconciling empirical Process Loss Rates (such as the 17.2 percent tearing/carding loss in S1302). [S28]
5. **Non-conformance downgrade rule:** Any bale exceeding 0.5 percent elastane or non-cellulosic trim is re-graded to the Tier-C non-woven insulation line at felt pricing, triggering a supervisor alert. [S24]

Exhibit 63, p. 217 summarises the seven clauses of this closed-loop commercial term sheet. [S28]

EXHIBIT 63 / COMMERCIAL TERM-SHEET SPECIFICATION

Contractual terms for a closed-loop CMT-to-spinner waste return and blended-fabric offtake agreement

Contract clause	Quantitative specification	Verification & settlement mechanism
1. Feedstock purity floor	>= 99.0% cotton fibre; <= 0.5% non-cellulosic trims; <= 8.5% moisture	Cutting-table barcode log plus hub NIR scan (900 to 1,700 nm, 91.7% accuracy)
2. Shade-family grading	4 grades: unbleached greige, bleached white, light pastel, dark/indigo	Bale tag linked to original fabric roll batch ID and Pantone dye code
3. Bale density & backhaul lot	Hydraulic bales of 250 to 350 kg (> 350 kg/m3); >= 5.0 t per truckload	Calibrated load-cell ticket reconciled to PMS Sustainability Log (< 0.5% variance)
4. Transfer price index (XAF)	Grade A white at 45%, Grade B dyed at 35% of CFA-zone virgin lint price	Monthly XAF credit note netted against fabric invoices (no FX conversion)
5. Blended fabric offtake	Ne 10 to Ne 24 rotor fabric with 20% to 30% recycled pre-consumer cotton	Accredited lab test for tensile/tear strength and CVm% unevenness per lot
6. GRS v4 chain of custody	Annual Scope Certificate at both sites; per-lot Transaction Certificate	Empirical tearing/spinning Process Loss Rate (~17.2%) audited in PLM/Excel spine
7. Quarantine & downgrade	Bales with > 0.5% elastane or polycotton diverted to non-woven felt line	1D-CNN elastane detector (92.6% accuracy); automatic re-pricing to felt tier

ILLUSTRATIVE [R32] [S24] [S26] [S28] [S1301] [S1302] Illustrative commercial term sheet designed by GFT for bilateral symbiosis between a Cameroon CMT plant and an upstream spinning pole. Pricing index references the 890-900 XAF/kg CFA-zone lint benchmark (S1301) under the 655.957 XAF/EUR peg (R32), NIR thresholds from S26, and GRS v4 custody rules from S28. Not legal advice.

Inspecting **Exhibit 63**, p. 217 shows how every commercial clause binds a physical tolerance to a shop-floor measurement tool: barcode logs, load cells, 900 to 1,700 nanometre NIR scans, and GRS v4 Transaction Certificates. [S26] What **Exhibit 63**, p. 217 cannot replace is local legal and tax review under OHADA commercial law regarding VAT treatment on industrial credit notes.

13.17

Foreign-exchange exposure under the XAF euro peg favours domestic secondary feedstocks over imported synthetics

Closing the loop inside Cameroon and CEMAC provides a currency shield. [R32] The Central African CFA franc (XAF) is pegged to the euro at 655.957 XAF per euro, placing the franc near 590 to 610 XAF per US dollar across GFT's 2023 study window and near 563 to 577 XAF per US dollar more recently (with conversions treated as estimates). [R32] In GFT's risk register (Feasibility Study Section 11), foreign-exchange delays and port clearance friction on imported inputs are major working-capital hazards. [R32] Relying on imported Asian polyester (part of the 75 million

tonnes or 60.5 percent synthetic share of global fibre in 2023, S01) or imported yarns exposes cost of goods sold to three frictions: 1. **US dollar / euro cross-rate swings:** Dollar-invoiced synthetics and ocean freight fluctuate against the euro-pegged XAF (655.957 parity). [R32] 2. **Import cash lock-up:** Ocean-freight fabric orders tie up capital for 90 to 150 days (illustrative import lead-time cycle). [R27] 3. **Customs and demurrage:** Extra-regional imports face tariffs and Douala port delays, whereas domestic cotton and clips move internally. [S1301]

13.18 DOMESTIC XAF BILLING INSULATES BOTH VIRGIN AND RECYCLED FIBRE LEGS FROM HARD-CURRENCY SHOCKS

When the CMT plant buys fabric from a domestic pole and settles clip returns via XAF credit notes as in **Exhibit 63**, p. 217, the loop runs in CFA francs: [R09]

- **Agricultural base in XAF:** SODECOTON supports 220,000-plus farmers and injects US$100 million a year into rural communities in XAF. [R04]
- **Spinning and tearing in XAF:** Power tariffs, wages (anchored on the XAF 43,969 SMIG floor, R14) and corridor trucking are billed in XAF. [S1301]
- **Revenues in XAF and EUR:** Domestic and CEMAC sales settle in XAF, while EU exports settle in euros at the 655.957 peg. [R32]

Substituting 50 tonnes a year of domestic card droppings and overlock trims (**Exhibit 59**, p. 208) for imported foam or polyester wadding in interlinings and acoustic panels eliminates hard-currency outflows. [S24]

UNRESOLVED INFRASTRUCTURE AND POLICY CONSTRAINTS ON THE REGIONAL LOOP

Sponsors must manage three external dependencies in the evidence register: [R12] 1. **Upstream commissioning timelines:** Camtext SA's preparatory phase opens in the first half of 2026 with optimal capacity around 2033 (R10, S1303), the SODECOTON-CICAM merger targets 2030 (R08), and CICAM restructuring estimates run from CFAF 30.7 to 48.2 billion (or 70.2 billion under one plan, R13). [R13] Phase 1 CMT operations must keep backup export off-takers (Moroccan or Tunisian recyclers, S24, S25) until domestic tearing lines start. [S25] 2. **Grid power reliability:** Translating Camtext SA's 180 billion XAF build into competitive cloth requires stable power; if outages force dyehouses onto diesel, colour-sorted melange recycling (skipping re-dyeing) becomes even more valuable. [S1301] 3. **Contraband competition:** Local producers hold only about 5 percent of the national market against contraband and second-hand imports, making verified provenance and Refashion durability testing essential. [R11]

13.19

By-product symbiosis extends to rural biomass energy and local packaging

Regional symbiosis also connects the garment plant to the northern agricultural and ginning co-products mapped in Chapter 2. [S17] Joint WTO, ITC and UNCTAD programmes in African cotton nations confirm that commercialising cotton by-products creates rural income and low-carbon industrial inputs. [S16] Across Cameroon's harvest of 314,455 tonnes in 2023 and 340,000 tonnes in 2024 (above 350,000 tonnes

projected in 2025), ginning yields roughly 54 percent cottonseed (crushed at SODECOTON's two oil mills) and 9,000 to 15,000 tonnes of short linters/motes, while fields leave 500,000 to 680,000 tonnes of woody stalks annually (derived in Chapter 2 from R01, R03, S17, S37). [R01]

13.20 DENSIFIED COTTON-STALK BRIQUETTES REPLACE HEAVY FUEL OIL AND FIREWOOD IN TEXTILE BOILERS

Wet processing consumes heavy boiler steam. [S20] UNCTAD projects show that densifying cotton stalks and gin husks into biomass briquettes replaces imported heavy fuel oil and firewood in textile boilers. [S18] Supplying northern stalk briquettes to partner dyehouses cuts embodied carbon for EU Digital Product Passports under Regulation (EU) 2024/1781 (S03) while keeping energy spend in rural Cameroon. [S03]

13.21 COTTON-STALK PULP AND SHORT LINTERS SUPPLY DOMESTIC CORRUGATED CARTONS AND GARMENT SWING TAGS

Routing northern stalks and gin motes into local paperboard converting (validated by UNCTAD, S17, S37) supplies unbleached corrugated cartons and 100 percent cotton-linter swing tags for GFT's e-commerce and CEMAC shipments, replacing imported kraft boxes. [S37] Excess purified second-cut linters and comber noils can be exported to dissolving-pulp mills (reducing cotton degree of polymerisation from 2,409 to 500 to 700 at 98.80 percent alpha-cellulose purity and 88.01 percent yield for viscose and Lyocell spinning, S34, S36). [S34]

13.22 OPERATIONAL OWNERSHIP AND CROSS-PAPER INTEGRATION LOCK IN THE REGIONAL LOOP

GFT locks this symbiosis into daily operations through four roles:

- **The Cutting-Room Supervisor** owns table shade sorting, lay mass balance and barcode logging in `GFT_Production_Tracking_Templates.xlsx`. [S33]
- **The Warehouse and Logistics Lead** owns hydraulic baling, weight logs, 5.0-tonne backhaul dispatch and GRS v4 declarations. [S28]
- **The Quality Lead** owns computer-vision roll inspection (above 90 percent accuracy across 40-plus defect types at up to 60 metres a minute, R29), Refashion 2026 durability testing (S23), and NIR spot-checks. [R29]
- **The Plant Manager and Commercial Director** run monthly S&OP reconciliation of XAF clip credits against blended fabric orders and Phase 2 machine-learning demand forecasts (cutting forecast errors 20 to 50 percent and inventory costs 35 to 40 percent, R27). [R27]

This chapter connects to wp01, wp08, wp13 and wp19, plus the cotton-value-flow, unit-economics, site-selection and xaf-exposure tools. [R07]

Symbiosis stream	Generator and location	Receiving partner and route	Primary unit and illustrative annual scale	Financial and compliance mechanism
Grade-A white/ greige cotton clips	GFT CMT cutting tables (Dibamba or Garoua)	Camtext SA / SODECOTON-CICAM rotor spinning	60 t/yr (250 to 350 kg bales, illustrative) [S24]	XAF credit at 45% of CFA lint price; GRS v4 TC [S1301]
Grade-B colour-sorted dyed clips	GFT CMT cutting tables (sorted by Pantone lot)	Partner melange rotor spinning (Ne 10 to Ne 24)	85 t/yr (bypasses wet re-dyeing, illustrative) [S1302]	XAF credit at 35% of CFA lint price; saves dye water [S24]
Roll-end remnants (> 0.5 m)	GFT spreading tables and vision splice outs	Internal CMT small-parts & children's line	15 t/yr (direct pattern re-nesting, illustrative) [S33]	Avoids US$0.75/kg virgin fabric purchase [S32]
Quarantined overlock & card waste	CMT sewing lines + partner mill card droppings	Regional airlaid/ needle-punch non-woven presser	50 t/yr (20 t CMT trims + 30 t mill noils, illustrative) [S24]	Sold for acoustic/ thermal building insulation [S24]
Cotton stalks, linters & hulls	SODECOTON 220,000+ farmers & 9 northern gins	Biomass briquetting, paperboard & dissolving pulp	9,000 to 15,000 t linters; 500,000+ t stalks [R01]	Boiler fuel substitution, local cartons & pulp export [S17]

A factory that stands alone throws away its margins at the loading bay; an industrial cluster weaves one plant's offcut into the next plant's warp.

CHAPTER SOURCE NOTES

R08 Business in Cameroon. Publication date unrecorded; inherited source-text check.

R09 Ecofin Agency. Publication date unrecorded; inherited source-text check.

R10 Ecofin Agency. Publication date unrecorded; inherited source-text check.

S24 United Nations Industrial Development Organization (UNIDO). 2023-11.

R06 Cameroon Trade Hub. Publication date unrecorded; inherited source-text check.

R07 Ecofin Agency. Publication date unrecorded; inherited source-text check.

S1301 Business in Cameroon. 2025-11-11.

R12 Business in Cameroon. Publication date unrecorded; inherited source-text check.

S32 Textile Learner. 2023-08-26.

S1302 United Nations Industrial Development Organization (UNIDO) and SwitchMed. 2023-11.

R03 SODECOTON. Publication date unrecorded; inherited source-text check.

S28 TraceWeave. 2026-07-27.

S25 Closed Loop Fashion and UNIDO SwitchMed. 2022.

R14 WageIndicator. Publication date unrecorded; inherited source-text check.

R01 Business in Cameroon. Publication date unrecorded; inherited source-text check.

S10 Fashion for Good and Reverse Resources. 2024-06.

R15 wage.is. Publication date unrecorded; inherited source-text check.

R17 just-style. Publication date unrecorded; inherited source-text check.

S33 iFactory. 2025.

R32 Wise; XE. Publication date unrecorded; inherited source-text check.

R05 Ecofin Agency. Publication date unrecorded; inherited source-text check.

S26 University of Groningen. 2026-04-22.

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R13 Business in Cameroon; MMI News. Publication date unrecorded; inherited source-text check.

R11 Business in Cameroon; MMI News. Publication date unrecorded; inherited source-text check.

S17 UNCTAD (UN Trade and Development). 2019-07-17.

S16 World Trade Organization (WTO). 2024.

S18 UNCTAD (UN Trade and Development). 2020.

S03 European Union (via LSE Grantham Research Institute Climate Change Laws of the World). 2024-06-28.

S37 UNCTAD (UN Trade and Development). 2019-10.

S34 National Library of Medicine (PubMed). 2026.

R29 MDPI; industry inspection literature. Publication date unrecorded; inherited source-text check.

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14

A four-phase circularity roadmap sequences zero-capex sorting before capital-intensive recycling

Rather than betting greenfield capital on unproven chemical reactors, a disciplined four-phase illustrative roadmap embeds cutting-table sorting and mass-balance measurement in Phase 1, scales regional mechanical blending in Phase 2, and gates advanced regeneration to Phase 3. [S28]

CHAPTER 14
DECISION TEST

Rather than betting greenfield capital on unproven chemical reactors, a disciplined four-phase illustrative roadmap embeds cutting-table sorting and mass-balance measurement in Phase 1, scales regional mechanical blending in Phase 2, and gates advanced regeneration to Phase 3. [S28]

A greenfield cotton-to-garment manufacturer in Cameroon achieves profitable, verifiable circularity by sequencing zero-capital cutting-table segregation and daily mass-balance measurement before committing capital to mechanical tearing or chemical dissolving-pulp partnerships. [S24] [S28] Global fibre production reached 124 million tonnes in 2023 and is projected to hit 160 million tonnes by 2030, yet 73 percent of clothing material is landfilled or incinerated and less than 1 percent returns to new clothing, losing more than US$500 billion in value annually. [S01] [S02] [S08] [S09] Cameroon experiences this linear asymmetry acutely: it harvests 314,455 tonnes (in 2023) to about 340,000 tonnes (in 2024) of seed cotton and projects over 350,000 tonnes in 2025 across more than 220,000 SODECOTON farmers, but exports roughly 95 percent of its lint raw against a 50 percent local-processing target by 2030 under the National Development Strategy (SND30). [R01] [R02] [R03] [R06] [R07] Closing this loop does not begin with post-consumer municipal collection or hundred-million-dollar chemical reactors. In GFT's Cameroon textile programme (prepared 31 January 2024, sources refreshed 2026), circular execution follows a four-phase spine: Phase 0 (Set up) locks in mono-material cotton bills of materials and cutting-room bin layouts at zero capital cost; Phase 1 (Launch and stabilise) deploys computer-vision fabric inspection and manual mass-balance logs on an illustrative 3.0 million garment a year cut-make-trim (CMT) line generating an estimated 135 to 210 tonnes of pure cotton clips; Phase 2 (Scale) switches on machine-learning demand forecasting, Global Recycled Standard (GRS v4) certification, and 20 to 30 percent mechanically recycled rotor-yarn blends; and Phase 3 (Optimise) integrates near-infrared (NIR) hub sorting, multi-model design pipelines, and chemical pulp exports. [R27] [R29] [S26] [S28] [S34]

14.1

Circular strategy must obey the same four-phase spine and condition gates as the core venture

Section 12 of GFT's Feasibility Study, Section 7 of the Performance-Management System Design, and Section 7 of the Digital Strategy all share a single implementation spine: Phase 0 (Set up), Phase 1 (Launch and stabilise), Phase 2 (Scale), and Phase 3 (Optimise). Each transition is governed by strict conditions precedent so the venture never commits capital to the next stage until the operational and commercial gates of the current stage are verified on the floor (illustrative governance basis). Applying this discipline to textile circularity prevents a classic greenfield error: buying heavy recycling machinery or enterprise software before the factory can reliably spread cloth, nest markers, supervise sewing lines, and keep pure cotton offcuts separate from floor sweepings. [S10] [S24] [S33]

14.2 WHY CAPITAL-HEAVY RECYCLING FAILS WHEN DEPLOYED AHEAD OF SHOP-FLOOR DISCIPLINE

Industrial recycling technologies carry steep minimum-scale thresholds and strict feedstock purity limits. [S10] [S20] [S35] As Fashion for Good and Reverse Resources document, as global textile-to-textile recyclers scale from 12,000 tonnes toward 200,000 tonnes a year, their primary bottleneck is the lack of clean, traceable pre-consumer waste supply chains. [S10] Similarly, UNCTAD's reviews of cotton by-products in Eastern and Southern Africa found that fragmented raw-material supply

prevents local processing ventures from reaching commercial utilisation. [S18] [S37] Inside Cameroon, incumbent manufacturer CICAM demonstrates the cost of underutilised equipment: a July 2023 report recorded capacity utilisation at 33.7 percent at Garoua, 48.9 percent at CICAM 1, and 10.83 percent at CICAM 2, costing roughly CFAF 2 billion in 2020 with restructuring estimates at CFAF 30.7 to 48.2 billion (or CFAF 70.2 billion under one relaunch plan) while domestic market share dropped from about 85 percent three decades ago to about 5 percent today. [R11] [R12] [R13]

If a greenfield garment sponsor builds a standalone mechanical garnetting line (requiring an estimated 1,500 to 3,000 tonnes a year of throughput for an illustrative US$600,000 to US$1.5 million capital outlay) or a chemical pulping reactor in Phase 1, the machinery will sit idle. [S20] [S24] An illustrative 3.0 million garment a year CMT plant purchases roughly 780 to 1,075 tonnes of fabric annually and generates an estimated 135 to 210 tonnes of cutting and sewing waste, less than one-tenth the volume needed for a dedicated tearing line. [S32] [S33] Moreover, without cutting-table shade segregation and exclusion of elastane waistbands or polyester sewing threads, even those 135 to 210 tonnes of offcuts degrade into low-value mixed sweeps. [S26] [S35] Sequencing zero-capex sorting and weighed mass-balance logs in Phases 0 and 1 builds the verified feedstock ledger and cash flow required to justify regional partnerships in Phases 2 and 3. [S28] [S40]

14.3 ALIGNING THE FEASIBILITY STUDY, PERFORMANCE-MANAGEMENT SYSTEM AND DIGITAL STRATEGY TIMELINES

The circularity roadmap is woven directly into the three programme deliverables (illustrative integration basis). In the Feasibility Study (Sections 5 and 12), Phase 1 capital is contained to CMT assembly while spinning and knitting are partnered upstream with SODECOTON, the announced SODECOTON-CICAM merger targeted for 2030, and the US$300 million (180 billion XAF) Camtext SA project announced on 12 November 2025. [R03] [R08] [R09] In the Performance-Management System Design (Sections 3, 4, and 7), the Sustainability KPI family (water, energy, and waste per unit) starts on Shift 1 inside the companion Excel tracking pack (`GFT_Production_Tracking_Templates.xlsx`) and matures over 18 months into connected load-cell scales and live dashboards. [S28] [S40] In the Digital Strategy (Sections 3, 4, and 7), computer-vision roll inspection launches in Phase 1 because pretrained optical models need only a camera feed, whereas machine-learning demand forecasting waits until Phase 2 after 12 months of domestic sales history accumulate, and multi-model physics-constrained design pipelines enter in Phase 3. [R27] [R28] [R29] [R31]

Before inspecting **Exhibit 64**, p. 225, note that its 36-month illustrative planning window measures numeric months from project sanction (Month 0). Each milestone represents a gated operational state rather than an unconditional calendar forecast.

EXHIBIT 64 / MONTHS FROM PROJECT SANCTION (ILLUSTRATIVE)

Four-phase circularity roadmap aligns zero-capex sorting, GRS certification and regional recycling with GFT's programme gates



0

Phase 0: Set up and BOM lock

Lock 100% cotton BOMs, cutting-room bin layout, Excel PMS mass-balance sheets and spinner terms.

6

Phase 1: Launch and manual mass balance

Start CMT lines, Tier-1 vision roll inspection, table shade sorting, scale weighing and clip baling.

12

Gate 1: First measured impact report

Publish 12-month empirical fabric utilisation, DHU and baled clip recovery ledger; verify 99% purity.

18

Phase 2: Scale, ML forecast and GRS v4

Switch on ML demand forecasting, connect load-cell scales, pass GRS v4 audit and launch 25% blends.

24

Gate 2: Regional industrial symbiosis

Reach 1,500-2,500 t/yr aggregated clip and card-waste volume with Dibamba/Garoua spinning partners.

30

Phase 3: Optimise, NIR hub and pulp export

Deploy Tier-3 CAD/BOM pipelines, ML-NIR spectroscopy, ESPR Digital Passports and linter pulp exports.

ILLUSTRATIVE [R09] [R27] [R29] [S26] [S28] [S40] Illustrative 36-month implementation sequence aligning circularity tasks with GFT's Feasibility Study (Section 12), PMS Design (Section 7, 18-month rollout) and Digital Strategy (Section 7). Dates are numeric months from approval; progression requires satisfying phase-gate conditions precedent.

As **Exhibit 64**, p. 225 shows, the first 12 months (Phases 0 and 1) restrict circularity hardware to colour-coded bins, a digital platform scale, and a vertical hydraulic baler (an illustrative US$8,000 to US$15,000 outlay), focusing shop-floor effort on pre-cut defect interception and 100 percent cotton clip capture. [R29] [S10] [S33] Third-party Global Recycled Standard (GRS v4) certification and blended rotor-yarn collections begin at Month 18 only after Gate 1 confirms 12 months of empirical mass-balance closure. [S28] Because **Exhibit 64**, p. 225 cannot prove external partner readiness by itself, every transition is bound to the gate matrix later in this chapter.

14.4

Phase 0 (Set up) locks in mono-material product specs, cutting-table bin layout and spinning-partner terms

Phase 0 covers the six-month setup window before lines start (Months 0 to 6 in the illustrative schedule). Leadership settles the Douala-Dibamba versus Garoua siting decision, trains the first supervisor cohort, and signs cotton and yarn offtake terms (illustrative Phase 0 scope, Feasibility Study Section 12). Embedding circularity into product specs and floor plans during Phase 0 costs zero extra capital while preventing downstream sorting and chemical fractionation penalties. [S23] [S35]

14.5 DESIGNING MONO-MATERIAL BILLS OF MATERIALS BEFORE CUTTING A SINGLE PROTOTYPE

VTT and MDPI's July 2026 review of polyester-cotton (PES/CO) recycling confirms that separating blended synthetic and cellulosic fibres requires aggressive alkaline, acid, or glycolytic reactors facing incomplete fraction purity, cellulose degree-of-polymerisation (DP) degradation, and high chemical cost. [S35] Even 2 to 5 percent polyurethane elastane tangles on carding cylinders and forms insoluble gels in dissolving baths, while triggering mandatory recyclability penalties under France's Refashion 2026 Eco-Modulations Guide. [S22] [S23] [S26] [S35] In Phase 0, product engineering enforces a mono-material rule across all Priority 1 collections (serving Cameroon households that spend about US$94.70 per person a year across 8.0 apparel and footwear items): [R26] [S23]

- Main fabric knitted or woven from 100 percent traceable SODECOTON cotton lint. [R03]
- Mercerised 100 percent cotton or lyocell sewing threads instead of polyester core-spun threads, eliminating the 1.5 to 3.0 percent synthetic contamination in overlock trimmings (illustrative BOM specification). [S23] [S35]
- Water-based direct neck prints or cotton labels instead of polyester satin labels, paired with corozo nut, mother-of-pearl, or removable metal fasteners. [S23] [S28]
- Mechanical-stretch rib, interlock, and piqué structures, quarantining any polycotton (65/35 PES/CO) uniform runs into separate lays with dedicated bins. [S24] [S26]

14.6 ENGINEERING THE CUTTING ROOM AND COMPANION EXCEL TRACKING PACK FOR SHIFT 1 MASS BALANCE

Retrofitting sorting into legacy plants fails when offcuts are swept into mixed sacks. [S10] [S25] In Phase 0, the blueprint for GFT's illustrative 3.0 million garment a year CMT plant allocates a 25-square-metre recovery bay at the cutting-room exit with colour-coded gaylord bins (unbleached, white, light, dark, and quarantined polycotton) and a 5-square-metre hydraulic baler and scale station (illustrative layout basis). Simultaneously, the companion Excel pack (`GFT_Production_Tracking_Templates.xlsx`) from Deliverable 2 is configured with mass-balance fields: roll batch ID, Transaction Certificate (TC) reference, net roll weight in (kg), CAD marker efficiency (%), cut panel weight out (kg), shade-sorted clip weight (kg), splice weight (kg), and overlock trim weight (kg) (illustrative PMS workbook). [S28] [S33] A validation formula flags any lay deviating by more than 0.5 percent from roll weight in, ensuring ISO 59020:2024 and GRS v4 audit readiness from Shift 1. [S28] [S40] [S1401]

14.7 CONTRACTING TWO-WAY MATERIAL LOOPS WITH SODECOTON, CAMTEXT SA AND REGIONAL SPINNERS

Phase 0 also locks in industrial symbiosis terms (Chapter 13) with SODECOTON (supporting over 220,000 farmers across nine gins and two oil mills), the announced SODECOTON-CICAM pole (targeted by 2030), and Camtext SA (processing 12,000 tonnes a year of cotton across Dibamba and Garoua with about 15,000 jobs and optimal capacity around 2033). [R03] [R08] [R09] [R10] Agreements pair forward delivery of traceable Cameroon yarn and fabric with reverse buy-back credits for GFT's baled, shade-sorted cotton clips for open-end rotor spinning, backhauled on returning fabric trucks in 250 to 400 kg bales (illustrative logistics basis). [R03] [R10] [S24] [S28]

14.8

Phase 1 (Launch and stabilise) deploys computer-vision roll inspection, manual mass balance and baled clip sales

Phase 1 (Months 6 to 18 in the illustrative schedule) opens once the first supervisor cohort is trained and the manual Performance-Management System is live, focusing on first-pass yield, marker efficiency, and 100 percent pure clip sorting. [R29] [S32] [S33]

14.9 STOPPING DEFECT WASTE BEFORE THE KNIFE VIA TIER-1 COMPUTER-VISION INSPECTION

Because fabric represents 50 to 60 percent of total garment cost, saving 2 percent of fabric consumption raises operating profit margin by roughly 1 percentage point. [S32] Manual inspection is only 60 to 70 percent accurate, missing 20 to 30 percent of defects. [R29] In Phase 1, GFT installs Tier-1 computer-vision defect detection on incoming roll perches, scanning at up to 60 metres a minute with above 90 percent accuracy across more than 40 defect types (part of an AI inspection market growing from US$523.4 million in 2024 to US$6,522.1 million by 2033 at 33.8 percent a year). [R28] [R29] Mapping fault coordinates before spreading lets operators splice out defects as clean unsewn strips for recycling while logging supplier chargebacks in the Quality Log (illustrative workflow). [R29] [S33]

14.10 ENFORCING DAILY CUTTING-TABLE SEGREGATION AND PUBLISHING THE MONTH 12 IMPACT REPORT

At the cutting table, operators drop inter-piece clips into barcoded, shade-sorted bins. [S10] [S33] UNIDO and SwitchMed assessments across Egypt (212,000 tonnes a year), Morocco (83,200 tonnes, with 42 percent cotton-rich blends and 14 percent pure cotton), and Tunisia (31,100 tonnes) confirm that colour-sorted 100 percent cotton clips retain 3.0 to 4.5 times the value of mixed sweepings (derived from UNIDO SwitchMed benchmarks). [S10] [S24] [S25] Phase 1 embeds these logs into the three PMS cadences (Deliverable 2, Section 5): 1. **Daily 10-minute huddle:** Supervisors review yesterday's consumption variance, defects per hundred units (DHU), first-pass yield, and clip bin purity on floor boards (illustrative rhythm). [S33] 2. **Weekly plant review:** Management cross-tabulates the Quality Log against the Sustainability Log to separate CAD marker void loss (10 to 18 percent) from width variance and rework, verifying the 0.5 percent mass-balance closure. [R29] [S32] [S33] 3. **Monthly S&OP review:** Leadership reconciles roll purchases, shipped garments, and pressed clip bales (40 to 60 bales a month at 250 to 300 kg at the 3.0 million unit illustrative run rate) for spinning partners. [S24] [S28]

In Months 11 and 12 (Feasibility Study Section 8), the venture publishes its first annual impact report using primary Excel PMS logs rather than marketing estimates (illustrative milestone), disclosing virgin cotton inflows, empirical loss rates, waste per garment, and baled clip tonnage in line with ISO 59020:2024 and Directive (EU) 2024/825. [S28] [S40] [S1401] Passing this 12-month audit is the mandatory gate for approving Phase 2 capital.

GFT NOTE

Never purchase enterprise PLM middleware or mechanical shredding machinery before the manual cutting-table mass balance closes within 0.5 percent for twelve consecutive weeks. In GFT's Cameroon programme, the Phase 1 Excel pack (`GFT_Production_Tracking_Templates.xlsx`) serves as both the Day 1 system of record and the functional specification for Phase 2 software. [S28] If supervisors cannot consistently weigh incoming rolls, track marker consumption, and keep polyester overlock trimmings out of 100 percent cotton clip bins using a scale and a spreadsheet, enterprise software will only digitise contaminated scrap. [S10] [S28] [S33]

14.11

Phase 2 (Scale) switches on ML demand forecasting, GRS v4 certification and 20-30 percent recycled-cotton collections

Phase 2 (Months 18 to 30 in the illustrative schedule) opens when four Phase 1 gates are met: (1) sewing first-pass yield exceeds 92 percent; (2) cutting mass-balance logs close within 0.5 percent over 12 months; (3) baled clips pass 99 percent purity checks; and (4) 12 months of domestic and CEMAC sales history are recorded (illustrative criteria).

14.12 SWITCHING ON TIER-1 ML DEMAND FORECASTING AND COMPLETING GRS V4 AUDITS

In the European Union, manufacturing waste and unsold stock represent 18 percent of the 6.95 million tonnes of annual textile waste, prompting Regulation (EU) 2024/1781 (ESPR, adopted 28 June 2024) to mandate unsold stock disclosure and ban unsold apparel destruction. [S03] [S12] [S14] With 12 months of sales history logged, Phase 2 activates Tier-1 machine-learning (ML) demand forecasting alongside Tier-2 inventory optimisation and digital sample printing (illustrative rollout). McKinsey's *The State of Fashion 2025* reports that AI forecasting cuts errors by 20 to 50 percent, reduces inventory costs by 35 to 40 percent, cuts lost sales by up to 65 percent, and raises revenue per customer by 15 to 25 percent (within a US$150 billion to US$275 billion sector profit opportunity). [R27] Pairing ML forecasting with two-to-four-week domestic replenishment in Cameroon (where apparel e-commerce grows at 13.41 percent a year from US$20.32 million in 2023 to US$33.61 million by 2027) eliminates deadstock. [R26] [R27] [S03]

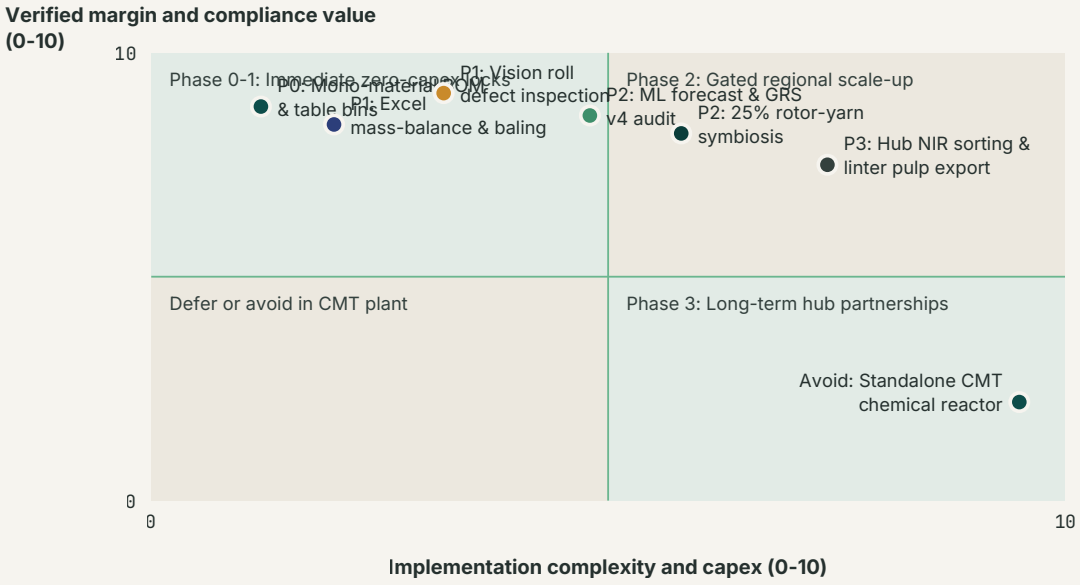
Simultaneously, connected load-cell scales at the inspection frame, cutting tables, and baler write batch weights directly into the central core data store (illustrative Phase 2 upgrade). As TraceWeave's July 2026 PLM study notes, Textile Exchange's Global Recycled Standard (GRS v4, minimum 20 percent recycled content) and Recycled Claim Standard (RCS v4, minimum 5 percent) require an annual Scope Certificate, per-shipment Transaction Certificates, and empirical Process Loss Rate mass balance, which GFT's Phase 1 logs directly support alongside ISO 59014:2024 and ISO 59020:2024 mandatory inflow (`A.2.2` to `A.2.4`) and outflow (`A.3.3` to `A.3.5`) indicators. [S21] [S28] [S40] [S1401] Partnering with Camtext SA (12,000 tonnes a year capacity) or modernised CICAM lines, Phase 2 blends 20 to 30 percent mechanically torn clips (18 to 24 mm illustrative staple) with 70 to 80 percent virgin SODECOTON

lint (27 to 30 mm) in open-end rotor yarns for uniforms and knitwear, qualifying for GRS v4 labels and Refashion 2026 recycled-content EPR bonuses while routing ultra-short droppings (under 10 mm) into non-woven building insulation. [R03] [R10] [S20] [S22] [S23] [S24] [S28]

To show how the governance gates enforce capital discipline across all four phases, **Exhibit 65**, p. 229 maps the four circularity stages across implementation complexity (horizontal axis, illustrative score 0 to 10) and verified margin and compliance value (vertical axis, illustrative score 0 to 10). The matrix positions seven concrete circular interventions within four decision quadrants. [S24] [S28]

EXHIBIT 65 / ILLUSTRATIVE SCORE (0 TO 10 SCALE)

Condition-precedent gate matrix defines what must be proven before committing capital to each circularity stage



ILLUSTRATIVE [R27] [R29] [S24] [S26] [S28] [S34] Illustrative governance matrix scoring circular interventions on implementation complexity/capex (x-axis, 0=zero capex to 10=high industrial capex) versus verified margin and compliance value (y-axis, 0=low to 10=high). Positions reflect greenfield CMT economics in Cameroon.

As **Exhibit 65**, p. 229 demonstrates, Phase 0 mono-material BOM locks (`x: 1.2, y: 8.8`), Phase 1 Excel mass-balance logging and baling (`x: 2.0, y: 8.4`), and Tier-1 computer-vision inspection (`x: 3.2, y: 9.1`) sit in the upper-left quadrant: they capture immediate fabric savings and high-purity bale value at minimal cost. [R29] [S32] [S33] Phase 2 interventions (`ML forecast & GRS v4 audit` at `x: 4.8, y: 8.6` and `25% rotor-yarn symbiosis` at `x: 5.8, y: 8.2`) move into the upper-right quadrant only after Phase 1 data de-risks them, whereas a standalone CMT chemical reactor (`x: 9.5, y: 2.2`) is rejected due to excessive capital intensity and insufficient single-plant feedstock. [R27] [S24] [S28] Because coordinates in **Exhibit 65**, p. 229 are illustrative ordinal scores, project sanction decisions must rely on the unit-economics arithmetic shown in our worked case below.

14.13

Phase 3 (Optimise) integrates multi-model circular design pipelines, NIR verification and cellulosic pulp exports

Phase 3 opens from Month 30 onward once multi-year production data has accumulated and regional spinning poles approach their 2030 SND30 targets. [R07] [R08] [R10]

14.14 DEPLOYING TIER-3 PHYSICS-CONSTRAINED DESIGN PIPELINES TO MAXIMISE MARKER EFFICIENCY AT THE SOURCE

Between 2023 and 2026, apparel generative AI advanced from 2D style ideation (Midjourney, Stable Diffusion) to multi-model garment-design pipelines coupling fabric construction, shade, and weave with physics-constrained 3D simulation validation (arXiv 2509.04705). [R30] [R31] In Phase 3, pattern engineers link physics-constrained 3D drape simulation directly to multi-size CAD marker nesting and Refashion 2026 durability rules, raising marker efficiency by an illustrative 3 to 5 percentage points and cutting physical sample waste by 60 to 80 percent before cloth is cut. [R31] [S23] [S32] [S33]

14.15 CERTIFYING MULTI-FACTORY REGIONAL WASTE BALES WITH MACHINE-LEARNING NIR SPECTROSCOPY

Scaling a regional tearing hub at Dibamba or Garoua to 2,000+ tonnes a year requires auditing waste bales from external CMT workshops that may contain unlabelled blends or elastane. [R10] [S24] [S26] In Phase 3, the regional hub deploys Near-Infrared (NIR) spectroscopy across the 900 to 1,700 nanometre band, referencing open spectral libraries such as the January 2025 NIST database. [S26] [S27] University of Groningen research (April 2026, across 181 certified samples) proved that a Weighted K-Nearest Neighbours (KNN) classifier on NIR spectra achieves 91.7 percent composition accuracy, while a 1D-CNN model achieves 92.6 percent binary elastane detection accuracy (95.2 percent specificity on elastane-absent cotton and 83.3 percent sensitivity on elastane-present fabrics), running on compact edge processors alongside GFT's vision architecture. [R29] [S26]

14.16 EXPORTING GRADED COTTON LINTERS, COMBER NOILS AND SHORT FIBRES TO CHEMICAL DISSOLVING-PULP MILLS

Two cellulosic streams in Cameroon are too short (below 12 to 15 millimetres) for mechanical apparel spinning (illustrative staple limit): [S20] [S37] 1. **Ginning linters and motes:** Delinting across SODECOTON's nine gins on a 340,000 to 350,000+ tonne harvest yields an estimated 9,000 to 15,000 tonnes a year of short-staple linters and motes (derived from Chapter 2). [R01] [R02] [R03] [S17] [S37] 2. **Comber noils and card droppings:** Spinning 12,000 tonnes of lint at Camtext SA scale plus mechanical tearing generates an estimated 1,000 to 2,000+ tonnes a year of short virgin noils and card droppings. [R10] [S24]

Phase 3 aggregates and grades these high-alpha-cellulose streams for chemical dissolving-pulp regeneration. [S34] [S36] Peer-reviewed research in 2026 (PubMed 42409144) demonstrated that targeted depolymerisation of waste cotton using a choline chloride and lactic acid deep eutectic solvent (DES) at 30 percent water content reduces cellulose degree of polymerisation from 2,409 into the 500 to 700 window, achieving 98.80 percent alpha-cellulose purity, 85.80 percent whiteness, 17.01 ppm iron, 88.01 percent pulp yield, and 80.80 percent solvent recovery for

wet-spinning into 1.27 cN/dtex regenerated fibres. [S34] [S35] [S36] Simultaneously, finished garments carry ESPR Digital Product Passports (Regulation (EU) 2024/1781 and revised Waste Framework Directive (EU) 2025/1892, in force 16 October 2025 after 1 January 2025 separate collection) exposing batch-level GRS v4 and ISO 59020 mass balance (cross-referenced with wp05). [S03] [S04] [S05] [S06] [S28] [S40]

WORKED EXAMPLE

Four-phase circular mass-balance and value reconciliation for an illustrative 3.0 million garment a year CMT plant

Consider GFT's illustrative baseline CMT factory in Cameroon producing 3,000,000 cotton garments a year at a 250 gram (0.250 kg) average finished weight, embodying 750 tonnes a year of cotton in shipped apparel (illustrative engineering model based on Feasibility Study Sections 5 and 6; not a performance forecast).

Step 1: Baseline linear factory. With manual inspection (60 to 70 percent accuracy) and single-size markers, total fabric loss across marker voids (16.0 percent), spreading/width losses (3.0 percent), and defect/sewing scrap (3.0 percent) equals 22.0 percent of purchased fabric. [R29] [S32] [S33]

- Purchased fabric required: 750 tonnes divided by (1 - 0.22) = 961.5 tonnes a year (illustrative calculation). [S32]
- Total pre-consumer waste generated: 961.5 - 750.0 = 211.5 tonnes a year (illustrative calculation). [S33]
- Hauling away 211.5 tonnes of unsorted mixed waste at an illustrative US$40 per tonne disposal cost loses -US$8,460 a year (about -XAF 5.08 million at 600 XAF/US$ under the 655.957 euro peg). [R32]

Step 2: Phase 1 (Vision inspection, multi-size CAD nesting, and table shade sorting). Computer-vision roll inspection (above 90 percent accuracy across 40+ defect types) and multi-size CAD nesting cut total fabric loss by an illustrative 4.0 percentage points to 18.0 percent. [R29] [S32] [S33]

- New purchased fabric required: 750 tonnes divided by (1 - 0.18) = 914.6 tonnes a year, saving **46.9 tonnes of virgin fabric a year** (an illustrative 4.88 percent reduction). [S32]
- At an illustrative fabric price of US$6.50/kg (US$6,500/tonne), saving 46.9 tonnes preserves **US$304,850 a year** (about XAF 182.9 million), confirming that a 2 percent fabric saving raises operating margin by roughly 1 percentage point. [R32] [S32]
- Remaining waste: 914.6 - 750.0 = 164.6 tonnes a year (illustrative balance), split into 15.0 tonnes of roll-end remnants reused internally, 130.0 tonnes of shade-sorted 100 percent cotton clips (433 bales at 300 kg), and 19.6 tonnes of quarantined overlock trims. [S24]
- Two baler handlers at Cameroon's XAF 43,969 a month SMIG floor (about US$76/month base, or US$110/month loaded with overtime at 1.2 times, versus US$204 in Cambodia and US$359 Cameroon average salary) cost an estimated US$2,640 a year. [R14] [R15] [R16] [R17]
- Selling 130.0 tonnes of sorted cotton clips to regional spinners at a conservative illustrative transfer credit of US$500/tonne (within the US$350 to US$850/tonne benchmark range) yields **US$62,360 a year net of labour**, plus US$8,460 in avoided disposal. [S10] [S24] [S25]

Step 3: Phase 2 (ML demand forecasting and 25 percent GRS v4 rotor-yarn loop). The spinning partner blends GFT's 130.0 tonnes of clips at 25 percent with 75 percent virgin SODECOTON lint to supply an illustrative 400 tonnes of GRS v4 fabric back to GFT. [R03] [S24] [S28]

- Blending recycled cotton (US$0.50/kg) with virgin lint (US$1.90/kg, illustrative) lowers fabric cost by an illustrative US$0.32/kg across 400,000 kg, saving **US$128,000 a year**. [S24] [S32]
- Switching on Tier-1 ML demand forecasting (cutting forecast errors 20 to 50 percent and inventory costs 35 to 40 percent) cuts deadstock markdowns from an illustrative 3.5 percent to 1.0 percent, saving **US$112,500 a year**. [R27]

Step 4: Total annual economic impact by Phase 2. Summing Phase 1 fabric prevention (US$304,850), net clip credits and avoided disposal (US$70,820), Phase 2 recycled-fabric savings (US$128,000), and ML deadstock reduction (US$112,500) yields an illustrative **US$616,170 a year** (about XAF 370 million a year) on a 3.0 million garment line, before counting EU EPR fee rebates. [R27] [R29] [R32] [S23] [S24] [S32]

14.17

Actionable recommendations assign concrete tasks to plant sponsors, upstream spinners and CEMAC policymakers

As UNEP's *Sustainability and Circularity in the Textile Value Chain: A Global Roadmap* notes across a global sector generating US$1.5 trillion in revenue while consuming 215 trillion litres of water annually and accounting for 9 percent of ocean microplastic losses, closing the loop requires coordinated action across four stakeholder groups: [S15] [S1402]

14.18 1. GREENFIELD GARMENT SPONSORS AND PLANT DIRECTORS

- **Mandate mono-material cotton BOMs in Phase 0:** Specify 100 percent cotton or cellulosic sewing thread, printed care labels, and zero elastane on core 100 percent cotton styles so clips require no de-trimming or elastane stripping. [S23] [S35]
- **Weigh and segregate every lay from Shift 1:** Position shade-coded bins at the cutting table, log roll-in and panel/clip-out weights in `GFT_Production_Tracking_Templates.xlsx`, and tie supervisor bonuses above the XAF 43,969/month SMIG floor to right-first-time yield and 99 percent clip purity. [R14] [S28] [S33]
- **Sequence vision in Phase 1 and ML forecasting in Phase 2:** Deploy computer-vision roll inspection (above 90 percent accuracy across 40+ defect types) before cutting, and activate ML demand forecasting once 12 months of domestic sales history accumulate. [R27] [R29]
- **Ban unsold garment destruction:** Under Regulation (EU) 2024/1781, route wearable cosmetic seconds (1 to 2 percent of output, illustrative) to unbranded outlet sales or social donations before shredding unwearable rejects. [S03]

14.19 2. UPSTREAM GINNERS AND INTEGRATED SPINNING POLES (SODECOTON, CAMTEXT SA, CICAM)

- **Install a 1,500 to 2,500 tonne a year modular mechanical tearing line at Dibamba or Garoua:** Co-locating a garnetting line alongside open-end rotor spinning at Camtext SA (12,000 tonnes a year capacity) or the SODECOTON-CICAM pole pools internal spinning waste (960 to 2,160 tonnes a year) with regional CMT clips. [R08] [R09] [R10] [S24]
- **Offer closed-loop clip buy-back credits in XAF:** Credit returned, GRS-documented cotton clip bales against forward yarn and fabric invoices inside the CFA-franc zone. [R32] [S24] [S28]
- **Aggregate gin linters, motes and cotton stalks across all nine SODECOTON gins:** Centralise 9,000 to 15,000 tonnes a year of short-staple linters/motes for medical cotton and chemical dissolving pulp while densifying field stalks into boiler briquettes. [R03] [S16] [S17] [S18] [S37]

14.20 3. CAMEROON, CEMAC AND AFCFTA POLICYMAKERS

Because Cameroon remains ineligible for US AGOA preferences (terminated 1 January 2020, listed ineligible through 2025), regional policy is decisive across an African textile market worth US$37.3 billion in 2025 and projected to reach US$49.41 billion by 2030 (or US$72.7 billion by 2035): [R18] [R24] [R25]

- **Score recycled local cotton in public uniform tenders:** Mirroring EU Regulation (EU) 2024/1781 green procurement, award tender points for school, military, and civil-service uniforms blending traceable SODECOTON cotton with at least 20 percent GRS-certified recycled local cotton. [R06] [R07] [S03] [S28]
- **Harmonise CEMAC and AfCFTA customs codes for sorted pre-consumer clips:** As AfCFTA finalises textile rules of origin beyond the 92.3 percent of tariff lines already agreed, classify Scope-Certified pre-consumer cotton clips as duty-free secondary industrial raw materials rather than prohibited waste. [R23] [S24] [S28]
- **Evaluate destination-country EPR levies on imported second-hand clothing bales:** EU used-textile exports rose from 550,000 tonnes in 2000 to 1.7 million tonnes in 2019 and 1.44 million tonnes in 2025, transferring unrecyclable synthetic waste to African ports without sharing EPR funds. [S11] [S13] [S29] [S30] [S31] Eco-modulated import levies on commercial `friperie` and fast-fashion imports can fund municipal non-woven recycling while applying ISO 59014:2024 safe-work standards for informal sorters. [S21] [S29] [S30] [S1402]

14.21 4. DEVELOPMENT-FINANCE INSTITUTIONS AND SUSTAINABILITY AUDITORS

- **Link green equipment leases to audited ISO 59020 and GRS v4 metrics:** Tie concessional interest rates on spinning, vision, and solar loans (cross-referenced with wp13, illustrative DFI structure) to verified consumption variance below 1.5 percent and clip recovery above 90 percent, while co-financing a shared regional NIR and Refashion 2026 durability lab at Dibamba or Garoua. [R10] [R29] [S23] [S26] [S28] [S40]

> **WARNING**
>
> **Legal, tax and investment disclaimer:** All regulatory summaries (including EU Regulation 2024/1781, Directive 2025/1892, Refashion 2026 rules, AGOA eligibility, and AfCFTA schedules) and all illustrative financial and mass-balance estimates in this chapter and across white paper wp11 are for engineering planning only. [S03] [S04] [S23] Nothing herein constitutes investment, legal, or tax advice.

14.22

What GFT measures: the twelve-metric circularity ledger that governs the factory from Day 1

True to GFT's **Warp and Signal** thesis, circularity is governed by twelve shop-floor indicators organised across Input Efficiency (M01 to M04), Sorting and Mass Balance (M05 to M08), and Circular Outflows, Inflows, and Value (M09 to M12), integrating Deliverable 2 (PMS Design) with ISO 59020:2024 mandatory inflow (A.2.3) and outflow (A.3.4) formulas and GRS v4 chain of custody. [S28] [S40] [S1401] Before inspecting **Exhibit 66**, p. 236, note that the target bands are illustrative Phase 1 to Phase 3 benchmarks calibrated during the first 90 days of production.

EXHIBIT 66 / SHOP-FLOOR GOVERNANCE SPECIFICATION

The GFT twelve-metric circularity ledger specifies formula, unit, data source, owner and target band for every shop-floor measure

ID & Metric	Formula & Boundary	Unit	Source & Owner	Target Band
M01 CAD Marker Efficiency	Pattern piece area / total marker rectangle area	%	CAD file / Pattern Lead	82-86% knit
M02 Consumption Variance	(Actual table kg - Planned BOM kg) / Planned kg	%	PMS Lay Log / Cutting Sup.	Under 1.5%
M03 Vision Defect Intercept	Defects spliced pre-cut / total roll defects	%	Vision Log / Quality Lead	Above 90.0%
M04 Sewing First-Pass Yield	Garments passing first audit / total sewn	%	Quality Log / Line Sup.	Above 94.0%
M05 Net Waste per Garment	Total cutting + sewing scrap (g) / good units	g/unit	Sustainability Log / Plant Mgr	42-55 g/unit
M06 Clip Shade Purity Rate	Bales passing 100% cotton & shade audit / total	%	Baler Log / Cutting Sup.	Above 99.0%
M07 NIR Elastane Rejection	Correctly flagged elastane/blend lots / tested	%	Hub NIR / Quality Lead	Above 92.6%
M08 Mass-Balance Closure	Sum(Panels + Clips + Remnants + Splices) / Roll In	%	PMS Excel / Plant Mgr	99.5-100.0%

ILLUSTRATIVE [R29] [S03] [S26] [S28] [S32] [S33] [S40] [S1401] Complete engineering specification of GFT's 12 circularity KPIs integrating Deliverable 2 (PMS Design), ISO 59020:2024 inflow/outflow taxonomy (S40, S1401), GRS v4 chain of custody (S28) and ESPR Regulation (EU) 2024/1781 (S03). Target bands are illustrative benchmarks.

EXHIBIT 67 / SHOP-FLOOR GOVERNANCE SPECIFICATION

The GFT twelve-metric circularity ledger specifies formula, unit, data source, owner and target band for every shop-floor measure, continued

ID & Metric	Formula & Boundary	Unit	Source & Owner	Target Band
M09 Circular Outflow Share	(Reused remnants + Recycled bales) / total scrap	% (ISO A.3.4)	TC Ledger / Plant Mgr	Above 95.0%
M10 Recycled Content Inflow	Certified GRS recycled cotton mass / total fibre	% (ISO A.2.3)	Supplier TCs / Sourcing	20.0-30.0%
M11 Unsold Destruction Rate	Weight of unsold garments destroyed / total made	% (ESPR)	S&OP Inventory / Director	0.0%
M12 Net Circular Value	(Fabric saved + Bale credit - Baler cost) / 1k units	US$/1k units	Finance Log / Finance Lead	US$150-210

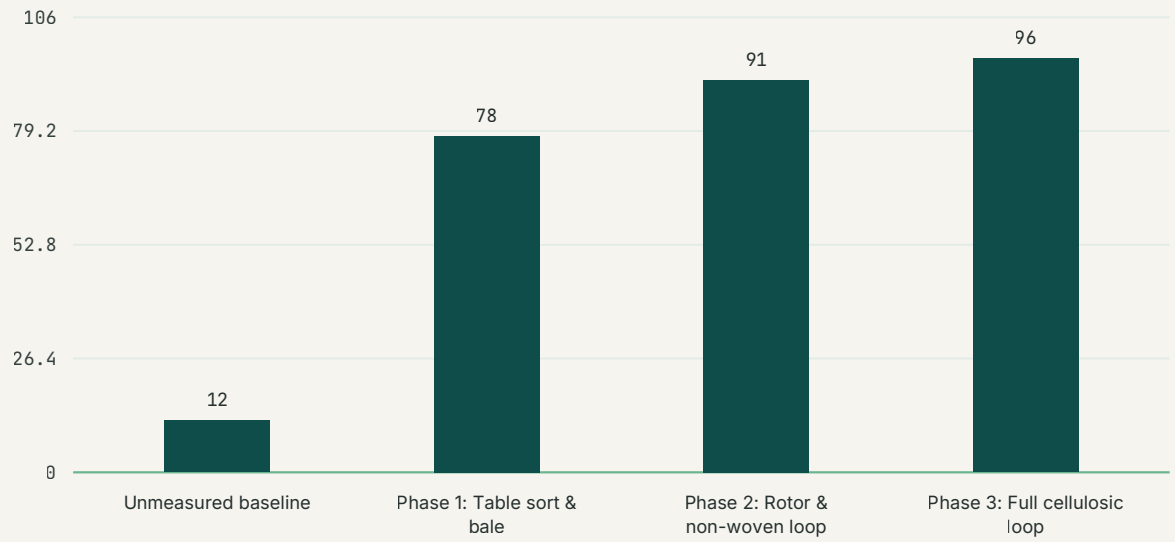
ILLUSTRATIVE [R29] [S03] [S26] [S28] [S32] [S33] [S40] [S1401] Complete engineering specification of GFT's 12 circularity KPIs integrating Deliverable 2 (PMS Design), ISO 59020:2024 inflow/outflow taxonomy (S40, S1401), GRS v4 chain of custody (S28) and ESPR Regulation (EU) 2024/1781 (S03). Target bands are illustrative benchmarks.

Every metric in **Exhibit 66**, p. 236 has a single operational owner so corrective actions occur at the daily huddle and weekly plant review. M08 Mass-Balance Closure locks physical weighing to documentary GRS v4 Transaction Certificates: any cutting lay deviating by more than 0.5 percent (99.5-100.0%) triggers an immediate supervisor check. [S28] [S33] Because **Exhibit 66**, p. 236 cannot prevent misreporting if incentives punish defect reporting, GFT pairs table logs with weekly bale weight audits and vision camera checks.

To show the cumulative physical result of this twelve-metric ledger, **Exhibit 68**, p. 238 compares the illustrative percentage of pre-consumer factory waste diverted from disposal across the unmeasured baseline and Phases 1, 2, and 3. [S24] [S40]

EXHIBIT 68 / PERCENT OF PRE-CONSUMER FACTORY WASTE DIVERTED FROM DISPOSAL

Full deployment of the four-phase roadmap diverts over 95 percent of factory fabric waste from disposal into higher-value loops



ILLUSTRATIVE [R27] [R29] [S24] [S28] [S34] [S40] Illustrative diversion rate progression for a 3.0 million garment a year CMT plant in Cameroon, comparing an unmeasured baseline against Phase 1 (table shade sorting + baling), Phase 2 (regional GRS rotor spinning + non-woven insulation symbiosis) and Phase 3 (AI design/forecasting + chemical pulp export for short fibres).

As **Exhibit 68**, p. 238 shows, an unmeasured baseline plant diverts only an illustrative 12 percent of offcuts (matching the global 12 percent downcycling rate across 92 million tonnes of textile waste). [S09] [S29] Phase 1 cutting-table shade sorting, remnant reuse, and baling raise diversion to 78 percent at near-zero capex; Phase 2 regional rotor-spinning and non-woven insulation symbiosis reaches 91 percent; and Phase 3 chemical dissolving-pulp export of short comber noils and cellulosic fines achieves 96 percent diversion. [S10] [S24] [S34] [S36] These illustrative pre-consumer diversion shares do not apply to unsorted post-consumer municipal waste.

Across all 14 chapters of white paper wp11, one conclusion governs from the cotton fields of Garoua to the cutting rooms of Douala and Dibamba: when a greenfield factory engineers mono-material cotton specs in Phase 0, intercepts roll defects with computer vision, weighs and sorts every cutting lay from Shift 1, forecasts demand

with machine learning, and loops baled clips into regional spinning poles under ISO 59020 and GRS v4 accounting, circularity turns from a cost into measured industrial margin. [R06] [R07] [R27] [R29] [S28] [S40]

Sort the thread where the knife leaves the cloth, weigh the bale before the shift ends, and let measured purity earn the right to scale.

CHAPTER SOURCE NOTES

S28 TraceWeave. 2026-07-27.
S24 United Nations Industrial Development Organization (UNIDO). 2023-11.
S01 Textile Exchange (via USB Certification). 2024-10-24.
S02 United States Fashion Industry Association (citing Textile Exchange). 2024-10-10.
S08 Ellen MacArthur Foundation. 2017-11-28.
S09 Ellen MacArthur Foundation. 2019-03-04.
R01 Business in Cameroon. Publication date unrecorded; inherited source-text check.
R02 Fibre2Fashion; Business in Cameroon. Publication date unrecorded; inherited source-text check.
R03 SODECOTON. Publication date unrecorded; inherited source-text check.
R06 Cameroon Trade Hub. Publication date unrecorded; inherited source-text check.
R07 Ecofin Agency. Publication date unrecorded; inherited source-text check.
R27 McKinsey, The State of Fashion 2025. Publication date unrecorded; inherited source-text check.
R29 MDPI; industry inspection literature. Publication date unrecorded; inherited source-text check.
S26 University of Groningen. 2026-04-22.
S34 National Library of Medicine (PubMed). 2026.
S10 Fashion for Good and Reverse Resources. 2024-06.
S33 iFactory. 2025.
S20 European Commission and Refashion. 2021-11.
S35 VTT Technical Research Centre of Finland and MDPI Textiles. 2026-07-31.
S18 UNCTAD (UN Trade and Development). 2020.
S37 UNCTAD (UN Trade and Development). 2019-10.
R11 Business in Cameroon; MMI News. Publication date unrecorded; inherited source-text check.
R12 Business in Cameroon. Publication date unrecorded; inherited source-text check.
R13 Business in Cameroon; MMI News. Publication date unrecorded; inherited source-text check.
S32 Textile Learner. 2023-08-26.
S40 International Organization for Standardization (ISO). 2024-05.
R08 Business in Cameroon. Publication date unrecorded; inherited source-text check.
R09 Ecofin Agency. Publication date unrecorded; inherited source-text check.
R28 DataIntelo. Publication date unrecorded; inherited source-text check.
R31 arXiv 2509.04705. Publication date unrecorded; inherited source-text check.
S23 Refashion. 2026-01-27.
S22 Refashion. 2026-01.
R26 Statista. Publication date unrecorded; inherited source-text check.
S25 Closed Loop Fashion and UNIDO SwitchMed. 2022.
S1401 CEN-CENELEC and ISO/TC 323 WG3. 2024-07-10.
R10 Ecofin Agency. Publication date unrecorded; inherited source-text check.

S03 European Union (via LSE Grantham Research Institute Climate Change Laws of the World). 2024-06-28.
S12 European Environment Agency (EEA). 2024-04-15.
S14 European Environment Agency (via European Circular Economy Stakeholder Platform). 2024-05.
S21 World Resources Forum. 2024-11.
R30 Design Journal (Taylor and Francis). Publication date unrecorded; inherited source-text check.
S27 National Institute of Standards and Technology (NIST). 2025-01-14.
S17 UNCTAD (UN Trade and Development). 2019-07-17.
S36 Chemical Engineering Transactions (AIDIC). 2024.
S04 European Commission Directorate-General for Environment. 2025-10-16.
S05 European Parliament. 2025-10.
S06 EURATEX (European Apparel and Textile Confederation). 2025-01.
R32 Wise; XE. Publication date unrecorded; inherited source-text check.
R14 WageIndicator. Publication date unrecorded; inherited source-text check.
R15 wage.is. Publication date unrecorded; inherited source-text check.
R16 WageIndicator. Publication date unrecorded; inherited source-text check.
R17 just-style. Publication date unrecorded; inherited source-text check.
S15 United Nations Environment Programme (via World Trade Organization TESSD). 2023-06.
S1402 United Nations Environment Programme (UNEP). 2023-12-01.
S16 World Trade Organization (WTO). 2024.
R18 Congressional Research Service IF10149; AGOA (Wikipedia). Publication date unrecorded; inherited source-text check.
R24 Mordor Intelligence. Publication date unrecorded; inherited source-text check.
R25 Market.us. Publication date unrecorded; inherited source-text check.
R23 MacMap; AfCFTA. Publication date unrecorded; inherited source-text check.
S11 European Environment Agency (EEA). 2023-02-27.
S13 European Environment Agency (EEA Circularity Metrics Lab). 2026-04-14.
S29 Pan African Climate Justice Alliance (PACJA). 2025-03-30.
S30 Wuppertal Institute for Climate, Environment and Energy. 2024-11.
S31 Greenpeace Africa. 2024-10-07.

Provenance travels with the claim.

Available inherited records and all chapter-local source records are graded below. Identical source identities are consolidated without losing citation aliases. Missing annex references are excluded. Unrecorded dates are disclosed rather than invented.

R01 Inherited evidence R01 GRADE C

Business in Cameroon. Publication date unrecorded. businessincameroon.com

Cameroon seed-cotton production 2022-2024: 330,000 t (2022), 314,455 t (2023), about 340,000 t (2024).

Inherited source-text check; original source not independently re-opened for this edition.

R02 Inherited evidence R02 GRADE C

Fibre2Fashion; Business in Cameroon. Publication date unrecorded. fibre2fashion.com; businessincameroon.com

2025 seed-cotton projection above 350,000 t.

Inherited source-text check; original source not independently re-opened for this edition.

R03 Inherited evidence R03 GRADE C

SODECOTON. Publication date unrecorded. sodecoton.cm

Company profile: more than 220,000 cotton producers supported in northern Cameroon; nine ginning plants; two oil mills.

Inherited source-text check; original source not independently re-opened for this edition.

R04 Inherited evidence R04 GRADE C

Financial Fortune Media. Publication date unrecorded. financialfortunemedia.com

SODECOTON injects roughly US$100 million a year into rural communities.

Inherited source-text check; original source not independently re-opened for this edition.

R05 Inherited evidence R05 GRADE C

Ecofin Agency. Publication date unrecorded. ecofinagency.com

CFA-zone cotton output 2.3 million t in 2024/25, down 11.5 percent.

Inherited source-text check; original source not independently re-opened for this edition.

R06 Inherited evidence R06 GRADE C

Cameroon Trade Hub. Publication date unrecorded. cameroontradehub.cm

About 95 percent of cotton fibre exported raw against 5 percent processed locally; industrialisation target of 50 percent local processing.

Inherited source-text check; original source not independently re-opened for this edition.

R07 Inherited evidence R07 GRADE C

Ecofin Agency. Publication date unrecorded. ecofinagency.com

SND30 restates the 50 percent local-processing target by 2030.

Inherited source-text check; original source not independently re-opened for this edition.

R08 Inherited evidence R08 GRADE C

Business in Cameroon. Publication date unrecorded. businessincameroon.com

Announced SODECOTON and CICAM merger to create a cotton-textile industrial pole targeted by 2030.

Inherited source-text check; original source not independently re-opened for this edition.

R09 Inherited evidence R09 GRADE C

Ecofin Agency. Publication date unrecorded. ecofinagency.com

Camtext SA integrated cotton-to-textile project, US$300 million (180 billion XAF); Panafritex and Arise with SODECOTON, CNPS and Marlo; 12 November 2025.

Inherited source-text check; original source not independently re-opened for this edition.

R10 Inherited evidence R10 GRADE C

Ecofin Agency. Publication date unrecorded. ecofinagency.com

Camtext SA: 12,000 t a year processed; about 12,000 jobs at the Dibamba hub and 3,000 at Garoua; return on investment near 11 years; optimal capacity around 2033.

Inherited source-text check; original source not independently re-opened for this edition.

R11 Inherited evidence R11 GRADE C

Business in Cameroon; MMI News. Publication date unrecorded. businessincameroon.com; mimimefoinfos.com

CICAM market share from about 85 percent three decades ago to about 5 percent today.

Inherited source-text check; original source not independently re-opened for this edition.

R12 Inherited evidence R12 GRADE C

Business in Cameroon. Publication date unrecorded. businessincameroon.com

CICAM capacity utilisation, July 2023 report: Garoua 33.7 percent, CICAM 1 48.9 percent, CICAM 2 10.83 percent; underutilisation cost about CFAF 2 billion in 2020.

Inherited source-text check; original source not independently re-opened for this edition.

R13 Inherited evidence R13 GRADE C

Business in Cameroon; MMI News. Publication date unrecorded. businessincameroon.com; mimimefoinfos.com

CICAM restructuring cost estimate CFAF 30.7 to 48.2 billion; one relaunch plan cited at 70.2 billion.

Inherited source-text check; original source not independently re-opened for this edition.

R14 Inherited evidence R14 GRADE C

WageIndicator. Publication date unrecorded. wageindicator.org

Cameroon minimum wage (SMIG) XAF 41,875 a month in 2023, raised to XAF 43,969 a month from 23 February 2024, about US$76, a rise of 5 percent.

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R15 Inherited evidence R15 GRADE C

wage.is. Publication date unrecorded. wage.is/cameroon

Average salary across sectors in Cameroon about US$359 a month.

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R16 Inherited evidence R16 GRADE C

WageIndicator. Publication date unrecorded. wageindicator.org

Informal share of employment about 90 percent; standard 40-hour week, 48-hour maximum, overtime at 1.2 times.

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R17 Inherited evidence R17 GRADE C

just-style. Publication date unrecorded. just-style.com

Cambodia garment-sector minimum wage US$204 a month for 2024 (labour-cost benchmark).

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R18 Inherited evidence R18 GRADE B

Congressional Research Service IF10149; AGOA (Wikipedia). Publication date unrecorded. congress.gov; en.wikipedia.org

AGOA: Cameroon terminated effective 1 January 2020 for gross human-rights violations; remained ineligible; listed ineligible for calendar year 2025.

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R23 Inherited evidence R23 GRADE C

MacMap; AfCFTA. Publication date unrecorded. macmap.org

Textiles and clothing among unresolved AfCFTA tariff-line categories; 92.3 percent of lines agreed excluding vehicles, textiles and clothing.

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R24 Inherited evidence R24 GRADE C

Mordor Intelligence. Publication date unrecorded. mordorintelligence.com

Africa textile market about US$37.3 billion in 2025, projected US$49.41 billion by 2030 at 4.73 percent a year.

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R25 Inherited evidence R25 GRADE C

Market.us. Publication date unrecorded. market.us

Africa textile market to about US$72.7 billion by 2035 at 6.9 percent a year; fashion and apparel 48.1 percent of the market in 2024.

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R26 Inherited evidence R26 GRADE C

Statista. Publication date unrecorded. statista.com

Cameroon clothing and footwear spend about US$94.70 a person in 2024 and about 8.0 pieces a person; apparel eCommerce revenue US$20.32 million (2023) to US$33.61 million (2027) at 13.41 percent a year; user penetration 18.0 percent (2023) to 22.7 percent (2027).

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R27 Inherited evidence R27 GRADE B

McKinsey, The State of Fashion 2025. Publication date unrecorded. mckinsey.com

AI at scale in fashion: inventory cost down 35 to 40 percent; forecast accuracy up 20 to 30 percent; revenue per customer up 15 to 25 percent; forecast errors cut 20 to 50 percent; lost sales down up to 65 percent; 75 percent of executives prioritising; sector operating-profit potential US$150 to 275 billion over three to five years.

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R28 Inherited evidence R28 GRADE C

DataIntelo. Publication date unrecorded. dataintelo.com

Fabric-defect-detection AI market US$523.4 million (2024) to US$6,522.1 million (2033) at 33.8 percent a year; Asia-Pacific about 46 percent in 2024.

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R29 Inherited evidence R29 GRADE C

MDPI; industry inspection literature. Publication date unrecorded. mdpi.com

Manual defect inspection 60 to 70 percent accurate, missing 20 to 30 percent of defects; computer vision above 90 percent across more than 40 defect types; line-scan inspection up to 60 metres a minute.

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R30 Inherited evidence R30 GRADE C

Design Journal (Taylor and Francis). Publication date unrecorded. tandfonline.com

Generative AI in apparel 2023-2024 mainly design-side image generation (Midjourney, Stable Diffusion) across style, silhouette, colour and pattern.

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R31 Inherited evidence R31 GRADE C

arXiv 2509.04705. Publication date unrecorded. arxiv.org/abs/2509.04705

By 2025-2026 the field moved to multi-model garment-design pipelines (fabric construction, shade, weave, silhouette) and physics-constrained generation coupling neural generation with simulation validation.

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R32 Inherited evidence R32 GRADE C

Wise; XE. Publication date unrecorded. wise.com; xe.com

CFA franc to US dollar reference rates; franc pegged to the euro at 655.957. The GFT study's method note places the franc near 590 to 610 per US dollar across the 2023 study window and near 563 to 577 more recently, and treats currency conversions as estimates.

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United States Fashion Industry Association (citing Textile Exchange). 2024-09-27. https://www.usfashionindustry.com/news/fashion-intel-analysis/textile-exchange-releases-the-2024-edition-of-its-materials-market-report

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Ellen MacArthur Foundation. 2017-11-28. https://content.ellenmacarthurfoundation.org/m/6d5071bb8a5f05a2/original/A-New-Textiles-Economy-Redesigning-fashions-future.pdf

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Stable definitions make comparisons useful.

Alpha-cellulose

The high-molecular-weight fraction of cellulose insoluble in 17.5 percent sodium hydroxide solution at 20 degrees Celsius; dissolving pulp for viscose and Lyocell spinning typically requires alpha-cellulose purity above 90 to 98 percent.

Acceptable Quality Limit (AQL)

The maximum percentage of defective units (commonly AQL 2.5 for major defects in apparel) permitted in a statistical sampling inspection before an entire production batch is rejected.

Air-gap wet spinning

The filament extrusion method used in Lyocell production where cellulose dissolved in NMMO passes through a spinneret across a short air gap before coagulating in an aqueous bath.

Carding strips

Short fibres, neps and seed-coat fragments removed by the revolving flats and cylinders of a carding machine during cotton yarn preparation.

Chain of custody

The chronological documentary trail recording the sequence of entities that take physical or legal custody of certified materials from waste origin to finished product.

Closed-loop recycling

Recycling processes in which post-industrial or post-consumer textile waste is reprocessed into new textile fibres and garments of equivalent functional quality (fibre-to-fibre recycling).

Comber noils

Short cotton fibres (typically shorter than 12 to 15 mm) combed out during the production of fine combed ring-spun yarns; a high-purity virgin cellulose co-product used in open-end rotor spinning, medical cotton and dissolving pulp.

Cut-Make-Trim (CMT)

The garment manufacturing stage encompassing fabric spreading, pattern cutting, sewing assembly, trimming, pressing and packaging.

Deadstock

Unsold finished garments or unused fabric rolls remaining in warehouse inventory after a retail season or order cancellation.

Deep Eutectic Solvent (DES)

A green solvent system formed by mixing a hydrogen-bond acceptor (such as choline chloride) and a hydrogen-bond donor (such as lactic acid or urea) whose melting point is far below that of its individual components, used for targeted cellulose depolymerisation.

Defects per Hundred Units (DHU)

A core shop-floor quality KPI calculated as total defects found divided by total garments inspected, multiplied by 100.

Degree of Polymerisation (DP)

The average number of glucose monomer units in a cellulose polymer chain; native cotton has a DP above 2,000, which must be reduced to roughly 500 to 900 for chemical dissolving pulp.

Digital Product Passport (DPP)

A structured digital record mandated under EU Regulation (EU) 2024/1781 linking a unique product identifier to verifiable lifecycle, composition, circularity and chain-of-custody data.

Dissolving pulp

High-purity bleached chemical pulp with tightly controlled alpha-cellulose content, intrinsic viscosity and low metal ash, manufactured from wood or waste cotton for chemical regeneration into viscose, modal or Lyocell fibres.

Downcycling (Cascading)

Reprocessing used textiles into lower-value, non-apparel products such as industrial wiping rags, thermal/acoustic building insulation, automotive felts or mattress stuffing.

Ecodesign for Sustainable Products Regulation (ESPR)

Regulation (EU) 2024/1781 establishing the European Union framework for mandatory product durability, recyclability, recycled content, Digital Product Passports and bans on destroying unsold consumer apparel.

Eco-modulation

The adjustment of Extended Producer Responsibility (EPR) financial fees through bonuses (discounts for durability, certification and recycled content) and penalties (surcharges for non-recyclable materials).

Elastane (Spandex)

A synthetic segmented polyurethane-urea filament known for high elasticity; even 2 to 5 percent elastane acts as a severe contaminant in mechanical cotton tearing and chemical cellulose dissolution.

Extended Producer Responsibility (EPR)

An environmental policy mechanism making producers, brands and importers financially and operationally responsible for the end-of-life collection, sorting, reuse and recycling of products they place on the market.

First-Pass Yield (FPY)

The percentage of garments exiting a sewing line that pass quality inspection on the first attempt without requiring rework or being downgraded to seconds.

Friperie (Mitumba)

Imported second-hand clothing traded in wholesale bales across French-speaking Central/West Africa (friperie) and East Africa (mitumba).

Garnetting (Mechanical tearing)

The mechanical recycling process that feeds fabric clips through high-speed cylinders clothed with saw-tooth wire to shred woven or knitted structures back into loose staple fibres.

Gin motes

Immature seeds, short-staple fibres and lint fragments separated by lint cleaners during cotton ginning; recoverable for coarse non-wovens or cellulose pulp.

Global Recycled Standard (GRS v4)

An international voluntary standard managed by Textile Exchange requiring at least 20 percent certified recycled content alongside chain-of-custody, social, environmental and chemical compliance.

Glycolysis

A chemical depolymerisation route that reacts polyethylene terephthalate (polyester) with ethylene glycol at elevated temperature to cleave polymer chains back into bis(2-hydroxyethyl) terephthalate (BHET) monomer.

Greige fabric

Unbleached, undyed woven or knitted cloth taken directly off the loom or circular knitting machine prior to wet processing.

Industrial symbiosis

A circular industrial relationship in which the residual waste or co-product of one manufacturing process (such as CMT cutting clips or spinning card strips) serves as the raw-material input for another process.

ISO 59004:2024

The foundational International Organization for Standardization standard defining circular economy vocabulary, core principles (such as resource stewardship and traceability) and implementation guidance.

ISO 59014:2024

The ISO standard specifying sustainability, traceability and safe social conditions (including for subsistence waste workers) in the recovery of secondary raw materials.

ISO 59020:2024

The ISO standard establishing mandatory and optional quantitative indicators for measuring and assessing circularity performance within defined system boundaries.

Linters

Short, fuzzy cellulosic fibres (<5 to 6 mm) that remain attached to the cottonseed hull after ginning removes spinnable lint; delinted in first and second cuts for medical cotton, speciality paper and dissolving pulp.

Lyocell process

A direct solvent-spinning process for regenerated cellulose fibres that dissolves pulp in aqueous N-Methylmorpholine N-oxide (NMMO) with over 99 percent solvent recovery and no carbon disulphide derivatisation.

Marker efficiency

The ratio of the total surface area of nested garment pattern pieces to the total rectangular area of the cutting marker plan, expressed as a percentage.

Mass balance

An accounting protocol that reconciles the mass of certified inputs entering a production process against the mass of certified outputs plus empirically verified process losses.

Mono-material design

Engineering a garment so that its body fabric, sewing thread, labels and trims share a single polymer family (such as 100 percent cellulosic cotton/lyocell) to enable direct recycling without component disassembly.

Near-Infrared (NIR) spectroscopy

A non-destructive optical technique measuring reflectance in the 700 to 2,500 nm wavelength band to identify textile fibre polymers and blends from their molecular bond vibrations.

Open-end (Rotor) spinning

A high-speed yarn spinning system that feeds individual opened fibres into a rapidly rotating rotor groove rather than using a ring and traveller, tolerating shorter mechanically recycled cotton fibres.

Pre-consumer (Post-industrial) waste

Material diverted from the waste stream during manufacturing (such as spinning waste, weaving selvedges, cutting-room clips and unsold deadstock) before the product ever reaches a consumer.

Producer Responsibility Organisation (PRO)

A collective body (such as Refashion in France) accredited by the state to collect EPR fees from brands and organise national textile waste collection, sorting and recycling.

Recycled Claim Standard (RCS v4)

A Textile Exchange standard verifying the chain of custody and percentage of recycled content (minimum 5 percent) in products without the additional social and chemical audits of GRS.

Scope Certificate (SC)

An annual facility-level certificate issued by an accredited certification body verifying that a factory or mill is qualified to process and handle certified materials under GRS or RCS.

Transaction Certificate (TC)

A shipment-specific document issued by a certification body confirming that a specific lot of material transferred between two Scope-Certified entities complies with GRS or RCS mass balance.

Follow the terms back to their context.

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