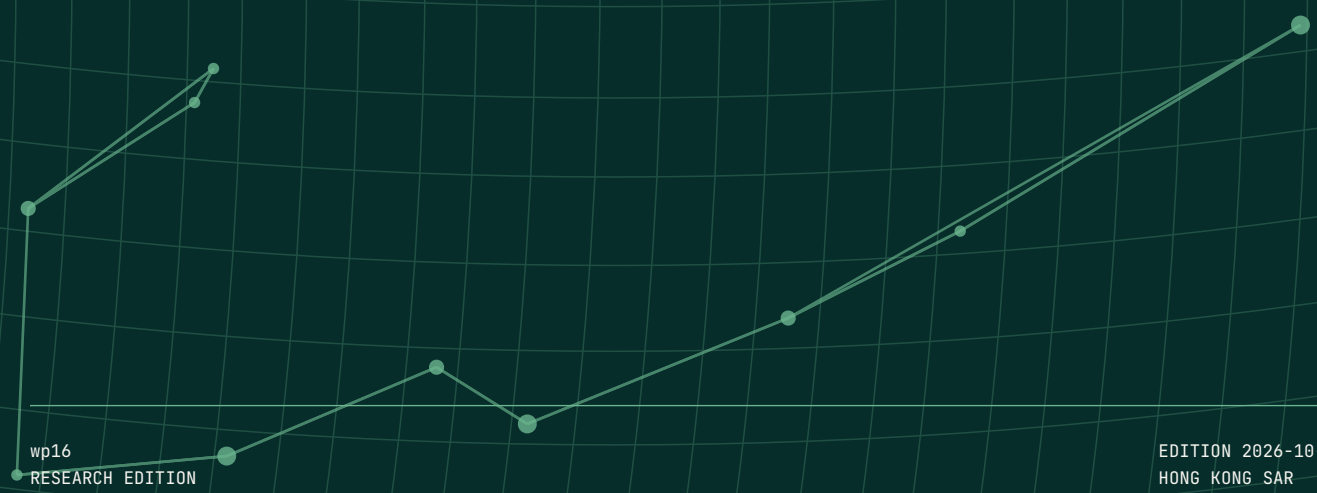
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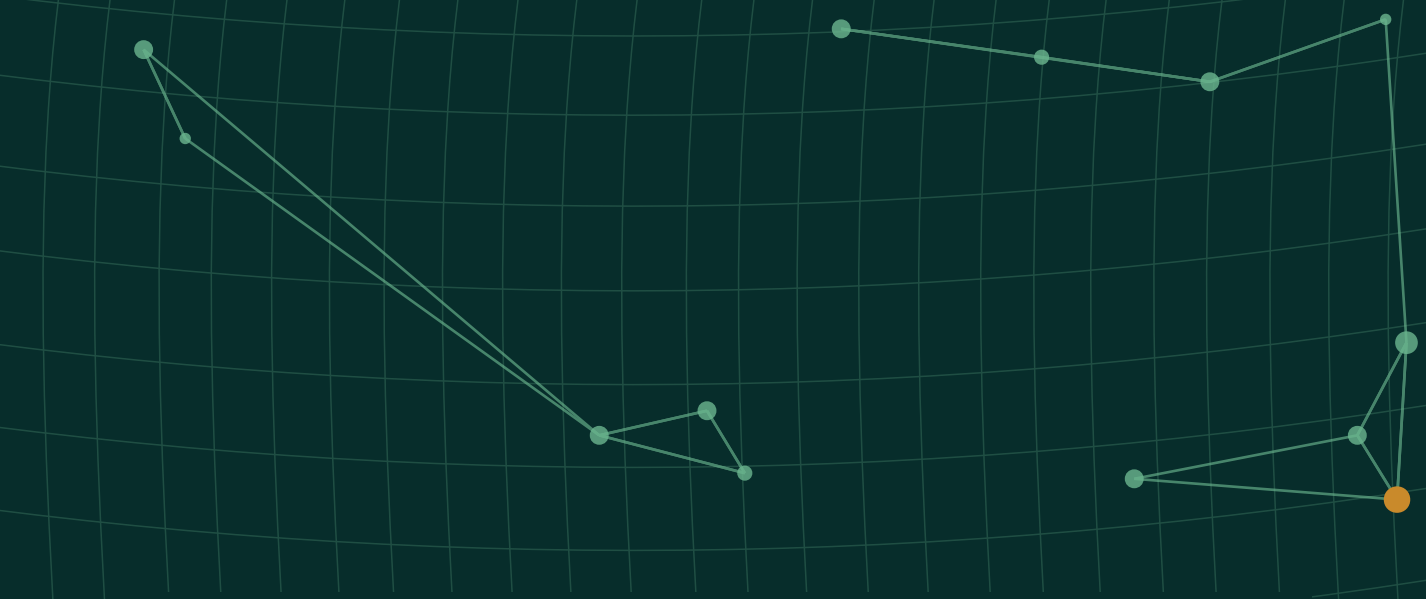
Carbon per Garment

Product carbon footprints and full-scope emissions accounting for apparel supply chains



wp16
RESEARCH EDITION

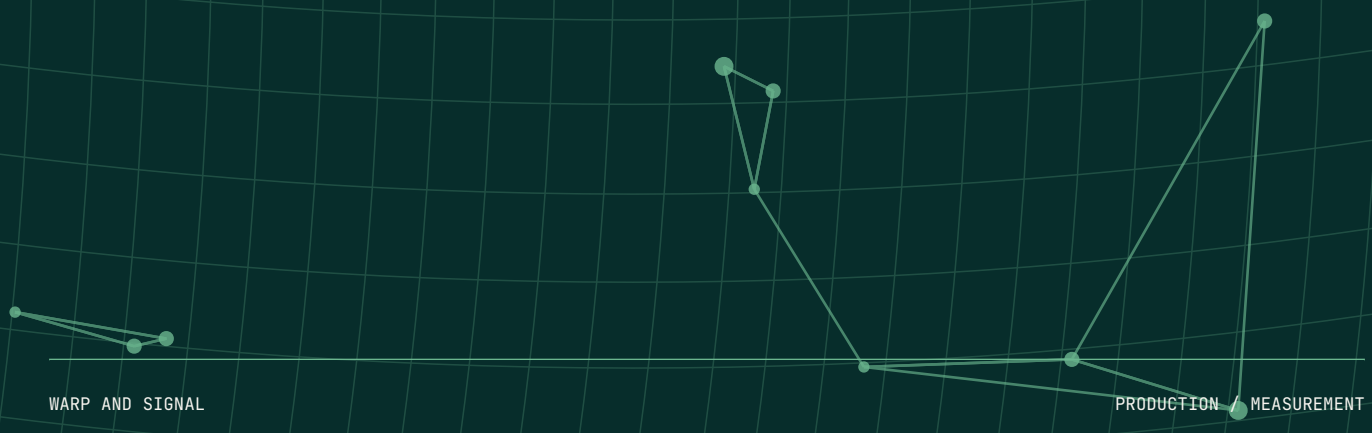
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HONG KONG SAR



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	wp16 / Carbon per Garment
EDITION DATE	2026-10-30
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STATUS	Research edition. Generated locally. Publication and operating-performance acceptance are separate decisions.
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Build the factory and its evidence as one system.

Carbon per garment is not a single property of a fibre or a factory. It is the result of boundaries, activity data, emission factors, allocation rules and use assumptions. This paper argues that an apparel maker needs two reconciled accounts: an organisational inventory across Scopes 1, 2 and 3, and product footprints that follow defined garments from cotton field to use and disposal. [R01] [R05] The account must preserve absolute emissions while showing intensity per garment and per wear. Using GHG Protocol, ISO 14040, ISO 14044 and ISO 14067, the paper builds a method for screening with secondary data, then replacing the largest uncertainties with metered and supplier-specific evidence. It examines cotton cultivation and co-products, spinning and wet processing, cut, make and trim operations, electricity and steam, freight, laundering, durability and end-of-life. Cameroon provides the application context, not a claimed baseline: no garment footprint is asserted before site data exist. The reduction programme prioritises energy measurement, process efficiency, lower-carbon heat and electricity, yield, logistics and longer service, while testing burden shifts and absolute growth. The final system links GFT's performance-management and digital work to versioned factors, supplier evidence, assurance, claims control and a four-phase roadmap. The result is a repeatable operating method for making carbon visible, reducing it and defending every published figure.

01 A corporate inventory and a product footprint answer different questions and must be reconciled rather than substituted for one another. [S01] [S02] [S04] [S23]

02 Fibre production, yarn preparation and wet processing often dominate apparel impacts, but the hotspot moves with product, geography and boundary. [S08] [S30] [S31]

03 A kilogram of fabric, a finished garment and a garment wear are different functional units, and fibre rankings can change when function is made equivalent. [S24] [S26] [S31]

04 Supplier-specific data are not automatically more accurate than industry averages, so data quality must be assessed rather than inferred from provenance. [S16] [S22] [S23]

05 Cradle-to-gate factors, combustion factors and upstream energy factors have distinct roles, and confusing them creates double counting or omissions. [S02] [S03] [S14] [S20] [S23]

06 Cotton accounting is sensitive to fertiliser, yield, cottonseed co-products, losses and the treatment of biogenic and soil carbon. [S26] [S29] [S31]

07 Electricity and steam choices can change a garment comparison materially, which makes dated regional factors and metered loads essential. [S14] [S28] [S31]

08 Use and end-of-life cannot be silently omitted from a public garment claim, because laundering, service life and disposal alter totals and rankings, and any partial footprint must be named accurately. [S01] [S06] [S12] [S26] [S27] [S30] [S32]

09 Absolute emissions and emissions per garment can move in opposite directions as output grows, so both must govern the reduction programme. [S07] [S08] [S23]

10 A defensible claim needs a versioned evidence chain from source activity to calculation, review and wording, not an offset-backed neutrality label. [S01] [S10] [S21] [S32]

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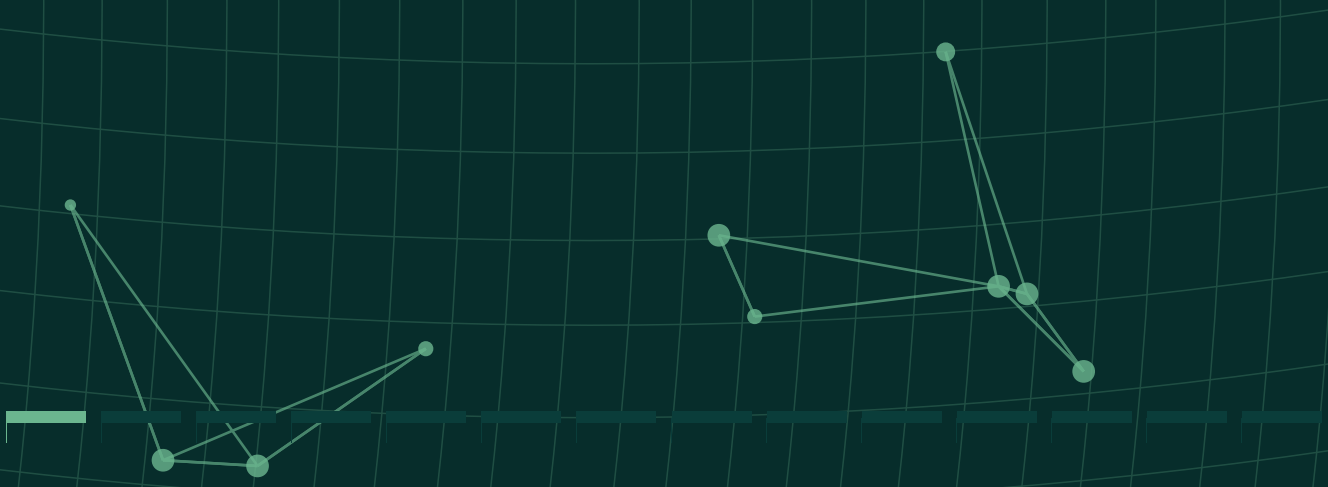
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01

PART I: BUILD THE ACCOUNT BEFORE THE CLAIM / THE ARGUMENT

Carbon per garment is an accounting discipline, not a slogan

A garment number becomes decision-ready only when its boundary, function, evidence and intended use are explicit.



CHAPTER 01
DECISION TEST

A garment number becomes decision-ready only when its boundary, function, evidence and intended use are explicit.

Carbon per garment is an accounting result, not an intrinsic property that can be read from a fibre label or a factory name. The result is constructed from a declared life cycle boundary, a defined garment and function, physical activity data, dated emission factors and explicit allocation rules. [S01] [S23] Change any of those choices and the number can change without any change on the production line. A useful footprint therefore begins with an evidence trail that another practitioner can inspect, not with a marketing adjective. Green Future Tech Limited (GFT) applies a simple sequence to its Cameroon textile programme: establish the account, use it to reduce emissions, and permit a public claim only after the evidence supports the wording. This chapter defines that discipline. Later chapters develop the detailed calculations, but the governing principle is already clear: a number that cannot explain its own scope cannot guide a decision.

1.1

A number without a boundary is not a footprint

A footprint must first answer the question, "Which emissions belong to this garment, over which period, for what function?" The GHG Protocol Product Standard covers raw materials, manufacturing, transportation, storage, use and disposal. [S01] A result limited to spinning, dyeing or garment assembly may be useful for supplier exchange or process control, but it is not a full life cycle result. Its name must preserve that limitation. "Cradle-to-gate carbon per defined shirt" and "full life cycle carbon per defined shirt" are different statements, not two wordings for the same calculation. [S01] [S23]

The boundary is more than a list of stages. It also determines whose electricity is included, whether inbound and outbound freight appear, how packaging and waste are treated, and whether consumer care and final disposal are measured or modelled. [S01] [S23] A factory can calculate its own utility emissions with care and still omit most of the garment system if purchased fabric, subcontracted wet processing or product use sit outside the account. Conversely, adding a supplier's cradle-to-gate factor to a full life cycle factor for the same material would introduce emissions twice. Boundary control therefore precedes arithmetic.

A partial account is not necessarily a weak account. A mill may need a gate-to-gate model to manage a boiler, while a buyer may need a cradle-to-gate record for a purchased fabric. The error lies in allowing the result to migrate into a wider claim without adding the missing stages. The GHG Protocol distinguishes cradle-to-gate factors, which stop at the supplier's point of sale, from life cycle factors that continue through subsequent stages. [S23] That distinction gives each module a proper use and prevents a convenient supplier number from becoming an unsupported garment claim.

1.2 FIVE FIELDS MAKE THE RESULT INTELLIGIBLE

Before reviewing a total, a reader should be able to inspect five fields: the boundary, the functional unit, the gases and global warming potential (GWP) convention, the activity data, and the emission factors. ISO 14067 confines a product carbon footprint to climate change, while Scope 3 guidance requires transparency about activity data, factors and GWP sources. [S05] [S23] **Exhibit 1**, p. 16 turns those requirements into a reading test for any garment figure. [S01] [S05] [S11] [S23]

EXHIBIT 01 / REQUIRED ACCOUNTING DECLARATIONS

Five fields make a garment footprint intelligible

Declared

Boundary

Name included and excluded life cycle stages.

Defined

Functional unit

Specify the garment, function and reference flow.

Versioned

Gases and GWP

Record gas coverage, metric source and time horizon.

Traceable

Activity data

Distinguish meters, records, estimates and proxies.

Dated

Emission factors

Preserve geography, period, unit and factor boundary.

SOURCED [S01] [S05] [S11] [S23] Sourced synthesis of full life cycle coverage in S01, the single climate impact category in S05, greenhouse gas metric assessment in S11, and activity data, emission factor and GWP disclosure in S23. The five fields are an organising device, not an additional reporting standard.

These fields expose different failure modes. An unclear boundary hides omissions. An undefined functional unit hides differences in garment mass, quality or service. An unrecorded GWP convention prevents consistent conversion of non-CO2 gases into CO2e. [S11] [S23] Untraceable activity data prevent the reader from returning to a meter, invoice or supplier record. An undated factor can attach the wrong geography or period to an otherwise sound physical measurement. Precision in the final decimal place cannot repair any of these defects.

The functional unit deserves particular restraint here. A kilogram of fabric, one finished garment and one wear are not interchangeable denominators. They support different decisions and require different reference flows. [S01] [S23] Moreover, the GHG Protocol Product Standard notes that its primary purpose is tracking a product's greenhouse gas inventory and reductions over time, whereas comparing two or more products for labels or performance claims requires additional methodological prescription on allocation rules and data sources. [S0101] The detailed functional-unit

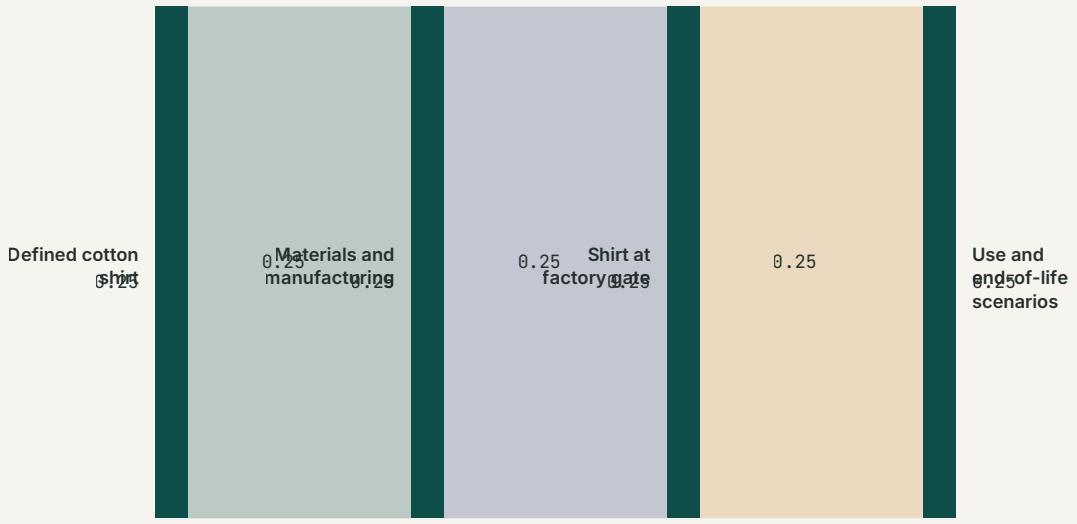
and comparison rules follow in the next chapters. For this opening argument, the requirement is simpler: state exactly what the denominator represents and do not allow it to change during comparison.

1.3 A REFERENCE SHIRT DEMONSTRATES WHY SCOPE COMES FIRST

Consider a defined cotton shirt with a baseline mass of 250 grams, the reference used in a comparative T-shirt life cycle study. [S31] That mass identifies a reference flow; it does not supply an emission factor, a cotton yield, a factory energy record or a downstream care scenario. **Exhibit 2**, p. 17 carries the same illustrative shirt reference through a boundary map without assigning any emissions. It is deliberately not a physical cotton mass balance, because losses, trims and other inputs remain to be measured. [S23] [S31]

EXHIBIT 02 / KG PER DEFINED COTTON SHIRT REFERENCE FLOW

A reference shirt cannot acquire a footprint before its boundary is declared



ILLUSTRATIVE [S31] Illustrative boundary model using the 250 g medium-size cotton shirt baseline in S31, expressed as 0.25 kg. Each link carries the same shirt-equivalent reference flow to preserve the denominator. This is not a physical mass balance and assigns no emissions. Losses, added materials, energy, freight, use and disposal require separate activity data and factors before calculation.

The exhibit shows why a footprint cannot be inferred from garment mass alone. The upstream module needs material and energy evidence. The factory-gate handover needs a clear statement of what the supplier included. The downstream module needs scenarios for distribution, laundering, service life and disposal, each labelled as observation or assumption. [S01] [S23] Only then can the modules form a full life cycle account without gaps or repetition.

1.4 CARBON IS ONE ENVIRONMENTAL ACCOUNT, NOT THE WHOLE SUSTAINABILITY ACCOUNT

ISO 14067 addresses climate change alone and excludes social, economic and other environmental impacts from its scope. [S05] A low carbon result therefore cannot establish low water use, acceptable effluent, low toxicity, fair work or garment durability. Nor can a high result prove the opposite. Carbon accounting earns its place by answering one question well, not by absorbing every question into a single score.

This limitation changes how claims should be written. "Lower CO2e per defined garment under the stated boundary" is a testable proposition if the evidence agrees. "Sustainable garment" is a much broader proposition that the carbon account cannot support on its own. [S05] [S32] GFT's carbon workstream therefore sits beside, rather than replaces, the operating records for water, energy, materials, quality and waste in its Cameroon textile programme.

1.5

Corporate and product accounts answer different questions

An organisational inventory and a product footprint share physical evidence, but they do not serve the same decision. The corporate account reports emissions within an organisational and value chain boundary for a reporting period. [S02] [S04] The product account follows a defined good through its life cycle and expresses the result against a functional unit. [S01] One asks what the organisation is responsible for managing. The other asks what burden attaches to the garment system being designed, purchased or sold.

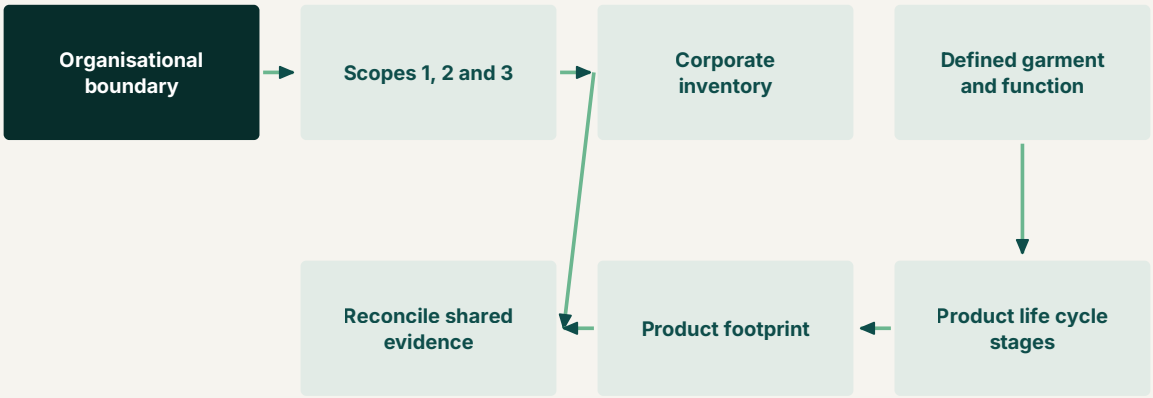
The GHG Protocol makes this separation explicit: its Scope 3 standard accounts at corporate level, while its Product Standard accounts at individual product level. [S02] Treating the corporate total divided by annual units as the footprint of every garment would conceal product mix, sourcing and life cycle differences. Treating one garment study as the corporate inventory would omit other products, sites, activities and relevant Scope 3 categories. The accounts must meet, but neither can substitute for the other.

1.6 SHARED ACTIVITY ENTERS THROUGH TWO CONTROLLED ROUTES

Exhibit 3, p. 19 shows the required architecture. Organisational Scopes 1, 2 and 3 form one route. Product definition and life cycle stages form the other. A reconciliation bridge then compares shared activities without assuming that the two totals should be numerically identical. [S01] [S02] [S04] [S23]

EXHIBIT 03 / ACCOUNTING ARCHITECTURE

One garment creates two linked carbon accounts



SOURCED [S01] [S02] [S04] [S23] Sourced process synthesis. S04 governs the corporate inventory, S02 its upstream and downstream Scope 3 coverage, S01 the product life cycle account, and S23 the calculation methods and evidence descriptions. Reconciliation compares shared activities, periods and boundaries; it does not assert that corporate and product totals are interchangeable.

The bridge is a control, not a forcing function. A garment factory's purchased electricity may appear in its Scope 2 inventory and, after allocation, in a shirt's cradle-to-gate footprint. [S01] [S04] The same kWh must retain one identity across both records. If the corporate inventory reports the full site period while the product model covers one order, the reconciliation must explain the difference in period and denominator rather than adjust one total until it resembles the other.

Scope 3 calculation guidance supplies methods by corporate category, including purchased goods, transport, use and end-of-life. [S02] [S23] Those categories provide a systematic completeness check for the organisation. They do not, by themselves, define a product's functional unit, allocation between co-products or equivalent garment performance. A category total cannot simply be relabelled as a product life cycle assessment. The product model needs its own goal and scope, while the corporate model needs assurance that every relevant category has been screened.

This separation also clarifies responsibility. The GHG Protocol Corporate Standard distinguishes greenhouse gas accounting from greenhouse gas reporting: accounting governs the recognition and consolidation of emissions and links data to specific operations, sites, geographic locations, business processes and owners, while reporting governs how that consolidated information is presented to users. [S0102] In an apparel business, the sustainability team may own the corporate inventory, product engineers may own the garment model, and procurement may own supplier evidence, but all three must use compatible identifiers for sites, suppliers, materials, orders and periods. [S04] [S0102] GFT's discipline is therefore administrative as much as mathematical: a carbon figure needs an owner, a version and a route back to source activity.

1.7

Scope 3 prevents a factory from outsourcing its carbon story

A factory does not remove emissions from its account by purchasing a material or subcontracting a process. The GHG Protocol Scope 3 framework covers upstream and downstream activities across 15 categories, providing a structure for screening emissions beyond owned operations. [S02] For an apparel business, that means the evidence plan must look beyond the sewing floor to purchased fibre, yarn, fabric and trims, outsourced processing, freight, waste, product use and disposal where relevant. [S02] [S08] [S23]

The word "relevant" matters. Scope 3 accounting does not require every activity to receive the same depth of measurement at the outset. The calculation guidance recommends an initial screen using less specific data, followed by more precise work on significant emissions, reduction opportunities and business priorities. [S23] This is a disciplined allocation of evidence effort. A small administrative purchase may remain a secondary-data estimate while a dominant fabric input justifies supplier-specific activity data and closer review.

1.8 APPAREL HOTSPOTS MAKE PURCHASED EVIDENCE AN OPERATING REQUIREMENT

Apparel and footwear guidance identifies significant value chain emissions and frequent hotspots in fibre production, yarn preparation, dyeing and finishing. [S08] A cut, make and trim operation can therefore have careful utility records and still lack evidence at the stages that drive much of the garment result. The correct response is not to assume a universal hotspot percentage. It is to screen the actual bill of materials and process route, then test where better evidence would change the decision. [S08] [S23]

This turns procurement into part of the measurement system. A purchase order identifies what was bought, but a carbon record also needs the supplier, product specification, quantity, production period and appropriate cradle-to-gate factor. [S23] Where a supplier provides a footprint, the buyer needs its boundary, allocation method, data sources, GWP convention and assurance status before using it. A PDF attached to an email is not sufficient if those fields are absent.

Supplier-specific evidence is not automatically superior. GHG Protocol guidance warns that supplier data can be less accurate than an industry average when granularity, source reliability or allocation is weak. [S23] A precise number calculated from an unrepresentative month, an unclear product allocation or an unrecorded proxy may be less useful than a transparent industry estimate. The evidence plan must assess fitness for the intended decision rather than award credibility on the basis of provenance alone.

METHOD

A minimum supplier evidence request should contain six linked records: product and site identity; reporting period; life cycle boundary; physical activity and output; emission factor and GWP versions; and allocation, proxy and assurance disclosures. The reviewer should test whether the supplied unit matches the purchased unit, whether the period fits the buyer's inventory, and whether any upstream transport or downstream stage is already included. Missing fields remain visible as evidence gaps rather than being silently replaced with zeros. This procedure applies the calculation and data-quality principles in the GHG Protocol guidance. [S23]

1.9 DATA REQUESTS SHOULD BUILD CAPABILITY RATHER THAN SHIFT AMBIGUITY

UNIDO's 2010 guide for garment, footwear and furniture suppliers anticipated growing pressure on developing-country suppliers to address their carbon footprints through business relationships. [S21] The practical lesson for a Cameroon programme is not to reproduce a buyer questionnaire and pass it upstream unchanged. It is to make the request physically intelligible to the spinner, dyer, logistics provider or garment line that holds the source record.

A useful request starts with quantities the supplier already controls: fuel used, electricity purchased, material received, accepted output, waste and transport work. It then asks for the factor and method needed to convert those quantities into CO2e. [S23] Where the supplier cannot respond, the buyer can use a labelled proxy from screening data and record who will replace it, by which review gate. That approach separates a temporary data limitation from a permanent exemption.

The same approach prevents double counting between commercial boundaries. If a fabric supplier's cradle-to-gate result already includes inbound yarn transport, the garment buyer must not add that leg again as an independent purchased-goods block. If a subcontractor reports only gate-to-gate energy, the remaining material and upstream inputs still need to be represented. [S23] Scope 3 therefore does more than enlarge the inventory. It forces each handover to state exactly what evidence accompanies the product.

1.10

Cameroon needs an operational baseline, not a borrowed label

Cameroon's industrial opportunity does not come with a pre-existing garment carbon factor. The inherited sector evidence records about 95 percent of cotton fibre exported raw and about 5 percent processed locally, with an industrialisation target of 50 percent local processing. [R06] Those figures describe the structure of the cotton sector in the inherited register, whose original publication date was not recorded. They are not measurements of carbon intensity, and they do not demonstrate that local processing will automatically lower emissions per garment.

Local production changes the system that must be measured. It can alter transport legs, electricity supply, thermal processes, yields, co-products and the division of activities between organisations. The carbon result depends on those actual condi-

tions, not on the location claim itself. A footprint assembled from an overseas fibre average, an unspecified grid factor and a generic garment study would be a screening model with proxies, not an operational Cameroon baseline. [S23]

1.11 THE PRODUCTION PERIOD BELONGS INSIDE THE BASELINE

Energy conditions also make vintage essential. The International Energy Agency country profile for Cameroon notes that electrification is relatively high for Central Africa, with 54 percent of the population having access to electricity while consumption remains low. [S09] Meanwhile, in January 2025, the World Bank described Cameroon's hydropower and solar development as part of an active shift substituting diesel-based generation to lower costs and cut carbon emissions. [S28] Reading those two public records side by side shows why source vintage matters: a country profile that retains an older access figure and a 2025 report on grid and solar investment describe different moments in a changing power system, and neither supplies a site-specific factor for an individual factory. [S09] [S28] A garment baseline must record when and where production occurred, which electricity and fuels were used, and which dated factor version converted those activities into CO2e. [S09] [S23] [S28]

An old national average should not be attached to a new production period merely because it is available. Equally, a newer factor should not be used to rewrite history without a recalculation rule. Scope 3 guidance requires significant data-quality improvements to trigger base-year recalculation where they materially change emissions estimates. [S23] The account therefore needs both an activity year and a factor lineage. Without them, a method update can masquerade as an operational reduction.

The baseline must also separate what happened from what was assumed. Metered electricity is observed activity. A supplier's missing fuel record replaced with an industry average is estimated activity. A future consumer-care pattern is a scenario. These inputs can coexist in a screening model, but they cannot carry the same claim status. [S23] Keeping them distinct allows the next data collection round to improve the account without pretending that the first model was measured end to end.

> **WARNING**
>
> No Cameroon garment footprint should be published as a measured national or GFT result before representative production records exist. A borrowed factor may support an explicitly labelled screening estimate, but it cannot resolve local yield, process energy, allocation, supplier performance or use conditions. The remedy is a dated pilot account with a proxy register and a plan to replace the uncertainties that matter most. [S23]

1.12 A BASELINE IS A REPEATABLE OPERATING RECORD

The practical starting unit is not a polished annual report. It is a controlled record joining production, procurement and utilities for the same period. Fabric and trim receipts identify purchased inputs. Meters and fuel records identify site activity. Accepted output identifies the production denominator. Supplier documents identify upstream boundaries. Each record carries an owner and a version so that corrections remain visible. [S04] [S23]

A baseline pilot should follow one representative garment through the complete method before expanding to every style. That pilot exposes mismatched units, missing stages and allocation problems while they are still inexpensive to correct. It also establishes which proxies dominate the result and therefore deserve supplier requests or meter investment first. [S23] Scaling a spreadsheet before resolving those issues would multiply confusion rather than produce coverage.

GFT's Cameroon textile programme already provides the operating context for this work through feasibility, performance-management system design and digital strategy. The carbon layer adds factors, gas conventions, life cycle boundaries and claims control to the production record. It does not presume a measured saving or a commercial advantage. Its first deliverable is a baseline that can survive recomputation and show management where action would matter.

1.13

Absolute emissions and intensity must travel together

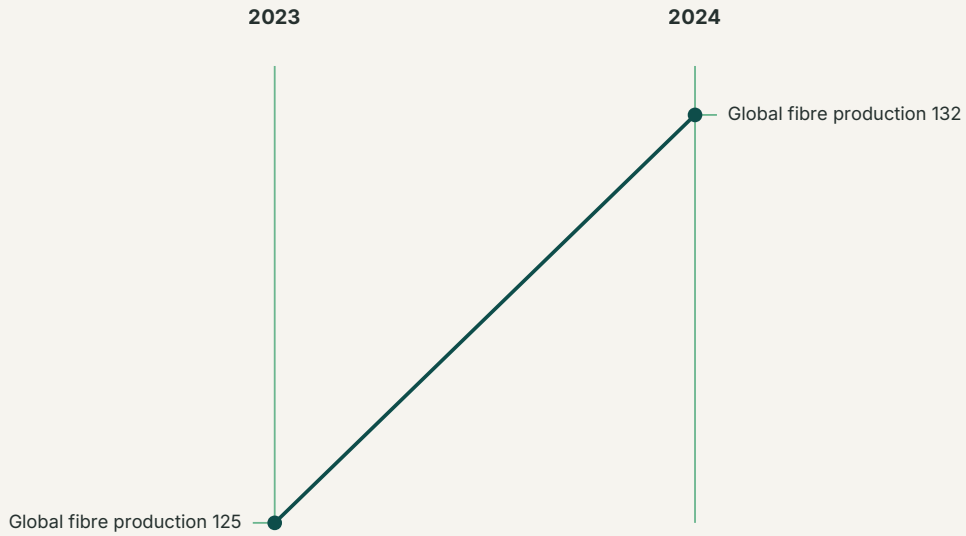
A lower footprint per garment does not necessarily mean lower total emissions. Absolute emissions equal production volume multiplied by emissions per unit when the boundary and product definition are held constant. If volume rises faster than intensity falls, the total increases. Apparel target guidance recognises both absolute contraction and physical intensity approaches, with intensity translated into absolute terms rather than treated as an end in itself. [S08] A serious operating review therefore retains total CO2e beside CO2e per accepted garment and, where the question concerns service, CO2e per wear. [S08] [S23]

The need for both measures is visible before any emissions calculation. Textile Exchange reports that global fibre production increased from 125 million tonnes in 2023 to 132 million tonnes in 2024 across apparel, home textiles, footwear and other applications. [S07] That is an increase of 7 million tonnes, or 5.6 percent derived as 7 divided by 125. [S07] It is not an emissions growth estimate, because fibre mix, geography and factors would need separate evidence. It does show why a production system cannot infer absolute climate progress from efficiency alone.

Exhibit 4, p. 24 preserves the two reported observations without converting them into CO2e. [S07]

EXHIBIT 04 / MILLION TONNES OF FIBRE PER YEAR

Global fibre volume increased before any emissions calculation



SOURCED [S07] Sourced observations from Textile Exchange Materials Market Report 2025 (S07): global fibre production across apparel, home textiles, footwear and other applications was 125 million tonnes in 2023 and 132 million tonnes in 2024. These are material volumes, not greenhouse gas emissions and not a Cameroon production baseline.

The exhibit establishes a change in physical throughput, not a change in carbon. The corresponding carbon account would need to know which fibres entered which processes, under which energy and allocation assumptions. [S07] [S23] That missing calculation is precisely the point: volume is an independent driver in the account and cannot be left outside the reduction narrative.

Product mix creates a related risk. If a factory shifts from lighter to heavier garments, emissions per piece may rise even when energy per kilogram falls. If it shifts towards products with longer verified service, emissions per wear may fall without the same movement per garment. The denominator must therefore remain attached to its decision, while the absolute total prevents a favourable ratio from concealing growth. [S08] [S23]

WORKED EXAMPLE

This illustrative case tests the relationship between volume, intensity and service. It does not represent a GFT factory, a measured garment or a forecast. The boundary is assumed to remain unchanged across both periods.

1. **Illustrative baseline:** A manufacturer produces `100,000` accepted garments at `4.0 kg CO2e` per garment. Absolute emissions are `100,000 * 4.0 = 400,000 kg CO2e`, or `400 tonnes CO2e`. These inputs are illustrative and chosen to make the arithmetic visible. [S08] [S23]
2. **Illustrative following period:** Output rises to `120,000` accepted garments while intensity improves to `3.5 kg CO2e` per garment. Absolute emissions become `120,000 * 3.5 = 420,000 kg CO2e`, or `420 tonnes CO2e`. Intensity falls by `0.5 / 4.0 = 12.5 percent`, but absolute emissions rise by `20,000 / 400,000 = 5.0 percent`, all derived from the illustrative inputs. [S08]
3. **Illustrative service extension:** If the baseline garments deliver `50` wears and the later garments deliver `70` wears under declared use scenarios, production emissions per wear are `4.0 / 50 = 0.080 kg CO2e` and `3.5 / 70 = 0.050 kg CO2e`. The per-wear result falls by `37.5 percent`, derived from the illustrative assumptions, but the annual absolute total still rises by `5.0 percent`. [S08] [S23]
4. **Decision:** The illustrative manufacturer has improved both product ratios and missed absolute reduction. The account should trigger a review of volume, energy, materials and sourcing rather than publish an unqualified reduction claim. Longer wear would support an absolute saving only if it actually displaced replacement production, which this arithmetic does not establish. [S08] [S23]

This is why the paper refuses to choose between absolute and normalised measures. Total CO2e shows the burden that must fall. Carbon per accepted garment exposes process and product performance. Carbon per wear connects the account to service, provided wear counts and displacement assumptions are explicit. [S08] [S23] Together they turn a reporting metric into a management constraint.

1.14

GFT's position is measure first, reduce second and claim last

The sequence begins with measurement because an unmanaged boundary can make any later statement ambiguous. It does not require perfect data before action. A factory can address an obvious energy loss while its wider Scope 3 screen is still developing. The rule is that the claimed effect must wait for a stable baseline, an activity record and a check that the burden has not moved elsewhere. [S01] [S23]

Measurement also has a defined order of value. The first account should reveal decisions, not merely fill a disclosure template. It should show which garments, suppliers, processes and periods carry the largest emissions or uncertainties; which records are observed; and which assumptions could change the ranking. [S23] If the model cannot direct a meter request, a supplier conversation or an engineering test, it is not yet an operating tool.

Reduction comes second because the account should govern the intervention. Energy efficiency, material yield, process control, logistics and lower-carbon supply may all deserve attention, but their order depends on the actual hotspot and the feasibility of changing it. [S08] [S23] Each action needs a baseline, an owner and a remeasurement plan. The review then separates three effects: a real change in activity, a change in production volume, and a change in emission factor or accounting method. Without that separation, a grid-factor update or a new proxy can be mistaken for an operational saving.

The absolute and intensity checks remain active during reduction. A successful line trial that lowers kWh per garment is useful evidence, but its scaled effect depends on runtime, output, product mix and any additional upstream burden. The product account tests whether the intervention lowers CO2e for the defined garment. The corporate account tests whether the organisation's relevant total falls over the comparable period. [S01] [S04] [S08] Reconciliation makes the two answers informative rather than contradictory.

Claims come last because their wording must inherit the account's limitations. A cradle-to-gate pilot can support a precisely named supplier-exchange result before it can support a full life cycle consumer claim. A scenario can disclose a possible use-phase outcome, but it cannot be described as measured consumer behaviour. A screening estimate can guide internal priorities without becoming a public product rating. [S01] [S23]

Directive (EU) 2024/825 supplies a clear claims-control principle within its legal context: relevant product climate claims should be based on the actual life cycle impact of the product, not on offsetting outside its value chain. [S32] This chapter uses that Directive as an accounting and claims-design reference, not as legal advice on any market. The operational lesson is straightforward. An environmental initiative and a product footprint are separate accounts, and purchasing an offset does not repair an incomplete garment inventory. [S32]

> **GFT NOTE**
>
> GFT should authorise a garment carbon statement only after three reviews agree. The accounting owner confirms the boundary, functional unit, factors and reconciliation. The operating owner confirms that activity records represent the stated production period and that reductions are separated from volume and method effects. The claims owner confirms that every public word stays inside the evidence, names partial boundaries and excludes offset-based neutrality. Any unresolved material proxy remains attached to the figure and to the next evidence action. [S01] [S23] [S32]

This sequence gives the Cameroon textile programme a practical carbon workstream rather than a parallel reporting exercise. Feasibility analysis identifies the production system to be modelled. Performance management supplies the operating cadence and ownership. Digital strategy preserves versions, links and permissions. Carbon

accounting joins those components by attaching a declared factor and boundary to physical activity, then carrying the result into product and corporate decisions. No measured footprint or saving is asserted before that evidence exists.

The discipline also sets a useful limit on ambition. GFT should not promise a universally lower-carbon Cameroon shirt, a complete environmental label or a neutral product. It should build the conditions under which a specific garment can be measured, compared on equivalent terms and improved without losing the absolute total. That is a narrower promise, but it is one that production evidence can support.

A garment footprint earns trust when every emissions unit can find its boundary, its evidence and its owner.

CHAPTER SOURCE NOTES

S01 GHG Protocol. 2011.

S23 GHG Protocol and Carbon Trust. 2013.

S05 International Organization for Standardization. 2018-08.

S11 Intergovernmental Panel on Climate Change. 2021-08-06.

S0101 World Resources Institute and World Business Council for Sustainable Development. 2011-09.

S31 Forfora et al., Sustainability. 2026-04-20.

S32 European Parliament and Council of the European Union. 2024-02-28.

S02 GHG Protocol. 2011.

S04 GHG Protocol. 2004.

S0102 World Resources Institute and World Business Council for Sustainable Development. 2004-03.

S08 Science Based Targets initiative and World Resources Institute. 2019.

S21 United Nations Industrial Development Organization. 2010.

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

S09 International Energy Agency. 2026.

S28 World Bank. 2025-01-16.

S07 Textile Exchange. 2025-09-18.

GREEN FUTURE TECH

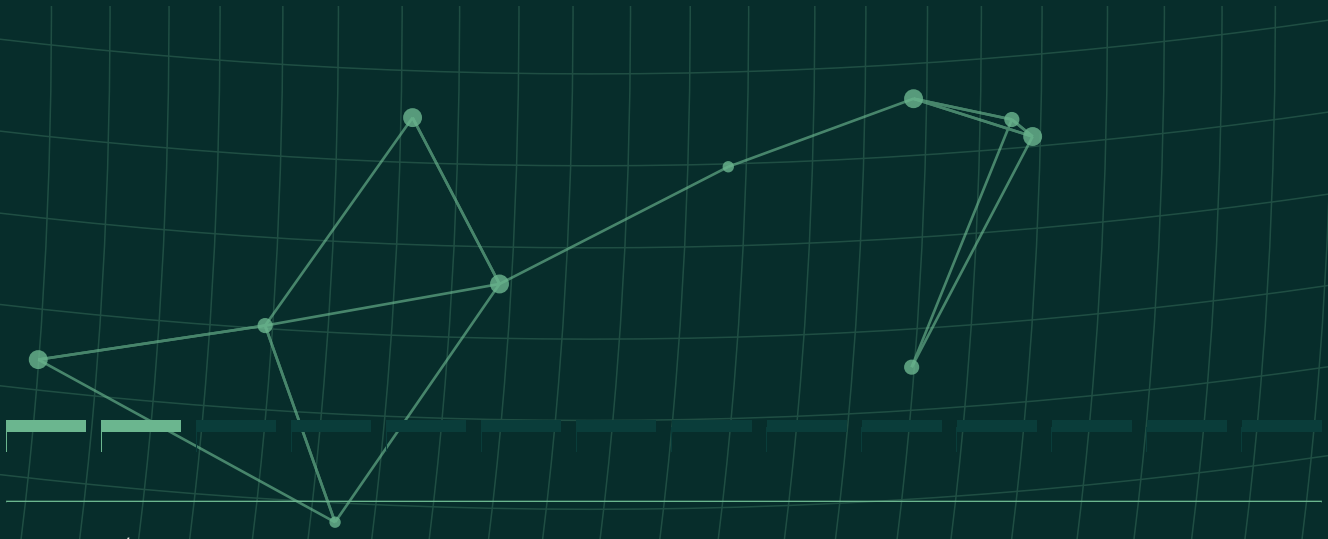
LIMITED / HONG KONG SAR

02

PART I: BUILD THE ACCOUNT BEFORE THE CLAIM / ACCOUNTING ARCHITECTURE

Corporate and product accounts must reconcile without double counting

A controlled chart of accounts lets site emissions, supplier emissions and product emissions meet once and only once.



CHAPTER 02
DECISION TEST

A controlled chart of accounts lets site emissions, supplier emissions and product emissions meet once and only once.

An apparel enterprise cannot manage carbon credibly by maintaining one spreadsheet for its annual corporate disclosure and an unconnected life cycle model for its garment labels. Corporate greenhouse gas inventories and product carbon footprints draw from the same physical industrial reality: diesel burned in standby generators, natural gas or biomass fired in steam boilers, mega-watt-hours drawn from the regional grid, cotton lint arriving from ginning plants, dyestuffs reacted in wet-processing vats, and containers moved across road and sea corridors. [S01] [S04] [S20] Yet the two accounting frameworks organise those physical flows around different denominators and different boundaries. The corporate inventory aggregates direct and indirect emissions across an organisation's facilities and value-chain categories over a defined twelve-month reporting period. [S02] [S04] The product carbon footprint accumulates emissions across the life cycle stages required to deliver a specified functional unit of clothing, regardless of which legal entity owns each stage or in which calendar quarter the upstream fibre was harvested. [S01] [S05] [S24] When a manufacturer builds both accounts without a shared chart of carbon accounts, three failure modes follow: upstream fuel and electricity burdens are counted twice across scopes, shared factory overheads vanish between product styles, and supplier cradle-to-gate totals collide with internal activity logs. [S20] [S23] Green Future Tech Limited (GFT), Hong Kong SAR, resolves this structural tension inside its Cameroon textile programme by treating carbon accounting as a double-entry engineering ledger: every metered activity record, supplier certificate and emission factor carries an explicit account code that maps simultaneously to an organisational scope category and to a product life cycle stage, with a formal reconciliation bridge explaining every legitimate divergence between the two totals. [S01] [S04] [S23]

2.1

The organisational boundary determines direct responsibility

Before a factory engineer can assign a single gram of carbon dioxide equivalent (CO2e) to a cotton shirt or a pair of workwear trousers, the reporting enterprise must define what the enterprise actually is. [S04] [S0201] Under the GHG Protocol Corporate Accounting and Reporting Standard and the complementary guidance of the United States Environmental Protection Agency, setting the organisational boundary is the mandatory first step of inventory design because it determines which legal entities, joint ventures, production sites and mobile assets enter Scope 1 and Scope 2, and which remain external value-chain counterparties inside Scope 3. [S02] [S04] [S0201] The standard recognises three consolidation approaches: equity share, financial control and operational control. [S0201] Under equity share, an organisation accounts for greenhouse gas emissions from operations according to its economic ownership interest, reflecting the extent of rights to the risks and rewards flowing from the asset. [S04] [S0201] Under financial control, the organisation accounts for 100 percent of emissions over which it can direct financial and operating policies to gain economic benefits, even where its equity holding sits below 50 percent. [S0201] Under operational control, the organisation accounts for 100 percent of emissions from operations where it holds full authority to introduce and implement operating policies at the plant floor, while excluding emissions from equity investments run by another operator. [S04] [S0201]

2.2 CONSOLIDATION RULES SHAPE MULTI-ENTITY TEXTILE POLES

In emerging textile economies, industrial capacity rarely sits inside a single wholly owned corporation, making the consolidation rule an immediate operational decision. [S04] [S0201] Consider the institutional structures documented in the public evidence base for Cameroon, where roughly 95 percent of cotton fibre is exported raw and about 5 percent is processed locally against a national target of 50 percent local processing by 2030. [R06] [R07] In northern Cameroon, SODECOTON supports more than 220,000 cotton producers and operates nine ginning plants and two oil mills. [R03] Public reporting also records an announced merger between SODECOTON and CICAM aimed at creating a cotton-textile industrial pole targeted by 2030, alongside the announced Camtext SA integrated cotton-to-textile project valued at US$300 million (180 billion XAF), structured on 12 November 2025 around Panafritex and Arise with SODECOTON, CNPS and Marlo to process 12,000 tonnes a year across hubs at Dibamba and Garoua. [R08] [R09] [R10] Neither SODECOTON, CICAM nor Camtext SA is a GFT client or a GFT operating result, and their announced structures remain sector observations rather than delivered footprints. [R08] [R09] They illustrate a strict accounting rule: when ginning, spinning, weaving, dyeing and garment assembly involve parastatals, pension funds and private operators, two analysts using different consolidation rules will draw the Scope 1 and Scope 2 boundary in different places. [S04] [S0201]

If an integrated textile venture adopts operational control as its corporate consolidation basis, any spinning hall, dyehouse or sewing plant where the venture's management sets shift schedules, boiler pressures and maintenance standards enters 100 percent into its Scope 1 and Scope 2 ledger. [S04] [S0201] Conversely, smallholder cotton farms and externally managed ginning plants sit outside operational control and enter the corporate inventory through Scope 3 Category 1 (purchased goods and services), even if an upstream entity holds minority equity in the garment company. [S02] [S23] [S0201] If the group instead selects equity share consolidation, a 30 percent illustrative equity stake in a joint-venture finishing mill brings 30 percent of that mill's fuel and electricity into corporate Scope 1 and Scope 2, while fabrics purchased from that mill require partitioning so that the group does not double count its equity-accounted energy inside Scope 3 Category 1. [S02] [S04] [S23] [S0201]

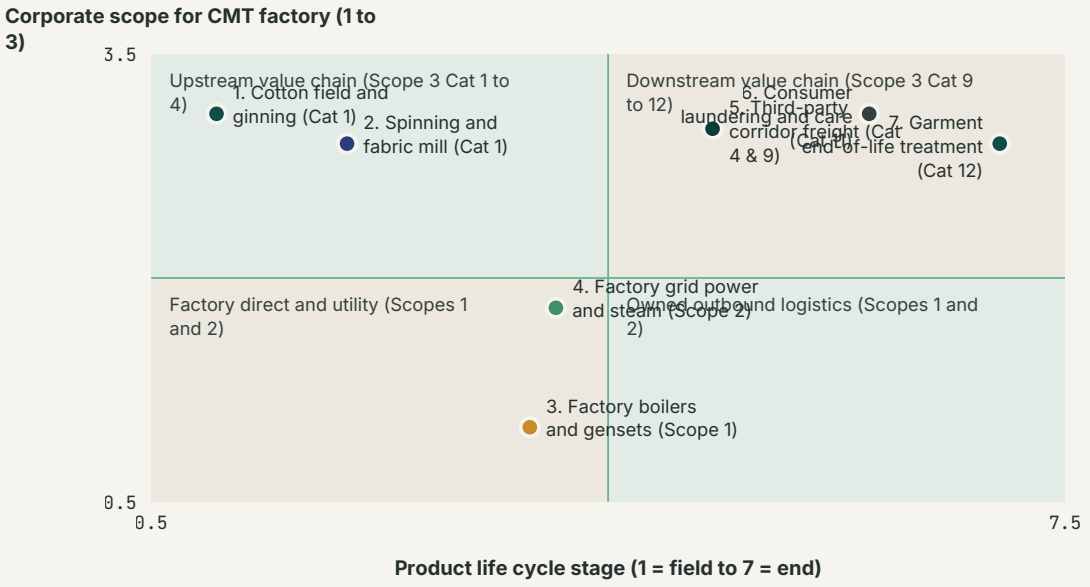
2.3 OPERATIONAL BOUNDARIES CAPTURE EVERY DIRECT SOURCE BEFORE PRODUCT ALLOCATION

Once the organisational perimeter is fixed, the operational boundary classifies direct emissions inside Scope 1 across four physical categories that every facility must register before product allocation. [S04] [S20] [S0203] First, stationary combustion covers fuels burned in fixed equipment owned or controlled by the enterprise: natural gas, heavy fuel oil, liquefied petroleum gas, diesel or biomass fired in steam boilers for yarn sizing, scouring, dyeing, drying and garment pressing, plus diesel burned in standby generators during grid outages. [S04] [S20] [S0203] Second, mobile combustion covers fuel burned in company-controlled forklifts, yard tractors, shuttle buses and delivery vans. [S04] [S20] Third, process emissions cover chemical transformations releasing greenhouse gases independently of fuel combustion, such as carbonate neutralisation in effluent treatment. [S04] Fourth, fugitive emissions cover intentional and unintentional releases from pressurised equipment, notably hydrofluorocarbon (HFC) refrigerant leaks from chillers and air-handling units, alongside methane from on-site anaerobic wastewater lagoons. [S04] [S11] [S20]

A garment maker must log these four Scope 1 streams in physical units first, recording litres of fuel and kilograms of refrigerant by specific gas blend, and convert them using documented factors and declared global warming potentials (GWP) inside an institutionalised Inventory Management Plan before dividing burdens across garment styles. [S11] [S20] [S0202] As **Exhibit 5**, p. 31 illustrates, the physical activities occurring across the seven stages of an apparel chain do not change when the analyst switches from a corporate inventory lens to a product life cycle lens, but their classification shifts from ownership-based scopes to process-ordered life cycle stages. [S01] [S02] [S04] [S23]

EXHIBIT 05 / STAGE INDEX (X) AND SCOPE INDEX (Y)

Scopes and product stages share activities but not accounting purpose



SOURCED [S01] [S02] [S04] [S23] Maps seven apparel value-chain activities for a standalone garment factory under operational control. X-axis orders product life cycle stages from cradle (1 = cotton field) to grave (7 = end-of-life) per S01. Y-axis maps corporate Scope assignment (1 = Scope 1 direct, 2 = Scope 2 purchased energy, 3 = Scope 3 value chain) per S02, S04 and S23.

What **Exhibit 5**, p. 31 establishes is a structural separation of coordinates. On the horizontal axis, the Product Life Cycle Accounting and Reporting Standard orders processes sequentially from raw material extraction through manufacturing, transport, consumer use and disposal. [S01] On the vertical axis, the Corporate Standard and Scope 3 Standard partition those same activities according to whether the reporting company controls the source (Scope 1), purchases conditioned energy (Scope 2), or relies on value-chain counterparties (Scope 3). [S02] [S03] [S04] What **Exhibit 5**, p. 31 cannot establish by itself is the emission magnitude of any point, nor does it fix vertical coordinates across different business models: if the reporting company acquires operational control of the spinning and dyeing mill, Point 2 drops vertically from Scope 3 into Scopes 1 and 2 while remaining at Stage 2 on the horizontal product axis. [S01] [S04] [S0201]

2.4

Scope 2 requires purchased energy evidence

Scope 2 occupies a distinct accounting position because fuel combustion occurs physically at a power station or district boiler house outside the factory fence, yet the resulting emissions are assigned to the consuming organisation's inventory because they result from its operational energy demand. [S03] [S0203] The GHG Protocol Scope 2 Guidance standardises this measurement across four purchased or acquired energy carriers: electricity, steam, heat and cooling. [S03] In textile industrial zones, factories often purchase piped process steam or chilled water from a central estate utility alongside grid electricity. [S03] [S20] When a dyehouse buys steam from a third-party boiler house across the estate road, the fuel burned in that boiler is the utility provider's Scope 1, while the emissions from generating the delivered steam belong in the textile factory's Scope 2. [S03] [S0203]

2.5 DUAL REPORTING SEPARATES PHYSICAL GRIDS FROM CONTRACTUAL INSTRUMENTS

Under the Scope 2 Guidance, any enterprise operating in a market with contractual energy instruments (such as energy attribute certificates or power purchase agreements) must report Scope 2 using two methods: the location-based method and the market-based method. [S03] The location-based method applies the average emissions intensity of the physical grids where consumption occurs, whereas the market-based method applies emission factors from contractual instruments meeting quality criteria (or a residual mix factor for untracked supply). [S03] [S14]

For a factory in Cameroon, this distinction is critical. The International Energy Agency records that 54 percent of Cameroon's population has access to electricity in its 2026 profile, and the World Bank notes in January 2025 that Cameroon is expanding hydropower and solar energy to lower costs and cut carbon emissions while addressing reliability constraints. [S09] [S28] Because grid dispatch shifts with new generation and seasonal hydrology, a factory must pair metered kWh with dated annual factors rather than an undated country average. [S09] [S14] [S28] Furthermore, electricity generated on site by diesel backup generators during grid outages is always Scope 1 stationary fuel combustion calculated from metered diesel litres, never Scope 2 electricity. [S03] [S04] [S20]

2.6 THREE ENERGY FACTOR COMPONENTS MUST REMAIN DISTINCT IN THE LEDGER

Double counting between corporate and product accounts frequently occurs when analysts collapse three separate energy-related emission factors into one unlabelled multiplier. [S14] [S20] [S23] Both the IEA Emissions Factors 2026 release and the UK DESNZ 2026 conversion factors separate direct generation factors, transmission and distribution (T&D) loss factors, and upstream well-to-tank (WTT) fuel-cycle factors. [S14] [S20] Every megawatt-hour of purchased electricity triggers three distinct accounting entries: [S01] [S03] [S20] [S23]

1. **Generation combustion factor (Corporate Scope 2; Product manufacturing stage):** Greenhouse gases released at the power station per kWh generated and delivered to the factory meter. [S03] [S14] [S20]

2. **Transmission and distribution loss factor (Corporate Scope 3 Category 3; Product manufacturing stage):** Power-station combustion emissions associated with electricity lost in high-voltage lines and transformers between power plant and factory substation. [S14] [S20] [S23]
3. **Upstream well-to-tank fuel-cycle factor (Corporate Scope 3 Category 3; Product manufacturing stage):** Extraction, refining and transport emissions of the primary fuels before combustion at the power station or in T&D losses. [S14] [S20] [S23]

Life cycle inventory databases such as ecoinvent and the World Apparel and Footwear Life Cycle Assessment Database (WALDB) bundle all three components into a single cradle-to-gate electricity process. [S16] [S17] [S23] If a sustainability team uses an LCA database electricity factor for corporate Scope 2 and also calculates Scope 3 Category 3 using standard WTT and T&D multipliers, grid losses and upstream fuel extraction are counted twice. [S20] [S23] Conversely, if a product analyst builds a garment footprint from corporate Scope 1 and Scope 2 totals while omitting the factory's Scope 3 Category 3 WTT and T&D entries, the garment footprint understates the life cycle burden of factory energy. [S01] [S20] [S23]

> **GFT NOTE**
>
> In GFT's Cameroon textile programme, the utility ledger stores physical consumption (`kWh_grid_metered`, `litres_diesel_genset`, `kg_steam_purchased`) once and links each record to a three-part dated factor vector (`ef_direct_scope1_or_2`, `ef_td_loss_cat3`, `ef_wtt_upstream_cat3`). [S14] [S20] [S23] Corporate Scope 2 queries sum `ef_direct_scope1_or_2` for purchased energy, Corporate Scope 3 Category 3 queries sum `ef_td_loss_cat3` plus `ef_wtt_upstream_cat3` (including WTT on Scope 1 fuels), and Product LCA queries sum all three components across allocated production lots. [S01] [S03] [S20] [S23] Reading from one metered table prevents both double counting and omission. [S20] [S0202]

2.7

The 15 Scope 3 categories become an apparel map

The GHG Protocol Corporate Value Chain (Scope 3) Standard divides indirect emissions outside Scope 2 into 15 mutually exclusive categories: eight upstream (Categories 1 to 8) and seven downstream (Categories 9 to 15). [S02] [S23] Guidance from the Science Based Targets initiative (SBTi) and World Resources Institute confirms that value-chain (Scope 3) emissions represent a major share of apparel sector impact, while UNIDO highlights growing buyer pressure on developing-country suppliers to quantify and limit carbon footprints. [S08] [S21] Because the 15 categories are an organisational sorting system rather than a product LCA, an apparel enterprise must map each category to its product life cycle boundary and define clear inclusion rules. [S01] [S02] [S23]

2.8 UPSTREAM AND DOWNSTREAM CATEGORIES SHIFT WITH VERTICAL INTEGRATION

How the 15 categories populate an apparel ledger depends on the company's position along the cotton-to-garment chain: [R06] [S02] [S08] [S23]

- **Standalone cut, make and trim (CMT) factory:** Purchases dyed fabric, thread, buttons, zippers and polybags. [S08] [S23] Cotton farming, ginning, spinning, weaving or knitting, and wet processing sit in **Scope 3 Category 1 (purchased goods and services)**, alongside subcontracted printing or embroidery. [S02] [S08] [S23] Because the factory sells finished clothing, **Category 10 (processing of sold products)** is zero, while **Category 11 (use of sold products)** and **Category 12 (end-of-life treatment)** cover consumer laundering and disposal. [S02] [S23]
- **Intermediate spinning or grey-fabric mill:** Purchases cotton lint (Category 1), spins yarn or weaves greige cloth (Scopes 1 and 2, plus Category 3), and sells unfinished textiles to external dyehouses and garment makers. [S02] [S08] [S23] Here **Category 10** is material because sold intermediate goods require downstream dyeing and sewing. [S02] [S23]
- **Vertically integrated fibre-to-garment enterprise:** Consolidates spinning, weaving, wet processing and sewing inside **Scopes 1 and 2** (plus Category 3), shrinking Category 1 to external farm inputs (such as synthetic nitrogen fertilisers, which emit greenhouse gases during manufacture, processing and application) or purchased seed cotton, dyes, chemicals and trims. [S02] [S04] [S23] [S29]

Consequently, comparing "Scope 3 share of corporate emissions" across companies with different vertical integration is meaningless; only mapping both into a common product boundary enables fair garment comparison. [S01] [S22] [S26] GFT operationalises this mapping through the four-layer accounting architecture shown in **Exhibit 6**, p. 35. [S01] [S02] [S04] [S23] [S0202]

EXHIBIT 06 /

A chart of carbon accounts links sites, suppliers, products and factors



ILLUSTRATIVE [S01] [S02] [S04] [S23] [S0202] Illustrative system architecture derived from GHG Protocol Corporate (S04), Scope 3 (S02, S23) and Product (S01) standards alongside US EPA Inventory Management Plan controls (S0202). Shows how one underlying activity record feeds both reporting views.

In **Exhibit 6**, p. 35, Layer 1 records plant-floor fuel, electricity, output, scrap and refrigerant data. [S20] [S0202] Layer 2 ingests supplier footprints under WBCSD PACT Version 3, freight logs under the GLEC Framework, background LCI proxies from ecoinvent or WALDB, and use-phase scenarios. [S10] [S16] [S17] [S18] Layer 3 applies consolidation rules, energy factor splits, co-product rules and line utility drivers, while Layer 4 outputs the reconciled corporate and product ledgers. [S14] [S20] [S23] [S26] Because **Exhibit 6**, p. 35 is an architectural design, it specifies required data controls rather than claiming existing site measurements. [S0202]

To translate Layer 2 and Layer 3 into procurement and operational practice, **Exhibit 7**, p. 36 maps all 15 Scope 3 categories to apparel examples, internal data owners, and product-account bridge and exclusion rules. [S01] [S02] [S08] [S18] [S23]

EXHIBIT 07 /

Upstream Scope 3 categories translate into apparel evidence requests

Scope 3 category	Apparel value-chain examples	Internal owner	Product-account bridge and exclusion rule
Cat 1: Purchased goods and services	Raw cotton, yarn, fabric, dyes, chemicals, trims, polybags, subcontracted wet processing	Procurement and material planning	Included in product cradle-to-gate via bills of materials (BOM) and scrap rates; exclude non-production office consumables
Cat 2: Capital goods	Spinning frames, looms, dye jets, sewing machines, boilers, solar arrays, building civils	Engineering and fixed-asset finance	Reported fully in corporate year of purchase; excluded from product LCA unless PCR requires amortised capital goods
Cat 3: Fuel- and energy-related activities	Upstream WTT extraction of boiler fuel and grid fuels; electricity T&D grid losses	Energy and facilities manager	Included in product manufacturing stage alongside Scope 1 and 2 energy; never fold into corporate Scope 1 or 2
Cat 4: Upstream transportation and distribution	Inbound freight of lint, fabric, trims and chemicals paid by the reporting maker, plus third-party hubs	Inbound logistics and customs team	Included in product footprint by tonne-km; check supplier PACT boundary so delivery is not counted in both Cat 1 and Cat 4
Cat 5: Waste generated in operations	Cutting-room fabric offcuts, rejected garments, yarn waste, dyehouse sludge, packaging scrap	Quality, cutting and EHS teams	Included in product manufacturing stage; gross material input sits in Cat 1 while treatment of waste sits in Cat 5
Cat 6: Business travel	Buyer showroom flights, supplier quality audits, technical engineer travel in third-party aircraft or cars	Human resources and travel desk	Corporate overhead; excluded from attributable product footprints under S01 unless directly attributable to one bespoke order
Cat 7: Employee commuting	Operator transport between homes and factory gates in third-party buses, taxis or personal vehicles	Human resources and site admin	Corporate overhead; excluded from product footprints (if factory owns shuttle buses, fuel is corporate Scope 1)
Cat 8: Upstream leased assets	Leased sewing annexes or off-site fabric warehouses not included in corporate Scope 1 and 2	Real estate and operations	Depends on consolidation rule; if outside Scope 1 and 2, allocate product-related storage or sewing energy to the garments processed

SOURCED [S01] [S02] [S08] [S18] [S23] Complete mapping of the 15 Scope 3 categories in S02 and S23 to apparel manufacturing operations (S08), logistics accounting (S18) and product life cycle boundaries (S01).

EXHIBIT 08 /

Downstream Scope 3 categories close the product boundary

Scope 3 category	Apparel value-chain examples	Internal owner	Product-account bridge and exclusion rule
Cat 9: Downstream transportation and distribution	Outbound sea, road or air freight after point of sale (when paid by buyer) and retail distribution centres	Commercial and outbound logistics	Included in cradle-to-grave product footprints; omitted from cradle-to-gate B2B declarations with explicit boundary label
Cat 10: Processing of sold products	Downstream dyeing, finishing or garment assembly of sold yarn or grey fabric by third-party buyers	B2B sales and technical product team	Applicable to yarn and fabric mills; zero for finished garment makers selling ready-to-wear clothing
Cat 11: Use of sold products	Consumer washing, tumble drying, ironing and detergent energy across garment service life	Product design and testing lab	Indirect use-phase scenario in corporate Cat 11 and cradle-to-grave product LCA; excluded from cradle-to-gate footprints
Cat 12: End-of-life treatment of sold products	Collection, landfill, incineration, reuse or recycling of discarded garments and consumer packaging	Sustainability and circularity lead	Included in cradle-to-grave product LCA and corporate Cat 12; disclose regional collection and disposal scenarios
Cat 13: Downstream leased assets	Company-owned machinery or retail fixtures leased out to external operators	Finance and property ledger	Non-product corporate activity; zero for standard garment manufacturing unless equipment leasing is a business line
Cat 14: Franchises	Franchised retail stores operating under a brand licence outside corporate Scope 1 and 2	Retail franchise management	Zero for B2B garment manufacturers; for retail brands, store energy enters cradle-to-grave distribution if material
Cat 15: Investments	Minority equity holdings or project finance not consolidated into corporate Scope 1 and 2	Corporate treasury and board	Financial portfolio category; excluded from individual garment product footprints to avoid double counting with Cat 1

SOURCED [S01] [S02] [S08] [S18] [S23] Complete mapping of the 15 Scope 3 categories in S02 and S23 to apparel manufacturing operations (S08), logistics accounting (S18) and product life cycle boundaries (S01).

Inspecting **Exhibit 7**, p. 36 highlights three structural rules. [S01] [S02] [S23] First, Categories 6, 7, 13 and 15 capture organisational activities (business travel, employee commuting in third-party vehicles, leased-out assets and minority investments) that belong in corporate Scope 3 where material, but are excluded from attributable product footprints under the Product Standard and ISO 14067. [S01] [S02] [S05] [S23] Second, Category 2 (capital goods) is recorded 100 percent in the corporate acquisition year without depreciation, whereas product LCA either excludes capital

equipment under product category rules or amortises a fraction across multi-year output. [S01] [S02] [S06] [S23] Third, Category 5 (waste generated in operations) covers only the downstream transport and waste-treatment emissions of scrap, because the upstream cradle-to-gate burden of producing the wasted fabric is already captured in the gross purchase quantity inside Category 1. [S02] [S23] [S31]

2.9

Cradle-to-gate and full life cycle factors have distinct uses

Even with clean boundaries, carbon accounts fail when calculation engines apply the wrong class of emission factor to an activity record. [S20] [S23] Every emission factor in the chart of accounts must be locked to one of four mutually exclusive boundary families: [S01] [S14] [S20] [S23]

1. **Direct gate-to-gate combustion or process factors (`EF_direct`):** Gases released at fuel oxidation or reaction (CO2, CH4, N2O per litre of fuel or per kWh at the power station), used strictly in Corporate Scope 1, Corporate Scope 2, or tank-to-wake transport. [S03] [S04] [S11] [S18] [S20]
2. **Upstream fuel-cycle or well-to-tank factors (`EF_wtt`):** Extraction, refining and transport of fuels prior to combustion plus electricity T&D grid losses, paired with `EF_direct` in product LCA while sitting strictly in Corporate Scope 3 Category 3. [S14] [S18] [S20] [S23]
3. **Cradle-to-gate material factors (`EF_ctg`):** Cumulative emissions from raw material extraction up to the supplier's gate per kilogram of yarn, fabric, dye or trim, used in Corporate Scope 3 Category 1 and upstream product stages. [S01] [S10] [S16] [S23]
4. **Cradle-to-grave full life cycle factors (`EF_full`):** Complete product footprints including distribution, consumer use and disposal, which are final outputs and must never be used as input multipliers for individual materials. [S01] [S05] [S06] [S23]

2.10 FIVE BOUNDARY COLLISIONS THAT CORRUPT APPAREL CARBON ACCOUNTS

Locking these four factor families prevents five common collisions in apparel accounting: [S10] [S18] [S20] [S23]

- **Collision 1: Stacking supplier cradle-to-gate fabric footprints onto raw-cotton proxies.** A fabric mill's PACT Version 3 cradle-to-gate footprint (`EF_ctg`) already encloses cotton farming, ginning and spinning alongside weaving and dyeing. [S10] [S23] Keeping a separate background proxy from ecoinvent or WALDB for raw cotton fibre in the same garment bill of materials counts cotton cultivation twice. [S16] [S17] [S23]
- **Collision 2: Embedding well-to-tank fuel burdens inside Scope 1 and repeating them in Category 3.** Using an LCA database fuel factor (which bundles upstream fuel extraction with combustion) in Corporate Scope 1 while also running a Scope 3 Category 3 WTT calculation double counts oil and gas extraction. [S16] [S20] [S23]

- **Collision 3: Double counting inbound freight between Category 1 (`EF_ctg`) and Category 4 (`GLEC`).** If a supplier delivers fabric on Delivered Duty Paid (DDP) terms and includes delivery to the buyer's gate in its PACT record, calculating Category 4 freight from the supplier's mill gate to the garment warehouse via GLEC tonne-kilometres counts the same truck or container leg twice. [S02] [S10] [S18] [S23]
- **Collision 4: Mixing spend-based EEIO screening factors with physical bills of materials.** Applying macroeconomic spend factors to chemical or textile invoices that are already accounted for by physical mass records duplicates emissions, and perversely penalises higher-priced low-carbon materials. [S23]
- **Collision 5: Claiming closed-loop recycling credits twice.** When cutting-room cotton offcuts are mechanically recycled into new yarn, either the waste-generating garment claims an end-of-life displacement credit OR the receiving yarn claims recycled content free of virgin cultivation burden, never both within the same portfolio. [S01] [S22] [S25] [S26]

2.11

Shared activities must be allocated once

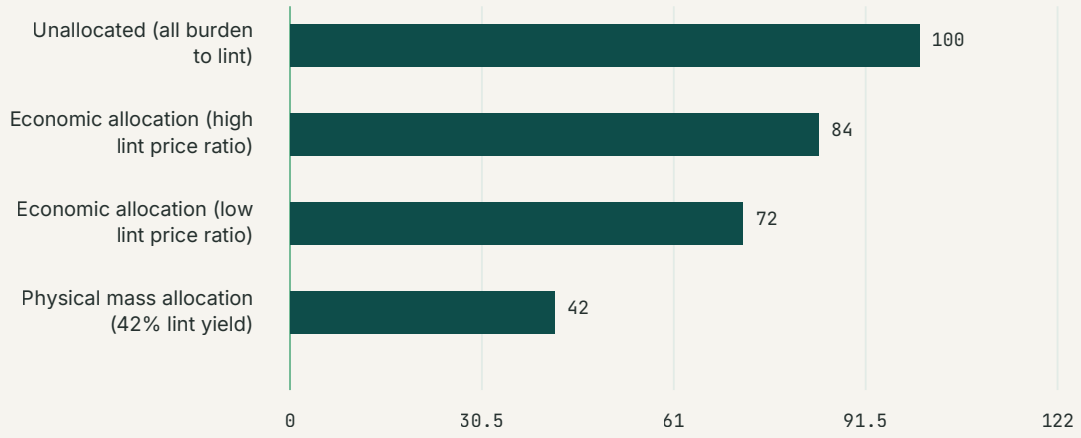
Virtually every textile process is multi-functional: cotton plants yield lint and cottonseed, gins turn out lint bales and seed for oil mills, and garment factories run multiple buyer styles across shared steam, compressed-air and lighting headers. [R03] [S23] [S26] [S31] Both ISO 14044 (with ISO 14067) and the GHG Protocol Product and Scope 3 standards enforce a strict allocation hierarchy: first, avoid allocation through sub-metering (process subdivision) or system expansion; second, partition shared burdens by underlying physical relationships (mass, energy, machine hours or standard minutes); third, use economic value (revenue share) only when physical relationships cannot be established. [S01] [S05] [S23] [S24] [S25]

2.12 CO-PRODUCT ALLOCATION AT THE COTTON GIN: LINT VERSUS COTTONSEED

Watson and Wiedemann show that inconsistent co-product allocation is a primary cause of conflicting fibre rankings across apparel rating tools, while Textile Exchange and Forfora et al.'s 2026 T-shirt LCA demonstrate how sensitive cotton results are to economic versus physical partitioning and processing losses. [S22] [S26] [S31] At the gin (such as SODECOTON's nine ginning plants paired with two oil mills in northern Cameroon), harvested seed cotton separates into roughly 35 to 42 percent lint fibre and 50 to 58 percent cottonseed by mass, with the balance lost as trash and moisture. [R03] [S26] [S31] Because cottonseed dominates physical mass while lint dominates market revenue, the choice of allocation rule shifts the farm burden assigned to lint, as shown in **Exhibit 9**, p. 40. [S24] [S26] [S31]

EXHIBIT 09 / PERCENT OF SEED-COTTON AND GINNING CO2E ASSIGNED TO LINT

Allocation rules shift the share of farm burden assigned to cotton lint



DERIVED [S24] [S26] [S31] Derived comparison illustrating the sensitivity documented in S26 and S31 under ISO 14040/14044 rules (S24). Compares (1) unallocated 100% assignment to lint, (2) illustrative economic allocation under a high lint-to-seed price ratio (84%), (3) illustrative economic allocation under a lower lint-to-seed price ratio (72%), and (4) illustrative physical mass allocation at a 42% net lint turn-out ratio.

To see the arithmetic in **Exhibit 9**, p. 40, take an illustrative 1,000 kg of clean gin output comprising 420 kg of lint and 580 kg of seed. [S26] [S31] Under physical mass allocation, lint receives 42 percent of farm and ginning emissions. [S25] [S26] Under economic allocation at an illustrative lint price of US$2.00 per kg (US$840 revenue) and seed price of US$0.276 per kg (US$160 revenue), lint receives 84 percent of the farm burden (840 / 1,000), double the mass-allocated share. [S23] [S26] [S31] If relative seed prices rise in a later harvest so lint's revenue share falls to an illustrative 72 percent, economic allocation alters the apparent footprint of cotton lint by 12 percentage points without any change in farm practices. [S23] [S26] What **Exhibit 9**, p. 40 cannot establish is a single universal ratio for Cameroon; instead, it proves that the allocation rule must be disclosed and held constant across base-year comparisons. [S22] [S23] [S26]

2.13 FACTORY-FLOOR ALLOCATION: ROUTING SHARED UTILITIES AND MATERIAL LOSSES TO GOOD GARMENTS

Inside the mill and garment factory, shared utility streams must follow physical causality: [S20] [S23] [S25]

- **Wet-processing steam and power:** Scale with fabric mass, liquor ratio and bath temperature rather than piece count. [S08] [S23] [S31]
- **Sewing and pressing halls:** Scale with **standard allowed minutes (SAM)** or machine-operating hours; an illustrative structured jacket requiring 45 SAM draws far more line power and pressing steam than a basic T-shirt requiring 8 SAM at the same 0.25 kg mass. [S20] [S23] [S31]
- **Base-load overheads and utilisation:** Lighting, HVAC and steam-header radiation run per shift regardless of throughput. [S20] [S23] In the Cameroon evidence register, a July 2023 report on CICAM recorded capacity utilisation of 33.7 percent at Garoua, 48.9 percent at CICAM 1, and 10.83 percent at CICAM 2, with

underutilisation costing about CFAF 2 billion in 2020. [R12] Low utilisation spreads fixed base-load energy across fewer good units, raising carbon per garment. [R12] [S20] [S23]

Cumulative material losses also magnify upstream burdens. [S31] Forfora et al.'s 2026 T-shirt study reports 31 percent cumulative cotton loss across cradle-to-gate processing, meaning a 0.25 kg finished shirt requires approximately `0.25 / (1 - 0.31) = 0.362 kg` of gross cotton input under that study's boundary. [S31] Similarly, if a sewing line starts 10,000 shirts and rejects 400 as unrepairable seconds (a 4 percent illustrative defect rate), all energy and material burdens of the 10,000 started units must be carried by the 9,600 accepted garments delivered to the buyer. [S23] [S25]

METHOD

Conservation test for multi-product factory allocation

For reporting period `t` and facility `f` producing `K` product families (`k = 1 ... K`) with accepted outputs `Q_accepted(k,t)`, let `E(f,j,t)` be the total emissions of utility or process stream `j` across Scope 1, Scope 2 and Scope 3 Category 3. [S03] [S04] [S23]

1. **Assign a physical driver `d(j,k,t)` to each stream `j`:** For wet-processing thermal loads, set `d(j,k,t) = M(k,t) * w(k)` (fabric mass times bath-intensity weight); for cutting, sewing and pressing halls, set `d(j,k,t) = Q_started(k,t) * SAM(k)` (total standard allowed minutes worked); for un-metered site HVAC and lighting, allocate by occupied floor-area-hours or total SAM. [S23] [S25]
2. **Compute the allocation share `alpha(j,k,t)`:** Set `alpha(j,k,t) = d(j,k,t) / sum_m d(j,m,t)` so that `sum_k alpha(j,k,t) = 1.000` for every utility stream `j`. [S23] [S25]
3. **Compute allocated gate-to-gate intensity:** Sum `E(k,t) = sum_j alpha(j,k,t) * E(f,j,t)` and divide by accepted first-quality units `Q_accepted(k,t)` to obtain `e_gate(k,t) = E(k,t) / Q_accepted(k,t)`. [S01] [S23]
4. **Enforce additive conservation:** Verify that `sum_k E(k,t) + E_unallocated(t) = sum_j E(f,j,t)`, ensuring 100.0 percent of facility Scope 1, Scope 2 and Scope 3 Category 3 emissions reconcile with zero residual gap. [S04] [S23] [S0202]

2.14

Reconciliation exposes gaps rather than manufacturing precision

Multiplying annual unit sales by each garment's cradle-to-grave product footprint should never blindly equal the unadjusted annual corporate Scope 1, 2 and 3 inventory, because the two accounts obey different rules for corporate overhead, capital

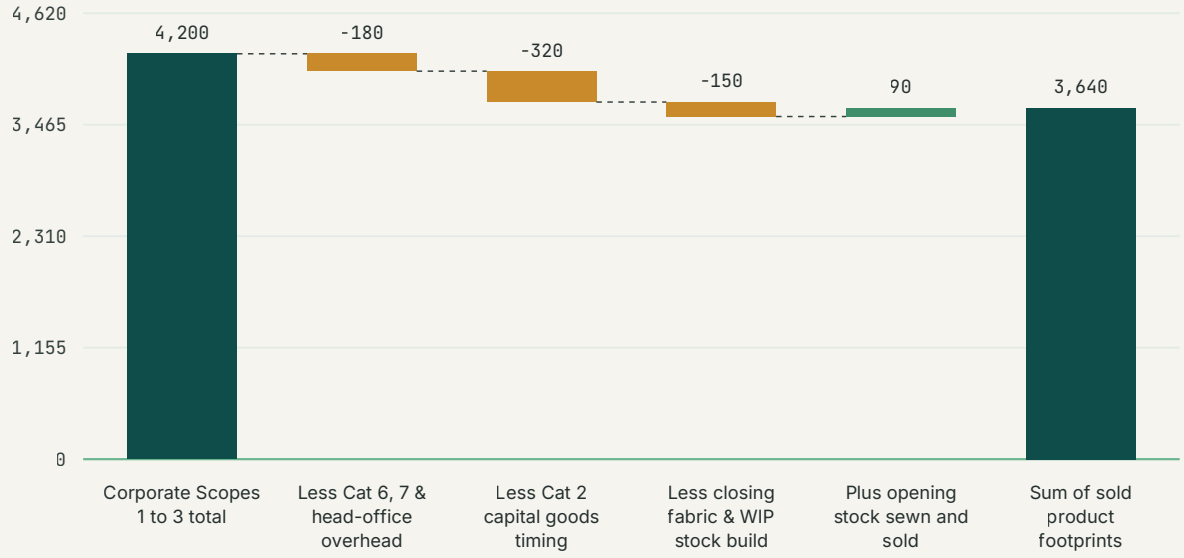
equipment and inventory cutoff dates. [S01] [S02] [S04] [S23] Reconciliation means constructing an auditable bridge across four legitimate accounting buckets: [S01] [S02] [S04] [S23]

1. **Bucket A: Non-product corporate overheads (`Delta_overhead`).** Business travel (Category 6), employee commuting (Category 7), head-office utilities, leased-out assets (Category 13) and minority investments (Category 15) sit in the corporate inventory but are excluded from attributable product footprints under the Product Standard and ISO 14067. [S01] [S02] [S05] [S23]
2. **Bucket B: Capital goods timing (`Delta_capex`).** Corporate Scope 3 Category 2 records 100 percent of newly acquired machinery and building civils in the year of purchase, whereas product footprints either exclude capital goods or amortise them over 10 to 20 years of output (a major distinction during factory expansion or restructuring programmes such as those reported in Cameroon). [R09] [R13] [S01] [S02] [S23]
3. **Bucket C: Inventory and work-in-progress timing shifts (`Delta_stock`).** Corporate Categories 1, 3, 4 and 5 plus Scopes 1 and 2 track materials purchased and energy used during Year `t`, whereas sold-product footprints and Categories 9, 11 and 12 track garments sold in Year `t`. [S01] [S02] [S23] Subtracting year-end closing fabric and WIP stock builds and adding prior-year opening stock sewn and sold in Year `t` reconciles the cutoff exactly. [S04] [S23]
4. **Bucket D: Boundary differences for cradle-to-gate declarations (`Delta_boundary`).** When a manufacturer issues B2B cradle-to-gate footprints under PACT Version 3, downstream distribution, use and end-of-life (Categories 9, 11 and 12) remain outside the product declaration and are bridged as a separate downstream block. [S01] [S10] [S23]

Exhibit 10, p. 43 demonstrates this bridge for an illustrative garment enterprise whose annual corporate inventory totals 4,200 tonnes of CO2e. [S01] [S02] [S04] [S23]

EXHIBIT 10 / TONNES CO2E PER REPORTING YEAR (ILLUSTRATIVE)

An illustrative reconciliation bridge links corporate total to product footprints



ILLUSTRATIVE [S01] [S02] [S04] [S23] Illustrative reconciliation model applying the boundary and timing rules of S01, S02, S04 and S23. Opening corporate total of 4,200 t CO2e reconciles via overhead (-180), unamortised Year-t capital goods (-320), closing stock build (-150) and opening stock draw (+90) to 3,640 t CO2e across sold product footprints (4200 - 180 - 320 - 150 + 90 = 3640).

In **Exhibit 10**, p. 43, the illustrative corporate total of 4,200 tonnes CO2e adjusts by subtracting 180 tonnes of travel and commuting overhead, subtracting 320 tonnes of unamortised Category 2 machinery purchases, subtracting 150 tonnes of year-end closing fabric and WIP stock build, and adding 90 tonnes of opening stock sewn and sold during the year, closing at 3,640 tonnes CO2e (4,200 - 180 - 320 - 150 + 90 = 3,640). [S01] [S02] [S04] [S23] While **Exhibit 10**, p. 43 is an illustrative model rather than a measured Cameroonian baseline, it proves that an explicit bridge prevents product emissions from hiding in corporate overhead and stops supplier emissions from being counted twice. [S04] [S23] [S0202]

WORKED EXAMPLE: RECONCILING A TWO-STYLE GARMENT FACTORY ACROSS CORPORATE SCOPES AND PRODUCT FOOTPRINTS

Consider an illustrative cut, make and trim (CMT) factory operating for one quarter. All figures are illustrative assumptions constructed solely to demonstrate the accounting method, not operating results from a GFT facility. [S01] [S04] [S23]

Step 1: Assumed production and material records (illustrative). Product Line A (cotton workwear shirts) produces and sells 100,000 accepted shirts at 0.30 kg per shirt (30,000 kg accepted output), consuming 36,000 kg of dyed woven fabric issued to cutting (a 16.67 percent illustrative cutting and defect loss share) and 20 standard allowed minutes (SAM) per shirt (2,000,000 SAM total). [S23] [S31] Product Line B (light cotton T-shirts) produces and sells 200,000 accepted T-shirts at 0.20 kg per T-shirt (40,000 kg accepted output), consuming 48,000 kg of dyed knitted jersey (a 16.67 percent illustrative loss share) and 10 SAM per T-shirt (2,000,000 SAM total). [S23] [S31] The factory purchases an illustrative 40,000 kg of woven fabric for Line A during the quarter, issues 36,000 kg to cutting, and holds 4,000 kg in quarter-end closing stock; all 48,000 kg of knitted jersey purchased for Line B is sewn and sold within the quarter. [S04] [S23]

Step 2: Metered factory energy allocation (illustrative). Metered Scope 1 boiler and generator fuel combustion equals 60.0 tonnes CO2e (`EF_direct`), metered Scope 2 location-based grid electricity equals 100.0 tonnes CO2e (`EF_direct`), and Scope 3 Category 3 WTT fuel extraction and grid T&D losses equal 40.0 tonnes CO2e (`EF_wtt`), totaling 200.0 tonnes CO2e (`60.0 + 100.0 + 40.0`). [S03] [S04] [S20] [S23] Allocated by SAM (`2,000,000 / 4,000,000 = 0.500` each), Line A receives 100.0 tonnes CO2e (1.000 kg CO2e per shirt) and Line B receives 100.0 tonnes CO2e (0.500 kg CO2e per T-shirt). [S23] [S25]

Step 3: Value-chain records (illustrative). Line A woven fabric carries a supplier PACT cradle-to-gate factor (`EF_ctg`, ex-works mill gate) of 8.00 kg CO2e/kg: across 40,000 kg purchased, Corporate Category 1 logs 320.0 tonnes CO2e, split into 288.0 tonnes (`36,000 * 8.00`) for Line A production and 32.0 tonnes (`4,000 * 8.00`) in closing stock. [S10] [S23] Line B knitted jersey carries an `EF_ctg` of 7.00 kg CO2e/kg: across 48,000 kg purchased and used, Corporate Category 1 and Line B production both log 336.0 tonnes CO2e. [S10] [S23] Inbound freight (Category 4, via GLEC tonne-km) at an illustrative 0.50 kg CO2e/kg across 88,000 kg delivered logs 44.0 tonnes CO2e in Corporate Category 4, split into 18.0 tonnes for Line A used fabric, 2.0 tonnes for Line A closing stock, and 24.0 tonnes for Line B used fabric. [S18] [S23] Cutting-room offcut waste treatment (Category 5) across 14,000 kg total scrap (6,000 kg Line A; 8,000 kg Line B) at an illustrative 0.25 kg CO2e/kg logs 3.5 tonnes CO2e (1.5 tonnes Line A; 2.0 tonnes Line B). [S02] [S23] Corporate non-product items log 45.0 tonnes CO2e across Category 6 travel (8.0 tonnes), Category 7 commuting (12.0 tonnes) and Category 2 new sewing machines (25.0 tonnes). [S02] [S23] Downstream distribution, laundering and disposal scenarios (Categories 9, 11 and 12) add an illustrative 1.20 kg CO2e per Line A shirt (120.0 tonnes) and 0.80 kg CO2e per Line B T-shirt (160.0 tonnes), totaling 280.0 tonnes CO2e. [S01] [S02] [S23]

Step 4: Reconciled product and corporate totals (illustrative). Line A's cradle-to-gate footprint sums `288.0 + 18.0 + 100.0 + 1.5 = 407.5 tonnes CO2e` (**4.075 kg CO2e per shirt**), and adding 120.0 tonnes of downstream scenarios gives a cradle-to-grave total of `527.5 tonnes CO2e` (**5.275 kg CO2e per shirt**). [S01] [S23] Line B's cradle-to-gate footprint sums `336.0 + 24.0 + 100.0 + 2.0 = 462.0 tonnes CO2e` (**2.310 kg CO2e per T-shirt**), and adding 160.0 tonnes of downstream scenarios gives a cradle-to-grave total of `622.0 tonnes CO2e` (**3.110 kg CO2e per T-shirt**). [S01] [S23] The sold-product portfolio sum is `527.5 + 622.0 = 1,149.5 tonnes`

CO2e. [S01] Meanwhile, the Corporate GHG Inventory sums Scope 1 (60.0 t), Scope 2 (100.0 t) and Scope 3 (656.0 t Cat 1 + 25.0 t Cat 2 + 40.0 t Cat 3 + 44.0 t Cat 4 + 3.5 t Cat 5 + 8.0 t Cat 6 + 12.0 t Cat 7 + 280.0 t Cat 9, 11, 12 = 1,068.5 t), giving **1,228.5 tonnes CO2e**. [S02] [S04] Subtracting Cat 6 and 7 overhead (20.0 t), Cat 2 capital goods (25.0 t), and closing Line A fabric stock (32.0 t Cat 1 + 2.0 t Cat 4 = 34.0 t) from 1,228.5 tonnes yields 1,228.5 - 20.0 - 25.0 - 34.0 = 1,149.5 tonnes CO2e, reconciling both accounts to the kilogram. [S01] [S04] [S23]

2.15 BASE-YEAR RECALCULATION AND AUDIT TRAILS PROTECT THE TIME SERIES

As a manufacturer replaces secondary proxies from ecoinvent or WALDB with verified supplier PACT records and sub-meters, apparent emissions can shift purely because measurement accuracy improved. [S10] [S16] [S17] [S23] Both the GHG Protocol standards and the US EPA Inventory Management Plan guidance require a formal base-year recalculation policy triggered when three conditions cross a declared significance threshold: (1) structural changes such as mergers, acquisitions or insourcing/outsourcing of spinning and dyeing; (2) methodology changes or data-tier upgrades from secondary proxies to primary data; and (3) discovery of significant errors. [R08] [S04] [S23] [S0201] [S0202] Conversely, the base year is never recalculated for organic production growth or contraction (such as global fibre output rising from 125 million tonnes in 2023 to 132 million tonnes in 2024) or genuine operational abatement. [S04] [S07] [S08] [S13] [S23]

> **WARNING**
>
> **Never confuse a factor update or data-tier upgrade with operational abatement**
>
> When annual factor releases (such as IEA Emissions Factors 2026 or UK DESNZ 2026 conversion factors) revise a grid factor, or when a supplier switches from a background proxy to a primary PACT record, the accounting engine must log the difference in a **method-and-factor variance column** rather than crediting it to engineering abatement. [S10] [S14] [S20] [S23] Without base-year restatement, comparing Year t primary data against Year 0 proxy data cannot support a reduction claim under ISO 14067 or EU Directive 2024/825. [S05] [S23] [S32]

> **GFT NOTE**
>
> In GFT's Cameroon textile programme, the carbon chart of accounts connects directly to the six KPI families of the performance-management system design (production, quality, delivery, cost, people and sustainability) under an Inventory Management Plan control checklist. [S0202] Every factor and allocation rule carries a version hash (factor_set_id, allocation_rule_version). When primary supplier data or new sub-meters arrive, the digital layer executes a dual calculation using both the prior factor version and the upgraded version, isolating real physical abatement from accounting restatement before any board report or buyer product record is issued. [S13] [S20] [S23] [S0202]

With the organisational boundary fixed, Scope 2 split cleanly from upstream energy losses, all 15 Scope 3 categories mapped to physical bills of materials, factor families locked against boundary collisions, and corporate totals reconciled to product portfo-

lios through an auditable bridge, the accounting architecture is complete. [S01] [S02] [S03] [S04] [S23] The next analytical decision is to define the exact denominator beneath each product's reconciled numerator: whether the footprint is expressed per kilogram of textile, per finished garment at the factory gate, or per consumer wear across a verified service life. [S24] [S26] [S31]

One activity ledger, governed by one chart of accounts, ensures that every gram of carbon enters the corporate inventory and the garment footprint without being counted twice or lost between boundaries.

CHAPTER SOURCE NOTES

S01 GHG Protocol. 2011.

S04 GHG Protocol. 2004.

S20 UK Department for Energy Security and Net Zero. 2026-06-11.

S02 GHG Protocol. 2011.

S05 International Organization for Standardization. 2018-08.

S24 International Organization for Standardization. 2006-07.

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S0201 United States Environmental Protection Agency. 2026-02-10.

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

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

R03 SODECOTON. 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.

S0203 United States Environmental Protection Agency. 2026-04-02.

S11 Intergovernmental Panel on Climate Change. 2021-08-06.

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S03 GHG Protocol. 2015.

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S09 International Energy Agency. 2026.

S28 World Bank. 2025-01-16.

S16 ecoinvent. 2025-11-05.

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S26 Watson and Wiedemann, Sustainability. 2019-07-15.

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GREEN FUTURE TECH

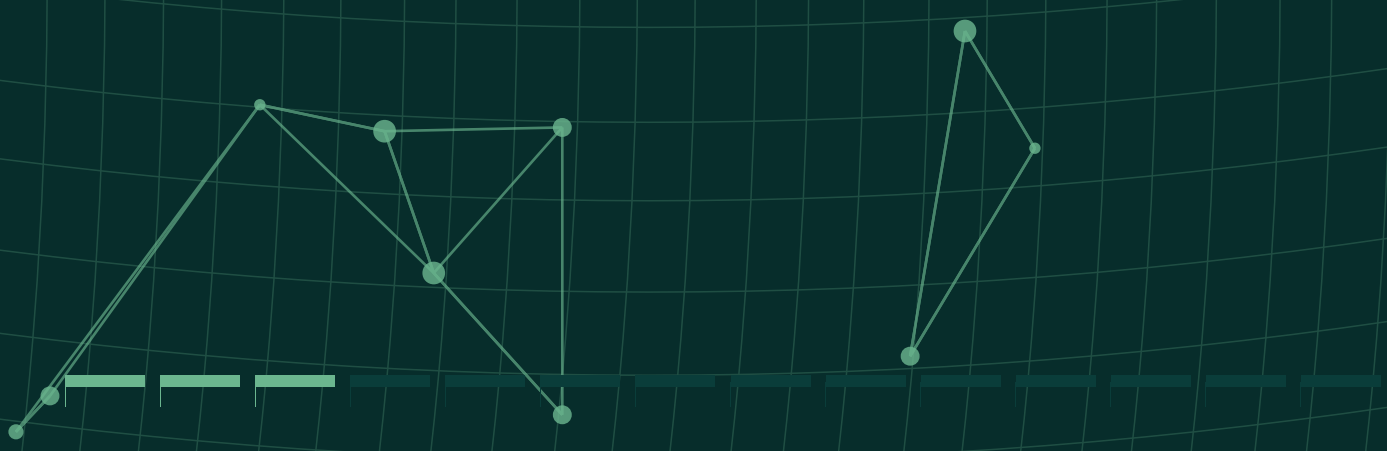
LIMITED / HONG KONG SAR

03

PART I: BUILD THE ACCOUNT BEFORE THE CLAIM / GOAL AND SCOPE

The functional unit decides what the footprint means

The same inventory can support a sourcing decision or mislead the public, depending on the function and boundary chosen.



CHAPTER 03
DECISION TEST

The same inventory can support a sourcing decision or mislead the public, depending on the function and boundary chosen.

A product carbon footprint has no independent meaning until its functional unit and system boundary are fixed to match the decision at hand. [S01] [S24] The same set of metered factory utilities, agricultural inputs and transport records can support a valid procurement comparison, distort a fibre substitution choice or mislead a retail buyer if the denominator shifts without disclosure. [S22] [S26] In apparel accounting, three product-level units and one organisational denominator appear repeatedly: a kilogram of processed fibre or fabric for mill engineering, a finished garment at the factory gate for business-to-business exchange, a single wear event across a defined service life for consumer and design comparisons, and annual corporate output for site intensity tracking. [S23] [S26] [S31] [S0301] Treating these four denominators as interchangeable is a primary source of false rankings in textile sustainability work. [S26] [S31] When a cotton shirt and a cellulosic or synthetic shirt are compared per kilogram of fabric, the result reflects process intensity per unit of mass; when they are compared at equivalent mechanical tenacity or per wear across a verified service life, required garment mass and downstream care change the calculation and can reverse the apparent ordering of materials. [S26] [S31] [S0302] Green Future Tech Limited (GFT) therefore establishes a strict scoping rule for its Cameroon textile programme: every footprint calculation must lock its intended application, functional unit, system boundary and allocation rule before activity data are aggregated, and no partial factory-gate metric may be published as a complete garment claim. [S01] [S06] [S24]

3.1

The study goal determines the system boundary

An inventory of greenhouse gas flows does not organise itself; the engineering question being asked dictates which unit processes enter the system boundary, which reference flow normalises the inputs and which downstream assumptions are permissible. [S01] [S24] In ISO 14040:2006, the intended application of a life cycle assessment (LCA) or life cycle inventory (LCI) study is defined during the initial goal and scope phase rather than appended after calculations are complete. [S24] A mill manager in northern Cameroon evaluating whether to upgrade a boiler or reduce yarn waste needs a process boundary centred on spinning, knitting or wet processing per kilogram of accepted output. [R03] [S23] [S31] A brand buyer comparing two cut, make and trim suppliers needs a cradle-to-gate product record anchored to a specified garment style, mass and bill of materials. [S10] [S23] A regulator or consumer evaluating a public marketing claim needs a full cradle-to-grave account that includes distribution, consumer laundering, service life and end-of-life treatment. [S06] [S32] [S0301] When an organisation uses a boundary designed for one goal to answer a different question, the arithmetic may remain internally consistent while the conclusion becomes invalid. [S22] [S24]

3.2 INTENDED APPLICATION GOVERNS WHAT A CARBON NUMBER MAY CLAIM

Goal definition in ISO 14040 requires the practitioner to state the reasons for carrying out the study, the intended audience and whether the results will be used in comparative assertions disclosed to the public. [S24] Each declaration alters the technical specification of the model. [S24] [S25] An internal screening model built to rank emissions hotspots inside a single factory can rely on secondary background data-

bases such as ecoinvent for non-core inputs, provided those proxies are logged for later replacement. [S16] [S23] By contrast, a study intended to support a public claim that one garment has a lower carbon footprint than a competing garment triggers strict requirements under ISO 14044:2006, the GHG Protocol Product Standard and European Union consumer law, including equivalent boundaries, validated functional performance, uncertainty analysis and critical review. [S01] [S25] [S32]

For Cameroon's cotton-to-garment value chain, separating internal engineering baselines from external comparative claims prevents premature disclosure. [R06] [S24] Sector evidence indicates that approximately 95 percent of Cameroonian cotton fibre is exported raw while about 5 percent is processed locally, against a national industrialisation target of 50 percent local processing by 2030. [R06] [R07] New industrial projects, such as the announced Camtext SA integrated venture targeting 12,000 tonnes a year of processed cotton, alongside restructuring plans for existing domestic mills, aim to build local spinning, weaving, dyeing and garment assembly capacity. [R08] [R09] [R10] During construction and ramp-up, the primary purpose of carbon accounting is operational control: establishing metered baselines for electricity, thermal energy, material yield and chemical consumption as lines enter service. [S20] [S23] Rushing to publish a headline footprint per garment from generic global averages before site meters and product specifications are stable serves neither factory engineering nor credible market positioning. [S16] [S22] [S23]

3.3 INVENTORY COUNTS AND IMPACT ASSESSMENTS SERVE DISTINCT ENGINEERING ROLES

Standards also draw a firm boundary between a life cycle inventory, a single-issue carbon footprint and a multi-indicator life cycle assessment. [S05] [S25] ISO 14044:2006 covers both LCA studies and LCI studies, recognising that an inventory of physical flows (kilograms of nitrogen fertiliser, kilowatt-hours of electricity, cubic metres of water and kilograms of solid waste) is a technical dataset that precedes impact characterisation. [S25] ISO 14067:2018 specifies requirements and guidelines for quantifying and reporting the carbon footprint of a product, while explicitly stating that the standard addresses only a single impact category: climate change. [S05]

This distinction carries major operational consequences in textile production, where trade-offs between climate change, water scarcity, ecotoxicity and plastic persistence are structural. [S31] [S0302] In the April 2026 comparative T-shirt LCA by Forfora et al., which evaluated viscose, Lyocell, cotton and polyester T-shirts across spinning, knitting, wet processing and assembly under consistent boundaries, cotton T-shirts produced in the China baseline scenario exhibited the lowest global warming potential at 14.1 kg CO2eq per kilogram of shirt, but recorded the highest water demand at 2.9 cubic metres per kilogram. [S31] [S0302] In the same study, polyester garments required less water but contributed 1.0 kg of persistent plastic accumulation per kilogram of shirt compared with 0.1 kg per kilogram for cellulose-based fibres. [S0302] Within man-made cellulosic fibres, closed-loop solvent recovery enabled Lyocell to reduce freshwater ecotoxicity by 35 percent and human non-carcinogenic toxicity by 62 percent relative to viscose, yet Lyocell registered the highest carbon footprint at 21.6 kg CO2eq per kilogram unless manufactured in regions with cleaner energy mixes. [S31] [S0302]

Because ISO 14067 isolates climate change, a low product carbon footprint can never be presented as proof of low overall environmental impact. [S05] [S0301] The European Union Product Environmental Footprint Category Rules (PEFCR) for Apparel and Footwear reinforce this rule by prohibiting brands from communicating a single aggregated score to consumers and requiring disclosure across at least four specific impact categories, including climate change and water use. [S06] [S0301] In GFT's performance-management design, the carbon account sits alongside water intake per unit, effluent quality, chemical consumption and solid waste generation as one governed metric within a broader operational record. [S05] [S25]

3.4

A kilogram, a garment and a wear are not interchangeable

Once the study goal and impact scope are declared, the practitioner must define the functional unit: the quantified performance of a product system for use as a reference unit. [S01] [S24] A review of methodological choices in LCA-based textile and apparel rating tools by Watson and Wiedemann demonstrates that clothing assessments routinely confuse reference flows of raw material mass with functional units of garment service. [S26] Comparing one kilogram of scoured cotton yarn with one kilogram of polyester filament measures an intermediate industrial output, not the function experienced by a wearer. [S26] [S31] Conversely, dividing a company's annual Scope 1, Scope 2 and Scope 3 emissions by the total number of garments shipped in a year creates an organisational intensity ratio across a shifting product mix, which cannot represent the physical footprint of any individual garment. [S04] [S23]

3.5 THREE PRODUCT UNITS AND ONE CORPORATE DENOMINATOR ANSWER FOUR SEPARATE QUESTIONS

To prevent denominator drift across engineering, commercial and board reporting, **Exhibit 11**, p. 52 sets out the three product functional units used in textile life cycle work alongside the corporate output denominator used in organisational intensity reporting. [S23] [S26] [S31] [S0301]

EXHIBIT 11 / ACCOUNTING BASIS AND DECISION SCOPE

Product functional units and corporate denominators answer different decisions

Denominator	Accounting level	Typical boundary	Primary decision supported	Principal misuse risk
1 kg processed fibre or fabric	Product intermediate	Cradle-to-mill gate	Process efficiency and mill energy benchmarking	Ignores yarn tenacity, fabric areal density and garment longevity
1 finished garment of defined spec	Product unit	Cradle-to-factory gate or grave	Buyer procurement, bill-of-materials design and line yield	Treats unequal garment lifespans and care regimes as equal
1 wear or use event of a garment	Product service	Full cradle-to-grave life cycle	Consumer comparison, circular design and durability valuation	Can mask high production emissions behind unverified wear counts
Annual accepted corporate output	Organisational intensity	Corporate Scopes 1, 2 and 3 over 12 months	Site performance tracking and corporate target monitoring	Blends product mix shifts with real process abatement

SOURCED [S23] [S26] [S31] [S0301] Comparison of three product-level functional units and one organisational intensity denominator compiled from GHG Protocol Scope 3 guidance (S23), textile LCA methodology review (S26), comparative T-shirt LCA scenarios (S31) and EU Apparel PEFCR overview (S0301).

As **Exhibit 11**, p. 52 establishes, each denominator is valid within its own domain and misleading outside it. [S23] [S26] First, one kilogram of processed fibre, yarn or fabric is the natural denominator for ginning, spinning, knitting, weaving and wet processing, where machine energy scales with substrate mass and moisture. [S26] [S31] However, one kilogram of fabric cannot establish which fibre produces a lower-carbon garment, because different fibres possess different mechanical strengths and densities, and are knitted or woven to different areal weights to achieve equivalent performance. [S26] [S31]

Second, one finished garment of a specified style, size and technical specification is the commercial unit of exchange between a garment factory and an apparel buyer. [S10] [S23] Moving from a kilogram of fabric to a finished garment introduces cutting efficiency, marker fallout, sewing loss, trims, packaging and first-pass quality yield. [S23] [S31] Yet a per-garment denominator at the factory gate still stops short of consumer service if two shirts require different washing temperatures, drying energy or replacement frequencies during use. [S12] [S26] [S30]

Third, one wear (or one defined use cycle, including the associated fraction of laundering and repair) represents the functional service of clothing. [S26] [S0301] Under the EU Apparel and Footwear PEFCR published in 2025, the functional unit is defined as one use of the garment, accounting for typical lifespan and number of washes based on product type. [S06] [S0301] This service-based denominator connects physical quality directly to environmental accounting, but requires standardised or empirically verified use-phase and durability parameters. [S26] [S0301]

Fourth, annual accepted corporate output serves as the physical denominator for an organisational intensity metric under the GHG Protocol Corporate Standard and Scope 3 guidance. [S04] [S23] Dividing monthly factory emissions by accepted pieces provides a useful shift management indicator when product mix is controlled, but cannot substitute for a product LCA because shifting the order book from lightweight shirts to heavy trousers raises emissions per piece even when machines run more efficiently. [S04] [S23]

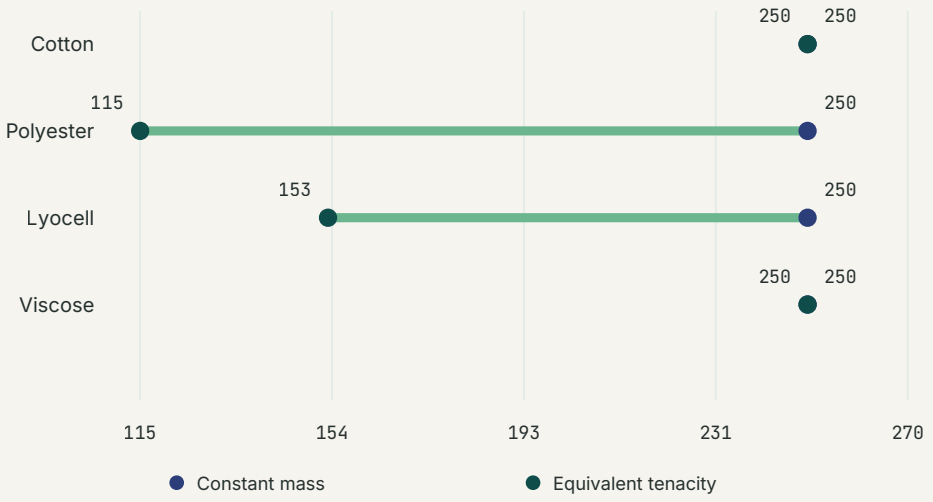
3.6 EQUIVALENT MECHANICAL TENACITY ALTERS GARMENT MASS AND MATERIAL RANKINGS

Moving from a mass-based reference flow to a function-based garment specification can cut the required material mass of high-tenacity fibres by more than half and invert comparative carbon rankings. [S31] Most published textile LCAs assume a constant garment mass across all fibres, such as a 250-gram T-shirt, implicitly treating one gram of weak fibre and one gram of strong fibre as functionally equal. [S26] [S31]

To test how mechanical performance alters the functional unit, Forfora et al. (2026) evaluated an equivalent-strength scenario alongside their baseline constant-mass scenario. [S31] Using tensile strength and tenacity relationships for each fibre and yarn system, they calculated the garment mass required for each T-shirt to withstand the same mechanical force as a 250-gram cotton reference shirt. [S31] **Exhibit 12**, p. 53 displays the resulting shift in required garment mass across the four fibres. [S31]

EXHIBIT 12 / GRAMS PER T-SHIRT

Equivalent tenacity changes the mass required for a garment



SOURCED [S31] Sourced from Forfora et al. (2026) comparative T-shirt life cycle assessment (S31). The baseline constant-mass scenario assigns 250 g per T-shirt to all four fibres; the equivalent-strength scenario adjusts garment mass for mechanical tenacity to 250 g for cotton, 115 g for polyester, 153 g for Lyocell and 250 g for viscose.

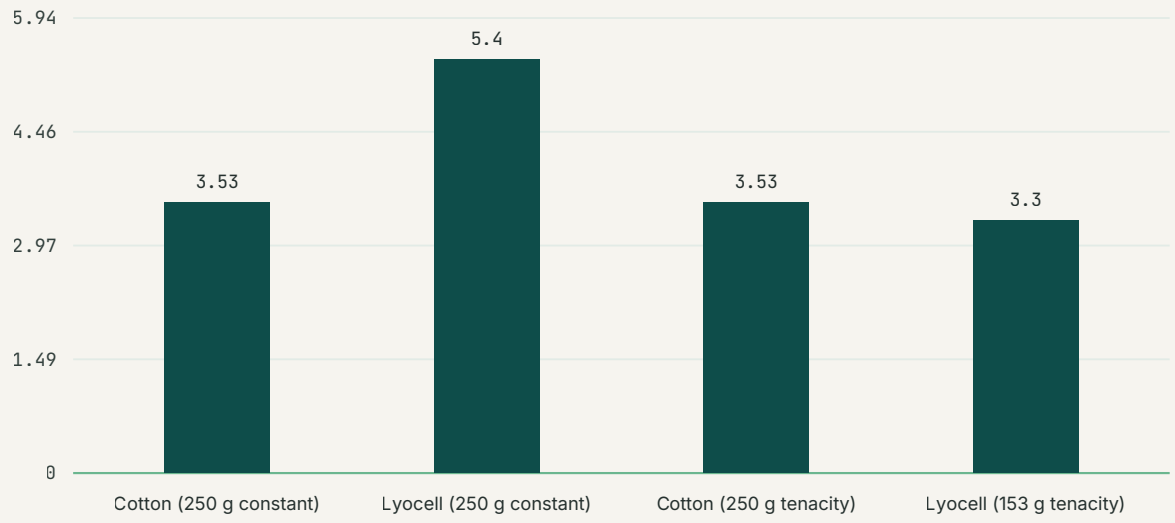
As **Exhibit 12**, p. 53 illustrates, holding mechanical strength constant leaves cotton and viscose at 250 grams per T-shirt, reduces Lyocell from 250 grams to 153 grams (a 38.8 percent reduction in required garment mass, derived as 97 grams divided by 250 grams), and reduces polyester from 250 grams to 115 grams (a 54.0 percent reduction in required garment mass, derived as 135 grams divided by 250 grams). [S31] While **Exhibit 12**, p. 53 establishes the physical mass sensitivity to tenacity

under the authors' mechanical equivalence model, it cannot prove that buyers will always specify a 115-gram polyester shirt or a 153-gram Lyocell shirt in place of a 250-gram cotton jersey, because opacity, hand and thermal comfort also govern commercial garment weight. [S26] [S31]

Nevertheless, when mechanical strength is the governing functional requirement, scaling the per-kilogram inventory by the tenacity-adjusted garment mass reverses the carbon ranking between cotton and Lyocell in the study's baseline production geography. [S31] [S0302] **Exhibit 13**, p. 54 demonstrates this derived arithmetic using the published China baseline cradle-to-gate carbon intensities for cotton (14.1 kg CO2eq per kilogram) and Lyocell (21.6 kg CO2eq per kilogram). [S31] [S0302]

EXHIBIT 13 / KG CO2E PER T-SHIRT (CRADLE-TO-GATE)

Switching from constant mass to equivalent tenacity reverses the cotton and Lyocell ranking



DERIVED [S31] [S0302] Derived by GFT from Forfora et al. (2026) China baseline global warming potentials of 14.1 kg CO2eq/kg for cotton (S0302) and 21.6 kg CO2eq/kg for Lyocell (S31, S0302), multiplied by the constant-mass (0.250 kg) and equivalent-tenacity (0.250 kg cotton, 0.153 kg Lyocell) garment masses reported in S31. Values rounded to two decimal places.

The arithmetic behind **Exhibit 13**, p. 54 shows why functional equivalence can matter more than small differences in background emission factors. [S31] [S0302] Under a constant 250-gram mass basis, a Lyocell T-shirt carries 5.40 kg CO2e against 3.53 kg CO2e for cotton, making Lyocell appear 53.2 percent more carbon-intensive per shirt. [S31] [S0302] Under the equivalent-tenacity functional unit, the 153-gram Lyocell shirt carries 3.30 kg CO2e against 3.53 kg CO2e for the 250-gram cotton shirt, making Lyocell 6.3 percent lower in carbon per garment before accounting for regional renewable energy options. [S31] [S0302] What **Exhibit 13**, p. 54 cannot establish is a universal preference for Lyocell over cotton, because the study's Monte Carlo uncertainty distributions overlap and the result depends on both regional energy mixes and whether a lighter fabric satisfies the garment's optical and tactile brief. [S26] [S31]

WORKED EXAMPLE

To see how functional-unit definitions alter procurement and design arithmetic, consider two comparative definitions compiled from the published parameters in Forfora et al. (2026). [S31] [S0302]

1. **Inputs from cited sources:** In the China baseline scenario, cradle-to-gate global warming potential is `14.1 kg CO2e/kg` for cotton and `21.6 kg CO2e/kg` for Lyocell. [S31] [S0302] The constant-mass reference assigns `0.250 kg` to both shirts, whereas the equivalent-tenacity scenario assigns `0.250 kg` to cotton and `0.153 kg` to Lyocell. [S31]
2. **Constant-mass garment calculation:** Multiplying intensity by constant mass gives `14.1 * 0.250 = 3.525 kg CO2e` (rounded to `3.53 kg CO2e`) for cotton and `21.6 * 0.250 = 5.400 kg CO2e` for Lyocell, a difference of `+1.875 kg CO2e` per shirt. [S31] [S0302]
3. **Equivalent-tenacity garment calculation:** Multiplying intensity by tenacity-adjusted mass leaves cotton at `3.525 kg CO2e` while reducing Lyocell to `21.6 * 0.153 = 3.3048 kg CO2e` (rounded to `3.30 kg CO2e`), a net difference of `-0.2202 kg CO2e` per shirt in favour of Lyocell. [S31] [S0302]
4. **Illustrative service-life extension:** Suppose an illustrative durability test shows the higher-tenacity garment achieves 60 wears before failure against 45 wears for the baseline garment (an illustrative assumption used solely to demonstrate the per-wear division). On an illustrative cradle-to-gate basis per wear, the 250-gram cotton shirt at 45 wears equals `3.525 / 45 = 0.0783 kg CO2e` per wear (`78.3 g CO2e`), whereas the 153-gram Lyocell shirt at 60 wears equals `3.3048 / 60 = 0.0551 kg CO2e` per wear (`55.1 g CO2e`), a derived illustrative difference of 29.7 percent per wear before adding laundering. This calculation demonstrates the mechanism of denominator selection; it is not a forecast or a measured GFT factory result. [S26] [S31]

3.7

Cradle-to-gate suits exchange but not every public claim

A functional unit cannot be interpreted without its accompanying system boundary. [S01] [S24] Across apparel supply chains, two system boundaries perform distinct roles: cradle-to-gate (covering raw material extraction and processing up to the point where an intermediate textile or finished garment leaves the supplier's facility) and cradle-to-grave (covering the full product life cycle from extraction through manufacturing, logistics, storage, consumer use and final disposal or recovery). [S01] [S23] Confusing a cradle-to-gate supplier certificate with a complete product footprint omits downstream stages that can account for 14 to 24 percent or more of total lifecycle emissions, depending on garment type and care regime. [S12] [S23] [S30]

3.8 SUPPLIER RECORDS PROVIDE MODULAR INPUTS FOR PURCHASED GOODS

For an upstream spinner, weaver, dyer or cut, make and trim manufacturer, a cradle-to-gate boundary is the only boundary over which the operator exercises direct measurement and operational control. [S10] [S23] Under the GHG Protocol Technical Guidance for Calculating Scope 3 Emissions and the WBCSD PACT Methodology Version 3, supplier-specific product carbon footprints are exchanged as cradle-to-gate

modules. [S10] [S23] When a garment factory in Cameroon purchases dyed fabric or sewing thread, or when an international brand purchases finished garments from that factory, the buyer requires the cradle-to-gate emissions per unit of purchased product to populate Scope 3 Category 1 (Purchased goods and services) without double counting downstream transport or consumer use that the buyer models separately. [S02] [S10] [S23]

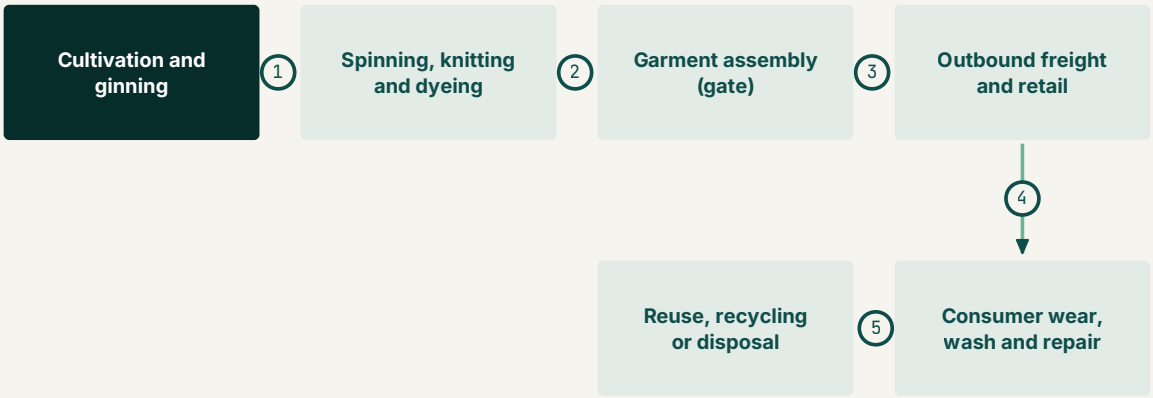
A modular cradle-to-gate boundary also protects data integrity. [S10] [S23] A spinning and weaving mill can meter its kilowatt-hours of electricity, litres of boiler fuel, kilograms of starch and dyes, bale weights of ginned lint and kilograms of yarn and fabric waste. [S20] [S23] It has no empirical visibility into whether the eventual retail customer washes the resulting shirt at 30 degrees Celsius or 60 degrees Celsius, dries it on an outdoor line in Douala or in an electric tumble dryer in Frankfurt, or discards it after 20 wears or 100 wears. [S12] [S23] [S30] Requiring an upstream supplier to embed speculative downstream consumer scenarios inside its business-to-business footprint would contaminate verified operational data with unverified scenario assumptions. [S10] [S23]

3.9 FULL LIFE CYCLE RULES REQUIRE DOWNSTREAM MODULES BEFORE PUBLIC COMPARISON

While cradle-to-gate footprints are right for business-to-business data exchange, they are insufficient for unqualified public claims about a finished garment's environmental impact. [S01] [S06] [S32] Both the GHG Protocol Product Standard and the EU Apparel and Footwear PEFCR define product life cycle accounting across the entire chain from raw material extraction, manufacturing and logistics to consumer use and end-of-life. [S01] [S06] [S0301] **Exhibit 14**, p. 57 illustrates how a supplier's cradle-to-gate handover record must be linked to downstream distribution, consumer care and end-of-life modules before a full cradle-to-grave garment footprint exists. [S01] [S06] [S23] [S0301]

EXHIBIT 14 / LIFE CYCLE BOUNDARY STAGES

Cradle-to-grave closes the gaps left by a supplier footprint



1. Lint and co-product rule
2. Fabric cradle-to-gate PCF
3. Garment gate handover
4. Sold product scenario
5. End of service life

SOURCED [S01] [S06] [S23] [S0301] Process and boundary architecture linking an upstream cradle-to-gate supplier record to the downstream distribution, use and end-of-life stages required for full life cycle assessment under GHG Protocol (S01, S23) and EU Apparel PEFCR rules (S06, S0301).

As **Exhibit 14**, p. 57 makes visible, the factory gate (cmt) is a handover node, not the end of the product system. [S01] [S23] Up to the garment gate, the inventory can progressively replace secondary proxies with primary metered activity data from the farm, gin, mill and sewing floor. [S10] [S23] Beyond the garment gate, the footprint relies on distribution logistics records and standardised or empirical scenarios for consumer care (care) and end-of-life (eol). [S06] [S23] [S0301] While **Exhibit 14**, p. 57 defines the structural linkage between upstream and downstream modules, it does not fix the percentage share of emissions in each module, because those shares shift with garment care labels, climate zones and domestic appliance mixes. [S12] [S30]

When an organisation publishes a partial footprint (such as a cradle-to-gate figure for a cotton T-shirt), standards require that the boundary restriction be named explicitly in the headline description and methodology note, and never implied to represent the complete life cycle. [S01] [S05] [S32] Omitting the use phase silently can bias comparisons between fibres requiring different laundering regimes, such as garments requiring hot washing and ironing versus garments washed cold and line-dried. [S12] [S26]

GFT NOTE

In GFT's Cameroon textile programme, every product carbon record is structured as a two-part object: a **Verified Cradle-to-Gate Operational Module** owned by the manufacturing facility, and an optional **Downstream Scenario Module** (covering outbound distribution, consumer care and end-of-life) attached only when a full cradle-to-grave view is required. [S01] [S10] [S23] In business-to-business procurement tenders, GFT recommends reporting only the cradle-to-gate module alongside physical garment specifications (areal density in grams per square metre, garment mass in grams and yarn tenacity) so buyers can integrate the record directly into their Scope 3 Category 1 models without scenario contamination. [S10] [S23] [S31]

3.10

Durability turns product mass into a service

If the purpose of clothing is to provide wearable service over time, then the physical durability and functional longevity of a garment directly govern its environmental footprint per unit of service. [S26] [S30] [S0301] A garment that loses dimensional stability, pills severely, tears at the seams or fades after ten wash cycles forces an early replacement purchase, multiplying the agricultural, spinning, dyeing and assembly burdens required to clothe a person over a year. [S30] [S0301] Conversely, extending the active service life of a garment distributes its embodied production carbon across a larger denominator of wears and, when it displaces the purchase of a new replacement garment, reduces absolute production emissions. [S12] [S27] [S30]

3.11 SERVICE LIFE DIVIDES EMBODIED PRODUCTION ACROSS DELIVERED WEARS

Sector-wide assessments show both why production dominates total textile emissions and why the use phase and service duration remain decisive levers. [S12] [S30] In a European consumption model published by the European Environment Agency (2022), approximately 80 percent of the total climate change impact of textiles consumed in Europe occurs in the production phase, 3 percent in distribution and retail, 14 percent in the use phase (washing, drying and ironing) and 3 percent at end-of-life. [S30] In another sector life cycle assessment carried out on behalf of the United Nations Environment Programme with a 2016 baseline year, the use phase was estimated to account for 24 percent of the fashion sector's greenhouse gas emissions. [S12] The difference between a 14 percent use-phase share and a 24 percent use-phase share reflects differing geographic assumptions about household electricity grids, washing temperatures, tumble-dryer penetration and average wears per garment lifecycle. [S12] [S26] [S30]

When the functional unit is defined as one wear of a garment over W total wears during its useful life, the cradle-to-grave carbon footprint per wear is the sum of two terms: the embodied production, distribution and end-of-life emissions divided by W, plus the per-wear care and maintenance emissions multiplied by the washing frequency per wear. [S26] [S30] [S0301] Because embodied emissions are divided by W while per-wear care emissions remain roughly constant under a steady care regime, doubling the number of wears from W to $2W$ cuts the embodied production burden per wear in half. [S12] [S26] [S30]

However, two strict conditions govern whether a lower footprint per wear translates into a real reduction in atmospheric greenhouse gases. [S26] [S27] [S30] First, the additional wears must represent real utilisation that displaces the production and purchase of a new garment, rather than an idle garment hanging unused in a wardrobe. [S27] [S30] Second, the heavier or more durable construction used to achieve longer life must not add more embodied carbon at the factory gate than it saves through avoided replacement over the actual period of consumer use. [S26] [S30]

3.12 INTRINSIC QUALITY TESTS MUST PRECEDE ANY LONGEVITY ADJUSTMENT

Because dividing a garment's footprint by a larger number of wears immediately lowers its reported impact per use, durability multipliers are an obvious target for manipulation if left unverified. [S26] [S32] A manufacturer or brand cannot simply assume that its T-shirt will be worn 90 times while a competitor's T-shirt is worn 45 times without empirical physical testing and standardised category rules. [S26] [S32] [S0301]

In their review of textile and apparel LCA rating tools, Watson and Wiedemann highlighted that early rating tools either ignored garment service life completely or lacked standardised physical testing protocols to link fabric construction to expected lifespan. [S26] The 2025 EU Apparel and Footwear PEFCR addresses this vulnerability by requiring garments to be assessed for intrinsic durability (including standardised laboratory tests for material strength, colour fastness, dimensional stability and pilling resistance) as well as repairability factors (spare parts availability, serviceability and repair cost ratio) before any adjustment to the reference number of uses is permitted. [S06] [S0301]

Furthermore, Directive (EU) 2024/825 on consumer protection for the green transition regulates sustainability and durability claims under European consumer law, requiring that environmental claims be substantiated by actual lifecycle evidence and prohibiting unverified assertions about a product's longevity or environmental superiority. [S32] In GFT's performance-management architecture, laboratory quality metrics (fabric weight, shrinkage, colour fastness, seam strength and defect detection rates) are not merely commercial acceptance checks; they are the primary physical evidence required to defend the denominator of a per-wear product carbon footprint. [R29] [S26] [S0301]

METHOD

Protocol for selecting and locking the functional unit in GFT product studies

1. **Declare the decision context and audience:** State whether the calculation supports (a) internal mill or sewing-line process engineering, (b) business-to-business intermediate or finished-garment supply, or (c) cradle-to-grave product design and public communication. [S01] [S24]
2. **Select the matching reference flow and functional unit:**
3. Use **1 kg of conditioned textile output** at a defined moisture regain for ginning, spinning, knitting, weaving and wet processing comparisons. [S26] [S31]
4. Use **1 finished, accepted garment** of a documented style, size, areal density (g/m2) and total mass (g) for factory-gate handovers. [S10] [S23] [S31]
5. Use **1 garment wear (use cycle)** with explicitly stated lifetime wears (W), wash interval, wash temperature, drying method and displacement assumption for full life cycle comparisons. [S06] [S26] [S0301]
6. **Check functional equivalence across compared alternatives:** When comparing garments made from different fibres or constructions, verify whether constant mass or equivalent mechanical performance (tensile strength, tear resistance, burst strength, opacity) governs the garment specification, and run sensitivity cases on both bases. [S26] [S31]
7. **Verify durability evidence before varying wears:** Hold the reference wear count (W) equal across compared garments unless laboratory physical test results under a recognised product category rule (such as the EU Apparel PEFCR intrinsic durability protocol) justify a differentiated service life. [S26] [S32] [S0301]

3.13

Co-products and counterfactuals belong in the scope

Fixing the functional unit and the downstream boundary still leaves a major structural choice inside the upstream boundary: how to partition burdens when a single production process yields more than one valuable output, and whether the study describes an average physical share of existing burdens (attributional accounting) or the system-wide effect of a change in demand (consequential modelling). [S01] [S25] [S26] In cotton and cellulosic apparel chains, co-product allocation and counterfactual assumptions can alter the calculated footprint per kilogram of fibre by tens of percent before a single bale reaches the spinning mill. [S26] [S31]

3.14 MULTI-OUTPUT GINNING AND PROCESSING REQUIRE EXPLICIT PARTITIONING RULES

Consider the first industrial stage of the cotton value chain: ginning seed cotton. [R03] [S26] In northern Cameroon, SODECOTON supports more than 220,000 cotton producers and operates nine ginning plants alongside two cottonseed oil mills. [R03] When seed cotton enters a gin, it does not produce cotton lint alone; it separates the harvest into cotton lint (destined for spinning into yarn), cottonseed (destined for crushing into edible cottonseed oil, livestock meal and hulls) and gin trash or linters.

[R03] [S26] Across cultivation and ginning, all agricultural inputs (synthetic nitrogen fertiliser, pesticides, tractor fuel, field nitrous oxide emissions and gin electricity) jointly produce both the lint and the seed. [S26] [S29]

ISO 14044:2006 and the GHG Protocol Product Standard establish a hierarchy for handling multi-functional processes: first, avoid allocation where possible by dividing the unit process into sub-processes or expanding the product system; second, where allocation cannot be avoided, partition the inputs and outputs between the products in a way that reflects the underlying physical relationships between them; third, where physical relationships alone cannot be established or used, allocate inputs and outputs in proportion to the economic value of the products. [S01] [S25]

In cotton accounting, the choice between mass allocation and economic allocation is decisive. [S26] By physical mass, cottonseed outweighs cotton lint in harvested seed cotton, whereas by market value, cotton lint commands a higher price per kilogram than cottonseed and generates the majority of crop revenue. [S26] Consequently, allocating cultivation and ginning emissions by physical mass shifts the majority of farm fertiliser and soil nitrous oxide burdens onto cottonseed oil and livestock meal, making cotton lint appear artificially low in carbon, whereas economic allocation assigns the dominant share of farm emissions to cotton lint. [S26] [S31]

The same partitioning challenge recurs in downstream processing and across competing fibres. [S26] [S31] Combing cotton yarn removes short fibres (comber noils) sold as a co-product into nonwovens or open-end spinning; forest pulping for viscose and Lyocell co-produces tall oil, turpentine, lignosulphonates and bio-energy alongside dissolving wood pulp; petrochemical refining co-produces paraxylene and monoethylene glycol alongside fuel and chemical fractions. [S26] [S31] In the 2026 comparative T-shirt LCA by Forfora et al., the authors tested sensitivity to economic partitioning alongside mass-based and tenacity-based functional units, confirming that allocation rules and co-product pricing must be declared alongside every published footprint. [S31]

3.15 ATTRIBUTIONAL ACCOUNTING AND CONSEQUENTIAL DISPLACEMENT CANNOT BE BLENDED SILENTLY

Beyond partitioning between co-products, scoping must distinguish between **attributional** accounting (which assigns a normative share of historical or current supply-chain emissions to a functional unit) and **consequential** modelling (which estimates how global emissions change in response to a specific intervention or purchasing decision, including market substitution effects). [S26] Both Corporate Scope 3 inventories and standard Product Carbon Footprints under ISO 14067, PACT Version 3 and the EU Apparel PEFCR are primarily attributional accounts. [S05] [S06] [S10] [S23] They sum the emissions occurring within the defined product system boundary and divide by the functional unit, without subtracting speculative credits for what might happen in external markets. [S01] [S26]

Problems arise when an analyst silently mixes attributional and consequential logic inside a single footprint number. [S26] [S32] Common examples in textile claims include:

- **System-expansion credits for cottonseed:** Subtracting the emissions of soy oil or palm oil production from a cotton T-shirt footprint on the consequential argument that cottonseed oil displaces other vegetable oils on world markets, while reporting the result as an attributional product footprint. [S26]
- **Unverified replacement credits for durability:** Subtracting the full cradle-to-gate production emissions of a second shirt from a durable shirt's footprint on the assumption of one-for-one replacement avoidance, rather than reporting the footprint per wear and testing displacement separately. [S26] [S30]
- **Recycled-content substitution claims:** Crediting a garment made from recycled polyester or mechanically recycled cotton with avoided virgin fibre production without accounting for collection, sorting, depolymerisation or shredding energy, fibre shortening losses and the allocation rules required by product standards. [S22] [S27] [S30]
- **Offset-backed neutrality deductions:** Subtracting carbon credits generated outside the garment's value chain (such as forestry or cookstove offsets) from the product's inventory to advertise a "zero-carbon" or "carbon-neutral" garment, a practice prohibited for consumer claims under Directive (EU) 2024/825. [S32]

To keep the accounting transparent, GFT separates the attributional product account from consequential decision scenarios. [S01] [S26] In the attributional account, cotton lint and cottonseed are partitioned using a documented economic allocation baseline (with physical mass allocation retained in sensitivity tables so users can inspect the difference when SODECOTON lint and cottonseed oil prices fluctuate), and zero external displacement credits or carbon offsets are deducted from the product footprint. [R03] [S26] [S32] Consequential questions (such as how processing 50 percent of Cameroon's cotton locally by 2030 alters net shipping corridors, domestic cottonseed meal supply or regional grid dispatch) are evaluated in dedicated scenario models where counterfactual assumptions are explicit and auditable. [R06] [R07] [S26]

> **WARNING**
>
> **Unresolved constraint: local ginning co-product ratios and economic partitioning in Cameroon**
>
> While the programme evidence register confirms that SODECOTON operates nine ginning plants and two oil mills supporting more than 220,000 producers across northern Cameroon, the inherited register does not record audited multi-year physical mass balances (lint, seed, hulls, linters and unrecovered trash per tonne of seed cotton) or multi-year ex-gin revenue shares between lint and seed for those specific plants. [R03] Until primary mass and revenue records are collected during Phase 1 site onboarding, any cradle-to-gate cotton lint footprint for Cameroon must label its ginning allocation factor as a secondary or sensitivity parameter and report results under both economic and physical partitioning rather than asserting a single fixed local percentage. [S16] [S22] [S26]

3.16

Comparison requires common rules and equivalent assumptions

The ultimate test of goal and scope definition arrives when two numbers are placed side by side to support a commercial or policy comparison. [S24] [S25] Across the apparel industry, buyers and commentators frequently assemble tables comparing a cotton figure taken from one published report, a polyester figure taken from a supplier declaration, and a viscose or recycled-fibre figure taken from a third database, then rank the fibres from best to worst. [S22] [S26] Textile Exchange explicitly warns against this practice, noting that results from LCA studies are highly sensitive to methodological choices, assumptions and boundaries, and cannot be compared directly unless those underlying conditions are aligned. [S22]

3.17 METHODOLOGICAL DRIFT INVALIDATES RANKINGS ASSEMBLED FROM SEPARATE STUDIES

When two textile LCA studies produce different carbon numbers for what appears to be the same garment, the divergence often stems from incompatible scoping rules rather than genuine physical differences on the factory floor. [S22] [S26] Drawing on the methodological review by Watson and Wiedemann (2019), Textile Exchange guidance (2026) and the comparative modelling in Forfora et al. (2026), six scoping mismatches routinely invalidate cross-study rankings: [S22] [S26] [S31]

1. **Incompatible functional units and fabric weights:** Study A evaluates 1 kg of greige fabric at the mill gate, whereas Study B evaluates a 250 g knitted and dyed T-shirt, or Study C evaluates a 115 g tenacity-equivalent shirt per wear across 45 washes. [S26] [S31] [S0301]
2. **Truncated or mismatched system boundaries:** One study includes agricultural soil nitrous oxide, ginning, spinning, wet processing, cutting waste and inter-factory transport, while another begins at baled lint at the spinning mill gate or omits cutting-room marker fallout. [S22] [S26] [S31]
3. **Cumulative material loss omissions:** Because each stage from raw fibre to finished garment generates waste, the mass of raw fibre entering the system is substantially larger than the mass of the finished garment. [S31] Forfora et al. (2026) report cumulative cotton losses of 31 percent across their cradle-to-gate T-shirt boundary, meaning that a 0.250 kg finished shirt requires approximately 0.362 kg of starting fibre input (`0.250 / 0.69 = 0.3623 kg`). [S31] Comparing a study that compounds stage-by-stage yield losses with a study that multiplies raw fibre intensity by finished garment weight alone introduces an immediate 31 percent downward bias. [S31]
4. **Divergent co-product allocation methods:** One cotton study applies physical mass allocation at the gin and comber, assigning most farm burdens to cottonseed and comber noils, while a competing study applies multi-year average economic allocation. [S26] [S31]

5. **Inconsistent background databases and energy vintages:** One study models spinning and dyeing using a national coal-heavy grid factor from an older background database version, while another uses a regional hydroelectric grid or unverified market-based renewable certificates without disclosing dual Scope 2 figures. [S03] [S16] [S31]
6. **Asymmetric uncertainty and cut-off criteria:** One study reports a single deterministic point value while omitting trims, sewing thread, packaging and chemical auxiliaries under a permissive cut-off threshold, whereas another reports median and confidence intervals from 1,000 Monte Carlo iterations across the complete bill of materials. [S25] [S31]

Because any one of these six discrepancies can shift a calculated garment footprint by 20 to 50 percent, ISO 14044:2006 mandates that comparative assertions intended for public disclosure undergo a critical review by a panel of independent experts to verify that system boundaries, data quality, allocation rules and impact assessment methods are equivalent across all compared product systems. [S25] [S26] Similarly, the European Union's Apparel and Footwear PEFCR and Directive (EU) 2024/825 establish harmonised product category rules and legal disclosure requirements so that companies making comparative claims evaluate all products under identical rules rather than cherry-picking favourable boundaries. [S06] [S32] [S0301]

3.18 GOVERNANCE LOCKS THE FUNCTIONAL UNIT BEFORE FACTORY DATA COLLECTION BEGINS

In an industrial programme, methodological consistency cannot be retrofitted at the end of the year by a consultant; it must be built into the factory's chart of accounts and production logs from the first shift. [S10] [S23] Global fibre production rose from 125 million tonnes in 2023 to 132 million tonnes in 2024 according to Textile Exchange's *Materials Market Report 2025*, underscoring why apparel manufacturers face intensifying scrutiny from buyers and regulators to prove both absolute emissions discipline and verifiable product-level footprints. [S07] [S21]

Within GFT's Cameroon textile programme, the scoping rules established in this chapter directly govern how production data and resource meters are joined in the digital architecture: [S10] [S23]

- **Style-level physical metadata are mandatory fields:** No garment style enters the production database without a locked specification recording its product category, target finished mass in grams, fabric areal density in grams per square metre, fibre composition, yarn count, tenacity class and bill-of-materials loss allowance. [S23] [S31]
- **Three product denominators and one site denominator are computed in parallel:** Rather than forcing one metric to serve every user, the GFT calculation engine outputs (a) emissions per kilogram of intermediate yarn or fabric for mill engineers, (b) cradle-to-gate emissions per accepted finished garment (alongside started garment) for buyer PACT exchanges, (c) cradle-to-grave emissions per wear under documented PEFCR reference scenarios for design and durability evaluations, and (d) total absolute emissions alongside corporate intensity per accepted unit for board governance. [S04] [S10] [S23] [S0301]

- **Allocation and boundary tags travel with every number:** Every exported figure carries machine-readable metadata stating its boundary (`cradle-to-gate` or `cradle-to-grave`), functional unit (`1 kg`, `1 garment` or `1 wear`), ginning and mill co-product allocation method (`economic` or `physical`), cumulative loss factor and primary-data share. [S10] [S23] [S26]

By locking the goal, scope, functional unit, boundary and co-product rules before aggregating activity data, the factory prevents its resource-efficiency metrics (kilowatt-hours per unit, cubic metres of water per unit and first-pass quality yield) from being misread as complete lifecycle footprints, while laying an auditable foundation for chapters that follow on data quality, field-to-lint cotton accounting, wet-processing energy, factory Scopes 1 and 2, logistics and consumer use. [S01] [S23] [S24]

A carbon footprint measures a function inside a boundary, and changing either one changes the question the number can answer.

CHAPTER SOURCE NOTES

S01 GHG Protocol. 2011.

S24 International Organization for Standardization. 2006-07.

S22 Textile Exchange. 2026-07-16.

S26 Watson and Wiedemann, Sustainability. 2019-07-15.

S23 GHG Protocol and Carbon Trust. 2013.

S31 Forfora et al., Sustainability. 2026-04-20.

S0301 European Commission Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs. 2025-07-22.

S0302 Aalto University Research Portal. 2026-04.

S06 European Commission. 2025-06-25.

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

S10 World Business Council for Sustainable Development. 2025-04-30.

S32 European Parliament and Council of the European Union. 2024-02-28.
S25 International Organization for Standardization. 2006-07.
S16 ecoinvent. 2025-11-05.
R06 Cameroon Trade Hub. Publication date unrecorded; inherited source-text check.
R07 Ecofin Agency. 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.
S20 UK Department for Energy Security and Net Zero. 2026-06-11.
S05 International Organization for Standardization. 2018-08.
S04 GHG Protocol. 2004.
S12 United Nations Environment Programme. 2021-11-08.
S30 European Environment Agency. 2022.
S02 GHG Protocol. 2011.
S27 Ellen MacArthur Foundation. 2017.
R29 MDPI; industry inspection literature. Publication date unrecorded; inherited source-text check.
S29 Food and Agriculture Organization of the United Nations. 2017.
S03 GHG Protocol. 2015.
S07 Textile Exchange. 2025-09-18.
S21 United Nations Industrial Development Organization. 2010.

GREEN FUTURE TECH

LIMITED / HONG KONG SAR

04

PART I: BUILD THE ACCOUNT BEFORE THE CLAIM / EVIDENCE QUALITY

Better data means representative data, not simply more data

A screening model earns its keep by showing where primary evidence will change the decision most.

CHAPTER 04
DECISION TEST

A screening model earns its keep by showing where primary evidence will change the decision most.

Better carbon data describe the production actually being assessed, preserve the boundary of each input and reveal whether uncertainty could change the decision. Collecting more records is useful only when those records resolve a material weakness. GFT therefore proposes an evidence ladder: screen the whole account, identify decision-sensitive gaps, test supplier submissions, replace weak proxies with representative observations and preserve each calculation version. This is a proposed method for the Cameroon textile programme, not a claim that a factory baseline has been measured. It follows the distinction between data specificity and accuracy made in GHG Protocol guidance. [S23]

The chapter takes the declared garment function and system boundary as its starting conditions. It does not choose a fibre, prescribe farm practices or calculate a national garment footprint. Its question is narrower: which evidence is sufficient for the intended use, and which additional observation would make the next decision more defensible? GFT recommends keeping that question beside the data request. Otherwise an apparently complete database can conceal missing production periods, incompatible factors or an allocation rule that no reviewer can reproduce.

4.1

Screening directs effort to the largest uncertainties

GHG Protocol recommends screening before committing to detailed collection, considering emissions significance, reduction opportunities and business relevance. Its calculation guidance permits different methods for different activities, rather than requiring the same precision everywhere. [S23] GFT would translate that principle into an evidence worklist. Each line would identify the activity, the current estimate, the weakness that matters, the decision exposed to that weakness and the person able to resolve it. The worklist should describe a decision problem, rather than reward whichever supplier submits the most attachments.

Begin with a process map and a completeness register. For every included process, record whether the model uses measured activity, an engineering estimate, an industry average or a scenario. Record exclusions separately. An empty field must remain distinguishable from an observed absence of activity. GFT recommends a specific missing-data flag, with a temporary proxy and an owner where a proxy is justified. A blank emissions cell must never become an apparently measured zero merely because the calculation software expects a numeric input.

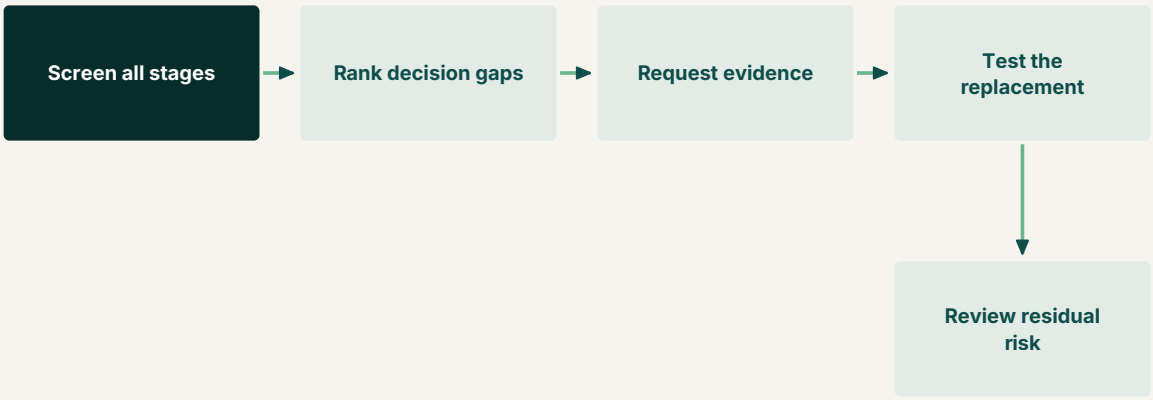
Next ask how a weak input could affect the result. A large estimated contribution is an obvious collection candidate, but it is not the only one. A smaller contribution may determine whether an apparent improvement survives, whether a contractual boundary is satisfied or whether an operating action can be checked. Conversely, a large contribution whose uncertainty would not change the immediate choice may be suitable for a bounded screening estimate while a different question is resolved. This is GFT's proposed decision discipline, rather than a universal materiality threshold.

The evidence ladder in **Exhibit 15**, p. 69 expresses that discipline. It is a proposed workflow informed by the screening guidance, not a statement that its sequence has been implemented. The final review can send the account back to collection when the

remaining uncertainty still affects the decision. Completion means the evidence is adequate for the declared purpose, rather than that every possible variable has become a direct measurement.

EXHIBIT 15 / PROPOSED EVIDENCE WORKFLOW

Screening gives every collection request a decision purpose



ILLUSTRATIVE [S23] Illustrative GFT workflow informed by GHG Protocol screening guidance. The sequence is a recommendation, not an observed operating system or a mandatory standard procedure.

A useful request states the uncertainty it is intended to reduce. Instead of asking for a complete sustainability report, ask for the fuel record covering the same production interval as the product output, or the site allocation schedule behind a supplied fabric factor. GFT recommends checking whether the requested evidence already exists in production, maintenance or purchasing records before creating another reporting form. Collection cost belongs in the decision, but it cannot justify hiding an unresolved hotspot or replacing an unavailable observation with a favourable assumption.

The worklist should distinguish a data owner from an action owner. GFT proposes that the holder of the original record confirms what it measures, while the carbon analyst confirms how it enters the model. A purchasing team can identify a supplier and a transaction period without being asked to approve a technical emission factor. A production supervisor can explain unusual operating conditions without being made responsible for an entire life cycle account. This division gives each request a practical route to resolution and avoids an unexplained transfer of judgement between departments.

Priority should also survive a change in the headline result. GFT recommends retaining the earlier screening estimate beside its replacement and documenting whether the activity moved up or down the collection worklist. A revised estimate may reveal that a formerly minor stage deserves attention. It may also show that the initial hotspot was largely a mismatch in the proxy. Neither result is a failure of screening if the method made the uncertainty visible and the replacement evidence is properly tested. Screening should guide learning rather than defend its original ranking.

The worklist also needs stopping rules. GFT would close a collection action when the source is readable, its boundary matches the model, the replacement calculation is reproducible and the remaining limitation is recorded. Where evidence is inaccessible, retain a dated screening estimate with a sensitivity test and a further collection trigger. Reopening should follow a changed process, a newly material uncertainty or a new intended use. A model adequate for internal investigation may need further evidence before it supports an external comparison.

> **GFT NOTE**
>
> Buy evidence against a named decision. Ask what observation could reverse the choice, who holds it and how the answer will enter the account. Keep unresolved activities visible, even when collection must wait. The proposed carbon data register should serve production and review together, so that an improvement in the evidence can be distinguished from an improvement in the factory.

4.2

Supplier-specific is not a synonym for accurate

Supplier-specific information can have weak granularity, unreliable source records or uncertain allocation. GHG Protocol explicitly warns that such information may be less accurate than an industry average. [S23] A supplier name attached to a factor is therefore provenance, not proof of fitness. GFT recommends treating a submission as an evidence package that must pass acceptance checks before replacing the existing proxy. An unsigned spreadsheet can still contain useful observations, while an attractive verification statement can leave the relevant product boundary unresolved.

GFT's proposed acceptance package begins with product identity, production site, reporting interval and declared unit. It then records included processes, excluded activities, activity sources, emission-factor sources, allocation basis, primary-data coverage and the extent of review. Keep the evidence behind a total as well as the total itself. If commercial confidentiality prevents detailed disclosure, record what an authorised reviewer can inspect and which limitations remain for the receiving organisation. Confidentiality can change the evidence route; it does not establish the correctness of an inaccessible calculation.

Representativeness needs separate tests rather than a single favourable label. The Product Standard identifies technology, geography, time, completeness and reliability as data-quality indicators. [S0401] GFT recommends preserving each dimension as a descriptive judgement. A recent figure from the wrong process should not become acceptable because its publication date is attractive. Likewise, a carefully measured period may remain unsuitable for annual extrapolation when the production conditions it represents differ from the intended reporting population.

The proposed acceptance tests in **Exhibit 16**, p. 71 adapt those dimensions to a garment account. The tests are GFT recommendations, while the dimensions come from the Product Standard. No numerical score is assigned: an average could conceal a decisive failure. The decision field should state whether the submission is accepted, accepted for screening only or held pending clarification, with reasons that another analyst can inspect.

EXHIBIT 16 / PROPOSED ACCEPTANCE TESTS

A quality profile preserves weaknesses that an average score hides

Dimension	Evidence to inspect	Reason to hold
Technology	Process and energy route	Different production route
Geography	Site and factor region	Unexplained location proxy
Time	Activity and factor periods	Period mismatch
Completeness	Coverage of operating states	Selected normal shifts only
Reliability	Source trail and checks	Unreconciled totals

ILLUSTRATIVE [S0401] Illustrative GFT acceptance tests mapped to the Product Standard's data-quality indicators. These tests are not standard-mandated wording, measured supplier scores or certification criteria.

The primary-data share should have a defined denominator. GFT recommends recording whether it describes activity records, model inputs or attributed emissions. These are different measures. A long list of direct observations does not demonstrate that the dominant emission contribution has direct support. Nor does a high emissions-weighted coverage figure demonstrate that every boundary choice is correct. Record the calculation used for the share and keep excluded stages visible beside it, rather than allowing coverage to function as an unexplained quality badge.

Review status needs the same care. The WBCSD PACT page describes verification pathways and warns that its methodology receives revisions. [S0402] GFT recommends requesting the actual method version, the scope of the review and any qualifications. A review of the supplier's organisational inventory should not be silently extended to a product allocation that the reviewer did not examine. Store assurance as a separate attribute from representativeness, so that a record can be well checked against its own rules while still unsuitable for the receiving account.

Sampling also needs a population. GFT proposes grouping suppliers or production records by process route, location and operating condition before extrapolating. Record which groups were observed, which remain proxied and why the observations are considered transferable. Do not let convenient access decide the entire sample. If only a cooperative supplier provides detail, retain a limitation on extrapolating that evidence to the rest. The appropriate response to a coverage gap is a bounded estimate and a collection plan, rather than an unsupported assertion that the unobserved population behaves similarly.

4.3

Background databases provide proxies, not site truth

Ecoinvent describes its processes as geographical production averages rather than company-specific or site-specific conditions. [S16] That distinction gives background data a useful role and a clear limit. A background process can supply a transparent starting point where direct evidence is unavailable. It cannot establish that a particular

mill uses the represented technology, energy mix or production yield. GFT recommends making every proxy visible in the model so that the analyst can replace it without reconstructing the account.

The first selection question is process identity. Write what enters and leaves the dataset, its reference product and its declared unit. Check whether it represents fibre, yarn, fabric or a finished good before attaching it to a purchasing quantity. GFT would also record moisture or conditioning assumptions where these affect the mass basis. A factor with the right material name but the wrong processing stage should be held as a candidate, not accepted automatically. The account needs a matching process boundary as well as a matching commodity description.

Geography should describe the process represented, rather than merely the address of the trader supplying it. GFT recommends keeping production location, purchase location and dataset geography in separate fields. Where the true production location is unknown, state that gap and test plausible alternatives. A purchase invoice can prove that a transaction occurred without proving the origin of its upstream electricity or heat. This distinction is particularly useful in a textile chain where intermediate goods can pass through several commercial owners before reaching the garment maker.

Quantis describes WALDB as an apparel and footwear database with disaggregated processing information and geographical modelling. [S17] Its sector coverage can help an analyst locate relevant candidate processes, but coverage alone does not settle transferability. GFT recommends requesting the dataset documentation before accepting a process match, including the model version and restrictions on use. The chapter relies on the provider's description of the resource, not on an inspection of its licensed underlying inventory. No proprietary process value is reproduced here.

Method consistency remains a separate test. Textile Exchange cautions that methodological choices, assumptions and boundaries affect LCA results, and advises against comparisons between unlike studies or datasets. [S22] GFT would therefore keep a candidate-factor register rather than assemble a ranking from unrelated published numbers. The register should show why a dataset was selected, what it substitutes for and which sensitivity case tests its weakest match. A common reporting unit cannot by itself make inconsistent models comparable.

GFT proposes recording both the foreground and background versions when a model combines direct factory observations with database processes. Otherwise a later software update may change the total even though the factory file is unchanged. Preserve the selected process identity, system model, impact method and any modifications made by the analyst. The record should explain whether a supplied value is a direct inventory flow or an already characterised impact result, so the receiving calculation does not apply characterisation again to an impact total.

Selection should include a rejection record. A plausible candidate may be unsuitable because its energy route is unknown, its product output differs or its boundary duplicates another included stage. GFT recommends recording the specific reason rather than merely marking the candidate as poor quality. That record prevents the next analyst from reinstating the same unsuitable factor during an update. It also makes a

collection request more focused: the supplier can be asked for the missing process description or coverage statement that would allow a decision, instead of being asked to repeat its entire submission.

A proxy replacement should leave an audit trail. GFT recommends retaining the original dataset identifier, the replacement identifier, the reason for change and the affected model lines. Do not overwrite a global factor because a supplier provides a more specific record for a particular purchase. Create a scoped replacement for the relevant product, site and period. That approach allows the analyst to discover whether an apparent improvement came from production change, a better process match or a changed modelling convention.

For a Cameroon application, the absence of local process evidence should remain a visible limitation, not become a claim of either advantage or disadvantage. GFT proposes selecting a documented screening proxy, identifying its mismatch and checking whether reasonable alternatives change the immediate decision. If they do, prioritise local collection before advancing the claim. If they do not, retain the proxy provisionally and revisit it when the purpose changes. This is an evidence strategy for a prospective account, not a measured conclusion about Cameroonian manufacturing.

4.4

Physical activity data support operating decisions

The UK conversion-factor page explains activity-based calculation using fuel quantities, purchased electricity and distance, and identifies the separate reporting scopes. [S20] GFT recommends preserving the physical observation before applying any carbon factor. Store the reading, unit, coverage period, source record and any transformation. The carbon result should remain reproducible from those fields. An activity total and its associated factor are different kinds of evidence, so each needs its own quality assessment and version history.

For operating decisions, GFT proposes a distinction between consumption, purchase and allocation. A delivery note records material received; a store reconciliation estimates material consumed; a batch record assigns consumption to production. These records can support each other without becoming interchangeable. The same approach should apply to a fuel tank or an energy meter: identify the physical boundary, account for transfers and match the observation interval to production. Avoid allocating an entire reporting period from a convenient short observation unless its representativeness has been tested.

A spend model answers a different arithmetic question. Holding its factor constant, a change in price changes estimated emissions even when physical quantity stays fixed. The illustrative example below isolates that effect. It does not show that spend screening is useless. It shows why GFT would retain quantity and price separately before interpreting a purchasing change as an operational carbon reduction. Where physical evidence is missing, preserve the spend estimate as a screening line with that limitation stated.

WORKED EXAMPLE: A PRICE DISCOUNT CHANGES THE ESTIMATE WITHOUT CHANGING PRODUCTION

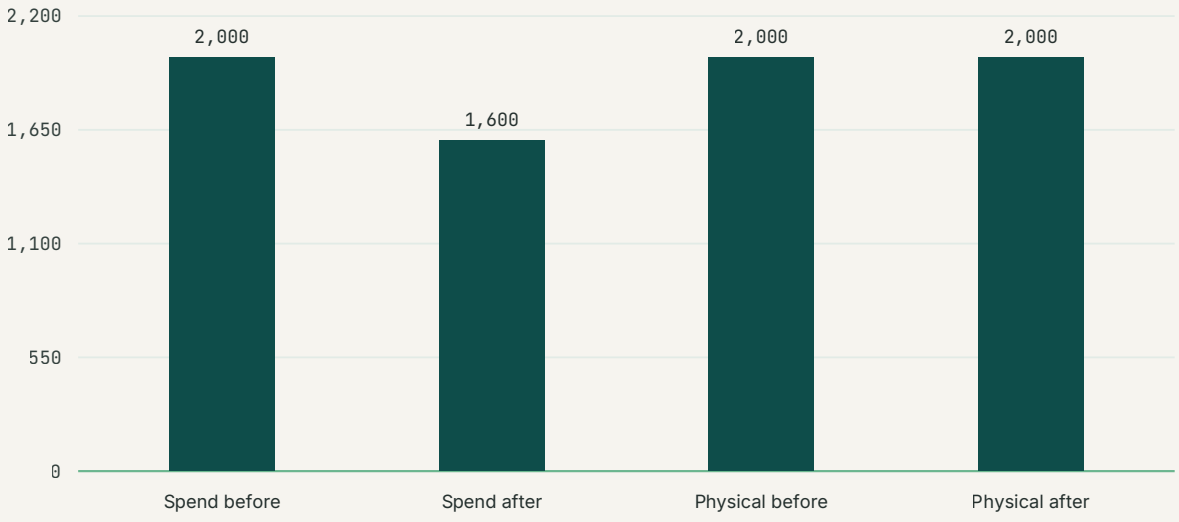
An illustrative purchase comprises 1,000 kg of identical fabric. Assume a price of XAF 5,000 per kg and a screening factor of 0.0004 kg CO2e per XAF, chosen solely to demonstrate spend arithmetic. The purchase is XAF 5,000,000 and estimated emissions are 2,000 kg CO2e. Assume a negotiated price of XAF 4,000 per kg for the same quantity and unchanged production. Spend becomes XAF 4,000,000 and the estimate becomes 1,600 kg CO2e. The apparent reduction is 400 kg CO2e, or 20 percent, entirely caused by the assumed price change.

For the same illustrative purchase, assume instead a fixed physical factor of 2 kg CO2e per kg of fabric. Multiplying 1,000 kg by that factor gives 2,000 kg CO2e at either price. Neither assumed factor is a Cameroon benchmark or a supplier observation. The calculation demonstrates a model mechanism; it does not establish which factor would be appropriate for an actual purchase.

The comparison in **Exhibit 17**, p. 74 keeps the physical case unchanged while the spend estimate falls. Its point is attribution: a purchasing saving and a production saving require different evidence. A real account would need a suitable factor, its price-year treatment where relevant and a boundary check before either result could be used.

EXHIBIT 17 / ILLUSTRATIVE KG CO2E PER PURCHASE

A price discount alone reduces the illustrative spend estimate



ILLUSTRATIVE Illustrative inputs: quantity 1000 kg; prices XAF 5000/kg and XAF 4000/kg; assumed spend factor 0.0004 kg CO2e/XAF. Results: $1000_{5000}0.0004=2000$ and $1000_{4000}0.0004=1600$. Assumed physical factor 2 kg CO2e/kg gives 2000 at either price. No observed reduction.

GFT recommends a reconciliation before a physical observation reaches the carbon model. Check opening stock, receipts, closing stock and recorded transfers against calculated consumption where that balance is applicable. Compare production output with the denominator used for allocation. Preserve unexplained differences as excep-

tions instead of forcing the balance to agree through an invisible adjustment. The reviewer should be able to distinguish an instrument reading, an estimated gap and an allocation choice even when the final calculation combines them.

The resulting collection request should be useful to the operator. Ask for the energy interval that matches the production batch, the rejected material that changes good output or the transport activity associated with an identified consignment. GFT would connect each request to an action that can be checked, while keeping carbon-factor selection under separate control. Better physical evidence can improve the account without proving abatement. Abatement requires evidence that the relevant activity or production conditions changed, assessed on a consistent basis.

4.5

Uncertainty tests whether rankings survive

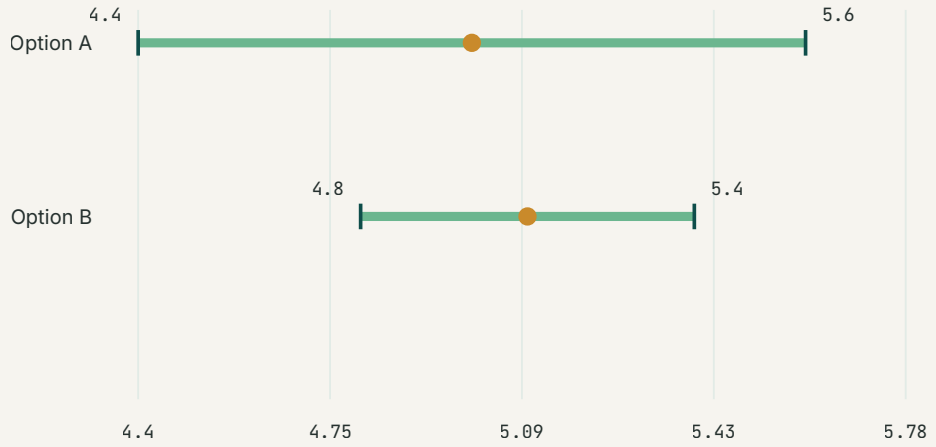
ISO's public description places interpretation, limitations, reporting and critical review inside the LCA framework. [S25] GFT recommends making uncertainty part of interpretation before selecting a preferred option. Separate uncertainty in a measured quantity from uncertainty in a factor, an allocation rule or a future scenario. These are different questions. A tighter meter tolerance cannot resolve an unknown production route, and a precise computational result cannot establish that a chosen use scenario represents the intended population.

Start with transparent sensitivity cases. GFT proposes changing a decision-sensitive input while holding other assumptions fixed, then documenting the direction and size of the effect. Where inputs interact, test coherent combinations rather than assembling impossible extremes. A change to fabric yield should carry its related input requirement through the model. A change to the represented electricity system should affect every process using that system consistently. The aim is to identify which uncertainty matters, not to generate a wide interval without an explanation.

The range exhibit in **Exhibit 18**, p. 76 is an illustrative endpoint exercise. Assume equal function and boundary for both options. Option A contains a fixed contribution of 4 kg CO2e per garment plus 2 kWh per garment with an assumed factor between 0.2 and 0.8 kg CO2e per kWh. Option B contains a fixed contribution of 4.6 kg CO2e per garment plus 1 kWh per garment using the same factor. These invented inputs isolate a shared source of uncertainty; they are not fabric or country emission factors.

EXHIBIT 18 / ILLUSTRATIVE KG CO2E PER GARMENT

The illustrative preferred option changes with a shared factor



ILLUSTRATIVE Illustrative equal-function scenarios, not probability or confidence intervals. Shared factor f is assumed between 0.2 and 0.8 kg CO2e/kWh. A=4+2*f gives 4.4 to 5.6; B=4.6+f gives 4.8 to 5.4. At f=0.5, results are 5.0 and 5.1. Other contributions are held fixed by assumption.

In this illustrative model, subtracting B from A gives the shared factor minus 0.6. A is lower when the factor is below 0.6 kg CO2e per kWh; B is lower above that value. At the assumed midpoint, A is lower by 0.1 kg CO2e per garment, but that central ranking is insufficient to choose across the stated factor range. Collection should target the shared factor or the energy evidence that determines whether the alternatives sit on either side of the crossing.

Overlapping ranges alone do not establish that a ranking can reverse. In GFT's proposed review, compare options under matched assumptions and inspect the difference directly. Shared inputs must remain shared. Treating the same grid factor as independently high for one option and low for another would answer a different scenario question. Conversely, suppliers operating in different electricity systems may need different factors. State the relationship being assumed and explain its evidence before interpreting the comparison.

Before collecting more evidence, GFT recommends identifying an action that remains sensible across all tested cases. A reversible investigation or a better meter record may be justified even while a supplier ranking remains unresolved. Keep that operational decision separate from a public comparative claim. If the carbon preference depends on an uncertain factor, the procurement record can describe the condition and the evidence still needed. This preserves momentum without turning a conditional result into an unconditional conclusion.

A failed sensitivity test should lead to a specific next step. Identify whether uncertainty comes from process mismatch, incomplete periods, an allocation choice or unknown factor coverage. Then choose the investigation that addresses that weakness. Repeating a calculation at greater numerical precision does not resolve any of those issues. GFT would require the analyst to explain how the proposed new observation changes the tested range or eliminates a disputed scenario before assigning further collection effort.

A probabilistic model should wait until distributions and dependencies have a defensible basis. GFT recommends recording why each distribution was chosen, whether its bounds represent observations or judgement and which inputs are correlated. A simulation's sample count is a computational setting, not evidence quality. Check convergence of the decision-relevant output, preserve the random seed for reproduction and report model limitations beside any probability. Where only plausible endpoints exist, publish scenario bounds without presenting them as a statistical confidence interval.

> **METHOD**
>
> GFT proposes a comparison record containing the common function and boundary, uncertain inputs, source or assumption for each range, dependency rules, sensitivity results and the evidence needed to resolve a reversal. Record whether the preferred option remains preferred throughout the tested cases. If it does not, state a conditional choice or defer the claim. A decision may still proceed for other documented reasons, but its carbon ranking must retain the condition that makes it true.

4.6

Factor vintage and recalculation protect the time series

Factor publication year and represented activity year are different fields. The IEA's September 2026 product description lists annual electricity and heat indicators with differing historical and provisional coverage. [S14] GFT recommends storing release date, observation period, geography, gas coverage, unit and process boundary separately. A newly released factor is not automatically a measurement of current production. The public product description establishes that such datasets exist; it does not supply a licensed Cameroon factor for use in this chapter.

The UK page provides a concrete reason to retain revision identity. Published on 11 June 2026 and updated on 31 July 2026, it explains that some unavailable values had appeared as zeros in the flat file. The correction restored blanks; the full set had retained the correct blanks. [S20] The example concerns those specified files and affected categories, not a finding that all government factors were wrong. GFT would nevertheless use it as a practical acceptance check: distinguish missing factors from zero-emission factors and archive the release actually used.

The record in **Exhibit 19**, p. 78 preserves this source history without importing any conversion-factor value. It supports a data-control lesson rather than a garment emissions calculation. An analyst can compare a stored file against a correction notice and identify whether any model line needs review.

EXHIBIT 19 / SOURCE PUBLICATION RECORD

A corrected factor release must remain distinguishable from its predecessor

Record	Date or treatment
First publication	11 June 2026
Flat-file correction	31 July 2026
Unavailable affected entries	Blank replaces incorrect zero
Full set	Correct blanks; not revised

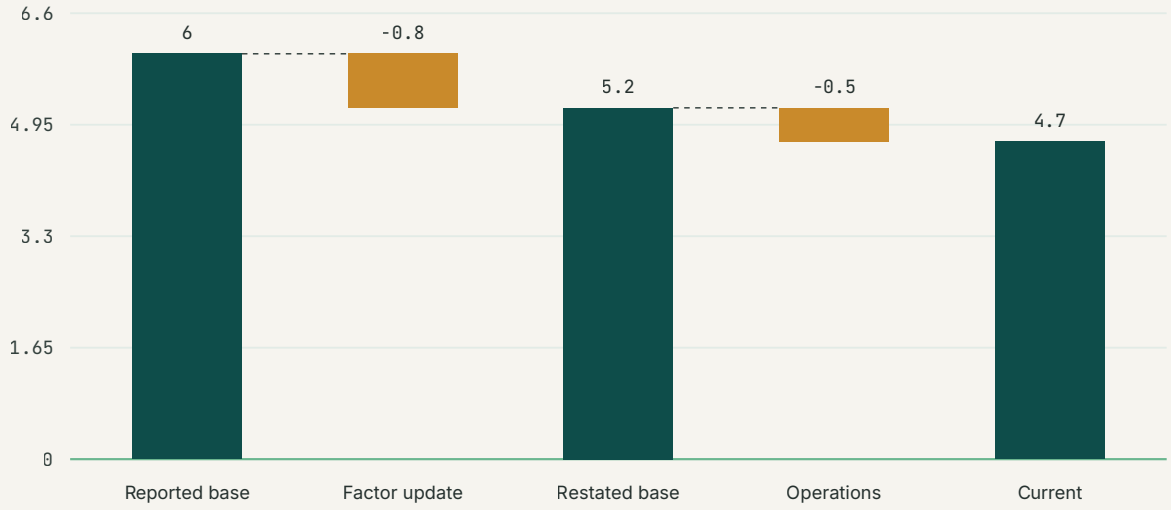
SOURCED [S20] Sourced from the UK government publication page opened on 2026-10-30. Its July correction concerned the flat file; the full set was not revised. No numerical conversion factors are reproduced.

The Product Standard requires base-inventory recalculation when significant methodological changes occur and discusses improvements in data quality among the reasons a comparison may need restatement. [S0401] GFT recommends a written recalculation policy before claiming progress. Define the review trigger, responsibility and disclosure route. A materiality threshold should suit the declared method and purpose, rather than be invented retrospectively to avoid an inconvenient revision. Where historical evidence cannot be reconstructed, state the limitation and consider a new comparable baseline instead of manufacturing missing observations.

The illustrative bridge in **Exhibit 20**, p. 79 separates a method update from operating change. Assume an originally reported intensity of 6 kg CO2e per garment. A better-matched factor would reduce that historical estimate by 0.8 kg, giving a restated baseline of 5.2 kg. Assume current production is 4.7 kg on the same revised method. The comparable operating reduction is 0.5 kg, or about 9.6 percent of the restated baseline. The apparent reduction against the original report would be about 21.7 percent, mixing the factor correction with operating change. All values are illustrative assumptions, not GFT results.

EXHIBIT 20 / ILLUSTRATIVE KG CO2E PER GARMENT

Restatement separates improved knowledge from operating improvement



ILLUSTRATIVE [S0401] Illustrative assumptions: original baseline 6.0; factor correction -0.8; restated baseline 5.2; operating change -0.5; current 4.7. Comparable change=(5.2-4.7)/5.2=9.615%; apparent change=(6.0-4.7)/6.0=21.667%. S0401 supports recalculation principles, not these invented values.

Keep a constant-method view for diagnosing operating change beside the reporting view required by the selected accounting rules. GFT recommends explaining differences due to production mix, activity, factors, allocation and corrections without forcing them into a single success narrative. A real change in the electricity system and a correction to its historical estimate are different events. This chapter proposes the distinction; the paper's abatement and claims chapters determine how the resulting evidence supports a reduction statement.

The handover should contain the selected factor register, accepted activity records, unresolved exceptions, sensitivity cases and the original and restated calculation versions. GFT recommends a reviewer check that each published total can be reconstructed from that package and that later edits cannot silently alter an earlier result. This connects carbon accounting to performance management: production supplies the physical observation, the data system preserves its meaning and the reviewer controls its use. The quality test is whether the next decision is better supported, not whether the database has grown.

The best evidence is the evidence that can change a decision and survive its review.

CHAPTER SOURCE NOTES

S23 GHG Protocol and Carbon Trust. 2013.

S0401 GHG Protocol, World Resources Institute and World Business Council for Sustainable Development. 2011-09.

S0402 World Business Council for Sustainable Development. 2026-06-02.

S16 ecoinvent. 2025-11-05.

S17 Quantis. 2026-10-09.

S22 Textile Exchange. 2026-07-16.

S20 UK Department for Energy Security and Net Zero. 2026-06-11.

S25 International Organization for Standardization. 2006-07.

S14 International Energy Agency. 2026-09-25.

GREEN FUTURE TECH

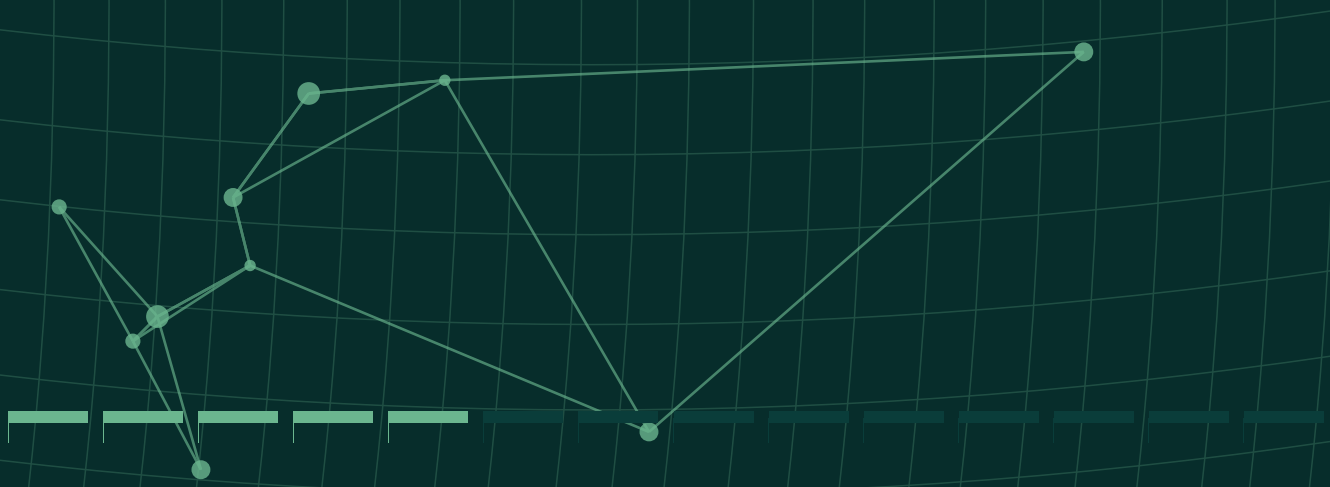
LIMITED / HONG KONG SAR

05

PART II: FOLLOW CARBON THROUGH THE GARMENT / FIELD TO LINT

Cotton's account begins with inputs, yields and co-products

A cotton footprint is built from farm activity and allocation choices, not from a generic natural-fibre label.



CHAPTER 05
DECISION TEST

A cotton footprint is built from farm activity and allocation choices, not from a generic natural-fibre label.

Cotton does not enter a garment factory with a fixed natural-fibre carbon score. Its cradle-to-gin-gate footprint is the arithmetic result of agricultural inputs per hectare, harvested seed-cotton yield per hectare, ginning outturn, cumulative processing losses, co-product allocation between lint and cottonseed, and the separate treatment of fossil, nitrous oxide, biogenic and soil carbon flows. [S26] [S29] [S31] Change any of those variables, or change the methodological rule that partitions farm burdens at the gin gate, and the carbon assigned to a kilogram of baled lint shifts materially even when nothing changes in the spinning mill or sewing hall. [S22] [S26] Green Future Tech Limited (GFT) therefore rejects generic fibre labels as an operating baseline for its Cameroon textile programme. A defensible cotton account must record physical farm and ginning parameters at defined boundaries, separate measured local evidence from regional screening proxies, and preserve the distinction between attributional product reporting and consequential substitution claims. [S01] [S16] [S26]

5.1

Yield determines how farm burdens reach lint

Agricultural production is an area-based activity, whereas textile manufacturing is a mass-based and unit-based activity. Farmers apply seed, water, fertiliser, crop-protection chemicals and field work to a hectare of land over a season, while spinners buy kilograms of baled lint and garment makers sell finished shirts. [S26] [S29] Yield bridges the field and factory boundaries through harvested seed-cotton mass per hectare and the ginning outturn that separates lint from cottonseed. [S26] [S31] Because farm emissions occur per hectare while product footprints are expressed per kilogram of fibre or per garment, yield sits in the denominator of every field-level emission source. [S22] [S26]

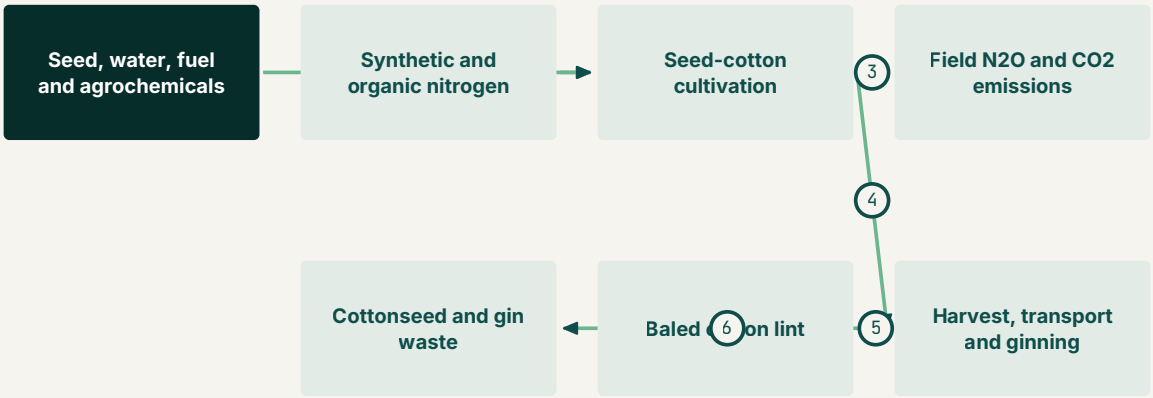
Identical input rates per hectare therefore produce very different carbon intensities per kilogram of lint. Where pest pressure, erratic rainfall or depleted soils depress seed-cotton yield, fixed emissions from land preparation, agrochemical manufacture and basal fertiliser application concentrate into a smaller harvest. [S26] [S29] Conversely, when agronomy improves lint yield per hectare without a proportional rise in synthetic nitrogen, irrigation pumping or field fuel, embodied carbon per kilogram of lint falls. [S26] [S29] A single global cotton factor conceals both the farm input numerator and the harvest yield denominator. [S16] [S22]

5.2 FIELD ACTIVITY AND GINNING OUTTURN FORM A STAGED PHYSICAL CHAIN

To prevent averages from obscuring physical causes, the inventory must map every flow from soil preparation to the gin bale press. In the comparative T-shirt assessment by Forfora et al., cradle-to-gate modelling of cotton shirts in China shows a global warming potential of 14.1 kg CO2eq per kilogram of T-shirt and water demand of 2.9 cubic metres per kilogram, showing that carbon and water burdens arise together from regional cultivation and processing conditions rather than fibre name alone. [S31] [S0504] **Exhibit 21**, p. 83 defines the cradle-to-gin-gate system boundary required before yarn spinning begins. [S26] [S29] [S31]

EXHIBIT 21 / CRADLE-TO-GIN-GATE SYSTEM BOUNDARY

Field-to-lint inventory tracks inputs and co-products



3. soil flux
4. seed cotton
5. allocated share
6. co-products

SOURCED [S26] [S29] [S31] Sourced process structure synthesising agricultural inputs, soil emissions, ginning co-products and waste flows from Watson and Wiedemann (S26), FAO (S29) and Forfora et al. (S31). This flow diagram defines the accounting boundary and does not assert site-specific Cameroon flow quantities.

Exhibit 21, p. 83 separates three boundaries that are frequently conflated in simplified rating tools: upstream chemical and energy supply to the farm, biological and chemical transformations in the managed soil during cultivation, and mechanical separation of seed cotton at the gin. [S26] [S29] [S31] While **Exhibit 21**, p. 83 establishes which physical flows must be tracked and where co-products diverge, it cannot by itself establish the numerical carbon intensity of any specific cotton bale without dated activity records and regional factors. [S16] [S22]

5.3 IRRIGATION, MECHANISATION AND ROTATION ALTER THE FARM NUMERATOR

The farm numerator varies sharply across cotton regions. In irrigated arid systems, electric or diesel pumping to lift groundwater or pressurise networks can dominate farm energy use, tying the footprint to pumping depth, water volume and grid or diesel carbon intensity. [S14] [S26] [S31] In rainfed smallholder systems, irrigation pumping is absent and tractor operations are limited, shifting the main anthropogenic source towards nutrient management, residue handling and any land-use change. [S26] [S29]

Pesticides, herbicides and defoliants add an upstream chemical manufacturing burden governed by active-ingredient mass per hectare. [S26] [S31] Although pesticide mass per hectare is smaller than fertiliser mass, high spray frequencies still require explicit inventory entries rather than exclusion. [S23] [S26] Because weather and pests

cause annual yield swings, Textile Exchange and LCA review literature emphasise that farm inventories should span a multi-year rotation or disclose the harvest year alongside historical yield variability. [S22] [S26]

5.4

Nitrogen creates both upstream and field emissions

In conventional cotton cultivation, nitrogen management is typically the largest driver of farm greenhouse gas emissions. [S29] The Food and Agriculture Organization of the United Nations (FAO) notes that manufacturing, processing and applying synthetic nitrogen fertilisers emit considerable greenhouse gases across industrial and agricultural stages. [S29] An auditable cotton inventory must never collapse fertiliser into one unlabelled coefficient. It must separate three physical mechanisms: industrial emissions during upstream ammonia and fertiliser manufacture, direct and indirect nitrous oxide (N2O) emissions from managed soils after nitrogen additions, and carbon dioxide (CO2) released from soil hydrolysis when urea or lime is applied. [S29] [S0501] [S0502]

Upstream manufacturing emissions belong to the chemical plant boundary and enter the farm account as a cradle-to-gate factor per kilogram of nutrient applied. [S23] [S29] Ammonia synthesis via the Haber-Bosch process requires hydrogen feedstock and process heat from natural gas, coal or fuel oil, while nitric acid production for nitrate fertilisers generates industrial nitrous oxide unless abated. [S16] [S29] Two cotton basins applying 60 kilograms of synthetic nitrogen per hectare can therefore import very different upstream burdens depending on the supplying fertiliser plants. [S16] [S23]

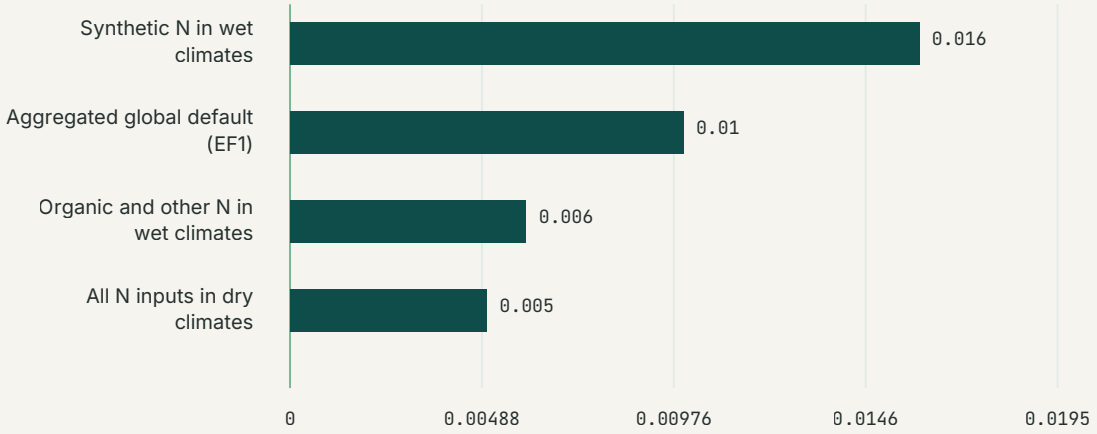
5.5 SOIL NITRIFICATION AND DENITRIFICATION CONVERT APPLIED NITROGEN INTO NITROUS OXIDE

Once nitrogen enters the field, soil microbes govern the second mechanism. Volume 4, Chapter 11 of the 2019 Refinement to the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines explains that soils produce nitrous oxide through nitrification (aerobic oxidation of ammonium to nitrate) and denitrification (anaerobic reduction of nitrate to nitrogen gas, where N2O escapes as an intermediate). [S0501] Adding nitrogen via synthetic fertilisers, manure, compost or crop residues expands the mineral nitrogen pool driving both pathways. [S29] [S0501]

Whereas the 2006 IPCC Guidelines used a single aggregated Tier 1 default factor (EF1) of 0.010 kg N2O-N per kilogram of nitrogen input (0.002 to 0.018 uncertainty range), the 2019 Refinement updates Table 11.1 by climate and nitrogen form: in wet climates, EF1 is 0.016 kg N2O-N per kg synthetic nitrogen (0.013 to 0.019) and 0.006 kg N2O-N per kg organic or other nitrogen (0.001 to 0.011), while in dry climates EF1 is 0.005 kg N2O-N per kg nitrogen across all forms (0.000 to 0.011). [S0501] **Exhibit 22**, p. 85 compares these four Tier 1 default values. [S0501]

EXHIBIT 22 / KG N2O-N EMITTED PER KG N APPLIED (EF1)

Updated IPCC Tier 1 direct soil nitrous oxide factors vary three-fold with climate and nitrogen form



SOURCED [S0501] Sourced directly from Table 11.1 (Updated) and Section 11.2.1.2 of the 2019 Refinement to the 2006 IPCC Guidelines, Volume 4, Chapter 11 (S0501). Values represent direct soil N2O-N emissions before stoichiometric conversion to N2O (multiply by 44/28) and before indirect volatilisation and leaching pathways.

Exhibit 22, p. 85 demonstrates why a cotton carbon model cannot treat soil nitrous oxide as a universal constant. [S0501] Applying the disaggregated wet-climate synthetic factor (0.016 kg N2O-N per kg N) produces 3.2 times the direct soil nitrous oxide of the dry-climate factor (0.005 kg N2O-N per kg N) for the exact same mass of applied synthetic nitrogen, derived as 0.016 / 0.005 = 3.2. [S0501] At the same time, **Exhibit 22**, p. 85 cannot establish the total field emissions of a cotton farm on its own, because the analyst must also include indirect nitrous oxide pathways, urea carbon dioxide hydrolysis, and the stoichiometric and GWP conversions required to express N2O-N as CO2e. [S11] [S0501] [S0502]

5.6 INDIRECT PATHWAYS, UREA HYDROLYSIS AND GWP CHOICES COMPLETE THE FIELD EQUATION

Direct emission from the treated field is only part of the soil nitrogen budget. Some applied nitrogen volatilises as ammonia (NH3) and nitrogen oxides (NOx) and redeposits on land and water, while another fraction leaches or runs off into waterways where further nitrification and denitrification occur. [S0501] In Table 11.3 (Updated) of the 2019 IPCC Refinement, the default synthetic fertiliser volatilisation fraction (FracGASF) is 0.11 aggregated, or disaggregated to 0.15 for urea, 0.08 for ammonium-based, 0.05 for ammonium-nitrate-based and 0.01 for nitrate-based fertilisers, converting to indirect nitrous oxide via the deposition factor EF4 (0.010 aggregated, 0.014 wet, 0.005 dry). [S0501] Where leaching and runoff occur, the default leached fraction (FracLEACH-(H)) is 0.24 kg N per kg N added, multiplied by EF5 of 0.011 kg N2O-N per kg N leached. [S0501]

When urea (CO(NH2)2) is applied, soil water and urease enzymes convert it into ammonium, hydroxyl ions and bicarbonate, releasing the carbon dioxide fixed during industrial urea manufacture. [S0502] Section 11.4 of the 2006 IPCC Guidelines sets a Tier 1 default factor of 0.20 tonnes of carbon per tonne of urea, multiplied by 44 / 12 (0.733 kg CO2 per kg urea). [S0502] [S0503] Every kg N2O-N is then converted to kg N2O

via the molecular ratio `44 / 28` (`1.5714`) and multiplied by the selected 100-year global warming potential (`GWP100`) to yield `kg CO2e`. [S11] [S0501] [S0503] Because IPCC AR6 Working Group I Chapter 7 updates emission metrics over time, both the GHG Protocol Product Standard and Scope 3 guidance require disclosing the exact IPCC GWP report and time horizon. [S11] [S23] [S0503]

> **METHOD**
>
> To calculate cradle-to-gin-gate field nitrogen emissions per hectare, record five terms before dividing by yield: (1) upstream manufacturing CO2e per kg of synthetic nutrient; (2) direct soil N2O-N from synthetic, organic and residue nitrogen via IPCC Table 11.1 (`EF1`); (3) indirect N2O-N from volatilisation (`FracGASF`, `FracGASM`, `EF4`) and leaching (`FracLEACH-(H)`, `EF5`) via IPCC Table 11.3; (4) fossil CO2 from urea or lime hydrolysis (`EF = 0.20` t C per t urea, times `44 / 12`); and (5) conversion of total N2O-N to N2O via `44 / 28`, multiplied by the declared IPCC 100-year GWP. [S11] [S0501] [S0502] [S0503]

5.7

Ginning and losses change the delivered denominator

Even after farm burdens are partitioned per kilogram of baled lint at the gin gate, a kilogram of lint does not equal a kilogram of finished shirt at the factory gate. [S31] Mechanical and wet processing from ginning through carding, combing, spinning, knitting and cutting removes short fibres, trash, yarn waste and offcuts. [S25] [S31] Because the functional unit is the delivered garment, the raw cotton reference flow must be scaled up to cover all cumulative material losses across the chain. [S24] [S31] [S0503]

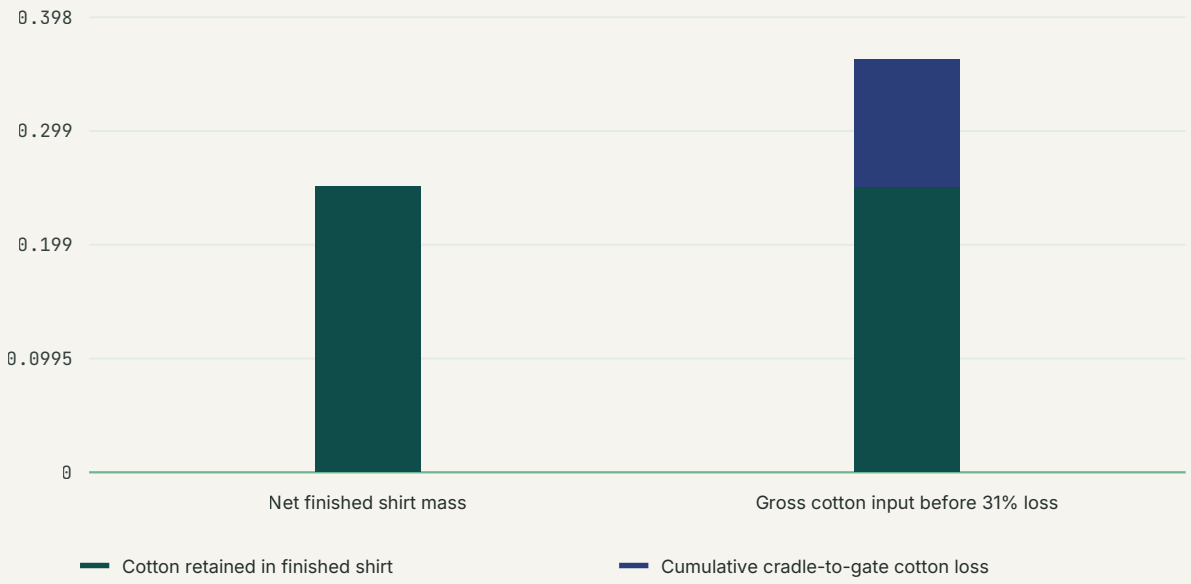
In the 2026 T-shirt assessment by Forfora et al., the baseline medium cotton shirt weighs 250 grams (`0.25` kg) and incurs `31 percent` cumulative cotton loss across its cradle-to-gate boundary. [S31] With `100 - 31 = 69 percent` (`0.69`) mass retention, one `0.25` kg shirt requires `0.25 / 0.69 = 0.3623` kg (362 grams) of cotton input before losses, meaning an extra `0.112` kg (112 grams, or `44.9 percent` of shirt mass) must be grown and ginned to cover process waste. [S31]

5.8 CUMULATIVE MATERIAL LOSS MULTIPLIES UPSTREAM AGRICULTURAL BURDENS

Exhibit 23, p. 87 illustrates this mass reconciliation between the net finished garment mass (`0.250` kg) and the gross cotton input required prior to the 31 percent cumulative loss (`0.362` kg). [S31]

EXHIBIT 23 / KG OF COTTON PER 0.25 KG FINISHED SHIRT

Cotton losses determine the input required for a finished shirt



DERIVED [S31] Derived from Forfora et al. (S31), which specifies a 250 g (0.25 kg) baseline cotton T-shirt and reports 31 percent cumulative cotton loss across the cradle-to-gate chain. Gross cotton required equals 0.25 / (1 - 0.31) = 0.3623 kg (shown as 0.250 kg retained plus 0.112 kg lost, totalling 0.362 kg). This arithmetic reflects the S31 study boundary, not a measured GFT factory loss rate.

The operational consequence of **Exhibit 23**, p. 87 is that every percentage point of waste in ginning, carding, combing, spinning, knitting and cutting acts as a multiplier on upstream farm emissions. [S23] [S31] An analyst who multiplies the emission factor of 1.0 kg of cotton lint by 0.25 kg to estimate the fibre footprint of a 250 g shirt understates the agricultural contribution by 31 percent (0.112 / 0.362), because the farm had to supply 0.362 kg of fibre to deliver 0.250 kg in the garment. [S31] At the same time, **Exhibit 23**, p. 87 reflects the specific process loss cascade modelled in the 2026 comparative T-shirt study and cannot be assumed to equal the actual loss rate of a combed versus carded yarn line or a specific Cameroon mill without stage-by-stage mass balance records. [S23] [S31]

5.9 WASTE TREATMENT AND BY-PRODUCT RECOVERY REQUIRE EXPLICIT ACCOUNTING RULES

What happens to the 0.112 kg of lost cotton per shirt also affects the carbon account. Under ISO 14044 and the GHG Protocol Product Standard, material that leaves the primary production stream is either a waste (an output with no economic value that requires disposal treatment) or a co-product or recyclable secondary material (an output with economic value that enters another product system). [S25] [S0503] In the T-shirt study by Forfora et al., waste streams and their incineration or recovery pathways are tracked within the inventory boundary rather than ignored. [S31]

If gin trash, motes, comber noils or cutting scraps go to landfill or open burning without energy recovery, the inventory bears the upstream burden of growing that lost mass plus direct methane (CH4), nitrous oxide or carbon dioxide from waste treatment. [S23] [S0503] If comber noils are sold to rotor-spinning mills or gin trash is composted for fields, the account must specify whether secondary flows follow co-product

allocation or closed-loop recycling under Chapter 9 of the GHG Protocol Product Standard. [S25] [S0503] Treating losses as an invisible adjustment hides a fast operational lever: improving bale-to-garment yield cuts agricultural carbon per shirt immediately. [S08] [S31]

5.10

Cottonseed changes the allocation question

Before lint leaves the gin, cotton cultivation presents a multi-output allocation problem. A cotton plant grows bolls of seed cotton that gin saws or rollers separate into baled lint and cottonseed, alongside gin trash. [S26] By mass at the gin gate, cottonseed outweighs lint: a ginning outturn of 35 to 42 percent lint implies roughly 55 to 62 percent cottonseed and a small trash fraction, or about 1.3 to 1.6 kilograms of cottonseed per kilogram of lint. [S26] Oil mills crush cottonseed into edible oil and protein-rich livestock meal or cake, alongside hulls and linters. [R03] [S26]

Because cultivation inputs, irrigation and soil nitrous oxide emissions occur upstream of the ginning saw, they are joint burdens shared by lint and cottonseed. [S26] Both ISO 14044 and Chapter 9 of the GHG Protocol Product Standard set a strict hierarchy for multi-functional processes: first, avoid allocation where possible through process subdivision, redefining the functional unit, or system expansion; second, where allocation is unavoidable, partition emissions by underlying physical relationships; third, when physical relationships alone cannot be established, apply economic allocation or another relationship reflecting the co-products. [S24] [S25] [S0503]

5.11 PHYSICAL, ECONOMIC AND SYSTEM-EXPANSION RULES PRODUCE DIVERGING LINT FOOTPRINTS

In cotton life cycle studies, choosing among these steps changes the lint footprint substantially. [S22] [S26] Process subdivision cannot split cultivation burdens between lint and seed because both grow inside the same boll. [S26] [S0503] Analysts must therefore choose between physical allocation (mass or energy), economic allocation (relative market revenue at the gin gate), or system expansion (crediting displaced vegetable oil and animal feed). [S26] [S0503] **Exhibit 24**, p. 89 compares these four options under ISO 14044 and the GHG Protocol Product Standard. [S24] [S25] [S26] [S0503]

EXHIBIT 24 / METHODOLOGICAL COMPARISON UNDER ISO 14044 AND GHG PROTOCOL

Co-product rules at the gin gate alter the share of farm burden assigned to lint

Allocation method	Partitioning basis at gin	Effect on lint burden	Standard rule and audit condition
Process subdivision	Sub-meter distinct unit operations	Separates post-ginning baling or crushing only	Preferred first step in S25 and S0503, but cannot split shared plant growth
Physical allocation	Mass or energy share of lint vs seed	Assigns minority share (often 35% to 45% by mass) to lint	Favoured by S25 and S0503 where a physical relationship governs the process
Economic allocation	Relative market value of lint vs seed	Assigns majority share (often 80% to 90% of value) to lint	Used in S26 and S31 when market revenue reflects the primary production driver
System expansion	Displaced oilseed meal and vegetable oil	Deducts or reports avoided co-product burden separately	Requires direct knowledge of co-product use (S0503) and consequential boundary (S26)

SOURCED [S24] [S25] [S26] [S0503] Sourced methodological synthesis from ISO 14040 (S24), ISO 14044 (S25), Watson and Wiedemann (S26) and the GHG Protocol Product Standard Chapter 9 (S0503). The table summarises how each standard rule partitions joint cultivation and ginning burdens between cotton lint and cottonseed.

As **Exhibit 24**, p. 89 shows, physical and economic allocation diverge sharply for cotton because mass and price move in opposite directions. [S26] Cottonseed forms the majority of boll mass, whereas lint commands a much higher price per kilogram, so economic allocation assigns most farm and gin emissions to lint while mass allocation assigns most to cottonseed. [S26] [S31] Watson and Wiedemann identify co-product allocation as a primary reason why rating tools generate conflicting fibre rankings. [S26]

Neither option is free of caveats. Economic allocation reflects that cotton is planted primarily for fibre revenue, which is why ecoinvent and Forfora et al. apply economic partitioning. [S16] [S26] [S31] Because lint and seed prices fluctuate across seasons, a multi-year average price ratio must be documented so market swings do not masquerade as farm efficiency changes. [S22] [S26] System expansion asks which marginal oilseed crop is displaced when cottonseed is crushed, a consequential question that must not be silently blended into an attributional product footprint. [S26] [S0503]

WORKED EXAMPLE

This illustrative case shows how yield, IPCC nitrous oxide factors, processing losses and co-product allocation determine the agricultural carbon assigned to a 0.25 kg (250 g) cotton shirt. All farm inputs and prices are illustrative assumptions to make the equations inspectable, not a measured GFT or Cameroon baseline. [S26] [S31] [S0501] [S0503]

1. **Illustrative farm activity and yield:** Assume 1.0 hectare receives 80 kg N as urea (173.9 kg urea at 46 percent N), 220 kg CO2e from fuel, agrochemicals and ginning, and 320 kg CO2e from upstream urea manufacture (4.0 kg CO2e per kg N). Harvested seed cotton is 1,500 kg per hectare, yielding 600 kg lint (40 percent), 840 kg cottonseed (56 percent), and 60 kg waste trash (4 percent). [S26] [S0503]
2. **Illustrative wet-climate field CO2 and N2O pathway:** Urea hydrolysis emits 0.1739 * 0.20 * (44 / 12) = 0.1275 tonnes CO2 (127.5 kg CO2), and volatilisation (FracGASF = 0.15) releases 80 * 0.15 = 12.0 kg N. [S0501] [S0502] Under IPCC wet-climate defaults (S0501), direct N2O-N is 80 * 0.016 = 1.280 kg, volatilisation N2O-N (EF4 = 0.014) is 12.0 * 0.014 = 0.168 kg, and leaching N2O-N (FracLEACH-(H) = 0.24, EF5 = 0.011) is 80 * 0.24 * 0.011 = 0.2112 kg, totalling 1.6592 kg N2O-N or 1.6592 * (44 / 28) = 2.6073 kg N2O. At an illustrative GWP of 273 (S11), soil N2O is 711.8 kg CO2e, giving 220 + 320 + 127.5 + 711.8 = 1,379.3 kg CO2e per hectare. [S11] [S0501] [S0502]
3. **Illustrative dry-climate unirrigated field CO2 and N2O pathway:** Under IPCC dry-climate defaults (S0501), direct N2O-N (EF1 = 0.005) is 0.400 kg, volatilisation N2O-N (EF4 = 0.005) is 0.060 kg, and leaching is 0.000 kg. Total soil N2O-N is 0.460 kg (0.7229 kg N2O), or 197.3 kg CO2e at an illustrative GWP of 273, giving 220 + 320 + 127.5 + 197.3 = 864.8 kg CO2e per hectare. [S11] [S0501] [S0502]
4. **Illustrative allocation between 600 kg lint and 840 kg cottonseed (1,440 kg co-products):** By mass (41.67 percent lint), lint receives 574.7 kg CO2e (0.958 kg CO2e per kg lint) in the wet climate and 360.3 kg CO2e (0.601 kg CO2e per kg lint) in the dry climate. [S26] [S0503] By illustrative economic value (85 percent lint, 15 percent seed), lint receives 1,172.4 kg CO2e (1.954 kg CO2e per kg lint) in the wet climate and 735.1 kg CO2e (1.225 kg CO2e per kg lint) in the dry climate. [S26] [S0503]
5. **Effect of 31 percent cumulative loss per 0.25 kg shirt (0.3623 kg lint required per S31):** Multiplying each illustrative lint intensity by 0.3623 kg yields 0.218 kg CO2e per shirt (dry, mass allocation) up to 0.708 kg CO2e per shirt (wet, economic allocation), a 3.25-fold swing from climate and allocation rule alone. [S26] [S31] [S0501]

5.12

Biogenic and soil carbon require separate treatment

Because cotton is a cellulosic fibre composed largely of carbon absorbed via photosynthesis, sponsors are sometimes tempted to subtract the embedded carbon of harvested fibre from fossil and nitrous oxide cultivation emissions and declare cotton carbon-negative at the farm gate. [S29] [S31] [S0503] That deduction is an accounting error unless strict boundary, reporting and end-of-life rules are met. Biogenic carbon

in the fibre, soil organic carbon changes in the field, and fossil or nitrous oxide emissions from farm inputs are three distinct flows that standards require to be tracked and disclosed separately. [S05] [S29] [S0503]

Chapter 7 (Box 7.2) and Chapter 11 of the GHG Protocol Product Standard establish clear rules: first, biogenic carbon removal reflects only the carbon physically embedded in the material (converted from elemental carbon to CO2 via 44 / 12); second, companies must report biogenic and non-biogenic emissions and removals separately, land-use change impacts separately, and, for cradle-to-gate inventories, the carbon contained in the intermediate product. [S0503] Embedded biogenic carbon in a shirt is temporary storage, not permanent sequestration: when the garment is incinerated or decomposes at end-of-life, that carbon returns to the atmosphere as biogenic CO2 or CH4. [S01] [S31] [S0503]

5.13 PARTIAL FOOTPRINTS MUST NOT CLAIM PERMANENT REMOVAL FOR TEMPORARY FIBRE STORAGE

In a cradle-to-grave footprint, photosynthetic CO2 uptake during growth and biogenic CO2 release during complete aerobic degradation or incineration cancel to zero net CO2 (while anaerobic conversion to landfill CH4 increases net warming because CH4 has a higher GWP than CO2). [S11] [S31] [S0503] In a partial cradle-to-gate footprint stopping at the gin or factory gate, crediting photosynthetic uptake without showing downstream end-of-life release creates an artificial carbon sink that vanishes when the boundary is completed. [S01] [S0503] Forfora et al. and European apparel rules therefore prevent temporary biogenic storage in garments from masking fossil and soil nitrous oxide burdens, while ISO 14067 requires separate disclosure of fossil, biogenic and land-use components. [S05] [S06] [S31]

Soil organic carbon (SOC) and land-use change (LUC) require even stricter verification. FAO guidance explains that conservation tillage, cover crops, residue retention and integrated soil fertility management can build soil organic matter, whereas deforestation, savannah conversion, deep tillage or residue burning depletes soil carbon and triggers mineralised nitrogen emissions (FSOM). [S29] [S0501] Because soil carbon gains are reversible if tillage or drought occurs, the GHG Protocol Product Standard prohibits arbitrary weighting factors for delayed emissions or removals inside the main inventory total. [S29] [S0503]

> **WARNING**
>
> Never subtract unverified soil carbon credits or temporary biogenic carbon in lint from fossil and nitrous oxide emissions to claim a reduced or net-negative cradle-to-gate cotton footprint. Under the GHG Protocol Product Standard and Directive (EU) 2024/825, biogenic removals, land-use change impacts and fossil emissions must be disclosed separately, and external offsets cannot substantiate a product carbon claim. [S32] [S0503] Soil carbon changes enter the account only when measured or modelled under an approved land-sector protocol over a multi-year period with permanence and reversal controls. [S29] [S0501] [S0503]

5.14

Cameroon cotton needs farm evidence, not imported averages

Applying these rules to Cameroon separates what the inherited programme register establishes from what remains unmeasured. In the inherited evidence base, Cameroon's seed-cotton output reached 330,000 tonnes in 2022, 314,455 tonnes in 2023 and about 340,000 tonnes in 2024, with a 2025 projection above 350,000 tonnes, within CFA-zone output of 2.3 million tonnes in 2024/25. [R01] [R02] [R05] The register records that the Société de Développement du Coton du Cameroun (SODECOTON) supports more than 220,000 cotton producers in northern Cameroon, operates nine ginning plants and two oil mills, and injects roughly US$100 million a year into rural communities. [R03] [R04] About 95 percent of Cameroon's cotton fibre is exported raw against 5 percent processed locally, with an SND30 target of 50 percent local processing by 2030. [R06] [R07]

Those inherited records, whose original publication dates were not recorded, establish two operational facts. First, Cameroon already has an institutional structure connecting smallholder agronomy, input distribution, seed-cotton collection, nine gins and two cottonseed oil mills, making farm input, ginning outturn and co-product boundaries identifiable. [R03] Second, none of those sector figures provides a measured emission factor per kilogram of Cameroonian seed cotton or lint. [R01] [R03] [R06] High raw export share (95 percent) and producer scale (220,000) describe industrial opportunity; they do not prove that northern Cameroonian lint has a lower or higher carbon footprint than global averages. [R03] [R06]

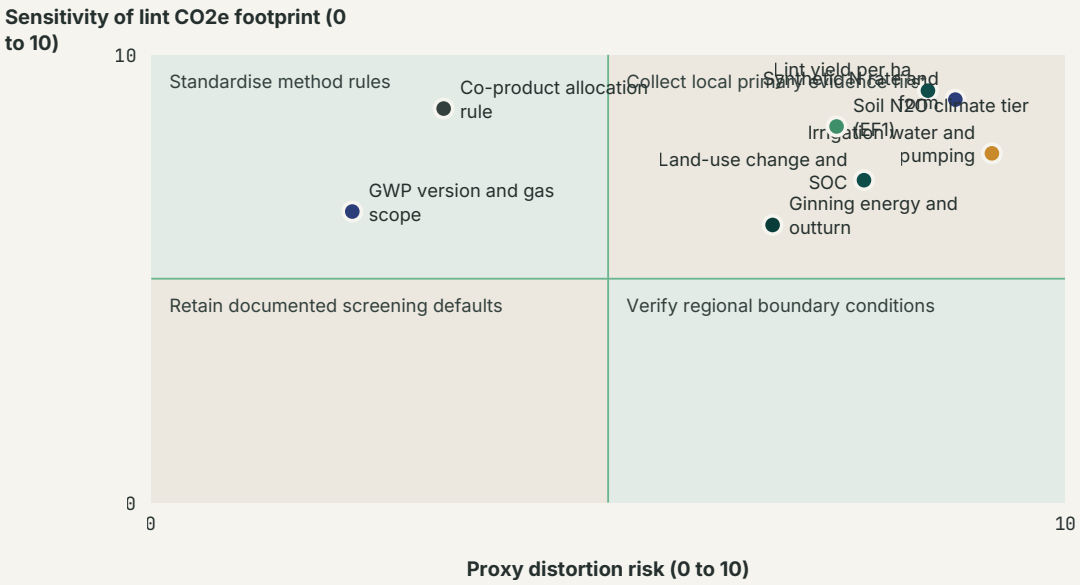
5.15 BACKGROUND DATABASE PROXIES MUST GIVE WAY TO A LOCAL FARM-TO-GIN REGISTER

When an apparel sponsor models a Cameroon cotton garment today, ecoinvent and apparel-specific databases such as the World Apparel and Footwear Life Cycle Assessment Database (WALDB) can supply initial screening proxies. [S16] [S17] However, ecoinvent explicitly states that its database processes represent average production conditions within a geographical location rather than company-specific or site-specific conditions, and Textile Exchange cautions that fibre LCA results are highly sensitive to methodological choices, assumptions and boundaries. [S16] [S22] Substituting a Chinese, United States or Rest-of-World irrigated cotton dataset for rainfed smallholder production in northern Cameroon introduces immediate technology, climate and geographic mismatches across irrigation energy, synthetic nitrogen rates, IPCC wet-versus-dry soil EF1 factors and gin power sources. [S16] [S23] [S0501]

To move from a secondary screening proxy to a representative Cameroon cotton account, GFT structures the evidence requirement as a prioritised governance matrix. **Exhibit 25**, p. 93 maps the eight core parameters of a cotton field-to-lint register across two decision dimensions derived from the literature: the sensitivity of the lint carbon result to the parameter (y axis) and the proxy distortion risk when relying on a generic global dataset instead of local Cameroon records (x axis). [S11] [S16] [S26] [S29] [S0501]

EXHIBIT 25 / PRIORITY SCORE FROM 0 (LOW) TO 10 (HIGH)

A cotton evidence register separates activity, factor and counterfactual priorities



SOURCED [S11] [S16] [S26] [S29] [S0501] Sourced governance classification mapped on a 0 to 10 decision grid. The eight register fields are drawn from IPCC metric and soil rules (S11, S0501), ecoinvent geographic proxy limits (S16), Watson and Wiedemann cotton LCA sensitivity review (S26) and FAO nitrogen guidance (S29). Coordinates represent analytical priority for primary-data replacement in GFT's Cameroon programme, not measured emissions.

Exhibit 25, p. 93 separates parameters that require field and gin data collection in northern Cameroon (upper-right quadrant) from parameters that require methodological governance in the accounting manual (upper-left quadrant). [S16] [S23] [S26] Specifically, lint yield per hectare, synthetic nitrogen application rate and fertiliser form (urea versus compound NPK), irrigation status (confirming rainfed cultivation rather than importing an irrigated proxy), soil climate regime (EF1 wet versus dry disaggregation under S0501), and land-use change history sit in the high-risk, high-sensitivity quadrant because global database averages do not reflect northern Cameroon agronomy. [S16] [S29] [S0501] Conversely, the co-product allocation rule between lint and cottonseed (S26) and the IPCC GWP version (S11) have low geographic proxy risk because they are methodological choices controlled directly by the practitioner, yet they exert strong influence over the final numerical result and must therefore be locked in the chart of accounts. [S11] [S26] [S0503] What **Exhibit 25**, p. 93 cannot do is substitute for those field records: until cohort-level agronomic data and gin energy logs are collected, any Cameroon cotton figure remains a screening estimate. [S23]

5.16 A PHASED SAMPLING PROTOCOL CONNECTS SMALLHOLDER COHORTS TO GIN BALES

Collecting primary data across more than 220,000 smallholder producers does not require placing an individual emissions meter on every two-hectare plot. [R03] [S23] The GHG Protocol Scope 3 guidance and PACT Methodology Version 3 support stratified sampling and supplier-cohort accounting where primary activity records are aggregated at natural operational bottlenecks. [S10] [S23] In northern Cameroon, the nine ginning plants and two oil mills recorded in the sector profile, together with producer-group input distribution ledgers, form that exact bottleneck. [R03]

Under GFT's digital strategy and performance-management architecture, a cotton field-to-lint account can be assembled in three operational tiers without inventing unsupported precision:

1. **Gin-gate physical mass balance and utility metering (Primary operational data):** Each ginning plant already weighs incoming seed cotton by catchment zone and outgoing baled lint, cottonseed and gin trash, while recording diesel, biomass or grid electricity consumed during the ginning campaign. [R03] [S20] Capturing these records per gin and harvest season fixes the exact ginning outturn, gate-to-gate gin energy intensity and physical co-product ratio between lint and cottonseed. [S23] [S26]
2. **Catchment-level agronomic input and yield ledgers (Stratified primary cohort data):** Because cotton farmers receive seed, synthetic fertiliser (such as compound NPK and urea) and crop-protection chemicals through organised seasonal credit and extension channels associated with the ginning catchments, total nutrient mass distributed per catchment divided by planted area and delivered seed-cotton tonnage yields a verifiable, cohort-specific nitrogen rate per hectare and seed-cotton yield per hectare. [R03] [S23] [S29] Combining those cohort records with meteorological rainfall and evapotranspiration records for the northern cotton belt allows the inventory to select the appropriate disaggregated IPCC Tier 1 (EF1, EF4, EF5) or country-specific Tier 2 soil nitrous oxide factors rather than defaulting to an undifferentiated global average. [S0501]
3. **Explicit proxy register for background upstream factors (Documented secondary data):** Until fertiliser suppliers provide verified cradle-to-gate product footprints compliant with PACT Version 3 or ISO 14067, the upstream manufacturing emissions of imported urea, NPK and agrochemicals should be modelled using documented ecoinvent or WALDB background processes, flagged explicitly in the proxy register with their database version and geographic scope. [S05] [S10] [S16] [S17]

> **GFT NOTE**
>
> In GFT's Cameroon textile programme, no garment footprint or marketing document may describe Cameroonian cotton as "low-carbon" or "carbon-negative" by default. Instead, the programme's cotton evidence specification requires every lint lot entering a domestic spinning mill (whether under existing operations or announced projects such as the SODECOTON-CICAM industrial pole or Camtext SA in the inherited register) to carry a six-field Gin-Gate Carbon Record: (1) harvest season and gin catchment identifier; (2) seed-cotton yield per hectare and ginning lint outturn percentage; (3) synthetic and organic nitrogen applied per hectare by chemical form, paired with the IPCC soil factor tier and GWP version; (4) gin electricity and fuel consumed per tonne of baled lint; (5) dual reporting of lint carbon intensity under both economic allocation and physical mass allocation alongside cottonseed; and (6) separate disclosure of embedded biogenic carbon (kg CO_2e per kg lint) and any verified land-use change impact. [R03] [R08] [R09] [S26] [S0501] [S0503]

This discipline links the agricultural foundation of the garment directly to the industrial stages that follow. When a spinning mill receives baled lint accompanied by a Gin-Gate Carbon Record that separates farm activity, soil nitrous oxide, gin energy, co-

product allocation and biogenic carbon, the mill can apply its own metered spinning, knitting and dyeing loads without losing sight of how much raw cotton had to be grown to survive cumulative processing waste. [S23] [S31] The field account ends at the gin bale press; the industrial energy account begins at the opening room.

A cotton bale carries the arithmetic of its harvest yield, its nitrogen regime and its co-product rule long before it touches a spindle.

CHAPTER SOURCE NOTES

S26 Watson and Wiedemann, Sustainability. 2019-07-15.

S29 Food and Agriculture Organization of the United Nations. 2017.

S31 Forfora et al., Sustainability. 2026-04-20.

S22 Textile Exchange. 2026-07-16.

S01 GHG Protocol. 2011.

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S0504 Aalto University Research Portal. 2026-04.

S14 International Energy Agency. 2026-09-25.

S23 GHG Protocol and Carbon Trust. 2013.

S0501 Intergovernmental Panel on Climate Change. 2019-05.

S0502 Intergovernmental Panel on Climate Change. 2006.

S11 Intergovernmental Panel on Climate Change. 2021-08-06.

S0503 World Resources Institute and World Business Council for Sustainable Development. 2011-09.

S25 International Organization for Standardization. 2006-07.

S24 International Organization for Standardization. 2006-07.

S08 Science Based Targets initiative and World Resources Institute. 2019.

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

S05 International Organization for Standardization. 2018-08.

S06 European Commission. 2025-06-25.

S32 European Parliament and Council of the European Union. 2024-02-28.

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

R02 Fibre2Fashion; Business in Cameroon. 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.

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

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

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GREEN FUTURE TECH

LIMITED / HONG KONG SAR

06

PART II: FOLLOW CARBON THROUGH THE GARMENT / PROCESSING HOTSPOTS

Fibre, yarn and fabric convert energy into embodied carbon

Processing geography, thermal energy and functional performance can matter as much as the fibre name.

CHAPTER 06
DECISION TEST

Processing geography, thermal energy and functional performance can matter as much as the fibre name.

A garment's embodied carbon is determined less by the generic name of its fibre than by the electrical grids, steam boilers, chemical recovery loops and mechanical specifications that convert raw feedstock into finished fabric. [S08] [S31] Across apparel supply chains, upstream material production, yarn preparation, fabric formation and wet processing routinely account for more than half of full life cycle greenhouse gas emissions, dwarfing the direct electricity used in final cut, make and trim assembly. [S08] [S31] In the April 2026 comparative T-shirt life cycle assessment (LCA) by Forfora et al., evaluated across cotton, polyester, viscose and Lyocell under one consistent cradle-to-gate model in China, 1 kilogram of cotton T-shirts records the lowest global warming potential at 14.09 kg CO2eq/kg (14.1 kg CO2eq/kg in headline summaries), followed by polyester at 14.41 kg CO2eq/kg, viscose at 20.68 kg CO2eq/kg and Lyocell at 21.61 kg CO2eq/kg (21.6 kg CO2eq/kg). [S31] [S0601] Yet three operational variables reorder that apparent hierarchy: shifting manufacturing from China's coal-heavy energy supply to Brazil's cleaner grid and biomass-rich steam mix cuts global warming impacts by up to 38 percent across the studied fibres, scaling garment weight to equivalent yarn tenacity reduces required polyester mass from 250 grams to 115 grams and Lyocell mass to 153 grams, and improving solvent or heat recovery alters process intensity within a single fibre class. [S31] [S0601] For Green Future Tech Limited (GFT) and its Cameroon textile programme, where about 95 percent of cotton lint is exported raw against 5 percent processed locally and national policy targets 50 percent domestic processing by 2030, localising spinning, knitting, weaving and dyeing will only yield low-carbon garments if electricity, steam, chemicals and stage losses are metered by process stage from the first shift. [R06] [R07] [S20] [S23]

6.1

Fibre production sets the first industrial burden

An accurate product carbon account begins by locating where physical energy and chemical transformations occur along the supply chain rather than treating the sewing factory as the centre of the inventory. [S08] [S23] In the value-chain architecture defined by the Science Based Targets initiative (SBTi) and World Resources Institute (WRI) for the apparel sector, manufacturing spans five tiers: Tier 4 covers raw material extraction and cultivation (cotton farming, pulp forestry, synthetic polymers); Tier 3 covers staple fibre and yarn spinning; Tier 2 covers material production and finishing (knitting, weaving, pretreatment, dyeing, printing and finishing); Tier 1 covers finished product assembly (cutting, sewing and packaging); and Tier 0 covers offices, distribution and retail. [S08] Because Tier 1 assembly relies on fractional-kilowatt sewing and cutting machines, whereas Tiers 2 to 4 require polymerisation, chemical regeneration, ring spinning and pressurised steam dyeing, the upstream tiers carry the dominant carbon burden. [S08] [S31]

6.2 UPSTREAM TIERS CARRY THE BULK OF APPAREL VALUE-CHAIN CARBON

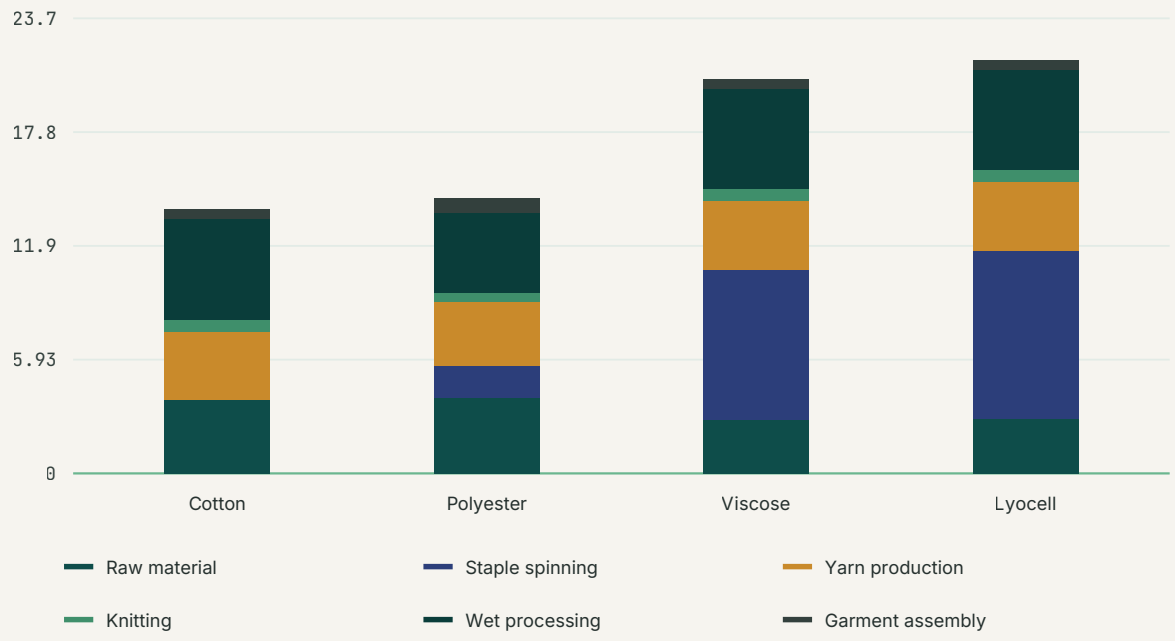
Sector inventories in the SBTi apparel guidance confirm that dyeing and finishing, yarn preparation and fibre production (Tiers 2 to 4) are the most carbon-intensive phases of apparel manufacturing and frequently represent more than 50 percent of full cradle-to-grave emissions. [S08] Corporate disclosures illustrate this concentration: in a 2016 full value-chain inventory for Levi Strauss and Co. totalling 5.24 million tonnes of CO2e, fabric production accounted for 31 percent of emissions and cotton cultiva-

tion for 10 percent, against 9 percent for assembly, 6 percent for sundries and 6 percent for transport. [S08] Similarly, C&A's 2017 inventory of 5,032,903 tonnes of CO2e recorded 95.86 percent of emissions in Scope 3, with 73.15 percent in Category 1 (Purchased goods and services), while Nike's footprint attributed 19 percent to polyester, 19 percent to colour and finishing, 15 percent to foam and rubber, 7 percent to cotton and 7 percent to leather, against 7 percent for assembly. [S02] [S08]

To isolate how each upstream stage contributes without methodological distortion across studies, Forfora et al. (2026) modelled 1 kilogram of finished T-shirts made from cotton, polyester, viscose and Lyocell across seven cradle-to-gate stages: raw material production, transport, staple spinning, yarn production (ring spinning), knitting, wet processing and finishing, and T-shirt manufacture. [S31] [S0601] **Exhibit 26**, p. 98 presents the exact stage-by-stage global warming potential (GWP) values from the study's Chinese baseline inventory (Tables S3 to S7). [S31] [S0601]

EXHIBIT 26 / KG CO2EQ PER KG OF FINISHED T-SHIRT

Cradle-to-gate contributions vary by process stage and fibre



SOURCED [S31] [S0601] Sourced directly from the six manufacturing stages in Tables S3, S4, S5 and S6 of Forfora et al. (2026) and its Supplemental Material (S31, S0601) for the China baseline scenario (100-year GWP, ReCiPe 2016 H). Raw-material rail transport adds 0.30, 0.09, 0.12 and 0.06 kg CO2eq/kg to reach full Table S7 totals of 14.09, 14.41, 20.68 and 21.61 kg CO2eq/kg.

As **Exhibit 26**, p. 98 shows, final garment assembly contributes only 0.51 kg CO2eq/kg for cotton, viscose and Lyocell (2.4 to 3.6 percent of cradle-to-gate totals) and 0.76 kg CO2eq/kg for polyester (5.3 percent, higher because cutting-waste incineration releases 2.31 kg CO2/kg synthetic waste whereas cellulosic combustion is biogenic). [S31] [S0601] The remaining 94.7 to 97.6 percent of emissions occur before dyed fabric reaches the cutting table. [S31] [S0601] While **Exhibit 26**, p. 98 establishes the exact stage breakdown for the Chinese baseline model, it cannot serve as a universal lookup table for other countries or mills, because each segment reflects China's coal-dominated energy factors and literature-average yields. [S16] [S31]

6.3 RAW MATERIAL AND STAPLE FIBRE MECHANISMS DIFFER SHARPLY ACROSS THE FOUR MAJOR FIBRES

Examining `Raw material` and `Staple spinning` in **Exhibit 26**, `p. 98` explains why natural, synthetic and man-made cellulosic fibres (MMCFs) enter the yarn mill with distinct energy and chemical profiles. `[S31]` `[S0601]` Global 2024 production reached roughly 90 million tonnes of polyester, 26.4 million tonnes of cotton, 6.4 million tonnes of viscose and 0.7 million tonnes of Lyocell, within a total fibre market that Textile Exchange reports rose from 125 million tonnes in 2023 to 132 million tonnes in 2024. `[S07]` `[S31]` Each fibre family reaches the spinning gate through a different mechanism: `[S31]`

1. **Cotton (lint directly to yarn spinning):** Cotton requires no chemical extrusion (`0.00 kg CO2eq/kg` in staple spinning) because ginned lint is already a staple fibre. `[S31]` `[S0601]` Its initial burden sits in `Raw material` at 3.83 kg CO2eq/kg shirt, plus 0.30 kg CO2eq/kg for 4,002 km of rail transport (`1.46` field emissions, `1.43` fertilisers at 116.3 kg N, 77.4 kg P2O5 and 49.4 kg K2O/t lint at 2.33 t/ha yield, `0.86` irrigation/ginning power at 657.3 kWh/t lint, and `0.08` heat). `[S31]` `[S0601]` At the staple gate, cotton lint registers 2.8 kg CO2eq/kg (range 1.0 to 5.2), while incurring the highest water use at 2.91 m3/kg shirt (2,310 m3/t irrigation), land use at 6.74 m2a crop eq/kg shirt and terrestrial ecotoxicity at 189.07 kg 1,4-DCB eq/kg shirt. `[S31]` `[S0601]`
2. **Polyester (PET resin and melt spinning):** Fossil PET resin contributes 3.93 kg CO2eq/kg shirt (`3.89` heat) plus 0.09 kg CO2eq/kg for 1,329 km of rail transport. `[S31]` `[S0601]` Melt-spinning PET pellets uses 4.9 MJ of heat (4.8 to 5.0 MJ) and 0.66 kWh of electricity (0.64 to 0.69 kWh) per kilogram of yarn, adding 1.69 kg CO2eq/kg shirt (`0.87` heat, `0.82` electricity) for a 3.1 kg CO2eq/kg staple gate intensity. `[S31]` `[S0601]` Melt spinning uses no solvents and keeps water use to 0.15 m3/kg shirt, but polymer persistence yields 1.0 kg/kg shirt of plastic accumulation versus 0.1 kg/kg for cellulosics. `[S31]` `[S0601]`
3. **Viscose (dissolving pulp and xanthate derivatisation):** Viscose and Lyocell start from eucalyptus forestry and pre-hydrolysis kraft (PHK) dissolving pulp. `[S31]` In the study's WinGEMS simulation of Chinese PHK mills (90.5 percent of China's 1.2 million tonnes of viscose-pulp capacity), wood-to-pulp yield is 36.3 percent (2,476.8 kg dry chips/t pulp), energy demand is 23.1 GJ/t pulp, and black liquor and hog fuel supply 87.3 to 88.6 percent of power while coal in the lime kiln (36.0 kg/t) and power boiler (139.2 kg/t) drives fossil emissions (`2.79 kg CO2eq/kg` viscose shirt). `[S31]` `[S0601]` The major carbon spike occurs in viscose staple spinning (`7.82 kg CO2eq/kg shirt`, or 37.8 percent of total viscose GWP): treating pulp with sodium hydroxide (0.55 kg/kg fibre) and carbon disulphide (CS2, 85.7 g/kg) and regenerating in sulphuric acid (0.77 kg H2SO4 and 12.2 g zinc/kg) uses 21.5 MJ of steam (19.4 to 25.5 MJ), 0.97 kWh of power (0.74 to 1.15 kWh) and 50.9 L/kg of water (`4.37` heat, `1.33` electricity, `2.12` chemicals). `[S31]` `[S0601]` Economic allocation between viscose (USD 2,000/t) and sodium sulphate (0.6 kg/kg fibre at USD 180/t) assigns 97.4 percent of burden to viscose, and CS2/sulphur emissions make viscose highest in ten of 18 ReCiPe categories. `[S31]` `[S0601]`
4. **Lyocell (NMMO dissolution and solvent recovery):** Lyocell shares the dissolving pulp base (`2.85 kg CO2eq/kg shirt`) and forms no sodium sulphate co-product. `[S31]` `[S0601]` Closed-loop N-methylmorpholine-N-oxide (NMMO) dissolution cuts

staple-spinning chemical emissions from 2.12 to 1.25 kg CO2eq/kg (54.3 g NMMO make-up, 214.1 g HCl, 158.4 g NaOH and 42.3 g H2O2/kg fibre) and lowers shirt water use to 0.12 m3/kg. [S31] [S0601] However, evaporating water to reconcentrate NMMO requires 24.4 MJ of steam (21.3 to 27.4 MJ) and 1.6 kWh of power (1.4 to 1.8 kWh) per kilogram of fibre, pushing Chinese Lyocell staple spinning to 8.75 kg CO2eq/kg shirt (5.07 heat, 2.42 electricity), a 6.1 kg CO2eq/kg staple intensity and a 21.61 kg CO2eq/kg shirt total. [S31] [S0601]

Under ISO 14067 and the GHG Protocol Product Standard, the headline totals of 14.09, 20.68 and 21.61 kg CO2eq/kg exclude the 1.8 kg CO2eq/kg shirt of embedded biogenic carbon (which would lower apparent gate totals to 12.3, 18.9 and 19.8 kg CO2eq/kg), because biogenic uptake and release must be tracked separately rather than netted against fossil process emissions. [S01] [S05] [S31]

6.4

Yarn preparation makes electricity a product input

Once staple fibres reach the spinning mill, conversion into yarn and greige fabric is mechanical: opening, carding, drawing, roving, ring spinning, winding and knitting or weaving. [R03] [S08] [S31] Mechanical yarn and fabric formation use virtually no steam in cellulosic lines, converting grid electricity directly into product carbon while multiplying upstream burdens through waste. [S31] [S0601]

6.5 RING SPINNING AND FABRIC FORMATION CONVERT GRID MEGAWATT-HOURS INTO YARN CARBON

In the Chinese T-shirt inventory (Tables 3, 4 and S3 to S6), ring spinning (Yarn production) averages 3.2 kWh of electricity per kilogram of undyed yarn (range 1.7 to 5.0 kWh/kg) plus 8.7 L/kg of conditioning water (8.3 to 9.1 L/kg), contributing 3.56 kg CO2eq/kg of cotton, viscose or Lyocell shirt (100 percent from purchased electricity) and 3.35 kg CO2eq/kg for polyester (3.34 from electricity). [S31] [S0601]

That single electrical load represents 25.3 percent of the cradle-to-gate footprint of a cotton T-shirt (3.56 / 14.09), 23.2 percent of polyester (3.35 / 14.41), 17.2 percent of viscose (3.56 / 20.68) and 16.5 percent of Lyocell (3.56 / 21.61). [S31] [S0601] The three-to-one literature spread (1.7 to 5.0 kWh/kg yarn) shows why secondary averages cannot replace sub-metering: fine combed compact yarns spun at high twist on older frames approach 5.0 kWh/kg, whereas modern carded or rotor lines with variable-frequency drives operate near 1.7 kWh/kg. [S23] [S31] Circular knitting adds 0.56 kWh/kg of undyed cellulosic fabric (0.09 to 1.39 kWh/kg), or 0.62 kg CO2eq/kg shirt, and 0.35 kWh/kg plus 0.19 MJ/kg heat for polyester (0.43 kg CO2eq/kg shirt). [S31] [S0601] Together, spinning and knitting emit 4.18 kg CO2eq/kg in cellulosic shirts and 3.78 kg CO2eq/kg in polyester shirts, roughly eight times final cutting and sewing (0.51 kg CO2eq/kg). [S31] [S0601]

6.6 MATERIAL YIELD LOSSES COMPOUND UPSTREAM ELECTRICAL AND AGRICULTURAL BURDENS

Attaching metered electricity to a product footprint requires tracking the mass cascade of process waste (Figure 2 and Tables 3 to 5 of Forfora et al., 2026): [S20] [S23] [S31]

- **Cotton (31 percent cumulative loss):** Delivering `1.00 kg` of shirts after `10%` assembly loss requires `1.11 kg` of dyed fabric; `8%` wet-processing loss requires `1.21 kg` of undyed fabric; `2.3%` knitting loss requires `1.23 kg` of yarn; and `14.9%` spinning loss (`15%` in Figure 2) requires `1.45 kg` of ginned lint. [S31]
- **Polyester (27 percent cumulative loss):** Delivering `1.00 kg` of shirts after `10%` assembly (`1.11 kg` dyed fabric), `3%` wet-processing (`1.14 kg` undyed fabric), `1.5%` knitting (`1.16 kg` yarn) and `15%` spinning loss requires `1.37 kg` of staple fibre and PET resin. [S31]
- **Viscose and Lyocell (31 percent textile loss; 73.8 percent from wood chips):** Both match cotton's `1.45 kg` to `1.00 kg` textile cascade (`31%` loss), while a `62%` wood loss in PHK pulping (`36.3%` mill yield) means `1.00 kg` of shirt requires `3.82 kg` of dry wood chips. [S31]

Because `1.00 kg` of cotton shirt requires spinning `1.23 kg` of yarn, the garment absorbs `1.23 * 3.2 = 3.94 kWh` of spinning power rather than `3.2 kWh`. [S31] For Cameroon's textile sector, where July 2023 capacity utilisation stood at 33.7 percent at Garoua, 48.9 percent at CICAM 1 and 10.83 percent at CICAM 2, and where Camtext SA targets 12,000 tonnes of cotton a year, low utilisation and waste impose a double penalty by spreading fixed HVAC and compressor loads over fewer kilograms of yarn while amplifying lint demand. [R09] [R10] [R12] [S20] [S23]

6.7

Wet processing combines heat, electricity and chemistry

Tier 2 wet processing and finishing (pretreatment, dyeing, printing, washing-off and stenter drying) is the primary industrial thermal hotspot because heating and evaporating water across high-liquor baths demands megajoules of steam alongside specialty chemicals. [S08] [S13] [S31]

6.8 STEAM GENERATION AND CHEMICAL AUXILIARIES DOMINATE DYEING AND FINISHING

In the Chinese baseline of Forfora et al. (2026), wet processing is the largest carbon stage in cotton (`5.26 kg CO2eq/kg shirt`, 37.4 percent) and polyester (`4.16 kg CO2eq/kg`, 28.9 percent), and second-largest in viscose (`5.26`, 25.4 percent) and Lyocell (`5.26`, 24.3 percent) (Tables 3, 4 and S3 to S6): [S31] [S0601]

- **Cellulosic wet processing (cotton, viscose, Lyocell):** Per kilogram of dyed fabric, the dyehouse uses `24.1 MJ` of steam, `0.76 kWh` of power and `159.6 L` of water (`8%` fabric loss), plus `74.5 g` salt, `21.3 g` soda ash, `4.4 g` dye, `4.3 g` acetic acid, `2.7 g` caustic soda, `2.7 g` hydrogen peroxide, `2.1 g` sequestering agent, `2.1 g` softener, `1.1 g` each of wetting agent, soap, silicon, antigrease agent and sodium thiosulphate, `0.5 g` each of oil remover and stabiliser, and `0.3 g` enzyme. [S31]

Scaled by cutting loss (1.11 kg dyed fabric/kg shirt), the 5.26 kg CO2eq/kg burden comprises 3.44 from steam (65.4 percent), 1.25 from chemicals (23.8 percent), 0.56 from electricity (10.6 percent) and 0.01 from other flows. [S0601]

- **Polyester wet processing:** Disperse dyeing without heavy scouring or salt uses 28 L/kg water and 0.47 kWh/kg power (2.3 g detergent, 2.2 g disperse dye, 1.0 g stabiliser, 0.7 g sodium dithionite and 0.1 g sodium carbonate; 3% loss), but pressurised dyeing and stenter heat-setting consume 22.9 MJ/kg of steam, emitting 4.16 kg CO2eq/kg shirt (3.27 heat, 0.48 electricity, 0.34 chemicals, 0.07 other). [S31] [S0601]

Exhibit 27, p. 102 sums the four driver categories across all seven cradle-to-gate stages from Tables S3 to S6. [S0601]

EXHIBIT 27 / KG CO2EQ PER KG OF T-SHIRT

Thermal heat and purchased electricity dominate embodied carbon across all four fibres

	Thermal heat	Electricity	Chemicals	Other and transport
Cotton	3.52	6.1	2.68	1.77
Polyester	8.05	5.51	0.34	0.51
Viscose	8.78	6.91	3.85	1.13
Lyocell	9.51	8.01	2.99	1.08

Cell scale: 0.34 to 9.51

SOURCED [S31] [S0601] Summed across all seven cradle-to-gate stages from Tables S3 (viscose), S4 (Lyocell), S5 (cotton) and S6 (polyester) in the Supplemental Material of Forfora et al. (2026) for the China baseline scenario (S31, S0601). Row sums equal 14.07 kg CO2eq/kg for cotton, 14.41 for polyester, 20.67 for viscose and 21.59 for Lyocell (matching Table S7 totals within 0.02 kg CO2eq/kg of table cell rounding).

Exhibit 27, p. 102 confirms that energy conversion (Thermal heat plus Electricity) accounts for 68.3 percent of cradle-to-gate carbon in cotton (9.62 / 14.09 kg CO2eq/kg), 94.1 percent in polyester (13.56 / 14.41), 75.9 percent in viscose (15.69 / 20.68) and 81.1 percent in Lyocell (17.52 / 21.61). [S31] [S0601] What **Exhibit 27**, p. 102 does not separate is low-temperature hot water (60 to 95 degrees Celsius) versus medium-pressure steam (130 to 180 degrees Celsius), which engineers must meter at the boiler header to size heat-recovery and heat-pump systems. [S13] [S20] [S31]

6.9 RESOURCE-EFFICIENCY PROGRAMMES PROVE THAT THERMAL AND WATER DISCIPLINE PRECEDES SUPPLY SHIFTS

Because every litre of water pumped into a dye bath must be heated and later drained or evaporated, cutting liquor ratios and recovering effluent heat directly reduces boiler fuel demand. [S13] [S0602] In Bangladesh, the International Finance Corporation (IFC)

Partnership for Cleaner Textiles (PaCT), cited in the SBTi sector guidance and IFC evaluations, began in wet processing across more than 200 factories. [S08] [S13] By pairing low-liquor-ratio dyeing machines, condensate return, economisers and effluent heat recovery with automated chemical dosing, participating mills cut water use by 21 billion litres per year, saved 2.5 million megawatt-hours of energy per year and avoided 460,000 tonnes of greenhouse gas emissions annually, while dyehouses such as Textown cut water use by 11 million litres per year alongside shorter batch times. [S13] Similarly, the WRI and Apparel Impact Institute *Roadmap to Net Zero* identifies six actions delivering roughly three-quarters of sector abatement for a 1.5 degree Celsius pathway: maximising material efficiency, scaling sustainable materials, accelerating innovative materials, proliferating energy efficiency, eliminating coal in manufacturing and shifting to 100 percent renewable electricity. [S0602] Lowering steam demand from 24.1 MJ/kg toward low-liquor benchmarks shrinks required boiler capacity before capital is committed to clean boilers. [S13] [S31] [S0602]

6.10

Energy mix can reorder a fibre comparison

Because thermal heat and electricity generate 68 to 94 percent of cradle-to-gate emissions (**Exhibit 27**, p. 102), regional energy supply can outweigh intrinsic differences between fibres. [S31] [S0601]

6.11 REGIONAL GRID AND STEAM FUEL COMPOSITIONS ALTER CRADLE-TO-GATE TOTALS BY UP TO 38 PERCENT

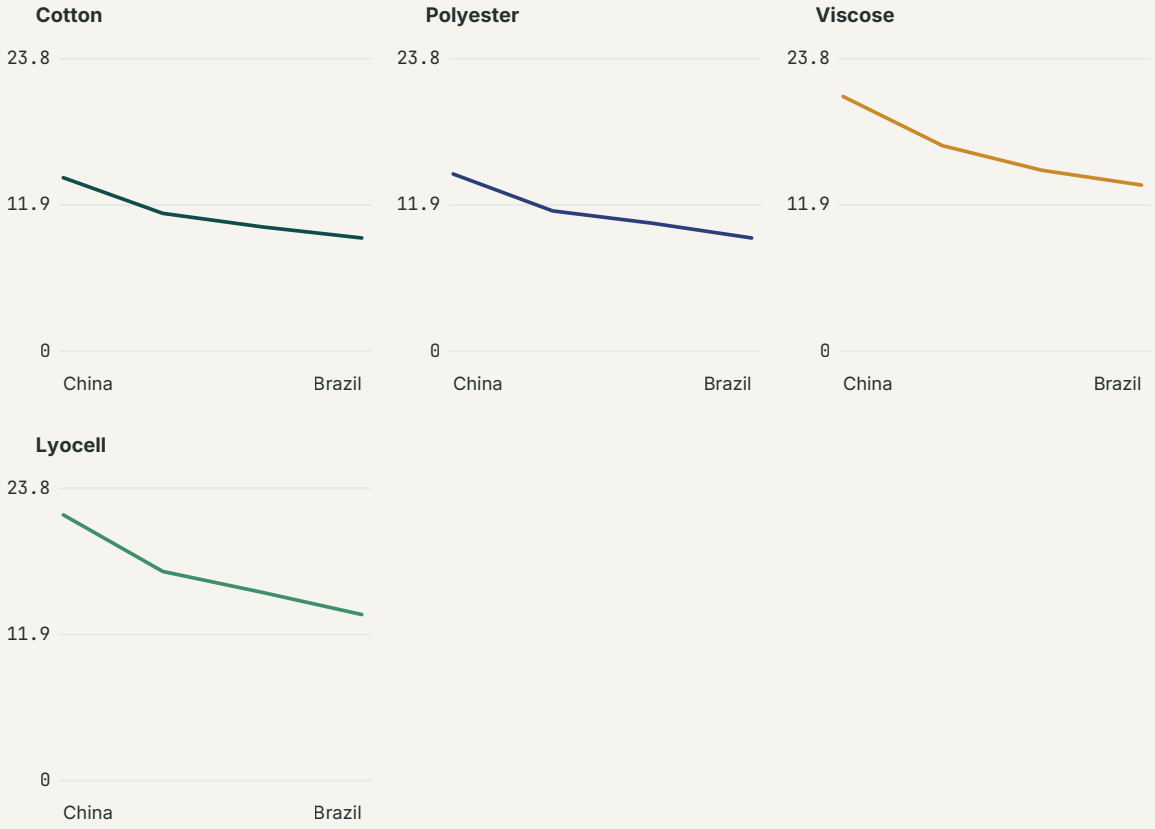
Forfora et al. (2026) tested regional sensitivity across China, the United States, Europe and Brazil by holding raw-material footprints and factory unit consumption rates constant while substituting regional grids (ecoinvent 3.10) and industrial steam mixes (IEA statistics): [S16] [S31]

- **China:** Steam from 67.7% coal, 20.2% biofuels/waste, 8.9% natural gas and 3.2% oil, with a coal-heavy grid. [S31]
- **United States:** Steam from 11.7% coal, 41.0% natural gas, 5.1% biofuels/waste and 42.2% oil. [S31]
- **Europe:** Steam from 16.7% coal, 30.4% natural gas, 13.1% biofuels/waste and 39.8% oil. [S31]
- **Brazil:** Steam from 5.4% coal, 10.2% natural gas, 40.0% biofuels/waste and 44.5% oil, with a predominantly hydroelectric grid. [S31]

Exhibit 28, p. 104 shows the resulting cradle-to-gate footprints from Figure 4 of the study. [S31]

EXHIBIT 28 / KG CO2EQ PER KG OF T-SHIRT (CRADLE-TO-GATE)

Four fibre footprints change with production geography



SOURCED [S31] Sourced from Figure 4 and Section 3.2 of Forfora et al. (2026) regional sensitivity analysis (S31). Raw material inputs (cotton lint, PET resin, dissolving pulp) and process unit efficiencies are held constant at baseline values while processing electricity (ecoinvent 3.10) and steam fuel mixes (IEA) are regionalised for China, USA, Europe and Brazil.

Three conclusions follow from **Exhibit 28**, p. 104: [S31] 1. **Up to 38 percent reduction in cleaner energy systems:** Shifting processing from China to Brazil cuts Lyocell from 21.6 to 13.5 kg CO2eq/kg (-37.5 percent, reported as up to 38 percent), viscose from 20.7 to 13.5 (-34.8 percent), polyester from 14.4 to 9.2 (-36.1 percent) and cotton from 14.1 to 9.2 (-34.8 percent). [S31] 2. **Cross-regional ranking inversions:** A Lyocell or viscose shirt made in Brazil (13.5 kg CO2eq/kg) emits less carbon per kilogram than a cotton (14.1) or polyester (14.4) shirt made in China, while European viscose (14.7) and Lyocell (15.3), where Austria holds 4.5 percent of world viscose and 22.1 percent of world Lyocell capacity, nearly match Chinese cotton and polyester before tenacity adjustments. [S31] 3. **Convergence of Lyocell and viscose:** In China, Lyocell's higher solvent-recovery energy (1.6 vs 0.97 kWh/kg and 24.4 vs 21.5 MJ/kg) puts it 0.93 kg CO2eq/kg above viscose (21.61 vs 20.68). [S31] [S0601] In Brazil, both converge to 13.5 kg CO2eq/kg, delivering Lyocell's 35 percent lower freshwater ecotoxicity and 62 percent lower human non-carcinogenic toxicity without a carbon penalty. [S31]

Because **Exhibit 28**, p. 104 holds upstream agriculture and pulping fixed and its 1,000-iteration Monte Carlo simulations (Tables S8 to S11) show overlapping uncertainty ranges, regional averages cannot replace site utility bills. [S14] [S16] [S31] [S0601]

6.12 CAMEROON'S INDUSTRIALISING TEXTILE HUBS REQUIRE DATED LOCAL GRID AND BOILER ACCOUNTING

For Cameroon, which aims to lift local cotton processing from roughly 5 percent to 50 percent by 2030 through the SODECOTON-CICAM industrial pole and the USD 300 million (180 billion XAF) Camtext SA project (12,000 tonnes/year across Garoua and Dibamba), processing energy will decide whether local garments are low-carbon. [R06] [R07] [R08] [R09] [R10] Cameroon's grid is predominantly hydroelectric with World Bank-backed hydro, solar and transmission expansions, alongside a 54 percent national access rate in the 2026 IEA profile. [S09] [S28] Under GHG Protocol Scope 2 (S03), IEA (S14) and UK conversion factor (S20) rules, a Cameroonian mill account must date grid factors to the production year, separate generation from transmission losses, meter Scope 1 diesel burned in backup generators during outages (plus Scope 3 Category 3 well-to-tank emissions), and meter boiler fuels directly, since hydroelectricity on spinning frames will not decarbonise a dyehouse boiler unless steam (24.1 MJ/kg) comes from sustainable biomass or heat pumps rather than heavy fuel oil. [R03] [S03] [S04] [S11] [S14] [S20] [S23]

6.13

Functional performance can change the material answer

Comparing fabrics solely per kilogram of mass ignores why engineers select specific fibres and yarn counts. [S26] [S31] Yarn tenacity governs how many grams of fabric are needed to withstand an identical mechanical load. [S31]

6.14 YARN TENACITY AND AREAL DENSITY LINK MECHANICAL ENGINEERING TO CARBON PER GARMENT

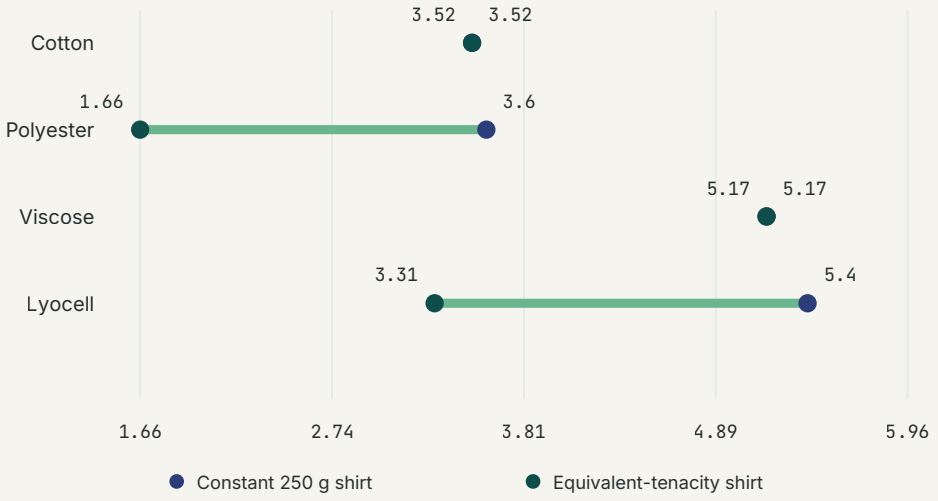
Drawing on Uster Statistics benchmarks (Section 2.3 and Table 2), Forfora et al. (2026) calculate the T-shirt mass required to withstand an equivalent force of 3,725 g·cN/tex against a 250 g cotton shirt: [S31]

- **Cotton (**14.9 cN/tex**,** 0.44 g/cm3**,** 6.1% **elongation):** 250 g (0.250 kg) per shirt. [S31]
- **Viscose (**14.9 cN/tex**,** 0.53 g/cm3**,** 14.7% **elongation):** 250 g (0.250 kg) per shirt. [S31]
- **Lyocell (**24.3 cN/tex**,** 0.63 g/cm3**,** 8.8% **elongation):** 153 g (0.153 kg), a 38.8 percent mass reduction. [S31]
- **Polyester (**32.5 cN/tex**,** 0.55 g/cm3**,** 11.8% **elongation):** 115 g (0.115 kg), a 54.0 percent mass reduction. [S31]

Exhibit 29, p. 106 shows how scaling from a constant 250-gram shirt to equivalent-tenacity mass reorders the four fibres in China (Figure 3A and Figure S7A). [S31] [S0601]

EXHIBIT 29 / KG CO2EQ PER T-SHIRT (CHINA BASELINE)

Tenacity-adjusted garment mass reorders the four-fibre carbon ranking



DERIVED [S31] [S0601] Derived from the exact China baseline GWP values in Table S7 of Forfora et al. (2026) Supplemental Material (14.09 kg CO2eq/kg cotton, 14.41 polyester, 20.68 viscose, 21.61 Lyocell; S0601) multiplied by the constant garment mass (0.250 kg for all four fibres; Figure 3A) and the equivalent-tenacity garment mass (0.250 kg cotton, 0.115 kg polyester, 0.250 kg viscose, 0.153 kg Lyocell; Table 2 and Figure S7A in S31, S0601).

Under a constant 250-gram mass (`start` in **Exhibit 29**, p. 106), cotton is lowest at `3.52 kg CO2eq/shirt` (`14.09 * 0.250`), followed by polyester at `3.60`, viscose at `5.17` and Lyocell at `5.40`. [S31] [S0601] Under equivalent tenacity (`end`), polyester drops to `1.66 kg CO2eq/shirt` (`14.41 * 0.115`) and Lyocell drops to `3.31 kg CO2eq/shirt` (`21.61 * 0.153`), both beating the 250-gram cotton shirt (`3.52`), while in Brazil's cleaner energy mix (`9.2` and `13.5 kg CO2eq/kg`) equivalent-tenacity shirts fall to `1.06 kg CO2eq` for polyester and `2.07 kg CO2eq` for Lyocell versus `2.30 kg CO2eq` for cotton. [S31] [S0601] Because buyers also specify fabric weight (`g/m2`) for opacity, drape and hand feel, GFT reports tenacity-adjusted footprints as a functional-equivalence sensitivity alongside actual shipped weight. [S24] [S26] [S31]

6.15 WORKED EXAMPLE: STAGE-BY-STAGE ENERGY, LOSS AND TENACITY ARITHMETIC FOR A MILL LOT

WORKED EXAMPLE

To see how an engineer reconciles stage mass losses, utility sub-meters and garment mass specifications into an auditable footprint, consider a **10,000-shirt production order** comparing a `250 g` cotton shirt against a tenacity-equivalent `153 g` Lyocell shirt using the parameters in Forfora et al. (2026) (`S31`, `S0601`) and an illustrative mill efficiency test. [S31] [S0601]

1. **Cotton mass cascade (`2,500 kg` net shirts):** Applying the stage losses in Figure 2 and Table 3 of `S31` (`10%` assembly, `8%` wet processing, `2.3%` knitting and `14.9%` spinning), `2,500 kg` of shirts requires `2,777.8 kg` of dyed fabric, `3,019.3 kg` of undyed fabric, `3,090.4 kg` of yarn and `3,631.5 kg` of ginned lint (`1.45 kg` lint/kg shirt). [S31]
2. **Tenacity-equivalent Lyocell mass cascade (`1,530 kg` net shirts):** Scaling by `1,530 / 2,500 = 0.612` across the same textile losses requires `1,700.0 kg` of dyed fabric, `1,847.8 kg` of undyed fabric, `1,891.3 kg` of yarn and `2,222.5 kg` of Lyocell staple fibre (`5,844.6 kg` of dry wood chips at `3.82 kg/kg` shirt). [S31]
3. **Cotton utility demand:** Using Table 3 of `S31`, spinning (`3.2 kWh/kg` yarn) uses `9,889.3 kWh`, knitting (`0.56 kWh/kg` fabric) uses `1,690.8 kWh`, wet processing (`0.76 kWh/kg` and `24.1 MJ/kg` dyed fabric) uses `2,111.1 kWh`, `66,945.0 MJ` (`66.95 GJ`) of steam and `443,337 L` of water (`159.6 L/kg`), and assembly (`0.56 kWh/kg`) uses `1,400.0 kWh`, totalling `15,091.2 kWh` (`1.509 kWh/shirt`). [S31]
4. **Lyocell utility demand:** Textile electricity scales by `0.612` to `9,235.8 kWh` while NMMO staple spinning (`1.6 kWh/kg` fibre) adds `3,556.0 kWh` (`12,791.8 kWh` total); dyehouse steam scales to `40,970.3 MJ` while NMMO recovery (`24.4 MJ/kg` fibre) adds `54,229.0 MJ` (`95,199.3 MJ` total). [S31]
5. **Carbon reconciliation and illustrative efficiency test:** Under China baseline intensities (`S0601` Tables S4 and S5), the `10,000` cotton shirts emit `2,500 * 14.09 = 35,225 kg CO2eq` (`3.52 kg CO2eq/shirt`, including `8,600 kg CO2eq` from dyehouse heat and `8,900 kg CO2eq` from yarn electricity), whereas the `10,000` tenacity-adjusted Lyocell shirts emit `1,530 * 21.61 = 33,063 kg CO2eq` (`3.31 kg CO2eq/shirt`). [S31] [S0601] In an **illustrative efficiency scenario** where low-liquor dyeing and condensate recovery cut cotton dyehouse steam by an illustrative `25 percent` (from `24.1` to `18.08 MJ/kg`, saving `0.86 kg CO2eq/kg` shirt) and variable-frequency spinning drives cut yarn electricity by an illustrative `25 percent` (from `3.2` to `2.4 kWh/kg`, saving `0.89 kg CO2eq/kg` shirt), cotton intensity falls by `1.75 kg CO2eq/kg` to an illustrative `12.34 kg CO2eq/kg` (`3.09 kg CO2eq/shirt`), saving `4,375 kg CO2eq` across the lot before any grid or fibre change. [S13] [S31] [S0601]

6.16

Process evidence must be requested by stage

Because a fabric lot's carbon footprint is governed by stage-specific yield losses, electricity kilowatt-hours, boiler fuels, chemical recipes and co-product allocation, primary evidence must be requested stage by stage rather than as a single bundled factor per kilogram of fabric. [S10] [S13] [S23]

6.17 SECONDARY FIBRE DATABASES SCREEN HOTSPOTS BUT CANNOT VALIDATE SUPPLIER ABATEMENT

Secondary databases such as ecoinvent (representing average geographical conditions rather than site-specific operations), the Quantis World Apparel and Footwear Life Cycle Assessment Database (WALDB), and the Higg Materials Sustainability Index (MSI) and Facility Environmental Module (FEM) referenced in the SBTi apparel guidance are essential for initial hotspot screening. [S08] [S16] [S17] [S24] However, three rules prevent secondary factors from validating supplier abatement: [S08] [S22] [S23] 1. **Boundary overlap between material and facility modules:** As the SBTi guidance warns for Higg MSI and FEM, combining secondary material factors with Tier 2 facility reports requires strict boundary reconciliation so spinning or dyeing is neither double counted nor omitted. [S08] [S23] 2. **Invisibility of mill efficiency gains:** Multiplying fabric mass by a static database average records zero carbon reduction when a mill in Garoua or Dibamba cuts spinning power from `3.2` to `2.2 kWh/kg`, lowers spinning loss from `14.9` to `9.0 percent`, or switches boiler fuels. [R10] [S20] [S23] [S31] 3. **Unverified supplier totals:** As the GHG Protocol Scope 3 Guidance notes, an unverified single figure from a supplier can be less accurate than an industry average if the supplier omits boiler fuels, misapplies co-product allocation or ignores process waste. [S10] [S23] [S31]

6.18 A STRUCTURED STAGE-GATE DATA REQUEST MAKES MILL AND DYEHOUSE RECORDS AUDITABLE

To make upstream data verifiable, GFT structures its supplier and internal mill requests around WBCSD PACT Version 3 (S10), IFC PaCT metrics (S13), UK activity-based conversion rules (S20) and GHG Protocol Scope 3 guidance (S23). [S10] [S13] [S20] [S23] **Exhibit 30**, `p. 109` presents GFT's illustrative stage-gate data request table. [S10] [S13] [S23]

EXHIBIT 30 / MANDATORY SUPPLIER REPORTING FIELDS BY TEXTILE STAGE

A process-stage data request makes supplier evidence comparable

Process stage	Physical output and spec	Electricity and thermal inputs	Water, chemicals and fuels	Losses, waste and co-products	Period, allocation and proof
1. Ginning or staple fibre	Net kg lint or staple fibre; staple length; linear density (dtex)	Grid kWh; captive generator kWh; process steam MJ by boiler fuel	Water m3/t; pulp or polymer kg/kg; solvent make-up (CS2 or NMMO g/kg)	Gin trash or pulp loss %; seed or Na2SO4 co-product kg and revenue share	12-month period; economic vs mass rule; utility bills and mass ledger
2. Yarn preparation (spinning)	Net kg conditioned yarn; yarn count (Ne or tex); tenacity (cN/tex)	Metered ring/rotor kWh/kg; humidification and compressor kWh/kg	Conditioning water L/kg; spinning oil or sizing chemicals g/kg	Incoming fibre loss %; card/comber noil kg sold vs waste incinerated	Production period; allocation by spindle-hours or count-adjusted kg
3. Fabric formation (knit/weave)	Net kg greige fabric; areal weight (g/m2); width and construction	Knitting/weaving machine kWh/kg; warping and sizing heat MJ/kg	Lubricating oil, warp size and desizing recovery inputs g/kg	Knitting/weaving fallout %; selvedge and yarn end waste treatment	Production period; machine-hour or mass allocation; quality log
4. Wet processing and finishing	Net kg finished fabric; colour shade depth; shrinkage and fastness	Metered dyehouse kWh/kg; boiler steam MJ/kg; condensate return %	Total water L/kg (liquor ratio); salt, alkali, peroxide, dye, auxiliaries g/kg	Wet-processing loss %; sludge kg; effluent treatment methane/N2O basis	Batch/period log; thermal fuel invoices; PACT/ISO 14044 review status

ILLUSTRATIVE [S10] [S13] [S20] [S23] [S31] Illustrative stage-gate supplier data request template designed by GFT from the primary-data, allocation and verification principles in WBCSD PACT Version 3 (S10), IFC PaCT textile resource-efficiency metrics (S13), UK GHG conversion factor activity rules (S20), GHG Protocol Scope 3 Calculation Guidance (S23) and the stage inventory structure of Forfora et al. (2026) (S31).

Exhibit 30, p. 109 enforces physical conservation checks across every tier: recording yarn count, tenacity (cN/tex) and fabric weight (g/m2) tests functional equivalence; separating grid kilowatt-hours, backup diesel and boiler steam fuel prevents suppliers from applying grid factors to thermal steam; pairing water liquor ratios (L/kg) with steam (MJ/kg) exposes under-reported boiler fuel; and logging stage losses (1.45 kg input fibre/kg shirt) and co-product revenue shares makes allocation auditable. [S03] [S10] [S13] [S20] [S23] [S26] [S31]

GFT NOTE

In GFT's Cameroon textile programme, GFT embeds the stage-gate fields of **Exhibit 30**, p. 109 directly into shop-floor operations. [S20] [S23] Automated computer-vision fabric inspection (achieving above 90 percent defect detection accuracy across more than 40 defect types at speeds up to 60 metres a minute, versus 60 to 70 percent for manual inspection that misses 20 to 30 percent of defects) catches knitting and dyeing faults at the machine frame before off-specification fabric consumes 24.1 MJ/kg of dyehouse steam or 10 percent cutting fallout, saving the upstream cascade of 1.45 kg lint, 3.2 kWh/kg spinning power and 159.6 L/kg water for every rejected kilogram avoided. [R28] [R29] [S31]

METHOD

Stage-by-stage calculation and reconciliation method for fibre, yarn and fabric modules

1. **Reconcile the backward mass cascade:** Record stage loss fraction `l_s` across spinning, knitting/weaving, wet processing and cutting, calculate required input mass `M_in(s) = M_out / product(1 - l_k for k ⩾ s)`, and verify that waste streams match `M_in(s) - M_out(s)`. [S23] [S25] [S31]
2. **Calculate electrical emissions by stage and grid zone:** Multiply stage-scaled electricity (`E_s` in kWh) by dated location-based grid factors (`EF_grid(r,t)`, keeping transmission losses and upstream fuel-cycle factors separate) alongside market-based instruments under Scope 2 rules. [S03] [S14] [S20]
3. **Calculate thermal steam emissions from fuel inputs:** Multiply metered boiler fuel (`F_f,s`) by direct combustion factors (`EF_comb(f)` covering CO2, CH4 and N2O) and upstream well-to-tank factors (`EF_WTT(f)`) rather than unverified steam averages. [S11] [S14] [S20] [S23]
4. **Add chemicals, co-product allocation and waste treatment:** Multiply chemical inputs by cradle-to-gate factors, apply declared physical or economic allocation (`alpha_s`) to co-products (cottonseed, comber noils, sodium sulphate), and account for fossil synthetic waste incineration (`2.31 kg CO2/kg` in `S31`) separately from biogenic carbon. [S23] [S26] [S31]
5. **Run geographic and functional-equivalence sensitivity checks:** Test sensitivity of cradle-to-gate results (`kg CO2e/kg` and `kg CO2e/garment`) across regional energy mixes and tenacity-adjusted garment masses (`g/m2` and `g/garment`). [S24] [S25] [S31]

WARNING

Unresolved constraint: absence of audited primary energy and steam sub-metering in Cameroonian textile mills

While GFT's evidence base records Cameroon's cotton-to-textile structure (more than 220,000 cotton producers, nine SODECOTON gins and two oil mills, July 2023 capacity utilisation of 33.7 percent at Garoua, 48.9 percent at CICAM 1 and 10.83 percent at CICAM 2, restructuring estimates of CFAF 30.7 to 70.2 billion, and the announced USD 300 million Camtext SA project), no public, audited sub-meter records exist for kilowatt-hours per kilogram of yarn spun or megajoules of steam per kilogram of fabric dyed in Cameroon. [R03] [R09] [R10] [R12] [R13] Until Phase 1 sub-meters are commissioned on spinning frames, knitting machines and boiler headers, Cameroonian carbon models must label process energy intensities (kWh/kg and MJ/kg) as secondary screening proxies (S31) paired with dated Cameroonian grid and fuel scenarios (S09, S14, S28), never as measured domestic mill performance. [S16] [S22] [S23] [S31]

The fibre names the feedstock, but the mill's meters write the footprint.

CHAPTER SOURCE NOTES

S08 Science Based Targets initiative and World Resources Institute. 2019.

S31 Forfora et al., Sustainability. 2026-04-20.

S0601 Forfora et al., Sustainability. 2026-04-20.

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

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

S20 UK Department for Energy Security and Net Zero. 2026-06-11.

S23 GHG Protocol and Carbon Trust. 2013.

S02 GHG Protocol. 2011.

S16 ecoinvent. 2025-11-05.

S07 Textile Exchange. 2025-09-18.

S01 GHG Protocol. 2011.

S05 International Organization for Standardization. 2018-08.

R03 SODECOTON. 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.

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

S13 International Finance Corporation. 2018-01-29.

S0602 World Resources Institute and Apparel Impact Institute. 2021-11-05.

S14 International Energy Agency. 2026-09-25.

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

S09 International Energy Agency. 2026.

S28 World Bank. 2025-01-16.

S03 GHG Protocol. 2015.

S04 GHG Protocol. 2004.

S11 Intergovernmental Panel on Climate Change. 2021-08-06.

S26 Watson and Wiedemann, Sustainability. 2019-07-15.

S24 International Organization for Standardization. 2006-07.

S10 World Business Council for Sustainable Development. 2025-04-30.

S17 Quantis. 2026-10-09.

S22 Textile Exchange. 2026-07-16.

R28 DataIntelo. Publication date unrecorded; inherited source-text check.

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

S25 International Organization for Standardization. 2006-07.

R13 Business in Cameroon; MMI News. Publication date unrecorded; inherited source-text check.

GREEN FUTURE TECH

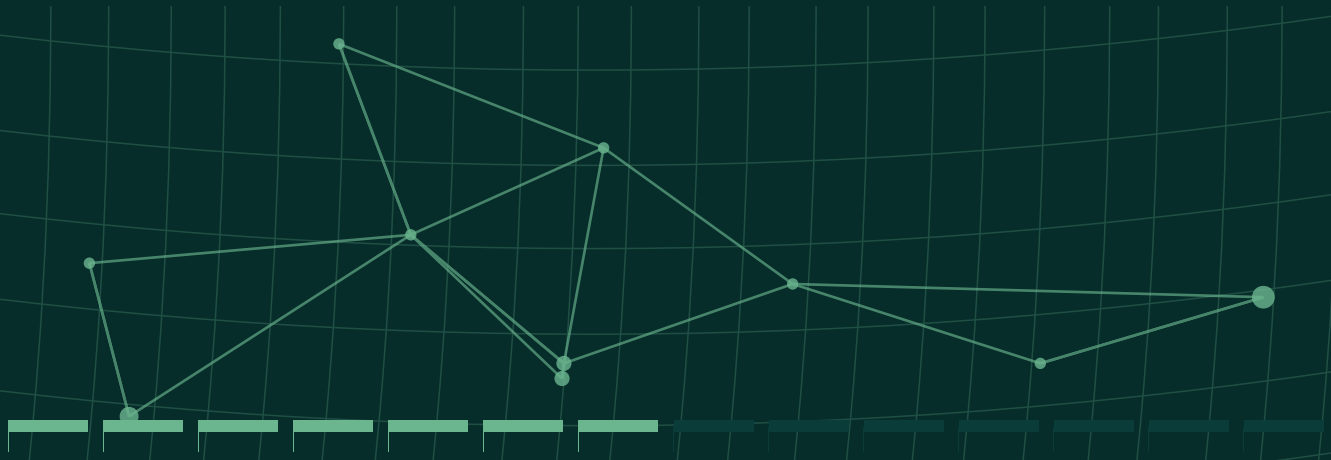
LIMITED / HONG KONG SAR

07

PART II: FOLLOW CARBON THROUGH THE GARMENT / CUT, MAKE AND TRIM

The garment factory turns meters, minutes and good units into Scope 1 and 2

A factory can account precisely for its own operations only when utilities, output and allocation share the same time and line structure.



CHAPTER 07
DECISION TEST

A factory can account precisely for its own operations only when utilities, output and allocation share the same time and line structure.

A garment factory cannot control or credibly report its operational carbon footprint until its utility meters, fuel and refrigerant ledgers, sewing-line time logs and quality records share one time and production hierarchy. [S04] [S20] In apparel life cycles, upstream fibre cultivation, spinning and wet processing often dominate product emissions, yet the cut, make and trim (CMT) factory is the boundary where fabric rolls, trims, thermal energy, power and labour converge into a saleable garment. [S08] [S31] Recording power only on a monthly utility bill, diesel only in a financial ledger and output only as gross bundles shipped prevents a plant from isolating process waste or assigning carbon accurately to styles and orders. [S23] [S0704] Green Future Tech Limited (GFT), in its three-part Cameroon textile programme prepared in January 2024 with sources refreshed in 2026, designed its factory performance-management and digital architecture so energy, water and waste per unit are captured alongside line output, availability and first-pass yield from the first shift. [R06] [S20] Extending that discipline to carbon accounting turns meter readings, standard allowed minutes and accepted good units into an auditable Scope 1 and 2 inventory that feeds product footprints without double counting or omission. [S01] [S04]

Corporate operational boundaries and product life cycle boundaries share the same activity records but apply different aggregation rules. [S01] [S04] At the corporate level, the factory compiles direct greenhouse gas emissions from owned or controlled stationary combustion, mobile sources and fugitive refrigerant leaks into Scope 1, and indirect emissions from purchased electricity, steam, heat and cooling into Scope 2. [S03] [S04] At the product level, those reconciled totals are partitioned across garment families, lines and orders using a causal allocation driver, and divided by accepted good garments rather than gross pieces started. [S23] [S24] Purchased fabrics, trims, packaging and subcontracted washing or printing remain upstream inputs in Scope 3 and in the cradle-to-gate material modules of the product footprint, ensuring every kilogram of carbon dioxide equivalent (CO2e) is recorded once and mapped to the garments that caused it. [S01] [S02] [S23]

7.1

Scope 1 starts with the fuel and fugitive register

Direct greenhouse gas emissions in a garment factory begin with an asset register covering every piece of equipment owned or controlled by the reporting company within its organisational boundary. [S04] [S0702] Under the GHG Protocol Corporate Standard and United States Environmental Protection Agency (EPA) guidance, organisational boundaries determine which entities and assets enter the Scope 1 and 2 account, whether consolidated by operational control, financial control or equity share. [S04] [S0703] Scope 1 sources fall into three classes: stationary combustion units (steam boilers, oil heaters, ovens and backup diesel generators), mobile sources (owned trucks, forklifts and shuttle buses) and fugitive sources (chillers, split air conditioners, fire-suppression cylinders and wastewater channels). [S20] [S0701] [S0702] Engineers tag each burner, tank, vehicle and refrigerant circuit with an identifier linked to its cost centre. [S04] [S0701]

7.2 STATIONARY COMBUSTION REQUIRES RECONCILED FUEL STOCKS AND METERED THERMAL LOADS

Stationary combustion in a garment plant is driven by steam generation for pressing, fusing, pleat setting, washing and drying, plus standby diesel generation during outages. [S08] [S0701] Boilers and generators burn diesel, heavy fuel oil, liquefied petroleum gas (LPG), natural gas or biomass, releasing carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O). [S0701] Carbon dioxide accounts for roughly 99 percent of fossil combustion CO2e, while methane and nitrous oxide vary with burner tuning and are quantified separately. [S0701] [S0704] Where a boiler burns biomass such as cotton gin trash or wood chips, biogenic carbon dioxide is reported separately from fossil Scope 1 totals, while methane and nitrous oxide remain inside Scope 1 CO2e. [S04] [S0701]

Activity data cannot rely on purchase invoices alone when fuel is stored in bulk tanks across periods. [S20] [S0701] A diesel tank delivery in late December may be burned across January and February. [S0701] To align fuel use with monthly garment output, the factory reconciles deliveries with calibrated flow meters on each boiler and generator line, or applies a stock balance where combusted fuel equals opening stock plus deliveries minus closing stock and transfers. [S20] [S0701] Each fuel stream is logged in its physical unit (litres, kilograms or cubic metres) with its calorific basis so the factor from the United Kingdom Department for Energy Security and Net Zero (DESNZ) or the International Energy Agency (IEA) matches the energy basis and gas coverage. [S14] [S20] Scope 1 uses only the direct combustion factor; upstream fuel extraction, refining and transport belong in Scope 3 Category 3. [S20] [S23] [S0701]

7.3 MOBILE COMBUSTION AND FUGITIVE REFRIGERANTS CLOSE THE DIRECT INVENTORY

Owned or controlled mobile equipment forms the second pillar of Scope 1. [S04] [S20] Forklifts, panel-transfer vans and owned delivery trucks burn road diesel, petrol or LPG under factory control. [S20] [S0703] Activity data come from fuel logs or receipts tied to registration numbers and odometer readings, with distance factors used only when volume records are incomplete. [S20] Third-party freight sits in Scope 3 Category 4 or 9 rather than Scope 1. [S02] [S23]

Fugitive emissions from refrigeration, air conditioning and fire suppression are often overlooked, yet high-global-warming-potential hydrofluorocarbons (HFCs) can form a material share of a tropical factory's Scope 1 footprint. [S11] [S0702] EPA fugitive guidance stresses that materiality can only be established after a source is assessed through an initial estimate. [S0702] Factories in warm, humid regions such as Littoral or northern Cameroon rely on chillers or split air conditioners to control temperature and humidity in offices, CAD rooms, cutting halls and sewing floors. [R03] [S0702]

Rather than relying on uncertain screening factors, GFT specifies a mass-balance refrigerant register. [S20] [S0702] Every chiller, split unit and fire-suppression cylinder is logged with its refrigerant code and charge capacity. [S0702] Fugitive leakage equals opening storage stock, plus purchases and charge in new units, minus closing stock, retiring capacity and certified recovery. [S0702] Leaked mass is multiplied by its 100-year Global Warming Potential (GWP100) from the declared Intergovernmental Panel on Climate Change (IPCC) Assessment Report, such as AR6 Working Group I Chapter 7, while regulated ozone-depleting substances (HCFCs) are tracked as memo items. [S04] [S11] [S20] [S0702]

GFT NOTE

In GFT's Cameroon programme, utility and maintenance logs are daily and weekly operational records rather than annual spreadsheets. [R06] [S20] GFT locks three Scope 1 controls into commissioning before the first shift: fit non-resettable flow meters on generator and boiler fuel lines; record tank dip readings every Sunday night so monthly fuel use reconciles within 2 percent of invoices; and require weighed cylinder mass before and after every air-conditioning service in the site fugitive register. [S20] [S0701] [S0702]

7.4

Scope 2 follows purchased energy into each process

Scope 2 captures indirect greenhouse gas emissions from generating purchased or acquired electricity, steam, heat and cooling consumed by the factory. [S03] [S0703] Although fuel combustion occurs at a power station or park boiler house outside the fence, those emissions result from the factory's energy demand and belong in its corporate inventory. [S03] [S0703] Purchased electricity powers spreaders, CNC cutters, sewing machines, bar-tackers, embroidery heads, irons, vacuum tables, compressors, lighting, fans and servers. [S08] [S20] Inside an industrial zone such as the planned Dibamba or Garoua hubs referenced in Cameroon announcements, a plant may also buy piped steam or chilled water or acquire power over a private wire. [R10] [S03] [S0704]

7.5 FACILITY BOUNDARY METERS AND INTERNAL SUB-METERS SERVE COMPLEMENTARY FUNCTIONS

A common failure in factory energy accounting is confusing the boundary meter needed for corporate Scope 2 totals with the sub-metering needed for process management and garment allocation. [S23] [S0704] EPA guidance establishes that utility bills and main incoming revenue meters provide the best activity data for corporate Scope 2 totals, whereas relying solely on internal sub-meters risks omitting perimeter lighting, pumps, canteen loads or transformer losses. [S0704] Conversely, a single substation meter cannot show how many kilowatt-hours (kWh) were used by Line 1 versus cutting, pressing or compressed air. [S20] [S23]

GFT resolves this with a two-tier metering topology. [S20] [S0704] Tier 1 is the calibrated revenue meter at the incoming switchboard, reconciled monthly against utility bills to fix the facility Scope 2 total. [S0704] Tier 2 comprises digital sub-meters on each feeder: cutting and CAD, each sewing line busbar, washing and drying, steam pressing, compressed air, HVAC, and general site services. [S20] [S23] At the close of every shift and month, Tier 2 sub-meters are reconciled against the Tier 1 boundary meter, with the small residual assigned to the shared site-services pool. [S23] [S0704]

7.6 DUAL REPORTING SEPARATES GRID PHYSICAL REALITY FROM CONTRACTUAL INSTRUMENTS

Under the GHG Protocol Scope 2 Guidance, a factory in a market offering contractual instruments (such as energy attribute certificates or power purchase agreements) must report Scope 2 using both the location-based and market-based methods. [S03] [S0704]

The location-based method uses the average emissions intensity of the physical grid serving the site (or a dedicated generator factor over a direct line), drawn from dated sources such as IEA Emissions Factors 2026. [S14] [S0704] In Cameroon, where IEA data record a 54 percent electrification rate and World Bank reporting highlights hydropower and solar additions alongside grid constraints, the location-based factor must be dated and refreshed annually. [S09] [S14] [S28] The market-based method reflects contractual instruments meeting GHG Protocol Scope 2 Quality Criteria, defaulting to the residual mix or grid factor where no qualifying instruments exist. [S03] [S0704]

7.7 SELF-GENERATION AND GRID LOSSES MUST SIT IN THEIR PROPER COMPARTMENTS

Factory electricity accounting separates owned on-site generation, purchased grid power and transmission and distribution (T&D) losses. [S14] [S20] [S0704] Many Central African factories combine the public grid, owned solar photovoltaics and owned diesel standby generators. [S15] [S28] Fuel burned in owned diesel generators sits in Scope 1, and power from owned solar arrays consumed on site carries zero Scope 1 or 2 combustion emissions; neither may be added to Scope 2 purchased kilowatt-hours, and exported on-site power is not netted off Scope 1 fuel or Scope 2 purchases. [S03] [S0704] Grid T&D losses and well-to-tank fuel emissions are separate fields in IEA and UK DESNZ tables and belong in Scope 3 Category 3. [S14] [S20] [S23]

To make these boundary rules unambiguous, **Exhibit 31**, p. 118 maps the principal factory sources to their governing scopes, activity units and double-counting safeguards. [S02] [S03] [S04] [S20]

EXHIBIT 31 / CATEGORICAL GOVERNANCE MATRIX

Every factory utility and material flow maps to one non-overlapping accounting compartment

Factory source or flow	Corporate scope	Primary activity data	Double-counting safeguard
Owned steam boilers and backup diesel generators	Scope 1 (stationary combustion)	Litres or kg of fuel from meters and tank stock balance	Exclude generated kWh from Scope 2; put fuel WTT in Scope 3 Cat 3
Owned delivery vans, trucks and forklifts	Scope 1 (mobile combustion)	Litres of fuel dispensed by vehicle registration log	Exclude from Scope 3 Cat 4 and Cat 9 third-party freight accounts
Chillers, split AC units and fire suppression	Scope 1 (fugitive emissions)	kg of refrigerant leaked via cylinder mass balance	Report regulated ODS as memo items; record IPCC GWP version
Grid electricity and third-party direct-line power	Scope 2 (purchased energy)	kWh at main incoming revenue meter reconciled to bills	Report location- and market-based separately; put T&D losses in Cat 3
Purchased district steam or chilled water	Scope 2 (purchased thermal)	MJ, kg of steam or ton-hours at boundary thermal meter	Do not apply a raw fuel factor where a delivered steam factor applies
Purchased fabric, yarn, trims and packaging	Scope 3 Category 1 (purchased goods)	kg or units received on supplier bills of lading	Never add upstream mill Scope 1 and 2 into factory Scope 1 and 2
Subcontracted garment washing, dyeing or printing	Scope 3 Category 1 (upstream services)	kg or units processed plus subcontractor utility allocation	Keep separate from owned in-house finishing line meters
Cutting-room fabric offcuts and packaging waste	Scope 3 Category 5 (waste in operations)	kg of segregated waste by treatment route (recycle, landfill)	Account for extra input fabric mass in Cat 1; waste treatment in Cat 5

SOURCED [S02] [S03] [S04] [S14] [S20] [S23] [S0701] [S0702] [S0704] Synthesised from GHG Protocol Corporate, Scope 2 and Scope 3 standards (S02, S03, S04, S23), IEA and UK DESNZ factor structures (S14, S20) and US EPA inventory guidance (S0701, S0702, S0704).

As **Exhibit 31**, p. 118 demonstrates, flow classification depends on asset ownership, transformation boundary and factor scope rather than convenience. [S04] [S20] While **Exhibit 31**, p. 118 sets the categorical rules, physical meter calibration and invoice completeness must still be verified during site audits. [S04] [S0704]

7.8

Purchased inputs remain in the product account

A standalone cut, make and trim factory does not grow cotton, spin yarn, weave fabric or dye cloth within its walls. [S08] [S31] It receives fabric rolls, threads, interlinings, labels, buttons, zippers, polybags and cartons from suppliers, assembles garments and ships the goods. [S08] [S23] Because fibre production, spinning and wet processing dominate a garment's cradle-to-gate footprint, purchased materials and subcontracted processing stay in Scope 3 Category 1 for corporate reporting and in upstream material modules for product reporting, never inside factory Scope 1 or 2. [S02] [S08] [S23]

7.9 CRADLE-TO-GATE SUPPLIER RECORDS ATTACH TO THE BILL OF MATERIALS

Under the GHG Protocol Product Standard, ISO 14067 and WBCSD PACT Version 3, cradle-to-gate emissions of purchased components travel with the bill of materials (BOM). [S01] [S05] [S10] Each input's embodied carbon equals gross mass purchased per accepted garment multiplied by its cradle-to-gate factor, which already contains the upstream mill's Scope 1 fuel, Scope 2 power, fibre burdens and inbound transport. [S23] [S31]

Two errors corrupt this boundary. [S23] Omission occurs when a garment plant publishes only its low Scope 1 and 2 sewing emissions per piece and calls that partial figure the garment footprint, omitting fabric and trims. [S01] [S08] [S31] Double counting occurs when an integrated group owning both a mill and a garment plant includes the mill's fuel and power in group Scope 1 and 2 and also counts internal fabric transfers in corporate Scope 3 Category 1. [S02] [S04] [S23] Within one corporate boundary, each owned site's fuel and power enter group Scope 1 and 2 once, while Scope 3 Category 1 records only externally purchased inputs; in the product account, every stage from field to garment is summed once. [S01] [S04] [S23]

7.10 CUTTING-ROOM MARKER LOSSES AND OUTSOURCED STAGES REQUIRE EXPLICIT MASS RECONCILIATION

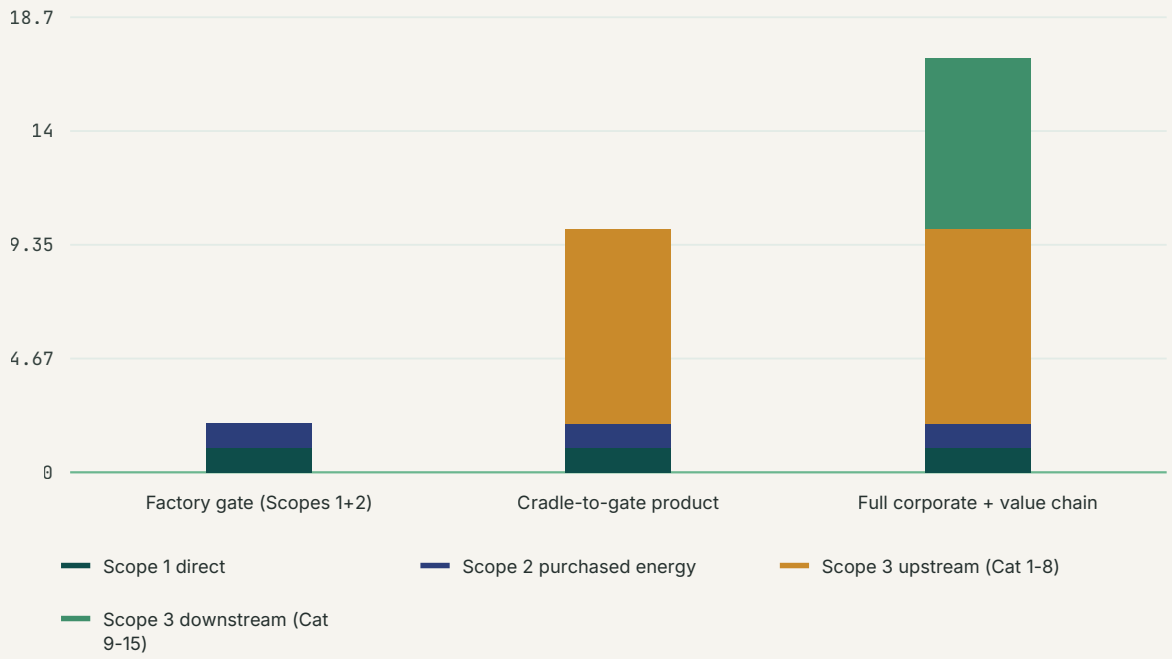
Although fabric sits in Scope 3 Category 1, factory engineering governs how much upstream fabric carbon enters each garment. [S23] [S31] In the 2026 T-shirt assessment by Forfora et al., cumulative cotton losses across the cradle-to-gate chain reach 31 percent, requiring 0.362 kilograms of raw cotton before losses to deliver a 0.250-kilogram shirt. [S31] Inside the garment plant, marker efficiency, remnants, splice losses and sewing rejects set the gross-to-net fabric ratio. [R29] [S31]

If a factory cuts 100 kilograms of dyed fabric at an 82 percent yield, 82 kilograms leave in garments and 18 kilograms leave as offcuts. [S25] [S31] Both the product footprint and corporate Scope 3 Category 1 include the full 100 kilograms of purchased fabric, while disposal of the 18 kilograms of offcuts is recorded in Scope 3 Category 5 using waste factors that exclude upstream production. [S02] [S20] [S23] When GFT's digital tools improve marker nesting or deploy automated defect inspection (where computer vision achieves above 90 percent accuracy across more than 40 defect types at up to 60 metres a minute versus 60 to 70 percent for manual inspection), the factory cuts Scope 3 fabric mass per good garment alongside Scope 1 and 2 energy. [R29] [S23] Subcontracted printing, washing or embroidery is recorded in Scope 3 Category 1 using primary subcontractor data or a documented secondary factor. [S10] [S23]

To show how corporate Scopes 1, 2 and 3 align with product stages without omission or overlap, **Exhibit 32**, p. 120 maps the 17 GHG Protocol inventory compartments across direct operations, purchased energy, upstream supply chain and downstream stages. [S01] [S02] [S03] [S04]

EXHIBIT 32 / NUMBER OF GHG PROTOCOL INVENTORY COMPARTMENTS

A factory Scope 1 to 3 bridge maps all seventeen GHG Protocol compartments to product stages



SOURCED [S01] [S02] [S03] [S04] [S23] Sourced structural mapping of the 17 GHG Protocol corporate inventory compartments: 1 Scope 1 direct group (S04), 1 Scope 2 purchased-energy group (S03) and 15 Scope 3 categories (8 upstream Categories 1 to 8 and 7 downstream Categories 9 to 15 in S02 and S23) across the three garment boundary views defined in S01.

As **Exhibit 32**, p. 120 shows, a factory gate operational report covers 2 of the 17 GHG Protocol compartments (Scopes 1 and 2), a cradle-to-gate product record combines those 2 scopes with relevant inputs from the 8 upstream Scope 3 categories (Categories 1 to 8), and a full corporate and cradle-to-grave account spans all 17 compartments including the 7 downstream categories (Categories 9 to 15). [S01] [S02] [S03] [S04] Because **Exhibit 32**, p. 120 counts standard compartments rather than tonnes of CO2e, it establishes scope completeness rather than an empirical emission share. [S02] [S23]

7.11

Good garments are the operating denominator

Once a factory has quantified its Scope 1 and Scope 2 emissions in kilograms of CO2e, it divides that total by a physical denominator to obtain an operational carbon intensity. [S08] [S23] Watson and Wiedemann and Forfora et al. show that the functional unit (1 kilogram of textile, 1 garment, or 1 wear) changes how burdens are interpreted. [S26] [S31] Inside the plant, three operational denominators must be separated: **started units** (cut bundles loaded to the line), **gross finished units** (units reaching the line end before rejection), and **accepted good units** (A-grade garments packed for shipment). [S23] [S26]

7.12 REWORK AND REJECTS CONSUME REAL ENERGY AND MUST BE BORNE BY ACCEPTED OUTPUT

When a line starts 1,000 shirts during an illustrative shift, every bundle draws power and steam. [S20] [S23] Suppose 880 shirts pass on the first pass (88 percent illustrative first-pass yield), 70 shirts fail for stitch or stain defects and are reworked before passing, and 50 shirts suffer irreparable defects and are scrapped. [R29] [S23] Machines sewed and pressed 880 units once, 70 reworked units twice, and 50 rejected units that cannot be sold. [S23] [S25]

Dividing shift Scope 1 and 2 emissions by 1,070 illustrative machine passes or 1,000 started units understates carbon intensity by spreading emissions onto defective work. [S23] [S26] Under ISO 14040, ISO 14044 and the GHG Protocol Product Standard, unit-process burdens are normalised against the net reference flow of functional product leaving that gate, making **accepted good units** (950 shipped shirts in this illustrative shift) the only valid product denominator. [S01] [S24] [S25]

Tracking **carbon per started garment** beside **carbon per accepted good garment** in GFT's dashboard quantifies the **quality carbon penalty** of the line. [S23] [S25] When a factory suffers high defect rates or low utilisation (as in Cameroon's legacy sector, where a July 2023 report recorded CICAM utilisation at 33.7 percent at Garoua, 48.9 percent at CICAM 1 and 10.83 percent at CICAM 2, costing about CFAF 2 billion in 2020), baseload power for lighting, HVAC, air leaks and boiler standby heat runs while accepted output falls, raising Scope 1 and 2 CO2e per good garment. [R12] [S20]

7.13 DAILY OPERATIONAL CAPTURE EMBEDS CARBON INTO EXISTING SHIFT LOGS

To calculate carbon per good garment without parallel paperwork, GFT's Cameroon programme embeds utility and waste fields into the daily line and sustainability logs kept by supervisors and technicians. [R06] [S20] At the close of every shift, the factory records six operational field groups, shown in **Exhibit 33**, p. 122. [S20] [S0701] [S0704]

EXHIBIT 33 / DAILY OPERATIONAL DATA SCHEMA

Daily capture joins carbon to the existing operating record across six shift field groups

kWh / shift

Purchased grid and direct-line electricity

Main revenue meter plus feeder sub-meters by line and utility room (S20, S0704)

L, kg or MJ

On-site fuel, steam and self-generation

Boiler fuel, steam flow, genset diesel and self-generated solar kWh (S20, S0701)

A-grade pieces

Started and accepted good units

Cut bundles loaded, first-pass accepted units and final shipped count (S23, S24)

pieces and SAM

Defects, rejects and rework SAM

Tagged by defect code, station and rework standard minutes (GFT programme, S23)

min / shift

Line operating and downtime minutes

Separates productive running time from idle baseload draw (GFT programme, S20)

kg / batch

Segregated process waste and leaks

Cutting offcuts, rejected seconds, carton scrap and refrigerant logs (S20, S0702)

SOURCED [S14] [S20] [S23] [S0701] [S0702] [S0704] Sourced from UK DESNZ and IEA activity-data requirements (S14, S20), GHG Protocol Scope 3 allocation guidance (S23), US EPA stationary, fugitive and electricity guidance (S0701, S0702, S0704) and GFT programme design.

The six shift field groups in **Exhibit 33**, p. 122 timestamp every kilowatt-hour, litre of fuel and kilogram of steam to the shift, line and order that consumed it. [S20] [S23] While **Exhibit 33**, p. 122 defines the shift capture schema, Phase 1 of GFT's roadmap records these six groups on structured digital forms backed by meter photographs before automated telemetry is installed. [S20] [S23]

7.14

Shared utilities require a defensible allocation rule

A garment factory rarely makes a single style all year. [S23] Lines 1 and 2 may sew jersey T-shirts while Lines 3 and 4 sew heavy woven workwear trousers requiring bar-tacking and steam pressing. [S23] [S31] Even when each sewing line has an electrical sub-meter, all lines share the cutting room, compressed-air header, boiler

house, warehouse, quality lab, offices and lighting. [S20] [S23] To report the Scope 1 and 2 footprint of each style, the factory partitions shared utilities using a defensible rule. [S23] [S24]

7.15 ISO 14044 AND THE GHG PROTOCOL ESTABLISH A STRICT ALLOCATION HIERARCHY

ISO 14044 and the GHG Protocol Product and Scope 3 standards set a three-step hierarchy for multi-product sites. [S01] [S23] [S25] First, **avoid allocation through subdivision**: sub-metered line electricity or dedicated boiler steam used by one style goes directly to that style. [S23] [S25] Second, where shared utilities cannot be subdivided, **allocate by an underlying physical relationship that reflects how inputs change with product function**. [S23] [S24] [S25] Third, use economic allocation only when physical causality cannot be established, disclosing sensitivity tests. [S23] [S25]

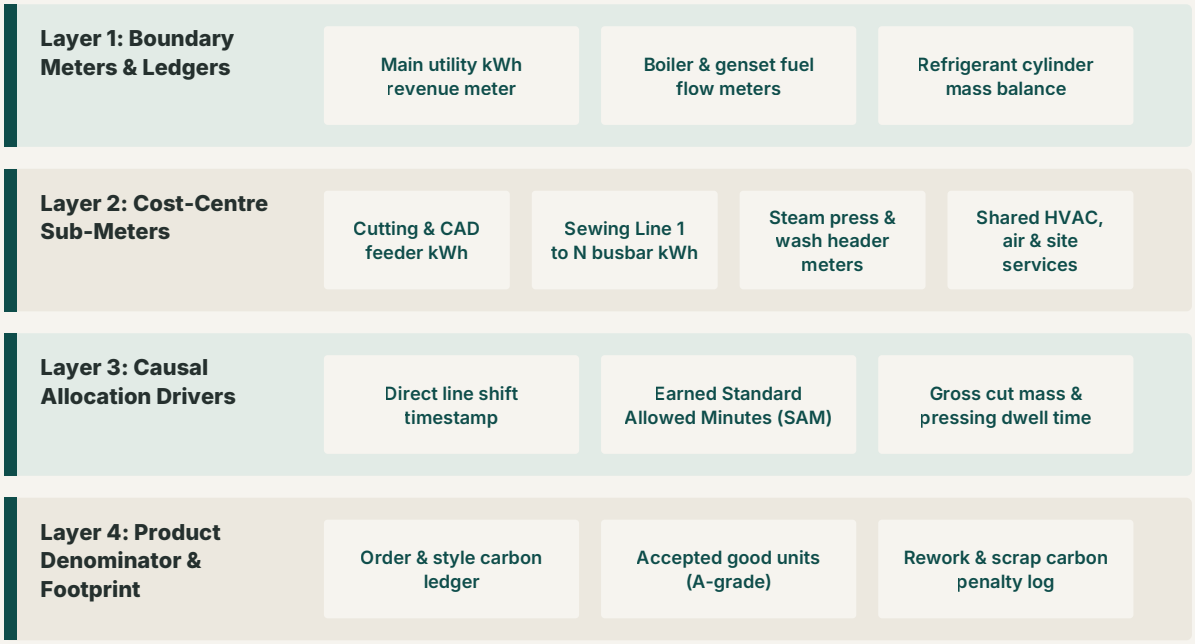
7.16 TESTING STANDARD ALLOWED MINUTES, MACHINE HOURS, MASS AND UNIT COUNTS

Four physical drivers are candidates for shared garment-factory utilities: [S20] [S23] [S24] 1. **Simple unit count:** Splitting factory emissions equally per piece violates causality whenever styles differ in sewing and pressing work content. [S23] [S24] 2. **Garment mass:** Allocating by mass suits spreading, cutting, washing and drying, where energy scales with fabric weight, but distorts sewing power when a light, complex garment requires more stitching than a heavy, simple item. [S23] [S26] [S31] 3. **Machine operating hours:** Allocating compressed air, HVAC and lighting by active machine-hours logged per line and order. [S20] [S23] 4. **Standard Allowed Minutes (SAM) produced:** Multiplying units processed by time-studied style SAM yields earned standard minutes. Because machine run-time, workstation occupancy, lighting, needle-cooling air and pressing dwell time scale with work content in standard minutes, SAM is the strongest causal driver for shared CMT assembly and site-service power. [S20] [S23] [S24]

GFT implements the **hybrid two-stage allocation architecture** in **Exhibit 34**, p. 124: sub-metered power and steam go to their measured cost centres, while shared cutting energy is allocated by cut fabric mass, shared pressing steam and power by pressing SAM, and shared site services plus refrigerants by total earned SAM, before dividing by accepted A-grade units. [S20] [S23] [S24] [S0704]

EXHIBIT 34 / FOUR-LAYER ALLOCATION ARCHITECTURE

A meter-to-line-to-garment allocation chain makes factory carbon traceable



ILLUSTRATIVE [S20] [S23] [S24] [S0704] Illustrative system architecture derived from UK DESNZ conversion structures (S20), GHG Protocol Scope 3 allocation hierarchy (S23), ISO 14040 causality principles (S24) and US EPA boundary metering rules (S0704).

As shown in **Exhibit 34**, p. 124, every kilowatt-hour and litre of fuel passes through a cost-centre sub-meter and a causal driver before reaching a garment order. [S20] [S23] [S0704] Because **Exhibit 34**, p. 124 is an illustrative system design, each factory must validate the physical correlation between SAM, mass and sub-metered energy during commissioning. [S23] [S25]

GFT FACTORY SCOPE 1 AND 2 ALLOCATION AND DENOMINATOR PROTOCOL

To calculate the operational carbon footprint `CF_op(s, t)` (`kg CO2e` per accepted good garment) for style `s` in period `t`, execute five steps that reconcile 100 percent of site Scope 1 and 2 emissions: [S04] [S20] [S23]

1. **Reconcile facility Scope 1 and 2 totals (`E1(t)` and `E2(t)`):** Sum direct combustion and mass-balance refrigerant leakage into `E1(t)`, and calculate location- and market-based `E2(t)` from boundary revenue meter purchases `M_main(t)`, excluding owned on-site diesel or solar `kWh`. [S03] [S11] [S14] [S20] [S0701] [S0702] [S0704]
2. **Partition into process pools (`p`) and shared services (`u`):** Using feeder sub-meters `M_p(t)`, assign power and steam to Cutting, each Sewing Line, Pressing, and Shared Site Utilities (`M_main(t)` minus feeder sub-meters). [S20] [S0704]
3. **Assign direct line energy by shift timestamps:** Partition each line's sub-metered power across styles using shift logs or earned sewing standard minutes (`N_started(s, t)` multiplied by `SAM_sew(s)`). [S23] [S24]
4. **Allocate shared pools by causal physical weights:** Allocate Cutting power by gross cut mass `m_cut(s, t)`, Pressing steam and power by pressing `SAM` (`N_started(s, t)` multiplied by `SAM_fin(s)`), and Shared Site Utilities plus refrigerants by total earned `SAM` (`N_started(s, t)` multiplied by `SAM_total(s)`). [S23] [S24]
5. **Divide by accepted good units (`N_good(s, t)`):** Divide allocated emissions `E_alloc(s, t)` by `N_good(s, t)` to report `CF_op(s, t)`, comparing against `E_alloc(s, t) / N_started(s, t)` to isolate the quality penalty. [S01] [S23] [S26]

WORKED EXAMPLE: RECONCILING METERS, STANDARD MINUTES AND GOOD UNITS ACROSS TWO GARMENT LINES

Consider an **illustrative** one-month record for a two-line CMT factory in Cameroon. All figures are **illustrative** inputs constructed to demonstrate the arithmetic, not measurements from a GFT or third-party site. [S20] [S23]

Illustrative monthly utility and Scope 1 and 2 ledger: The incoming meter records 30,000 kWh purchased at an illustrative location-based factor of 0.300 kg CO2e/kWh (9,000.0 kg CO2e in Scope 2). [S14] [S0704] Sub-meters record 3,000 kWh (900.0 kg CO2e) in Cutting, 5,000 kWh (1,500.0 kg CO2e) on Line 1 (**Style A: Basic T-Shirt**), 10,000 kWh (3,000.0 kg CO2e) on Line 2 (**Style B: Work Shirt**), 4,000 kWh (1,200.0 kg CO2e) in Pressing, and 8,000 kWh (2,400.0 kg CO2e) in Shared Services. [S20] [S0704] In Scope 1, an owned generator burns 1,000 litres of diesel at an illustrative 2.680 kg CO2e/litre (2,680.0 kg CO2e), an owned LPG boiler serving Pressing burns 2,000 litres at 1.560 kg CO2e/litre (3,120.0 kg CO2e), and an AC top-up logs a 0.50 kg leak at GWP100 = 2,000 (1,000.0 kg CO2e). [S11] [S20] [S0701] [S0702] Illustrative Scope 1 is 6,800.0 kg CO2e, Scope 2 is 9,000.0 kg CO2e, and combined Scope 1 and 2 is 15,800.0 kg CO2e. [S04] [S20]

Illustrative style parameters: Line 1 (**Style A**) logs 25,000 started units, 24,000 good units (96.0 percent yield), 6,000 kg cut fabric (0.240 kg/unit), 8.0 SAM/unit (200,000 SAM total) and 1.0 pressing SAM/unit (25,000 pressing SAM). [S23] [S24] Line 2 (**Style B**) logs 15,000 started units, 12,750 good units (85.0 percent yield), 6,000 kg cut fabric (0.400 kg/unit), 20.0 SAM/unit (300,000 SAM total) and 5.0 pressing SAM/unit (75,000 pressing SAM). [S23] [S24]

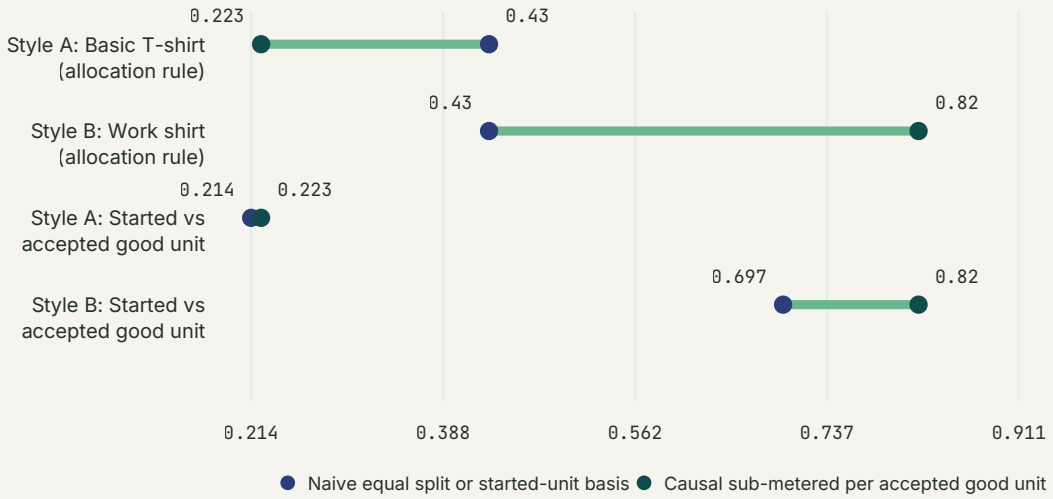
Illustrative pool allocation and per-garment results (combined electrical load 11,680.0 kg CO2e):

- **Cutting pool (1,168.0 kg CO2e illustrative):** Split 50.0 percent each by cut mass (6,000 kg each), assigning 584.0 kg CO2e **to Style A** and 584.0 kg CO2e **to Style B**. [S23] [S24]
- **Direct Line busbars (illustrative):** Line 1 assigns 1,946.7 kg CO2e **to Style A** (5,000 / 30,000) and Line 2 assigns 3,893.3 kg CO2e **to Style B** (10,000 / 30,000). [S23] [S0704]
- **Pressing pool (1,557.3 kg CO2e power plus 3,120.0 kg CO2e boiler = 4,677.3 kg CO2e illustrative):** Split 25.0 percent vs 75.0 percent by pressing SAM (25,000 vs 75,000), assigning 1,169.3 kg CO2e **to Style A** and 3,508.0 kg CO2e **to Style B**. [S23] [S24]
- **Shared Services and Refrigerant pool (3,114.7 kg CO2e power plus 1,000.0 kg CO2e refrigerant = 4,114.7 kg CO2e illustrative):** Split 40.0 percent vs 60.0 percent by total SAM (200,000 vs 300,000), assigning 1,645.9 kg CO2e **to Style A** and 2,468.8 kg CO2e **to Style B**. [S23] [S24]
- **Reconciled intensity (illustrative):** Style A totals 5,345.9 kg CO2e, or 0.214 kg CO2e per started unit and 0.223 kg CO2e **per accepted good garment** (+4.2 percent quality penalty). Style B totals 10,454.1 kg CO2e, or 0.697 kg CO2e per started unit and 0.820 kg CO2e **per accepted good garment** (+17.6 percent quality penalty). Both sum to 15,800.0 kg CO2e (100.0 percent reconciliation), whereas an equal split across 36,750 good units (0.430 kg CO2e/garment) overstates Style A by **92.8 percent** and understates Style B by **47.6 percent**. [S23] [S24]

To make the findings of this worked example comparable across allocation and denominator choices, **Exhibit 35**, p. 127 plots the shift from naive unit averaging to causal sub-metered allocation for both styles, alongside the shift from started units to accepted good garments. [S23] [S24]

EXHIBIT 35 / KG CO2E PER GARMENT (ILLUSTRATIVE SCOPE 1 AND 2)

Causal allocation and good-unit denominators prevent severe cross-subsidy between garment styles



ILLUSTRATIVE [S20] [S23] [S24] Illustrative values from the Chapter 7 worked example comparing naive equal-unit averaging against GFT's causal sub-metered and SAM-weighted method, and comparing started units against accepted good units (S20, S23, S24).

As **Exhibit 35**, p. 127 illustrates, replacing a site-wide unit average with feeder sub-meters and SAM-weighted thermal and electrical pools separates the 0.223 kg CO2e basic T-shirt from the 0.820 kg CO2e work shirt, while moving from started units to accepted good units exposes the 0.123 kg CO2e per garment quality penalty on Line 2. [S23] [S24] Because **Exhibit 35**, p. 127 displays an illustrative calculation, it demonstrates the accounting mechanism rather than an empirical Cameroonian benchmark. [S20] [S23]

7.17

Indirect operations complete the factory inventory

Beyond purchased materials (Scope 3 Category 1), upstream fuel and power losses (Category 3) and freight (Categories 4 and 9), a garment factory generates indirect emissions across additional Scope 3 categories requiring a relevance screen under the GHG Protocol Scope 3 Standard. [S02] [S23] The 15 categories require an organisation to screen all activities first and focus primary data collection where emissions, reduction potential and stakeholder relevance are highest. [S02] [S23]

7.18 CAPITAL GOODS, OPERATIONAL WASTE, EMPLOYEE COMMUTING AND BUSINESS TRAVEL REQUIRE TARGETED SCREENING

Four operational Scope 3 categories require explicit screening rules: [S02] [S23]

- **Category 2 (Capital goods):** Embodied emissions of buildings, solar racks, sewing machines, cutters and boilers enter Corporate Scope 3 Category 2 in the acquisition year, while product footprints under ISO 14067 and European apparel Product Environmental Footprint Category Rules (PEFCR) follow applicable product category rules with disclosure. [S01] [S05] [S06] [S23]
- **Category 5 (Waste generated in operations):** Segregated masses of offcuts, cones, packaging scrap and wastewater are logged by disposal route and multiplied by UK DESNZ route-specific factors. [S02] [S20] [S23]
- **Category 6 (Business travel) and Category 7 (Employee commuting):** Garment plants are labour-intensive; Cameroon announcements for the planned Camtext SA project reference roughly 12,000 jobs at Dibamba and 3,000 at Garoua. [R10] Commuting across 40-hour to 48-hour weeks (Category 7) and auditor or engineer travel (Category 6) enter Corporate Scope 3, excluding owned shuttle buses in Scope 1. [R16] [S02] [S04] [S23]
- **Category 8 (Upstream leased assets):** Utilities of leased spaces not consolidated in Scopes 1 and 2 sit in Category 8. [S02] [S23]

7.19 SECONDARY PROXIES ARE ACCEPTABLE FOR MINOR CATEGORIES WHEN DOCUMENTED

The GHG Protocol Scope 3 Calculation Guidance authorises secondary proxies (commuting survey bands, flight calculators and ecoinvent processes) for minor categories representing a small share of total emissions. [S16] [S23] In product footprints, the GHG Protocol Product Standard separates attributable life cycle processes from non-attributable overhead so corporate Scope 3 completeness is preserved while product records exchanged under WBCSD PACT Version 3 focus on material, energy, waste and transport flows. [S01] [S10] [S23]

> **WARNING**
>
> **Unresolved operational constraints and GFT's commissioning controls**
>
> Three constraints can corrupt a factory's Scope 1 and 2 account in Cameroon if left unmanaged: [S09] [S28] 1. **Unmetered diesel transfers during outages:** Manual drum transfers bypass invoice checks. [S28] [S0701] *Resolution:* Fit inline flow meters on each generator and boiler and cross-check litres weekly against alternator kWh. [S20] [S0701] 2. **Contractor refrigerant top-ups without weighing:** Flat-fee servicing hides kilogram-scale HFC leaks. [S0702] *Resolution:* Require before-and-after cylinder weighing and refrigerant code logging on every maintenance gate pass. [S0702] 3. **Mismatched shift cutoffs between meters and bundles:** Midnight meter reads paired with morning bundle scans distort daily kWh per garment. [S23] [S0704] *Resolution:* Synchronise sub-meter timestamps with end-of-line quality scans across completed batch or monthly windows. [S20] [S23]

By embedding fuel flow meters, refrigerant mass balances, two-tier sub-meters, standard allowed minutes and first-pass yields into one daily record, the garment factory turns Scope 1 and 2 accounting into a live control system. [S04] [S20] [S23]

Once the factory gates are measured and allocated cleanly to every accepted garment, the next task is to follow those garments across multimodal freight corridors without shrinking the fuel boundary. [S01] [S18]

The meter measures the kilowatt, the stopwatch measures the minute, and the inspection table names the garment that must carry them both.

CHAPTER SOURCE NOTES

S04 GHG Protocol. 2004.

S20 UK Department for Energy Security and Net Zero. 2026-06-11.

S08 Science Based Targets initiative and World Resources Institute. 2019.

S31 Forfora et al., Sustainability. 2026-04-20.

S23 GHG Protocol and Carbon Trust. 2013.

S0704 United States Environmental Protection Agency. 2023-12.

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

S01 GHG Protocol. 2011.

S03 GHG Protocol. 2015.

S24 International Organization for Standardization. 2006-07.

S02 GHG Protocol. 2011.

S0702 United States Environmental Protection Agency. 2023-12.

S0703 United States Environmental Protection Agency. 2026-04-02.

S0701 United States Environmental Protection Agency. 2023-12.

S14 International Energy Agency. 2026-09-25.

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S09 International Energy Agency. 2026.

S28 World Bank. 2025-01-16.

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S05 International Organization for Standardization. 2018-08.

S10 World Business Council for Sustainable Development. 2025-04-30.

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

S25 International Organization for Standardization. 2006-07.

S26 Watson and Wiedemann, Sustainability. 2019-07-15.

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

S06 European Commission. 2025-06-25.

R16 WageIndicator. Publication date unrecorded; inherited source-text check.

S16 ecoinvent. 2025-11-05.

S18 Smart Freight Centre. 2024.

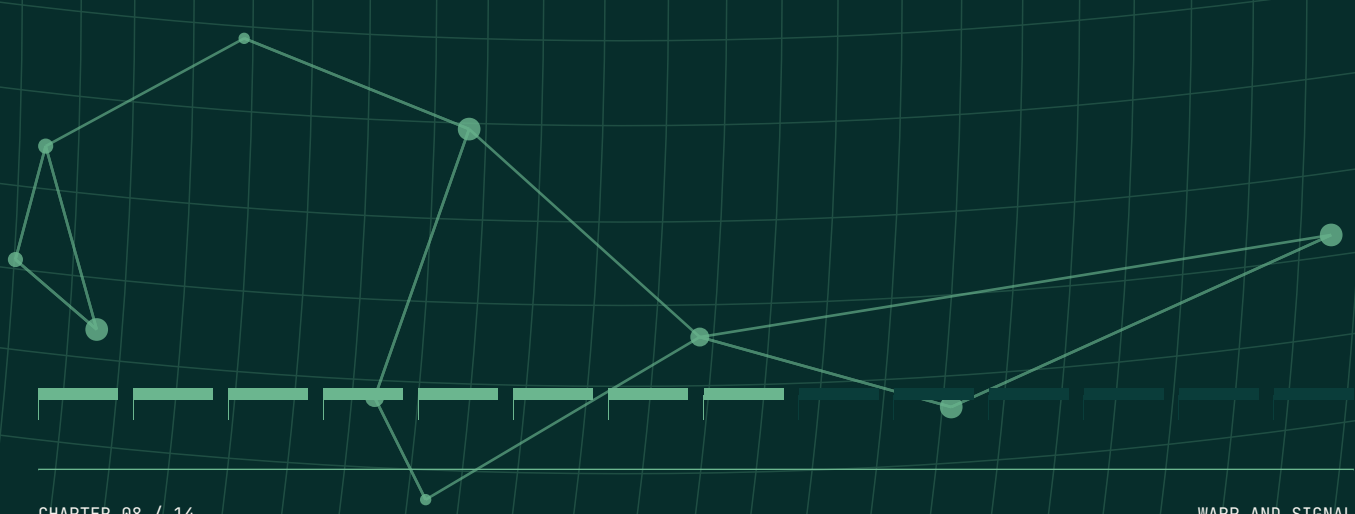
GREEN FUTURE TECH
LIMITED / HONG KONG SAR

08

PART II: FOLLOW CARBON THROUGH THE GARMENT / FREIGHT

Logistics requires transport work and fuel life cycles, not distance alone

A route footprint depends on mass, loading, mode, fuel, empty running and upstream energy, not only kilometres.



CHAPTER 08
DECISION TEST

A route footprint depends on mass, loading, mode, fuel, empty running and upstream energy, not only kilometres.

A garment's freight footprint cannot be calculated by measuring the map distance between a cotton gin, a spinning mill, a garment factory and a retail warehouse. [S18] Freight emissions are governed by transport work, defined as the product of consignment mass and distance travelled across each discrete leg, combined with the throughput handled at intermediate logistics hubs and the full well-to-wake life cycle of the fuels and electricity consumed. [S18] [S0802] Two shipments covering the same corridor between northern Cameroon and an export port can differ severalfold in carbon dioxide equivalent (CO2e) per garment when one moves in a lightly loaded road truck with an empty return leg and the other moves on a consolidated rail-and-sea intermodal service with backhaul cargo. [S18] [S0802] In GFT's accounting architecture, every freight movement is decomposed into sequential transport chain elements (TCEs), matched to representative vehicle and hub operation categories, and split into upstream energy provision (well-to-tank) and direct operational combustion or leakage (tank-to-wake) before any CO2e is assigned to a garment. [S18] [S19] [S0802]

Treating freight as a simple kilometre multiplier hides the operational levers that procurement, logistics and inventory teams control. [S18] Across Cameroon's cotton-to-textile geography, where more than 220,000 producers and nine ginning plants operate in the northern belt while major port infrastructure sits at Douala, domestic and export corridors span hundreds of kilometres of mixed road and rail networks. [R03] [S0801] Because roughly 95 percent of Cameroonian cotton fibre has historically been exported raw while national policy targets 50 percent local processing by 2030, shifting from raw lint export to domestic yarn, fabric and garment manufacturing alters the mass moved, packaging ratio, container utilisation and modal split along the corridor. [R06] [R07] Recording those physical parameters at each leg and terminal turns logistics from a static proxy into an auditable engineering account. [S18] [S20]

8.1

Transport work begins with tonne-kilometres

International harmonisation of freight carbon accounting rests on the Global Logistics Emissions Council (GLEC) Framework, developed by the Smart Freight Centre, and its codification into ISO 14083:2023 for quantifying and reporting greenhouse gas emissions from transport chain operations. [S18] [S0802] [S0804] Under both ISO 14083 and the GLEC methodology, a complete freight movement from consignor to consignee is defined as a transport chain (TC) and partitioned into an ordered sequence of transport chain elements (TCEs). [S18] [S0802] Every TCE represents either a vehicle leg between two locations or a handling process inside a logistics hub. [S0802] Rather than multiplying total route distance by a generic modal average, the practitioner quantifies the physical transport activity of each leg in tonne-kilometres (tkm) and the hub activity of each terminal in tonnes (t) of cargo throughput. [S18] [S0802]

The numerator of freight intensity is the greenhouse gas activity of the transport operation (TO) or hub operation (HO), comprising measured or modelled fuel consumption, electricity intake and refrigerant leakage converted into CO2e using 100-year global warming potentials (GWPs). [S0802] The denominator is the transport work performed for the cargo. [S0802] Because an individual shipment rarely occupies an entire train or container vessel alone, ISO 14083 groups similar operations over a

period of up to one calendar year into a transport operation category (TOC) or hub operation category (HOC). [S0802] Each TOC aggregates vehicles sharing comparable technical and operational traits, including vehicle class, drivetrain, emission standard, payload capacity, temperature control, load factor and empty-running share, so that a representative emission intensity in g CO2e per tkm can be multiplied by the specific tkm of the garment consignment. [S18] [S0802]

8.2 DISTANCE ADJUSTMENT RULES BRIDGE PLANNED ROUTES AND ACTUAL VEHICLE TRAVEL

Calculating tonne-kilometres requires an explicit rule pairing the distance metric of the consignment with the distance basis of the emission factor. [S0802] ISO 14083 defines two reference conventions alongside actual driven distance: the shortest feasible distance (SFD), representing the shortest practical route executable by the vehicle class on existing road, rail or waterway infrastructure, and the great circle distance (GCD), measuring the geodesic path between two coordinates. [S0802] When primary fuel logs are unavailable and the account uses an emission intensity per actual tkm, multiplying by an unadjusted SFD or GCD understates emissions because vehicles deviate for traffic, weather and terminal approaches. [S0802]

To prevent this downward bias, ISO 14083 specifies normative distance adjustment factors (Table 3 of the CLECAT and German Environment Agency guide) that convert reference distances into estimated actual distances when odometer or vessel tracks are absent: SFD multiplied by 1.05 for road (a 5 percent surcharge), SFD multiplied by 1.15 for maritime shipping (a 15 percent surcharge), GCD plus 95 km for air freight, and SFD with no surcharge (1.00) for rail freight. [S0802] If a database already reports its TOC intensity normalised to SFD (such as 143 g CO2e per actual tkm converted by the 1.05 road factor into 150 g CO2e per SFD tkm in S0802), the practitioner multiplies that adjusted intensity directly by SFD tonne-kilometres so the correction is applied only once. [S0802]

Under ISO 14083, consignment mass includes the product plus primary and transport packaging (polybags, cartons, pallets or bale straps), whereas the tare mass of reusable intermodal load carriers (such as a 2.25-tonne steel twenty-foot container shell) is excluded from the cargo tkm denominator because its deadweight is already reflected inside the TOC fuel intensity. [S0802] Where weighed gross mass is absent during screening, ISO 14083 and the GLEC Framework provide secondary defaults of 10 tonnes per twenty-foot equivalent unit (TEU) and 300 kg per pallet. [S18] [S0802] Furthermore, as documented in the comparative T-shirt life cycle assessment (LCA) by Forfora et al., cotton processing incurs cumulative material losses of 31 percent across cradle-to-gate stages. [S31] Producing an illustrative 0.25 kg finished cotton garment therefore requires 0.362 kg of ginned lint input (0.25 kg divided by 0.69), meaning that upstream bale transport from northern ginning plants must account for the fibre mass lost during spinning and cutting. [S31]

8.3 LOAD FACTORS AND EMPTY REPOSITIONING GOVERN THE CARBON COST PER GARMENT

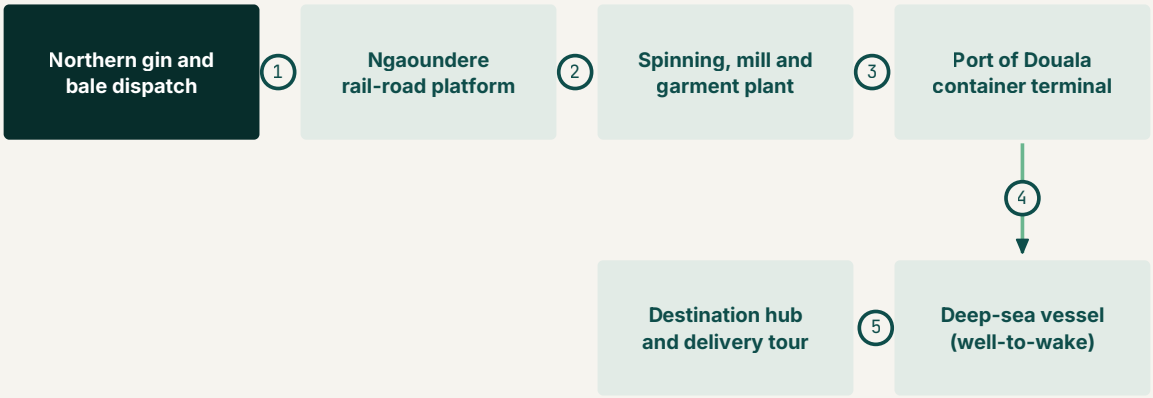
Distance and consignment weight do not suffice to select a freight emission factor unless vehicle loading and empty running are specified. [S18] [S20] [S0802] Heavy goods vehicles, trains and ships consume a large share of their tractive energy moving the tare weight of the vehicle itself; as payload utilisation falls, that fixed energy burn is divided across fewer tonnes of cargo, raising CO2e per tkm non-linearly. [S20] [S0802]

Commercial freight networks also rarely achieve balanced bidirectional flows: a truck hauling cotton bales or yarn cones from Garoua to a southern mill or port may return northward empty or partially loaded. [R03] [S0801] [S0802]

Under ISO 14083 and the GLEC Framework, the fuel and emissions of empty repositioning legs belong inside the TOC boundary and are amortised across the loaded tonne-kilometres of that TOC. [S18] [S0802] In the ISO 14083 benchmark, a 40-tonne articulated Euro 6 diesel truck operating with a 10-tonne average payload and 20 percent empty running records 143 g CO2e per actual tkm (150 g CO2e per SFD tkm), whereas an electric container block train at a 48 percent load factor and 20 percent empty running records 14 g CO2e per tkm. [S0802] UK Department for Energy Security and Net Zero (DESNZ) conversion factors similarly stratify heavy goods vehicle (HGV) intensities by weight class and percentage laden (0 percent, 50 percent, 100 percent and fleet average) so reporters never apply a fully laden factor to a partially loaded truck. [S20] **Exhibit 36**, p. 133 maps this sequential chain structure from northern cotton ginning to final customer delivery. [S18] [S19] [S20] [S0802]

EXHIBIT 36 / TRANSPORT CHAIN ELEMENTS

A corridor-to-customer chain preserves the full fuel boundary



1. TCE 1: road haul
2. TCE 2-3: hub + rail
3. TCE 4: drayage
4. TCE 5-6: port + sea
5. TCE 7-8: hub + road

ILLUSTRATIVE [S18] [S19] [S20] [S0802] Illustrative transport chain architecture derived from GLEC Framework, IMO marine fuel LCA and ISO 14083 guidance in S18, S19, S20 and S0802. Each leg and hub records both energy provision (well-to-tank) and operation (tank-to-wake) flows.

As **Exhibit 36**, p. 133 illustrates, a garment supply chain alternates between vehicle legs (measured in tkm) and transhipment hubs (measured in tonnes), each carrying dual fuel-boundary fields. [S18] [S0802] Because **Exhibit 36**, p. 133 is an architectural flow model, it defines accounting boundaries rather than asserting measured emissions for a specific Cameroonian shipment. [S0802]

8.4

Well-to-wake prevents the fuel boundary from shrinking

Restricting a transport calculation to exhaust-pipe combustion creates severe distortions whenever electric traction, biofuels, synthetic electro-fuels or liquefied natural gas (LNG) enter the logistics mix. [S19] [S0802] [S0803] An electric train or battery-electric truck emits zero greenhouse gases at the vehicle exhaust, while a ship burning hydrotreated vegetable oil (HVO) or fatty-acid methyl ester (FAME) biodiesel reports near-zero fossil CO2 from onboard combustion. [S19] [S0802] Stopping the boundary at the vehicle tank or pantograph makes fuel switching appear to eliminate the footprint overnight, even when power generation, oilseed cultivation, refining or gas liquefaction released substantial emissions upstream. [S19] [S0802] [S0803]

To prevent this boundary shrinkage, both ISO 14083 and the International Maritime Organization (IMO) mandate full fuel life-cycle accounting across all modes. [S19] [S0802] [S0803] In maritime shipping, the IMO Marine Environment Protection Committee (MEPC) adopted the 2024 Guidelines on life cycle GHG intensity of marine fuels (Resolution MEPC.391(81), superseding Resolution MEPC.376(80)), as documented by the IMO and Hong Kong SAR Marine Department Information Note No. 64/2024. [S19] [S0803] The 2024 LCA Guidelines evaluate all marine fuels across the well-to-wake (WtW) chain: feedstock extraction, cultivation, conversion and bunkering (well-to-tank, WtT), plus onboard utilisation (tank-to-wake, TtW), covering CO2, methane (CH4) and nitrous oxide (N2O) and verified through a Fuel Lifecycle Label (FLL). [S19] [S0803]

8.5 ENERGY PROVISION AND OPERATION MUST REMAIN SEPARATE FIELDS IN EVERY FACTOR

To apply the same mathematical structure to vehicles, vessels, aircraft and stationary hubs, ISO 14083 (Section 1.2 of S0802) defines two normative components across every factor: energy provision GHG emissions (GE, corresponding to WtT upstream extraction, refining, power generation and distribution) and operation GHG emissions (GO, corresponding to TtW combustion, fuel slippage and refrigerant leakage), which sum to total well-to-wake emissions (GT, or intensity gT). [S0802]

ISO 14083, the GLEC Framework and the GHG Protocol require storing operation (TtW) and energy provision (WtT) as separate fields before summing. [S18] [S20] [S0802] For company-operated fleets or warehouses, operational fuel burn and refrigerant refills sit in Scope 1, purchased electricity sits in Scope 2, and upstream energy provision sits in Scope 3 Category 3. [S02] [S03] [S04] [S20] For outsourced freight (Scope 3 Category 4 and Category 9) and product footprints under ISO 14067 and PACT Version 3, combining both into total well-to-wake emissions prevents upstream omissions while keeping the split visible so practitioners never add a duplicate WtT factor onto a WtW factor. [S10] [S18] [S20] [S23]

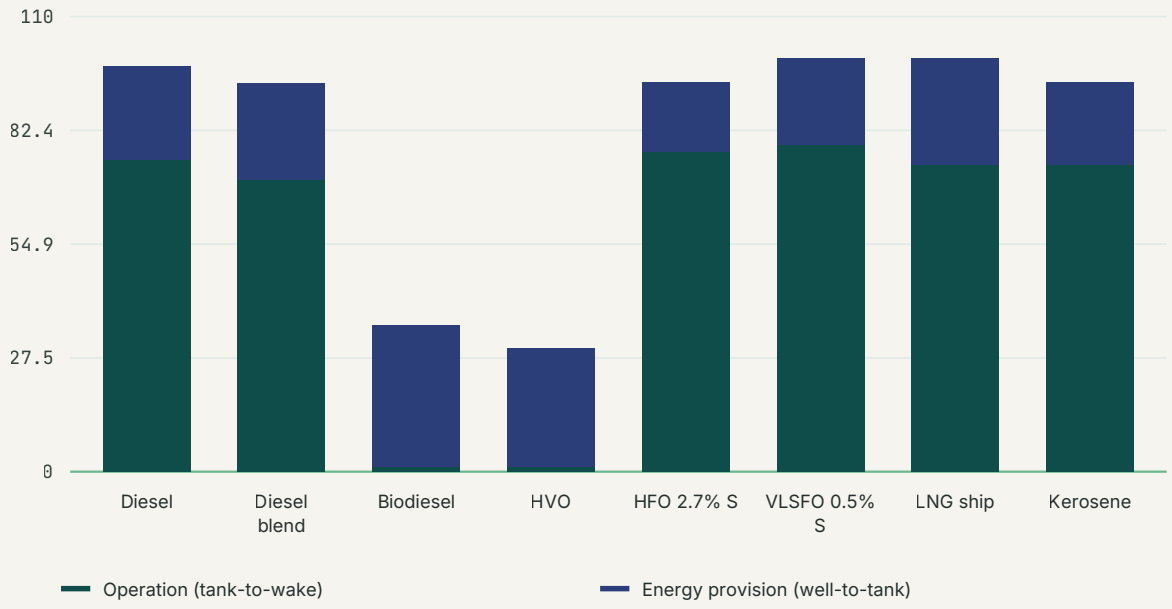
8.6 ALTERNATIVE FUELS AND METHANE SLIP FAIL WITHOUT UPSTREAM ACCOUNTING

Empirical emission factors compiled for ISO 14083 by the ifeu Institute and Fraunhofer IML (Table 17 of S0802, based on EcoTransIT World and ecoinvent 3.9.1 under IPCC AR6 100-year GWPs) show why ranking transport fuels by exhaust emissions alone produces false abatement claims. [S0802] As plotted in **Exhibit 37**, p.

135, fossil road diesel (42.8 MJ/kg) generates 75.26 g CO2e/MJ in operation plus 22.56 g CO2e/MJ in energy provision (97.82 g CO2e/MJ total), while a 6.3 percent biodiesel blend generates 70.60 g CO2e/MJ in operation and 23.22 g CO2e/MJ in energy provision (93.80 g CO2e/MJ total). [S0802]

EXHIBIT 37 / G CO2E PER MJ OF LOWER HEATING VALUE

Upstream energy provision changes the ranking of transport fuels



SOURCED [S0802] [S19] [S0803] Sourced from the ISO 14083 guide Table 17 (ifeu Institute and Fraunhofer IML, based on EcoTransIT World and ecoinvent 3.9.1 under IPCC AR6, S0802) and aligned with IMO well-to-wake guidance (S19, S0803). Operation covers combustion and methane slip; energy provision covers upstream feedstock, refining and distribution.

Inspecting **Exhibit 37**, p. 135 reveals two critical lessons. [S19] [S0802] First, for Biodiesel (50 percent rapeseed, 40 percent used cooking oil, 10 percent soy) and HVO (50 percent rapeseed, 50 percent used cooking oil), fossil CO2 from combustion is 0 g/MJ and non-CO2 operational emissions are 1.16 g CO2e/MJ, appearing as a 98.5 percent cut under a tank-to-wheel boundary; including upstream energy provision (34.22 g CO2e/MJ for biodiesel and 28.56 g CO2e/MJ for HVO) sets their well-to-wheel totals at 35.38 g CO2e/MJ (63.8 percent below fossil diesel) and 29.72 g CO2e/MJ (69.6 percent below fossil diesel). [S0802] Second, for a medium-speed dual-fuel LNG ship (49.1 MJ/kg), direct combustion CO2 is 56.42 g/MJ (27.2 percent below VLSFO combustion CO2 of 77.54 g/MJ), but unburned methane slip (3.1 mass-percent of fuel) adds 17.68 g CO2e/MJ of operational methane (74.10 g CO2e/MJ total operation) and gas supply and liquefaction add 25.77 g CO2e/MJ upstream. [S0802] The resulting well-to-wake total for the LNG ship is 99.87 g CO2e/MJ, exceeding heavy fuel oil (HFO at 93.95 g CO2e/MJ) and matching VLSFO (99.85 g CO2e/MJ). [S0802] Because **Exhibit 37**, p. 135 is normalised per MJ of fuel, translating these figures into g CO2e per garment still requires drivetrain efficiency, payload utilisation and route distance. [S18] [S0802]

8.7

Mode and geography determine the factor

Even with identical fuel boundaries, a tonne-kilometre of freight carries vastly different emissions across modes and geographic corridors. [S18] [S20] [S0802] Air cargo (kerosene at 94.13 g CO2e/MJ total intensity combined with high energy burn per tkm lifted), road haulage, diesel or electric rail, inland waterways and deep-sea container ships differ by orders of magnitude in energy required per tkm. [S18] [S20] [S0802] Under ISO 14083 (Appendix A.2 of S0802), air TOCs separate short-haul (under 1,500 km) from long-haul (over 1,500 km) and belly freight from dedicated freighters; maritime TOCs stratify by cargo type, vessel size and temperature condition; and road and rail TOCs stratify by weight class, traction type, load factor and empty running. [S20] [S0802]

8.8 MULTIMODAL CHAINS REQUIRE MODE-SPECIFIC OPERATION CATEGORIES

Where primary fuel logs from carriers are unavailable, ISO 14083 (Section 7.2.2) enforces a strict three-tier hierarchy: primary measured data first, modelled secondary data calibrated to the TOC second, and default values last with explicit justification, prohibiting data-tier selection aimed at lowering reported emissions. [S0802] To combine road, rail, sea and hub segments consistently, ISO 14083 sums the absolute CO2e emissions of all vehicle legs (tkm multiplied by g CO2e/tkm) and intermediate hubs (tonnes multiplied by g CO2e/t) into total chain emissions (GT,TC), and divides that sum by total vehicle transport activity (sum of tkm, excluding hub tonnes from the denominator) to report overall chain intensity (gT,TC). [S0802]

8.9 CORRIDOR INFRASTRUCTURE AND NATIONAL FACTORS GOVERN REGIONAL ACCURACY

Applying European or UK default factors uncritically to Central African corridors introduces geographic proxy error that must be logged and progressively replaced. [S16] [S20] [S23] [S0802] In Cameroon, cotton cultivation and ginning sit in the northern belt around Garoua (R03, R10), while major spinning, weaving and export infrastructure spans Garoua, the Dibamba industrial hub near Douala (12,000 tonnes a year of planned integrated processing under the announced Camtext SA project, with 3,000 planned jobs at Garoua and 12,000 at Dibamba) and the Port of Douala. [R03] [R09] [R10] Moving cotton lint, yarn, fabric and garments along this spine relies on the Douala-Yaounde-Ngaoundere-Garoua-N'Djamena intermodal corridor. [S0801]

Primary empirical evidence from the World Bank's Implementation Status and Results Report (Sequence No. 6, published 5 January 2026) for the Cameroon-Chad Transport Corridor Project (P167798) documents the operational baseline along this intermodal artery as of 12 December 2025. [S0801] Total freight transit time from departing the Port of Douala to arriving in N'Djamena stands at 20.00 days (against a June 2032 target of 12.20 days), comprising 7.10 days of rail transit from Douala to the Ngaoundere rail-road platform (target 5.00 days), 1.70 days of platform transfer at Ngaoundere (target 1.00 day), 4.20 days of onward road transport northward (target 2.20 days) and 7.00 days of customs clearance (target 4.00 days). [S0801] Baseline corridor transport cost is US$155.38 per tonne (target US$141.16), comprising US$60.00 per tonne for rail to Ngaoundere (target US$55.00), US$1.38 per tonne for platform offloading (target US$1.16) and US$94.00 per tonne at baseline (US$64.00 as of December 2025, target US$85.00) for road haulage northward,

while the rail line carries 1.33 million tonnes (target 1.53) with 0.60 derailments per 1,000 trains (target 0.20) and 2 calibrated axle-load stations (target 6) operating on the road network. [S0801]

Because Camrail operates diesel-electric locomotives on the Douala-Ngaoundere line rather than the electric catenary assumed in European default rail tables (14 g CO2e/tkm in S0802), applying a European electric-rail factor would misstate both operational and upstream emissions. [S0801] [S0802] Equally, when hubs in Douala, Dibamba, Ngaoundere or Garoua draw grid power, the account must use dated Cameroonian grid factors from the International Energy Agency (IEA Emissions Factors 2026, S14) and national hydro and solar references (S09, S28) rather than European (493.96 g CO2e/kWh in S0802) or UK (S20) factors. [S09] [S14] [S20] [S28] [S0802] **Exhibit 38**, p. 137 defines the minimum dataset required for reproducible freight calculations. [S18] [S20] [S0802]

EXHIBIT 38 / ISO 14083 AND GLEC DATA FIELDS

A minimum logistics dataset supports reproducible freight calculations

Field	Required unit or code	Accounting role in the transport chain
Transport chain element	TCE ID, origin, destination	Separates each vehicle leg and transhipment hub
Mode and TOC class	Road, rail, sea, air, hub class	Matches operation to a representative vehicle or hub category
Consignment mass	Tonnes (cargo plus packaging)	Sets the numerator for tonne-kilometres and hub throughput
Distance and basis	km (actual, SFD or GCD)	Applies ISO 14083 distance adjustment when actual km are absent
Loading and empty run	Load factor %, empty %	Captures capacity utilisation and repositioning fuel burden
Energy carrier and WTW	Litres, kg or kWh by pathway	Separates operation (tank-to-wake) and energy provision (well-to-tank)
Hub utilities and leaks	kWh, fuel, refrigerant refill kg	Assigns terminal handling, cooling and fugitive gases to throughput
Allocation and Scope	tkm share, TEUeq, Scope 1/2/3	Prevents double counting between inbound Category 4 and outbound Category 9

SOURCED [S18] [S20] [S0802] Compiled from GLEC Framework (S18), UK conversion factor methodology (S20) and the CLECAT/Umweltbundesamt ISO 14083 guide (S0802). Every transport chain element requires both activity and boundary metadata before an emission factor is applied.

As **Exhibit 38**, p. 137 shows, every freight record pairs physical movement parameters with energy-pathway and scope metadata. [S18] [S20] [S0802] While **Exhibit 38**, p. 137 defines the mandatory schema for an auditable ledger, any record relying on a secondary default (such as 20 percent empty running or 10 tonnes per TEU) must flag its data-quality tier for primary replacement. [S23] [S0802]

SIX-STEP TRANSPORT CHAIN CALCULATION AND RECONCILIATION PROTOCOL

The six-step calculation sequence under ISO 14083 and the GLEC Framework proceeds as follows. [S18] [S0802]

1. **Decompose the transport chain (TC) into elements (TCEs):** List every sequential vehicle leg (i = 1 to m) and hub (j = 1 to k) from supplier gate to customer delivery. [S18] [S0802]
2. **Quantify physical activity:** Record cargo plus packaging mass M_i (tonnes) and distance D_i (km, applying 1.05 road, 1.15 sea or +95 km air adjustments where actual km are absent) to compute transport work T_i = M_i * D_i (tkm), and record hub throughput H_j (tonnes). [S0802]
3. **Assign operation categories (TOCs and HOCs):** Map each TCE to its representative TOC or HOC by mode, size, fuel pathway, temperature control, load factor and empty running. [S18] [S0802]
4. **Determine separate operation (GO) and energy-provision (GE) intensities:** Establish operational intensity gO and energy-provision intensity gE (g CO2e/tkm for legs, g CO2e/t for hubs), with gT = gO + gE. [S19] [S20] [S0802]
5. **Calculate element emissions and reconcile shared loads:** Compute GHG_i = T_i gT,i *and* $GHG_j = H_j$ gT,j, applying SFD tkm shares for multi-drop tours and TEUeq or temperature-group keys for mixed vessels and hubs. [S0802]
6. **Aggregate chain totals and normalise per garment:** Sum GT,TC = sum(GHG_i) + sum(GHG_j) (preserving GO,TC and GE,TC separately), compute chain intensity gT,TC = GT,TC / sum(T_i), and divide GT,TC by accepted garment units N_good, verifying that allocated consignment emissions sum to 100 percent of TOC and HOC emissions. [S23] [S0802]

8.10

Inbound and outbound legs need separate allocation

In a product life cycle assessment under ISO 14040, ISO 14044 and ISO 14067, every transport leg from raw cotton field to garment disposal belongs inside the cradle-to-grave boundary regardless of who paid the carrier. [S01] [S05] [S24] In a corporate greenhouse gas inventory under the GHG Protocol, however, operational control and commercial payment terms (Incoterms) divide those same movements across Scope 1, Scope 2, Scope 3 Category 1, Scope 3 Category 4 and Scope 3 Category 9. [S02] [S03] [S04] [S23] Copying product-level freight numbers into a corporate ledger without checking delivery boundaries causes systematic double counting or omissions. [S23] [S0802]

8.11 INCOTERMS AND OPERATIONAL CONTROL SEPARATE CATEGORY 4 FROM CATEGORY 9

The GHG Protocol Scope 3 Standard and its Technical Guidance establish three boundary rules for freight. [S02] [S23] First, when the reporting manufacturer operates its own vehicles or forklifts, direct fuel burn and refrigerant refills belong in Scope 1, purchased charging electricity belongs in Scope 2, and upstream well-to-tank energy provision belongs in Scope 3 Category 3. [S02] [S03] [S04] [S20] Second, Scope 3 Category 4 (Upstream transportation and distribution) captures third-party transport and

warehousing of purchased inputs between tier-one suppliers and the reporting company, plus outbound third-party freight paid for by the reporting company (under delivered Incoterms such as CIF, CIP or DDP). [S02] [S23] Third, Scope 3 Category 9 (Downstream transportation and distribution) captures third-party transport and storage of sold products after the point of sale when not paid for by the reporting company (such as garments sold Ex Works or FOB Douala). [S02] [S23] Every supplier cradle-to-gate footprint aligned with WBCSD PACT Version 3 must also carry an explicit gate boundary tag so tier-one inbound transport is counted once in Category 4 and never duplicated inside Category 1. [S10] [S16] [S23]

8.12 MULTI-DROP TOURS AND MIXED CONTAINERS ALLOCATE BY TRANSPORT WORK

When a vehicle or vessel carries multiple consignments, total emissions must be partitioned using a physical driver that reflects transport work rather than order count or stop sequence. [S18] [S23] [S0802] In a multi-stop collection or delivery tour (milk run), allocating fuel by cumulative driven distance up to each drop penalises the final stop for the entire circuit. [S0802] ISO 14083 (Example 3 and Table 6 of S0802) prevents stop-order bias by allocating tour emissions proportional to each shipment's direct tonne-kilometres calculated from the hub-to-destination shortest feasible distance (SFD, or GCD) multiplied by shipment mass. [S0802] Across the 14-stop, 44 km tour carrying 45.3 kg in Table 6 of S0802 (total 0.3632 SFD tkm), Stop 1 (8 km driven, 7 km SFD, 4 kg mass) generates 0.0280 tkm and receives 7.7 percent of tour emissions; Stop 3, carrying a 0.25 kg consignment (matching one cotton T-shirt in S31) to a destination 9 km SFD from the hub (14 km driven), generates 0.00225 tkm (0.0023 tkm rounded) and receives a 0.5 percent allocation key; and Stop 14 (40 km driven, 7 km SFD, 0.5 kg mass) generates 0.0035 tkm and receives 1.0 percent of tour emissions. [S31] [S0802]

A parallel rule protects dry garment containers on mixed ocean voyages carrying refrigerated (reefer) cargo (Example 4 of S0802). [S0802] On a 16,000 km voyage carrying 6,000 TEU (5,050 ambient TEU and 950 reefer TEU) burning 88,090,000 MJ of marine fuel oil, ISO 14083 applies a 1.17 weighting factor for reefer containers (Dobers et al. 2023b in S0802) when auxiliary engine sub-metering is absent. [S0802] The 950 reefer TEU equal 1,112 TEU equivalents (TEUeq), bringing the vessel total to 6,162 TEUeq at 14,297 MJ per TEUeq and allocating 82.0 percent of voyage fuel (72,199,059 MJ) to ambient containers and 18.0 percent (15,890,941 MJ) to reefer containers. [S0802]

8.13

Ports and warehouses are part of the logistics account

Unlike earlier European guidance (EN 16258:2012), both the GLEC Framework and ISO 14083:2023 treat transhipment terminals, rail-road platforms, container ports and warehouses as mandatory elements of the transport chain. [S18] [S0802] Under Table 1 and Table 2 of S0802, a hub TCE normatively includes internal cargo-handling equipment (cranes, reach stackers, forklifts, conveyors), terminal shunting equipment, building services (lighting, heating, ventilation and air conditioning) and on-site ICT infrastructure, while high-bay storage equipment and repackaging materials are

optional and employee commuting is excluded. [S0802] Energy used on hub premises by incoming or outgoing transport vehicles (ship shore power or auxiliary engines at berth, locomotive idling, truck charging or reefer-container refills) is assigned to the respective vehicle leg TCE so that hub and leg accounts never overlap. [S0802]

8.14 HUB OPERATION CATEGORIES CAPTURE TRANSHIPMENT, STORAGE AND REFRIGERANTS

Within each hub operation category (HOC), fugitive refrigerant leakage is a critical operation (GO) source alongside fuel and electricity. [S0802] In a survey of approximately 850 logistics hubs conducted between 2021 and 2023 (Dobers and Jarmer 2023, Section 4.2.4 of S0802), 66 percent of operators reported annual refrigerant refills, led by R-410A (19 percent of sites, IPCC AR6 100-year GWP 2,255.5 kg CO2e/kg) and R-404A (19 percent, AR6 GWP 4,728.0 kg CO2e/kg), followed by R-717 (15 percent), R-407C (8 percent, GWP 1,907.9), R-134a (6 percent, GWP 1,530.0), and R-448a (GWP 1,494.4) and R-744 (GWP 1.0) at 5 percent each. [S0802] At a hub consuming 2,000,000 kWh of electricity (987,926 kg CO2e at 493.96 g CO2e/kWh), refilling 15 kg of R-410A adds 33,833 kg CO2e of operational emissions (3.3 percent of electricity emissions), and non-calendar maintenance records (1.700 kg across 2022/23 and 1.805 kg across 2023/24) are prorated by monthly share (1.7788 kg for the calendar year); where primary records are absent, S0802 provides defaults of 0.5 g R-404A per tonne of ambient cargo and 1.2 g R-404A per tonne of chilled cargo. [S0802]

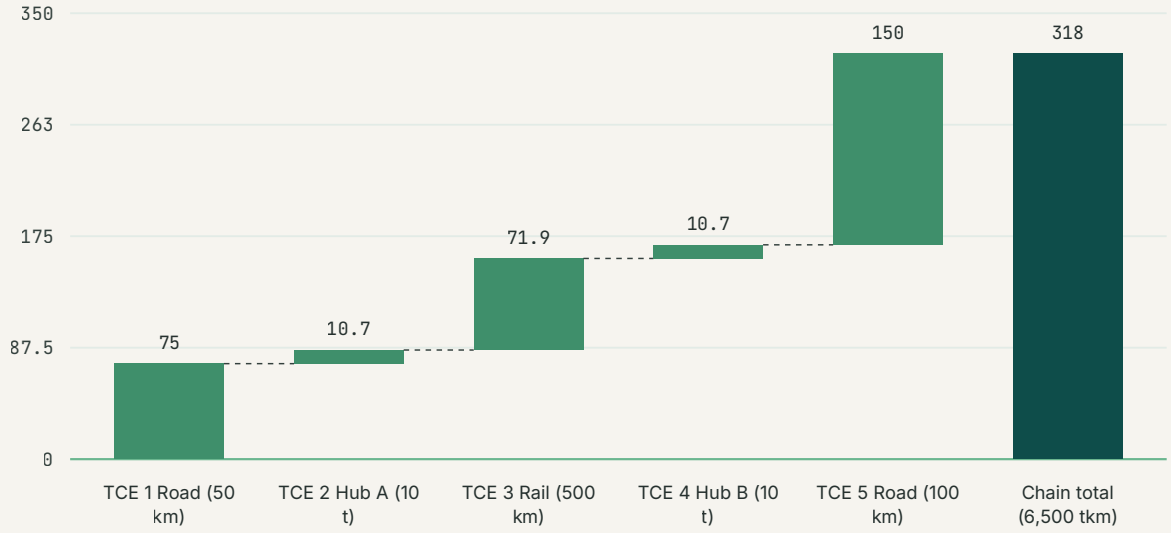
8.15 MULTI-TEMPERATURE AND MULTI-SERVICE HUBS REQUIRE TWO-STAGE ALLOCATION

When a logistics hub handles both ambient apparel and chilled goods, averaging all site utilities across total tonnage overcharges ambient garments for cold-store power and refrigerants. [S0802] ISO 14083 (Example 5, Table 7 of S0802) mandates a two-stage allocation across an HOC combining Hub A (4,000 t chilled, 70,000 t ambient) and Hub B (2,000 t chilled, 67,000 t ambient), for 143,000 tonnes total throughput (6,000 t chilled and 137,000 t ambient). [S0802] Isolating dedicated chilled cooling and lighting electricity (101,728 kWh = 50,250 kg CO2e energy provision) plus 9 kg of R-410A refills (20,300 kg CO2e operation) for the chilled group, isolating ambient heating (52,000 kWh natural gas and 37,000 kWh district heating = 10,310 kg CO2e operation and 17,503 kg CO2e energy provision) for the ambient group, and distributing shared yard diesel (11,110 l), LNG (5,500 kg) and residual electricity (170,272 kWh) across all 143,000 tonnes (42,888 kg CO2e operation and 98,782 kg CO2e energy provision) yields an ambient hub intensity of 1.19 kg CO2e/t (0.38 kg CO2e/t operation and 0.82 kg CO2e/t energy provision) versus 12.75 kg CO2e/t for chilled cargo, avoiding a 41 percent overcharge relative to the unallocated site average of 1.68 kg CO2e/t. [S0802]

Combining road drayage, container terminals and rail in an intermodal chain (Case example A in S0802, moving 10 tonnes of ambient cargo across 50 km SFD pre-carriage road, CT Terminal A, 500 km SFD rail, CT Terminal B and 100 km SFD on-carriage road) reveals how legs and hubs interact, as plotted in **Exhibit 39**, p. 141. [S18] [S0802]

EXHIBIT 39 / KG CO2E PER 10-TONNE CONTAINERISED CONSIGNMENT

Short road drayage legs dominate an intermodal rail transport chain



DERIVED [S0802] [S18] Derived from the ISO 14083 freight transport chain calculation in S0802 (10 tonnes cargo across 6,500 tkm total shortest feasible distance). Road legs (150 km combined, 23.1 percent of distance) account for 225.0 kg CO2e (70.7 percent of total 318.3 kg CO2e), rail (500 km) accounts for 71.9 kg CO2e (22.6 percent) and two hub transfers account for 21.4 kg CO2e (6.7 percent).

As **Exhibit 39**, p. 141 demonstrates, across the 650 km total route (6,500 tkm), the 500 km rail leg covers 76.9 percent of the distance but generates only 71.9 kg CO2e (22.6 percent of the 318.3 kg CO2e chain total), whereas the 50 km and 100 km road drayage legs cover 23.1 percent of the distance (1,500 tkm) but generate 225.0 kg CO2e (70.7 percent) at 0.150 kg CO2e/tkm, and the two container terminals (at the GLEC default of 1.07 kg CO2e/t, of which 0.384 kg CO2e/t is operation) add 21.4 kg CO2e (6.7 percent) for an overall chain intensity of 49.0 g CO2e/tkm. [S18] [S0802] What **Exhibit 39**, p. 141 cannot establish is the footprint of a diesel-hauled railway or a deep-sea shipping leg; each corridor requires its own TOC and HOC inputs, as shown in the worked garment calculation below. [S0801] [S0802]

WORKED EXAMPLE

Illustrative corridor calculation for a consignment of 40,000 cotton T-shirts [S31] [S0802]

To demonstrate how GFT's footprint calculator translates transport work, hub throughput and well-to-wake fuel factors into carbon per garment, consider an explicitly illustrative production and export batch of 40,000 accepted cotton T-shirts (0.25 kg net finished mass per shirt from S31, or 10.00 tonnes net batch mass). [S31] This is a method demonstration built from cited ISO 14083 and S31 parameters, not a measured GFT operating result. [S31] [S0802]

1. **Mass balance across upstream and downstream legs:** Using the 31 percent cumulative cradle-to-gate cotton loss in S31, producing 10.00 tonnes of finished shirts requires 10.00 / 0.69 = 14.49 tonnes of ginned lint (14.50 tonnes rounded, plus 0.30 tonnes of bale wrapping = 14.80 tonnes gross inbound mass). [S31] At the factory gate, the 10.00 tonnes of shirts are packed with 1.00 tonne of cartons and polybags (11.00 tonnes gross outbound mass, or 0.275 kg packed mass per garment) in one container. [S0802]
2. **Element 1 (TCE 1, Northern gin to Ngaoundere platform by road):** Moving 14.80 tonnes an illustrative 280 km SFD by road generates 4,144 SFD tkm; at 150 g CO2e per SFD tkm (108 g operation and 42 g energy provision in S0802), TCE 1 emits 621.6 kg CO2e (447.6 kg operation and 174.0 kg energy provision). [S0801] [S0802]
3. **Element 2 (TCE 2, Ngaoundere rail-road platform transfer):** Transhipping 14.80 tonnes at the GLEC terminal benchmark of 1.07 kg CO2e/t (0.384 kg operation and 0.686 kg energy provision in S0802) adds 15.8 kg CO2e (5.7 kg operation and 10.1 kg energy provision). [S18] [S0802]
4. **Element 3 (TCE 3, Ngaoundere to southern mill and garment hub by diesel rail):** Moving 14.80 tonnes an illustrative 850 km SFD generates 12,580 tkm; at an illustrative diesel-rail TOC intensity of 32 g CO2e/tkm (24.6 g operation and 7.4 g energy provision, reflecting the diesel split in S0802 Table 17), TCE 3 adds 402.6 kg CO2e (309.5 kg operation and 93.1 kg energy provision). [S0801] [S0802]
5. **Element 4 (TCE 4, Factory to Port of Douala drayage and terminal handling):** Moving the 11.00-tonne packed batch an illustrative 40 km SFD by road (440 tkm at 150 g CO2e/tkm = 66.0 kg CO2e) and through the Port of Douala terminal (11.00 t at 1.07 kg CO2e/t = 11.8 kg CO2e) adds 77.8 kg CO2e (51.7 kg operation and 26.1 kg energy provision). [S0801] [S0802]
6. **Element 5 (TCE 5, Deep-sea voyage and destination delivery):** Sailing an illustrative 8,000 km SFD (9,200 km actual after the 1.15 maritime factor in S0802 Table 3) generates 88,000 SFD tkm (101,200 actual tkm); at an illustrative VLSFO container-ship intensity of 11.5 g CO2e per actual tkm (13.225 g per SFD tkm, split 79.0 percent operation and 21.0 percent energy provision per S0802 Table 17), the sea leg emits 1,163.8 kg CO2e (919.4 kg operation and 244.4 kg energy provision). [S19] [S0802] Adding destination port transfer (11.8 kg CO2e), ambient hub handling (11.00 t at 1.19 kg CO2e/t = 13.1 kg CO2e from S0802 Table 7) and 120 km SFD regional road delivery (1,320 tkm at 0.150 kg CO2e/tkm = 198.0 kg CO2e) adds 222.9 kg CO2e (149.7 kg operation and 73.2 kg energy provision). [S0802]
7. **Reconciled chain total and garment intensity:** Across 106,484 SFD tkm of total transport work, operation (tank-to-wake) emissions are 1,883.6 kg CO2e (75.2 percent), energy provision (well-to-tank) emissions are 620.9 kg CO2e (24.8 percent), and total well-to-wake emissions are 2,504.5 kg CO2e, or an illustrative

62.6 g CO2e per garment across 40,000 shirts (28.0 g domestic and 34.6 g export). [S31] [S0802] Omitting well-to-tank energy provision would understate the footprint by 15.5 g CO2e per garment (24.8 percent), and omitting the 31 percent upstream fibre loss mass would understate inland lint transport by 319.9 kg CO2e (8.0 g CO2e per garment). [S31] [S0802]

8.16

Route redesign tests carbon against service and inventory

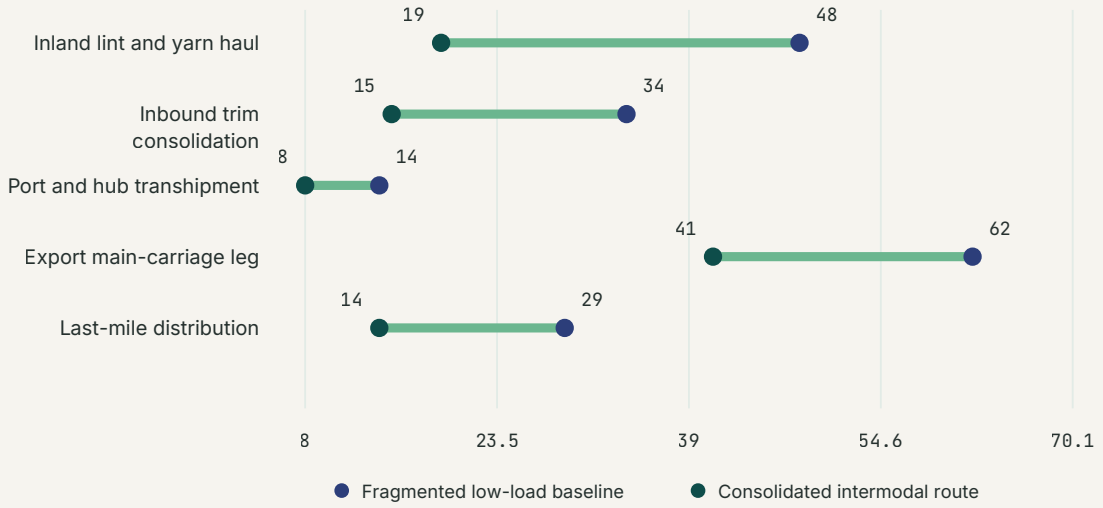
The purpose of building a granular ISO 14083 and GLEC freight account is not merely to publish an annual Scope 3 table; it is to redesign routes, loading rules, modal choices and inventory buffers so that absolute freight emissions and cost per garment fall together. [S18] [S0801] [S0802] Whereas spend-based proxies falsely inflate emissions whenever freight tariffs or biofuel surcharges rise, physical activity accounting captures the real engineering gains from consolidation, modal shift and local processing. [S20] [S23] [S0802]

8.17 MODAL SHIFT AND CONSOLIDATION CUT TRANSPORT WORK BEFORE FUEL SWITCHING

Across an apparel supply chain, the largest logistics reductions come from eliminating high-intensity transport work before purchasing alternative fuel credits. [S18] [S0802] First, replacing fragmented, partially loaded road dispatches with consolidated full-container-load (FCL) movements and shifting long inland hauls from road (150 g CO2e per SFD tkm in S0802) to rail (14 to 32 g CO2e per SFD tkm) cuts energy burn per tkm by more than two-thirds, reinforced by the World Bank corridor investments in Douala-Yaounde-Ngaoundere rail rehabilitation (US$368.0 million) and intermodal platform modernisation (US$24.1 million). [S0801] [S0802] Second, localising cotton processing inside Cameroon between Garoua and Dibamba avoids shipping the 31 percent processing-loss mass (S31) across oceans before manufacturing garments for domestic and African consumer markets (valued at about US$37.3 billion in 2025 in R24, with Cameroon spending about US$94.70 and 8.0 pieces per person in 2024 in R26), while retaining cottonseed co-products at SODECOTON's northern oil mills. [R03] [R06] [R09] [R10] [R24] [R26] [S31] **Exhibit 40**, p. 144 compares an illustrative fragmented low-load corridor baseline against a consolidated intermodal route across five garment logistics stages. [S18] [S20] [S0801] [S0802]

EXHIBIT 40 / ILLUSTRATIVE G CO2E PER 0.25 KG GARMENT

Route scenarios compare work and fuel rather than distance alone



ILLUSTRATIVE [S18] [S20] [S0801] [S0802] Illustrative corridor comparison for a 0.25 kg garment (0.275 kg packed mass) using ISO 14083 modal intensities and hub factors from S0802 and corridor structure from S0801. High-work case assumes fragmented road haulage and low load factor; consolidated intermodal case uses rail transfer and full container loading.

As **Exhibit 40**, p. 144 shows, holding physical route kilometres constant while shifting from fragmented low-load road haulage to consolidated rail-and-sea intermodal operations cuts the illustrative garment freight total from 187 g CO2e per garment (48 + 34 + 14 + 62 + 29) to 97 g CO2e per garment (19 + 15 + 8 + 41 + 14), a 48.1 per-cent reduction achieved through higher load factors, lower empty running and modal shift. [S18] [S0801] [S0802] Because **Exhibit 40**, p. 144 is an illustrative sensitivity com-parison across operating modes rather than a verified baseline of an existing exporter, actual savings require dispatch logs before and after consolidation. [S23] [S0802]

8.18 SCHEDULE RELIABILITY PREVENTS EMERGENCY AIR FREIGHT AND EXCESS BUFFER STOCK

A route redesign cannot be judged on carbon per tonne-kilometre alone if slower or erratic transit forces a factory or buyer to hold excess safety stock or resort to emergency air freight. [R27] [S18] [S0801] Shifting even 5 to 10 percent of a garment order from ocean shipping to long-haul air cargo to recover from a production or cus-toms delay can multiply the transport footprint of the entire production run several times over. [S18] [S20] [S0802]

Along the Douala-Ngaoundere-N'Djamena corridor, cutting total transit duration from the 20.00-day baseline to the 12.20-day target (reducing rail transit from 7.10 to 5.00 days, Ngaoundere platform transfer from 1.70 to 1.00 day, road haulage from 4.20 to 2.20 days and customs clearance from 7.00 to 4.00 days via customs inter-connection and e-GUCE single-window workflows in S0801) compresses lead time by 39.0 percent while keeping cargo on surface and sea modes. [S0801] Pairing cor-ridor reliability with artificial-intelligence forecasting and supply-chain planning (associated in McKinsey's State of Fashion 2025 evidence with 20 to 50 percent lower forecast errors, 35 to 40 percent lower inventory costs and up to 65 percent

fewer lost sales in sector benchmarks) and with GFT's inventory and working-capital controls in wp12 eliminates the root causes of emergency air-freight expediting. [R27] [S18] [S0801]

GFT NOTE

Embed ISO 14083 transport-work fields directly into the factory dispatch and receiving log. [S18] [S0802]

GFT recommends that an apparel manufacturer capture six mandatory fields on every inbound bale or fabric lot and every outbound garment bill of lading from Day 1 rather than reconstructing freight from annual invoices: (1) TCE sequence (origin, hubs, destination and Incoterm); (2) gross consignment mass (tonnes of product plus packaging) and carrier units (pallets or TEU); (3) mode and TOC code; (4) SFD distance (km) and applicable ISO 14083 adjustment factor (1.05 road, 1.15 sea, 1.00 rail); (5) carrier load-factor and empty-running tier; and (6) separate operation (TtW) and energy-provision (WtT) factor IDs with their publication vintage. [S18] [S20] [S0802] Tracking g CO2e per garment from freight alongside on-time-in-full (OTIF) delivery and container-fill percentage in the weekly performance cadence rewards full-container surface consolidation and flags schedule slippage before it triggers air freight. [S18] [S23]

UNRESOLVED CORRIDOR DATA GAPS AND REQUIRED VERIFICATION STEPS

Three empirical constraints limit freight carbon precision in Cameroon as of 2026 and must remain visible in any published footprint. [S0801] [S0802] 1. **Absence of calibrated primary fuel and empty-running telemetry on domestic trucking:** As of 12 December 2025, only 2 of the 6 planned calibrated axle-load monitoring stations and 0 of the formal transporter registration and freight-allocation procedures along the Douala-Ngaoundere-N'Djamena corridor had reached full operational target status in the World Bank project record, requiring modelled road TOC intensities with disclosed sensitivity ranges until carrier fuel and backhaul logs are collected. [S0801] [S0802] 2. **Proxy emission factors for Central African diesel rail and port terminals:** Default rail (14 g CO2e/tkm electric in S0802) and container-terminal (1.07 kg CO2e/t in S18 and S0802) factors reflect European infrastructure; resolving this proxy requires primary locomotive diesel and net tkm records from Camrail and annual electricity (matched to IEA Cameroon factors in S14), fuel and refrigerant refill logs from the Port of Douala and the Ngaoundere platform. [S14] [S0801] [S0802] 3. **Marine fuel pathway verification:** Claiming lower ocean-freight emissions from biofuels, HVO or LNG requires a verified IMO Fuel Lifecycle Label (FLL) under the 2024 LCA Guidelines (MEPC.391(81)) and an ISO 14083 carrier statement separating well-to-tank and tank-to-wake components, including methane slip. [S19] [S0802] [S0803]

A map measures only the road between two gates; a carbon account measures the mass moved, the vehicle that carried it and the fuel pathway that powered the journey.

CHAPTER SOURCE NOTES

S18 Smart Freight Centre. 2024.

S0802 CLECAT, German Environment Agency (Umweltbundesamt), ifeu Institute and Fraunhofer IML. 2024-11-14.

S19 International Maritime Organization. 2024.

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

S0801 World Bank. 2026-01-05.

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

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

S20 UK Department for Energy Security and Net Zero. 2026-06-11.

S0804 German Environment Agency (Umweltbundesamt). 2025-01-16.

S31 Forfora et al., Sustainability. 2026-04-20.

S0803 Marine Department, Government of the Hong Kong Special Administrative Region. 2024-12-02.

S02 GHG Protocol. 2011.

S03 GHG Protocol. 2015.

S04 GHG Protocol. 2004.

S10 World Business Council for Sustainable Development. 2025-04-30.

S23 GHG Protocol and Carbon Trust. 2013.

S16 ecoinvent. 2025-11-05.

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

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

S09 International Energy Agency. 2026.

S14 International Energy Agency. 2026-09-25.

S28 World Bank. 2025-01-16.

S01 GHG Protocol. 2011.

S05 International Organization for Standardization. 2018-08.

S24 International Organization for Standardization. 2006-07.

R24 Mordor Intelligence. Publication date unrecorded; inherited source-text check.

R26 Statista. Publication date unrecorded; inherited source-text check.

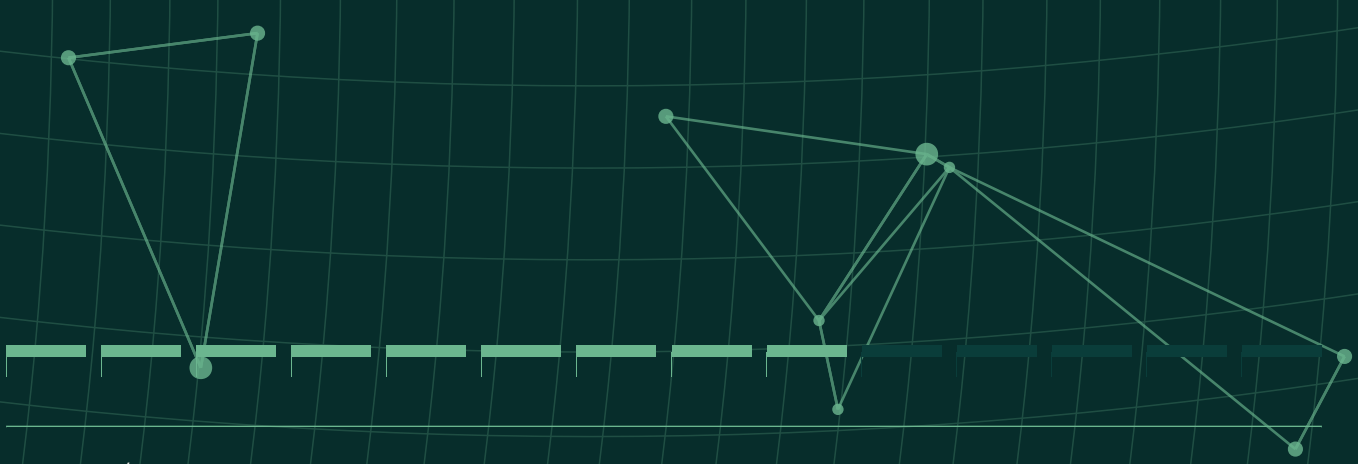
R27 McKinsey, The State of Fashion 2025. Publication date unrecorded; inherited source-text check.

09

PART II: FOLLOW CARBON THROUGH THE GARMENT / AFTER THE FACTORY GATE

Use, durability and end-of-life complete the garment account

A garment is not fully accounted until care, service life and disposal are made explicit.



CHAPTER 09
DECISION TEST

A garment is not fully accounted until care, service life and disposal are made explicit.

A garment carbon account is incomplete at the factory gate whenever the decision or claim extends to how clothing performs in service or what remains after discard. [S01] Under the GHG Protocol Product Standard and ISO 14067, a footprint that stops at the exit of a spinning mill, dyehouse or cut, make and trim facility is a cradle-to-gate inventory, not a complete life cycle. [S01] [S05] That boundary suits business-to-business exchange when a buyer combines supplier records with its own downstream models. [S10] [S23] Once an organisation compares fibres, evaluates garment longevity, designs circular recovery routes or publishes a consumer-facing figure, however, the boundary must encompass laundering, drying, ironing, active wear life and end-of-life treatment. [S06] [S26] [S30] Because no factory meter directly records household care or municipal waste treatment, downstream accounting requires a strict separation between primary manufacturing evidence and sensitivity-tested post-gate scenarios. [S01] [S23] Within GFT's Cameroon textile programme (prepared 31 January 2024, sources refreshed 2026), this boundary ensures domestic garment lines supply verified cradle-to-gate records while modelling use and disposal without conflating assumed consumer habits with measured factory reductions. [R06] [S23] [S32]

9.1

Laundering turns the consumer scenario into an emissions driver

Once a garment passes through distribution and retail into a wardrobe, its ongoing carbon footprint is governed by the frequency and thermal intensity of care. [S12] [S30] Unlike upstream spinning, knitting, dyeing and sewing, where energy consumption occurs in concentrated industrial facilities over days or weeks, use-phase emissions accumulate incrementally across dozens of domestic washing, drying and ironing cycles spread over years. [S08] [S12] The relative weight of this post-purchase stage in a cradle-to-grave inventory is substantial, yet it varies across regional models, garment types and baseline years. [S12] [S22] [S30]

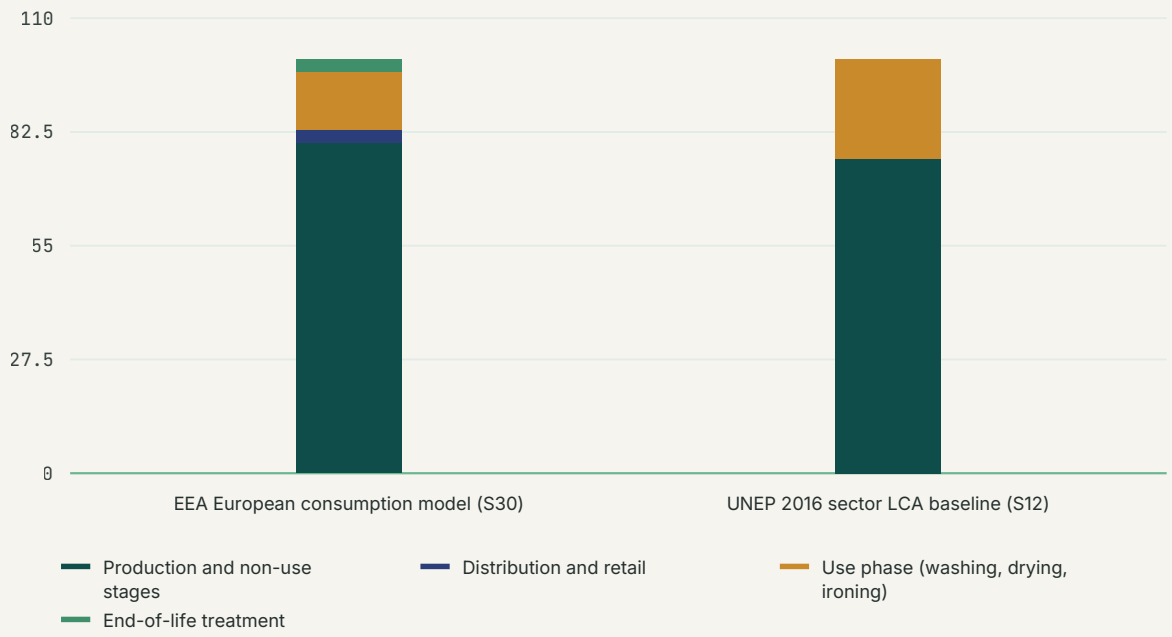
Two institutional syntheses illustrate why analysts must never treat the use-phase share as a fixed universal constant. [S12] [S30] In one life cycle assessment carried out on behalf of the United Nations Environment Programme (UNEP) with a baseline year of 2016, the use phase was considered responsible for 24 percent of the global fashion sector's greenhouse gas emissions, leaving 76 percent across raw material extraction, processing, assembly, logistics and disposal. [S12] By contrast, the European Environment Agency (EEA) consumption model published in 2022 attributes about 80 percent of the total climate change impact of textiles consumed in Europe to the production phase, 3 percent to distribution and retail, 14 percent to the use phase and 3 percent to end-of-life management. [S30]

The 10 percentage point difference between the 24 percent use-phase share in the 2016 UNEP sector baseline and the 14 percent share in the 2022 EEA European consumption model reflects genuine physical and methodological differences rather than an accounting error. [S12] [S22] [S30] First, the European consumption basket includes imported clothing produced in manufacturing hubs where coal-heavy electricity grids and thermal boilers elevate the absolute production burden, compressing the relative share of downstream care conducted on cleaner European grids. [S14] [S30] [S31]

Second, aggregating all textile categories into one sector share blends items washed after almost every wear, such as cotton T-shirts and work shirts, with items washed rarely, such as wool coats and household furnishings. [S26] [S30] **Exhibit 41**, p. 150 contrasts these two reference profiles to show why every garment study must state the underlying model geography, product mix and year before quoting a stage percentage. [S12] [S30]

EXHIBIT 41 / PERCENT OF TOTAL CLIMATE CHANGE IMPACT

A full life cycle adds use and end-of-life to production



SOURCED [S30] [S12] European consumption model shares from S30 (80 percent production, 3 percent distribution and retail, 14 percent use, 3 percent end-of-life) compared with the 2016 baseline sector LCA cited by UNEP in S12 (24 percent use phase, 76 percent all non-use stages combined). Neither benchmark is a universal constant for an individual garment.

While **Exhibit 41**, p. 150 confirms that upstream production carries the majority of sector-wide climate impacts in both assessments, a 14 percent to 24 percent downstream share is large enough to reverse the ranking of two garments whose factory footprints lie within a narrow margin. [S12] [S30] [S31] Moreover, the chart cannot establish the use-phase share of any specific garment style without disaggregating the physical mechanics of laundering. [S22] [S26]

9.2 WASHING, DRYING AND IRONING REQUIRE EXPLICIT PHYSICAL PARAMETERS

In an activity-based inventory built under ISO 14040, ISO 14044 and ISO 14067, consumer care is not modelled by multiplying cradle-to-gate emissions by an arbitrary markup. [S05] [S24] [S25] Instead, the practitioner links the functional unit to six observable or scenario-defined parameters: total wears over the garment's service life, wears before each wash cycle, wash water temperature and machine load efficiency, detergent mass and formulation, the fraction of wash loads dried in a mechanical tumble dryer versus ambient air, and the duration of electric ironing. [S12] [S20] [S26] [S30]

Each parameter acts on a distinct energy or chemical vector. [S20] [S30] Heating water to 40 degrees Celsius or 60 degrees Celsius dominates washing machine electricity demand, whereas cold-water cycles at 20 degrees Celsius to 30 degrees Celsius require power primarily for drum rotation and pumping. [S12] [S30] Mechanical tumble drying often consumes more electricity per kilogram of damp cotton fabric than washing because evaporating retained moisture requires substantial latent heat, whereas line drying in ambient air reduces drying energy to zero. [S12] [S30] Ironing adds an electrical load that scales with crease retention, and every kilowatt-hour of appliance electricity is multiplied by the dated location-based grid emission factor of the region where the garment is worn, supplemented by upstream fuel-cycle and transmission loss factors where required. [S14] [S20] [S31]

Geography therefore exerts as much influence over the use phase as it does over spinning and dyeing. [S14] [S31] A cotton garment worn in a household that washes at 40 degrees Celsius and uses an electric tumble dryer on a fossil-fuelled grid accumulates a heavy post-gate burden. [S12] [S14] The identical garment worn in Cameroon, where 54 percent of the population has access to electricity while consumption remains low, hydropower and solar expansion shape the grid mix, and solar line drying in ambient air is standard practice, generates a fraction of that use-phase footprint. [S09] [S28] With Cameroon clothing and footwear expenditure estimated at about US$94.70 per person and about 8.0 pieces per person in 2024 in the inherited evidence base, a domestic garment footprint calculated using imported European tumble-drying defaults would systematically misstate local post-gate emissions. [R26] [S16] [S22]

9.3

Use-phase scenarios are not measured consumer behaviour

A core rule of carbon accounting is that provenance and epistemological status must remain visible alongside every number. [S01] [S23] When a vertically integrated mill or garment factory records fuel burned in its boiler or kilowatt-hours drawn by its spinning frames, those figures represent historical primary activity data bounded by operational control. [S03] [S04] [S20] When the same manufacturer estimates the emissions generated over the next three years as customers wash and iron the garments they buy, the resulting number is a forward-looking scenario projection under Scope 3 Category 11 (Use of Sold Products). [S02] [S23]

The GHG Protocol Technical Guidance for Calculating Scope 3 Emissions recognises that Category 11 calculations rely on assumptions about user behaviour, product lifespan and regional grids, creating inherent scenario uncertainty. [S23] Within Category 11, the standard distinguishes products that directly consume energy or fuels during operation, such as vehicles and boilers, from products that indirectly consume energy during use through auxiliary maintenance processes, notably apparel requiring laundering. [S02] [S23] Because indirect use-phase emissions depend on appliances chosen by the consumer rather than engineered into the garment itself, mixing uncertain laundering projections into a single undifferentiated cradle-to-grave figure hides the boundary between factory performance and scenario modelling. [S01] [S23]

For an apparel supplier in Cameroon working toward the national target of processing 50 percent of cotton fibre locally by 2030 from a baseline where about 95 percent is exported raw and 5 percent processed locally, this separation is commercially vital. [R06] [R07] Buyers and verifiers exchanging product carbon footprints under the World Business Council for Sustainable Development (WBCSD) PACT Methodology Version 3 require verifiable cradle-to-gate figures up to the supplier's exit gate so they can compare factories on equal terms. [S10] [S23] If a supplier bundles an optimistic consumer cold-wash scenario into a single headline footprint, buyers cannot isolate whether a low reported number stems from clean factory energy or from lenient care assumptions. [S10] [S22] [S23]

DOWNSTREAM USE-PHASE BOUNDARY AND SCENARIO DECOMPOSITION

To preserve auditability across Scope 3 Category 11 reporting and ISO 14067 product footprints, GFT separates the garment account into four modular stages before aggregation: [S01] [S05] [S23]

1. **Module A (Cradle-to-gate production):** Cultivation, ginning, spinning, fabric formation, wet processing, assembly, packaging and inbound transport up to the finished garment gate (`E_gate`, in kg CO2e per accepted garment). [S01] [S10] [S23]
2. **Module B (Outbound distribution and retail):** Transport work from factory gate to distribution centre, store or parcel delivery, plus storage energy (`E_dist`, in kg CO2e per garment). [S02] [S18] [S23]
3. **Module C (Parameterised use-phase scenario):** Calculated from declared scenario variables using `E_use = (W / n_wear) * m_garment * [ (e_wash(T) + s_dry * e_dry + s_iron * e_iron) * EF_grid(r, y) + d_det * EF_det + v_water * EF_water ]`, where `W` is lifetime wears, `n_wear` is wears per wash, `m_garment` is garment mass in kilograms, `e_wash(T)`, `e_dry` and `e_iron` are specific electricity demands per kilogram, `s_dry` and `s_iron` are tumble-dried and ironed shares, `EF_grid(r, y)` is the dated electricity factor for region `r` and year `y`, and `d_det` and `v_water` capture detergent and water inputs. [S12] [S14] [S20] [S23] [S30]
4. **Module D (End-of-life disposition):** Collection, sorting, transport and treatment across reuse, recycling, incineration and landfill pathways (`E_eol`, in kg CO2e per garment), with consequential substitution credits reported separately. [S01] [S23] [S25] [S26]

9.4 SENSITIVITY TESTING REPLACES FALSE DOWNSTREAM PRECISION

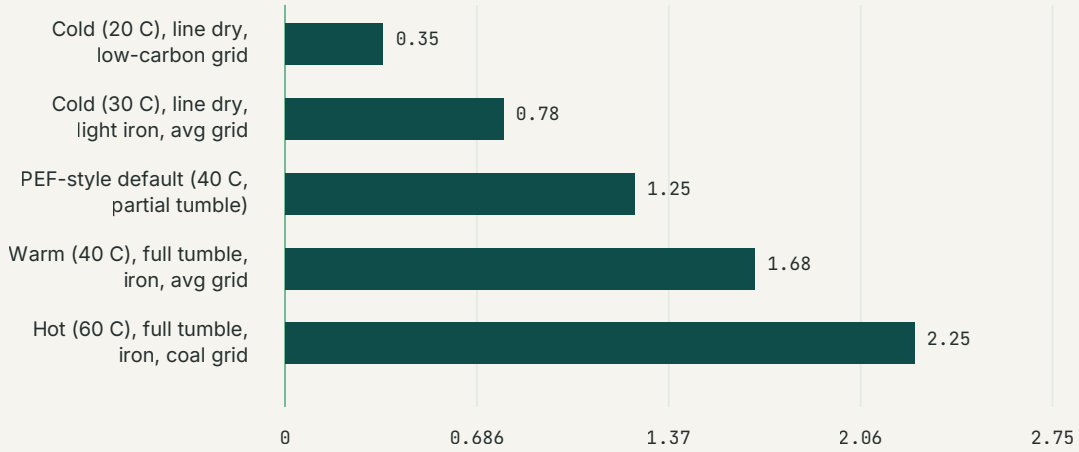
Because the variables inside Module C cannot be metered by the garment manufacturer, ISO 14040 and ISO 14044 require sensitivity checks during interpretation to test how methodological assumptions affect conclusions. [S24] [S25] In comparative apparel assessments, the European Commission's Product Environmental Footprint Category Rules (PEFCR) for clothing and shoes establish standardised default use-phase and end-of-life parameters so competing brands cannot manipulate wash temperature, load size or wear frequency to claim a spurious advantage. [S06] [S26]

Reporting only a single regulatory default, however, obscures the range of downstream outcomes across different markets. [S12] [S22] **Exhibit 42**, p. 153 illustrates how varying wash temperature, drying method, ironing frequency and grid

carbon intensity across five illustrative care regimes alters the cumulative use-phase footprint of an illustrative 0.25 kg cotton T-shirt worn 50 times and washed after every second wear (25 wash cycles total). [S12] [S14] [S30] [S31]

EXHIBIT 42 / ILLUSTRATIVE KG CO2E OVER 50 WEARS (25 WASHES)

Care habits and grid factors drive a sixfold range in illustrative use-phase emissions



ILLUSTRATIVE [S12] [S14] [S30] [S31] Illustrative sensitivity model for a 0.25 kg cotton garment (mass basis from S31) washed 25 times over 50 wears. Scenarios vary water temperature, tumble drying, ironing and illustrative grid electricity factors (0.15 to 0.65 kg CO2e/kWh, informed by S14, S12 and S30). Values demonstrate scenario sensitivity, not a measured GFT result.

As **Exhibit 42**, p. 153 shows, the illustrative cumulative use-phase footprint over 25 wash cycles spans from 0.35 kg CO2e under cold washing, ambient line drying and a low-carbon grid up to 2.25 kg CO2e when washed at 60 degrees Celsius, tumble-dried and ironed on a carbon-intensive grid. [S12] [S14] [S30] What this illustrative chart cannot establish is which specific care regime actual buyers practise without survey evidence, so GFT requires every cradle-to-grave report to publish both the reference scenario and bounded regional sensitivity cases. [S06] [S23] [S25]

9.5

Durability matters per wear, not by assertion

A garment is purchased for the service of being worn rather than for its raw polymer or cellulose mass. [S26] [S30] When an inventory stops at one kilogram of dyed fabric or one finished shirt at the factory gate, building a heavier, more durable garment with higher-tenacity yarns, denser construction, reinforced seams and superior dye fastness almost always increases the reported footprint per garment. [S26] [S31] Only when the functional unit is defined as one wear does the accounting framework capture how extended garment life amortises initial manufacturing and final disposal emissions over a larger denominator. [S24] [S26] [S30]

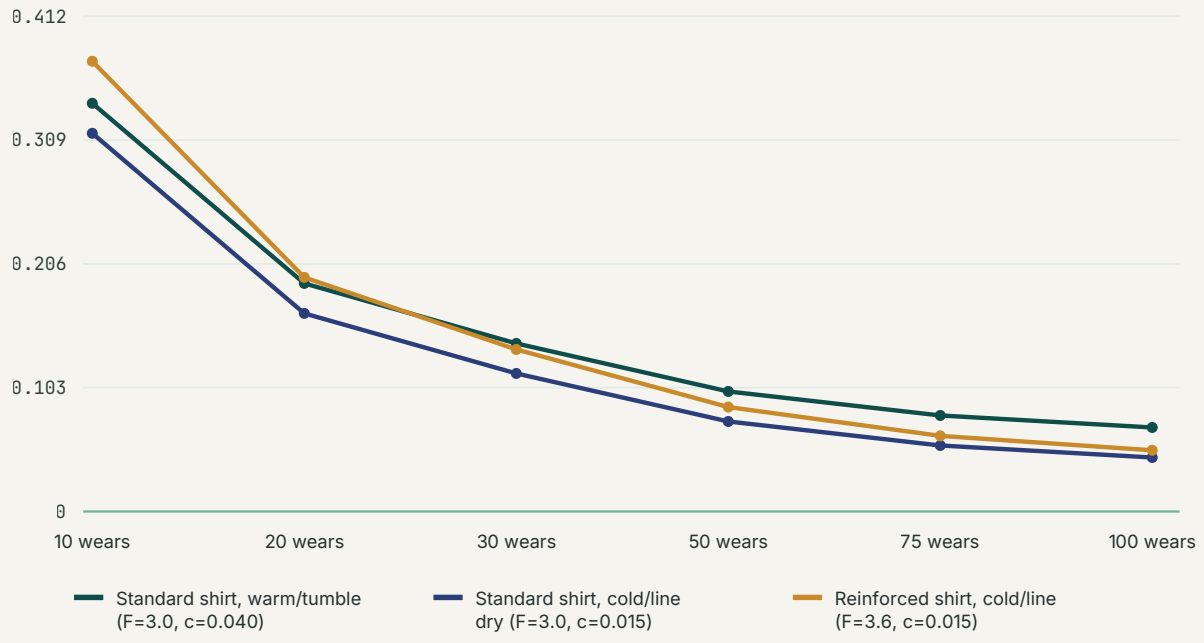
Watson and Wiedemann's review of LCA-based textile rating tools highlights that omitting service life and functional equivalence systematically biases material rankings. [S26] Similarly, the 2026 comparative T-shirt life cycle assessment by Forfora et al. demonstrates that shifting from an equal-mass baseline (250 g per T-shirt across

all fibres) to an equivalent-tenacity scenario alters the required garment mass to 250 g for cotton, 250 g for viscose, 153 g for Lyocell and 115 g for polyester, materially shifting their relative cradle-to-gate footprints. [S31] Extending this principle from initial tensile tenacity to multi-year wear life means that resistance to abrasion, seam slippage, pilling, shrinkage and colour fading governs the reference flow required to satisfy a given period of clothing use. [S26] [S30] [S31]

Mathematically, if a garment carries a combined cradle-to-gate, distribution and end-of-life burden of F kilograms of CO2e, is worn W times before discard, and incurs a care burden of c kilograms of CO2e per wear, the total carbon footprint per wear is CF_wear(W) = (F / W) + c. [S12] [S26] [S30] As W increases, the fixed term F / W decays hyperbolically toward zero, while the marginal care term c forms an asymptotic floor. [S12] [S26] **Exhibit 43**, p. 154 plots this derived relationship across wear counts from 10 to 100 wears for three illustrative profiles: a standard garment under energy-intensive care (F = 3.0 kg CO2e, c = 0.040 kg CO2e per wear), the same standard garment under cold washing and line drying (F = 3.0 kg CO2e, c = 0.015 kg CO2e per wear), and a reinforced garment whose heavier construction raises fixed emissions by 20 percent (F = 3.6 kg CO2e, c = 0.015 kg CO2e per wear). [S12] [S26] [S30]

EXHIBIT 43 / ILLUSTRATIVE KG CO2E PER WEAR

Carbon per wear falls as wears increase, while absolute savings depend on displacement



DERIVED [S26] [S30] [S12] Derived arithmetic from CF_wear = (F / W) + c (based on S26, S30 and S12). Profile 1 assumes illustrative fixed non-use burden F = 3.0 kg CO2e and warm/tumble care c = 0.040 kg CO2e/wear. Profile 2 assumes F = 3.0 kg CO2e and cold/line-dry care c = 0.015 kg CO2e/wear. Profile 3 assumes reinforced construction F = 3.6 kg CO2e and c = 0.015 kg CO2e/wear. Per-wear reduction yields absolute savings only when extra wears displace new purchases.

Three conclusions follow from **Exhibit 43**, p. 154. [S12] [S26] [S30] First, doubling a standard garment's active life from 20 wears to 40 wears cuts the fixed manufacturing burden per wear in half. [S27] [S30] Second, when a reinforced garment

(F = 3.6 kg CO2e) achieves 50 wears (0.087 kg CO2e per wear in the cold-wash scenario) while a lighter standard garment (F = 3.0 kg CO2e) fails after 30 wears (0.115 kg CO2e per wear), the heavier garment achieves a 24.3 percent lower footprint per wear despite its 20 percent higher factory-gate footprint. [S26] [S30] Third, **Exhibit 43**, p. 154 alone cannot prove that absolute sector emissions fell: if a consumer buys the reinforced shirt, wears it 30 times, and still replaces it because of styling turnover, its higher fixed burden F increases total emissions. [S07] [S26] [S30]

9.6 EXTENDED SERVICE LIFE REQUIRES PHYSICAL PROOF AND A REPLACEMENT COUNTERFACTUAL

Global fibre production rose from 125 million tonnes in 2023 to 132 million tonnes in 2024 according to Textile Exchange, while the Ellen MacArthur Foundation highlights that declining clothing utilisation has driven rising production volumes and waste. [S07] [S27] A manufacturer cannot simply divide its cradle-to-gate footprint by an arbitrary assumed lifespan of 100 wears to publish a low per-wear number. [S26] [S32]

To justify a durability adjustment, two evidentiary tests must be met. [S06] [S26] [S32] First, physical longevity must be demonstrated through standardised laboratory testing of tensile and tear strength, abrasion resistance, pilling, wash shrinkage, seam strength and colourfastness. [S06] [S26] [S31] In GFT's operating model, where manual inspection achieves 60 percent to 70 percent accuracy and misses 20 percent to 30 percent of defects whereas automated computer vision exceeds 90 percent accuracy across more than 40 defect types at line speeds up to 60 metres a minute, catching structural defects before shipment directly prevents early garment failure. [R29] Second, any consequential claim that longer garment life avoids new production must state the assumed replacement rate and test sensitivity to partial displacement. [S26] [S30]

WORKED EXAMPLE: RECONCILING REINFORCED GARMENT MASS AGAINST EXTENDED SERVICE LIFE AND CARE

Consider an illustrative engineering decision for a cotton polo shirt evaluated under GFT's methodology, using the 0.25 kg baseline shirt mass from the 2026 comparative T-shirt study as the reference: [S23] [S26] [S31]

- **Option A (Baseline specification):** Finished mass is an illustrative 0.25 kg at an illustrative cradle-to-gate and distribution intensity of 12.0 kg CO2e/kg plus 0.20 kg CO2e at end-of-life, giving fixed burden `F_A = (0.25 * 12.0) + 0.20 = 3.20 kg CO2e` and tested service life `W_A = 32 wears`. [S26] [S31]
- **Option B (Reinforced specification):** Combed ring-spun yarn and taped seams raise finished mass by 16 percent to an illustrative 0.29 kg at 12.5 kg CO2e/kg plus 0.23 kg CO2e at end-of-life, giving `F_B = 3.855 kg CO2e` (20.5 percent higher at the gate), while laboratory testing validates `W_B = 64 wears`. [S26] [S30] [S31]
- **Break-even wear threshold:** To match Option A's illustrative fixed non-use carbon per wear of `3.20 / 32 = 0.100 kg CO2e/wear`, Option B must achieve at least `W_break-even = 3.855 / 0.100 = 38.55 wears` (39 wears). [S26] [S30]
- **Service comparison over 64 wears (32 washes):** Under an illustrative European heated-wash and partial tumble-dry care burden of 0.10 kg CO2e/kg per wash, two Option A shirts require `6.40 + 0.80 = 7.20 kg CO2e` (0.1125 kg CO2e/wear), whereas one Option B shirt requires `3.855 + 0.928 = 4.783 kg CO2e` (0.0747 kg CO2e/wear), an illustrative saving of 2.417 kg CO2e (33.6 percent) under full displacement. [S12] [S26] [S30] Under an illustrative Cameroon cold-wash and solar line-dry regime of 0.03 kg CO2e/kg per wash, two Option A shirts total 6.64 kg CO2e versus 4.133 kg CO2e for one Option B shirt, an illustrative saving of 2.507 kg CO2e (37.8 percent). [S09] [S26] [S28] If Option B is discarded after 35 wears, however, its fixed burden (0.1101 kg CO2e/wear) exceeds Option A, so the record reports `F_B = 3.855 kg CO2e` alongside the 39-wear threshold. [S23] [S26]

9.7

Disposal routes create different carbon outcomes

When a garment exits active use, it enters a physical waste and secondary-commodity system bounded by household disposal habits, municipal collection infrastructure, manual sorting capacity, international used-clothing trade and waste treatment. [S30] [S0901] [S0902] Under the GHG Protocol Product Standard and Scope 3 Category 12 (End-of-Life Treatment of Sold Products), the product inventory must reflect the actual or representative baseline fate of discarded textiles in the disposal market rather than assuming closed-loop recovery. [S01] [S02] [S23]

Empirical evidence from the European Environment Agency's 2024 assessment of used and waste textiles in Europe shows how wide the gap remains between circular rhetoric and physical waste flows, even where separate collection mandates take effect in 2025 under the Waste Framework Directive. [S0901] In 2020, the EU-27 generated an estimated 6.95 million tonnes of textile waste, or around 16 kilograms per person. [S0901] Post-consumer textiles accounted for 82 percent of that volume, while

18 percent originated from manufacturing waste or unsold retail stock; an estimated 4 percent to 9 percent of all textile products placed on the European market are destroyed before use, amounting to between 264,000 and 594,000 tonnes a year. [S0901]

Out of the 16.0 kilograms generated per person in the EU-27 in 2020, only 4.4 kilograms per person (27.5 percent by arithmetic from the cited EEA figures) were collected separately for reuse and recycling, while 11.6 kilograms per person (72.5 percent) ended up in mixed household residual waste routed to incineration or landfill. [S0901] Across Europe's waste composition analyses, the EEA notes an average capture rate for textile waste of only 12 percent, with top systems in Luxembourg (50 percent), Belgium (50 percent), the Netherlands (37 percent) and Austria (30 percent) still leaving half or more of discarded textiles outside separate collection. [S0901] **Exhibit 44**, p. 157 maps this 2020 EU-27 per-capita mass balance. [S0901]

EXHIBIT 44 / KG PER PERSON PER YEAR (EU-27, 2020)

Most discarded European textiles enter mixed waste before recycling can occur



SOURCED [S0901] Sourced from the 2024 EEA briefing (S0901) for EU-27 textile waste generation in 2020: around 16.0 kg per person generated in total, of which 4.4 kg per person (27.5 percent) were collected separately for reuse and recycling and 11.6 kg per person (72.5 percent) ended up in mixed household waste destined for incineration or landfill.

As **Exhibit 44**, p. 157 makes visible, nearly three-quarters of discarded European textiles bypass circular recovery at household disposal. [S0901] Furthermore, among separately tracked textile waste in the EU-27 between 2010 and 2020, landfilling fell from 21 percent (220,000 tonnes) to 11 percent (150,000 tonnes), while incineration with energy recovery rose from 9 percent (90,000 tonnes) to 16 percent (220,000 tonnes). [S0901] What **Exhibit 44**, p. 157 cannot show on its own is the fate of separately collected textiles exported outside Europe. [S0901] [S0902]

9.8 LANDFILL, INCINERATION, REUSE AND EXPORT CARRY DISTINCT GREENHOUSE GAS MECHANICS

In life cycle inventory analysis under ISO 14044 and ISO 14067, each disposition pathway converts garment mass into greenhouse gases through a distinct mechanism: [S05] [S25]

- **Untreated or partially captured landfill:** Anaerobic decomposition of cellulosic fibres (cotton, viscose and Lyocell) converts organic carbon into methane (CH4) alongside biogenic CO2, creating a positive greenhouse gas burden under IPCC AR6 metrics unless landfill gas is captured. [S11] [S25] [S31] Polyester resists biological degradation in landfills, so a climate-only footprint under ISO 14067 records near-zero landfill gas for polyester while omitting plastic persistence. [S05] [S30] [S31]
- **Municipal incineration with and without energy recovery:** Combustion oxidises synthetic fibres into fossil CO2 and releases biogenic CO2 from cellulosic fibres, tracked separately under ISO 14067. [S05] [S25] [S31] Where the plant exports heat or power, the inventory states whether energy recovery stays with the municipal user under cut-off rules or generates a consequential credit. [S25] [S26] [S0901]
- **Domestic and cross-border reuse:** Reuse preserves the intact garment at a fraction of manufacturing energy. [S30] [S0901] However, in 2020, 1.95 million tonnes of textiles were collected in the EU-27 against 1.41 million tonnes treated domestically. [S0901] Between 2000 and 2019, EU used-textile exports tripled from slightly over 550,000 tonnes to almost 1.7 million tonnes (3.8 kilograms per person, or 25 percent of annual EU consumption of 14.8 kilograms to 15 kilograms per person), while the average export price dropped to EUR 0.57 per kilogram in 2019. [S0902] In 2019, 46 percent of EU used textile exports went to Africa and 41 percent to Asia. [S0902] Because unwearable fractions in exported bales mostly enter open landfills and informal waste streams in receiving countries without Extended Producer Responsibility funding from Europe, an accounting model cannot assign a 100 percent reuse credit to exported bales. [S23] [S0901] [S0902]

9.9

Recycling credits depend on allocation and displacement

When discarded textiles cannot be reused as clothing, mechanical or chemical recycling can recover fibres or monomers, yet the Ellen MacArthur Foundation reports that less than 1 percent of clothing material globally is recycled into new clothing, against 1.2 billion tonnes of CO2 equivalent emitted by global textiles production in 2015. [S27] Within Europe, the EEA's 2024 review identifies 17 recycling companies expecting to recycle 1.25 million to 1.3 million tonnes of fibres annually through 2025 (1.0 million tonnes mechanical and 250,000 tonnes chemical), alongside EU sorting storage capacity of 1.5 million tonnes per year (including 200,000 tonnes in the Netherlands and 300,000 tonnes in Poland). [S0901] Most mechanically recycled fibres are downcycled into rags or insulation rather than spun into apparel yarn. [S0901]

ISO 14044, the GHG Protocol Product Standard and the Scope 3 Guidance recognise two primary approaches to modelling recycling across product systems, which must never be mixed within one inventory: [S01] [S23] [S25] [S26]

1. **The recycled-content (cut-off or 100-0) method:** Each product accounts for the virgin material it consumes and disposal of unrecycled waste at end-of-life. [S23] [S26] Recycling process emissions belong to the subsequent product using the recycled input, so a virgin cotton garment receives zero end-of-life credit for recyclability, while a garment using post-consumer recycled fibre captures the lower upstream burden at the start of its life. [S22] [S23] [S26]
2. **The closed-loop approximation (avoided-burden or 0-100) method:** A credit is calculated at end-of-life for virgin material displaced by recovered output, minus sorting and recycling emissions, scaled by a quality factor. [S01] [S25] [S26] ISO 14044 restricts unadjusted closed-loop credits to systems where inherent material properties do not change, requiring quality adjustment when mechanical shredding shortens cotton staple length or when chemical cellulosic regeneration consumes substantial process energy (up to 21.6 kg CO2eq/kg for virgin Lyocell in fossil-heavy grids). [S25] [S26] [S31] Claiming recycled content at the start of life and avoided virgin production at the end of life double counts the same recycling event. [S22] [S23] [S26]

Exhibit 45, p. 160 summarises the boundary, energy recovery rules, displacement mechanics and primary uncertainties across the five principal end-of-life pathways. [S25] [S27] [S30] [S0901]

EXHIBIT 45 / ACCOUNTING RULES BY DISPOSAL PATHWAY

End-of-life scenarios expose allocation and substitution assumptions

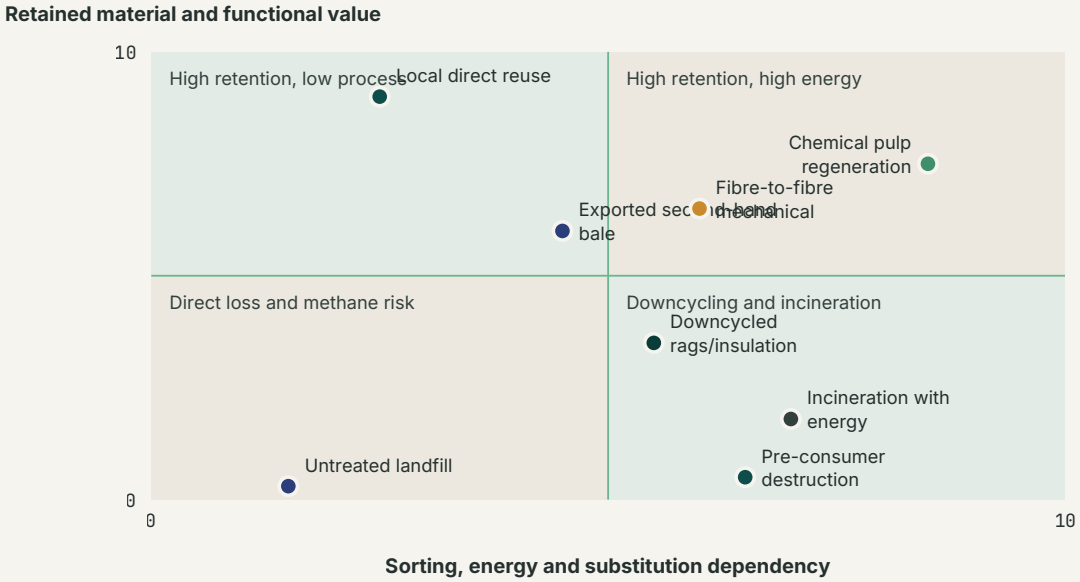
Pathway	System boundary and energy flow	Displacement and quality rule	Key accounting uncertainty
Direct reuse	Collection, transport, manual sorting and cleaning	Displaces new garment only to the extent worn; export reject share excluded	Actual replacement rate and unwearable fraction in export bales (46% to Africa in S0902)
Mechanical recycling	Sorting, button/zip removal, shredding and carding electricity	Shortens cotton staple; often downcycled to rags or insulation (1.0 Mt EU capacity in S0901)	Quality-adjusted substitution ratio against virgin spinning lint vs industrial wipers
Chemical recycling	Depolymerisation or cellulose dissolution, solvent recovery and thermal energy	Can regenerate virgin-equivalent Lyocell/viscose pulp or monomer (0.25 Mt EU capacity in S0901)	High process heat and electricity sensitivity (see regional energy effect in S31)
Incineration with energy recovery	Waste transport, combustion (fossil CO2 from synthetics, biogenic CO2 from cotton) and heat/power export	Under cut-off, energy credit belongs to energy user; consequential check tests grid heat displacement	Fossil vs biogenic carbon split in poly-cotton blends and municipal boiler efficiency
Untreated or managed landfill	Waste transport, compaction and multi-decade anaerobic decomposition	Zero material or energy displacement; pure waste burden	Methane generation rate of cellulosic fibres, GWP time horizon (S11) and landfill gas capture

SOURCED [S25] [S27] [S30] [S0901] Synthesised from ISO 14044 allocation requirements (S25), Ellen MacArthur Foundation recycling classifications (S27) and EEA circularity and waste treatment assessments (S30, S0901). Attributional product inventories use the cut-off boundary; consequential substitution credits must be reported separately with empirical yield and quality ratios.

To complement **Exhibit 45**, p. 160, **Exhibit 46**, p. 161 places these disposition routes onto two operational dimensions derived from the EEA and Ellen MacArthur Foundation waste hierarchy: dependency on sorting, processing energy and substitution assumptions on the horizontal axis, and retained material and functional value on the vertical axis. [S27] [S30] [S0901]

EXHIBIT 46 / ILLUSTRATIVE INDEX (0 TO 10)

Disposition pathways separate intact functional retention from high-energy recovery



ILLUSTRATIVE [S25] [S27] [S30] [S0901] Illustrative positioning informed by the waste hierarchy and processing characteristics in S25, S27, S30 and S0901. Horizontal axis indexes dependence on sorting purity, process energy and substitution assumptions (0 = minimal processing, 10 = complex chemical/energy conversion). Vertical axis indexes retained product or fibre value (0 = complete loss, 10 = intact garment function). Coordinates are analytical illustrations, not measured scores.

Together, **Exhibit 45**, p. 160 and **Exhibit 46**, p. 161 establish why GFT uses the cut-off rule based on documented regional waste shares in its core ISO 14067 and PACT Version 3 product footprint, while evaluating potential recycling or take-back benefits in a separate consequential module. [S05] [S10] [S22] [S25] [S26]

9.10

Care and design claims need consumer-grade evidence

Design decisions made before cloth is woven govern how a garment behaves during care, how long it survives in service and whether it can be recycled at end-of-life. [S30] The EEA's 2022 analysis of circular design identifies four pathways: longevity, repair, reuse and fibre-to-fibre recyclability. [S30] Yet design intent alone delivers zero carbon reduction if collection infrastructure is missing or if a design choice shifts burdens across stages. [S30] [S0901] Blending elastane or polyester into cotton can improve abrasion resistance and reduce ironing energy during use, but intimate blends obstruct mechanical and chemical cotton recycling at end-of-life, routing discards toward downcycling or incineration. [S26] [S27] [S30] Conversely, a 100 per-cent mono-material cotton garment sewn with cotton thread is compatible with cellulosic recycling, but only lowers life cycle emissions if its yarn twist, weave density and pre-shrinkage finishing prevent premature failure. [S30] [S31] Even pre-consumer waste responds to digital discipline: where McKinsey's State of Fashion 2025 reports that artificial intelligence at scale can cut inventory costs by 35 percent to 40 percent

and forecast errors by 20 percent to 50 percent, matching production batches to verified demand directly reduces the 4 percent to 9 percent of European textiles destroyed unsold before use. [R27] [S0901]

Regulatory frameworks now enforce strict proof for any downstream claim. [S06] [S32] In the European Union, Directive (EU) 2024/825 requires climate-related claims to rest on the actual lifecycle impact of the product in question, and prohibits equating greenhouse gas offsetting outside the product's value chain with lifecycle emissions reductions. [S32] Similarly, the European Commission's 2025 PEFCR rules for clothing and shoes establish an impartial method across extraction, production, logistics, use and end-of-life, preventing selective boundary truncation in public comparisons. [S06]

GFT NOTE

In GFT's Cameroon textile programme (prepared 31 January 2024, sources refreshed 2026), downstream use and end-of-life accounting follows four operational rules: [R06] [S10] [S23] [S32]

1. **Separate cradle-to-gate records from post-gate scenarios:** Every garment lot carries a primary cradle-to-gate footprint (Module A) under PACT Version 3 and ISO 14067, while distribution, use and end-of-life (Modules B, C and D) attach as versioned scenario layers. [S01] [S05] [S10] [S23]
2. **Tie durability parameters to laboratory test certificates:** No garment model may extend assumed wears `W` above the category baseline without test records for tensile strength, seam slippage, pilling, wash shrinkage and colourfastness, paired with in-line computer-vision inspection records. [R29] [S06] [S26] [S31]
3. **Use regionalised care and waste baselines by destination market:** Garments for domestic Cameroon and Central African sales (where announced projects such as the US$300 million, 12,000-tonne-per-year Camtext SA venture and the 50 percent local-processing target by 2030 aim to expand local value addition) use regional grid factors, ambient line-drying practices and local waste baselines, whereas European exports report alongside mandatory PEFCR defaults. [R06] [R07] [R09] [R10] [S06] [S09] [S28]
4. **Preserve scope boundaries across the white-paper library:** This chapter sets the carbon accounting boundary, functional-unit equations and allocation rules for use, durability and disposal, supplying the accounting interface for circular product design in `wp11` and zero-defect manufacturing in `wp20` without duplicating their engineering analyses. [R29] [S01] [S25] [S30]

UNRESOLVED DOWNSTREAM EVIDENCE CONSTRAINTS IN REGIONAL AND EXPORT MARKETS

Three empirical gaps must be disclosed in study interpretations under ISO 14044: [S25]

- **Absence of household laundering surveys in Central Africa:** While IEA and World Bank records confirm Cameroon's 54 percent electricity access rate and renewable expansion, no representative survey in the register measures domestic wash temperatures, detergent dosing or ironing minutes across Cameroonian households, keeping regional use-phase modules as labelled scenario estimates. [R26] [S09] [S23] [S28]
- **Unverified reject and open-burning shares in imported second-hand textiles:** While 46 percent of EU used textile exports went to Africa in 2019 and unwearable fractions mostly enter open landfills and informal waste streams, country-level sorting reject rates and open-burning emission factors remain unquantified. [S0901] [S0902]
- **Incomplete tropical landfill decay kinetics:** Standard landfill conversion factors reflect temperate municipal waste models, whereas methane generation rates of cellulosic fibres in tropical open dumps require local calibration under IPCC AR6 metrics. [S11] [S16] [S20]

Closing the product boundary through care, service life and disposal while keeping scenario assumptions transparent prevents manufacturers from hiding upstream emissions behind optimistic consumer habits or unverified recycling promises. [S01] [S26] [S32] With the full life cycle mapped across Part II, Part III turns to how an industrial operator executes and verifies real emissions reductions at the hotspots that matter most. [S01] [S08] [S23]

A garment account ends not when the shirt leaves the sewing line, but when its last thread returns to soil, atmosphere or a new yarn under a declared rule.

CHAPTER SOURCE NOTES

S01 GHG Protocol. 2011.

S05 International Organization for Standardization. 2018-08.

S10 World Business Council for Sustainable Development. 2025-04-30.

S23 GHG Protocol and Carbon Trust. 2013.

S06 European Commission. 2025-06-25.

S26 Watson and Wiedemann, Sustainability. 2019-07-15.

S30 European Environment Agency. 2022.

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

S32 European Parliament and Council of the European Union. 2024-02-28.

S12 United Nations Environment Programme. 2021-11-08.

S08 Science Based Targets initiative and World Resources Institute. 2019.

S22 Textile Exchange. 2026-07-16.

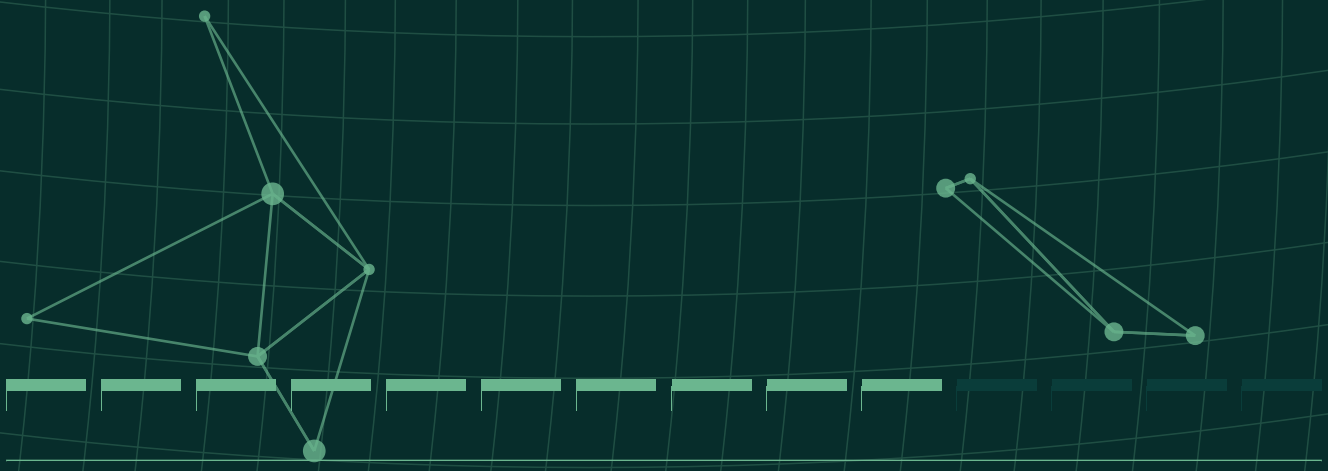
S14 International Energy Agency. 2026-09-25.
S31 Forfora et al., Sustainability. 2026-04-20.
S24 International Organization for Standardization. 2006-07.
S25 International Organization for Standardization. 2006-07.
S20 UK Department for Energy Security and Net Zero. 2026-06-11.
S09 International Energy Agency. 2026.
S28 World Bank. 2025-01-16.
R26 Statista. Publication date unrecorded; inherited source-text check.
S16 ecoinvent. 2025-11-05.
S03 GHG Protocol. 2015.
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S02 GHG Protocol. 2011.
R07 Ecofin Agency. Publication date unrecorded; inherited source-text check.
S18 Smart Freight Centre. 2024.
S27 Ellen MacArthur Foundation. 2017.
S07 Textile Exchange. 2025-09-18.
R29 MDPI; industry inspection literature. Publication date unrecorded; inherited source-text check.
S0901 European Environment Agency. 2024-05-21.
S0902 European Environment Agency. 2023-02-27.
S11 Intergovernmental Panel on Climate Change. 2021-08-06.
R27 McKinsey, The State of Fashion 2025. 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.

10

PART III: REDUCE CARBON WITHOUT MOVING THE PROBLEM / REDUCTION METHOD

Abatement starts at hotspots and proves what changed

A reduction claim is credible only when a measured action changes a defined baseline without shifting the burden elsewhere.



CHAPTER 10
DECISION TEST

A reduction claim is credible only when a measured action changes a defined baseline without shifting the burden elsewhere.

Abatement in an apparel supply chain succeeds only when engineering effort follows the largest verified sources of greenhouse gas emissions and proves, against a stable counterfactual baseline, that physical activity intensity or energy carbon intensity fell. [S01] [S23] [S1001] A garment maker cannot treat every operational change, database update, or supplier questionnaire as a climate reduction. [S23] Under the GHG Protocol Product Standard and Scope 3 calculation guidance, an inventory earns its cost by ranking hotspots across raw materials, yarn and fabric production, garment assembly, logistics, care, and disposal, then focusing metering and capital where intervention changes the total most. [S01] [S23] Any claim that carbon per garment fell must separate four effects: total production volume, physical resource use per accepted garment, verified energy or material emission factors, and methodological recalculations from replacing secondary proxies with primary evidence. [S04] [S20] [S23] [S1003]

For Green Future Tech Limited (GFT), Hong Kong SAR, and its three-part Cameroon textile programme (feasibility study, performance-management system design, and digital strategy prepared 31 January 2024, sources refreshed 2026), this discipline links factory engineering to the carbon chart of accounts. [R06] [S04] Because Cameroon exports about 95 percent of its cotton fibre raw and processes about 5 percent locally against a 50 percent target by 2030, an industrialising cotton-to-garment chain cannot rely on retrospective paper adjustments or generic benchmarks to prove low-carbon production. [R06] [R07] [S16] Instead, the reduction method starts on the first shift: sub-metering utility loads, cutting scrap and rework before sizing thermal and electrical plant, upgrading supplier process efficiency, and locking the baseline so every abated tonne of carbon dioxide equivalent (CO2e) traces to a meter, an invoice, or a verified process change. [S13] [S20] [S23] [S1001]

10.1

Hotspots set the order of work

Product life cycle accounting reveals the largest greenhouse gas reduction opportunities across the product system from cradle to grave. [S01] In apparel chains, emissions concentrate upstream. Science Based Targets initiative (SBTi) and World Resources Institute (WRI) guidance shows that value-chain (Scope 3) emissions dominate corporate footprints, led by raw material extraction, fibre production, yarn preparation, and wet processing. [S08] The WRI and Apparel Impact Institute roadmap estimated global apparel emissions at 1.025 gigatonnes of CO2e in 2019 and projected growth to 1.588 gigatonnes by 2030 without intervention, missing the 45 percent absolute cut required for a 1.5 degree Celsius pathway. [S1002] That study identified six interventions delivering roughly three quarters of needed abatement: maximising material efficiency, scaling sustainable materials and practices, accelerating innovative materials, proliferating manufacturing energy efficiency, eliminating coal in thermal processes, and shifting to 100 percent renewable electricity. [S1002]

Replacing office lighting or buying offsets while ignoring dyehouse steam, spinning power, and cutting waste reverses the engineering order. [S08] [S32] [S1002] Under GHG Protocol Scope 3 guidance, a screening inventory using secondary databases such as ecoinvent identifies which stages dominate the footprint and carry the highest

reduction potential. [S16] [S23] Management then freezes spending on minor categories and directs primary metering and engineering design toward the dominant hotspots. [S23]

10.2 SCREENING SEPARATES MATERIAL HOTSPOTS FROM ADMINISTRATIVE NOISE

A hotspot screen evaluates each stage across four Scope 3 criteria: share of life cycle CO2e, technical and economic feasibility of abatement, operational or procurement influence, and proxy uncertainty. [S23] Comparative life cycle assessment evidence for T-shirt production across cotton, polyester, viscose, and Lyocell confirms why stage-level resolution is essential. [S31] In that 2026 study, cradle-to-gate impacts shift sharply with fibre chemistry and regional energy mixes: Lyocell reaches 21.6 kg CO2e per kilogram of fibre under a coal-heavy grid unless produced with cleaner energy, and total global warming impact drops by up to 38 percent when production shifts from China to Brazil in the modelled scenario. [S31]

Treating an ecoinvent average as site truth hides whether the top priority is farm nitrogen management, spinning motor efficiency, dyehouse condensate recovery, or diesel backup displacement in cut, make, and trim (CMT) assembly. [S16] [S31] Screening ranks these stages first so upstream demand reductions shrink downstream energy plant capacity. [S08] [S13] [S1002]

10.3 BURDEN-SHIFTING CHECKS PROTECT THE BOUNDARY BEFORE CAPITAL IS COMMITTED

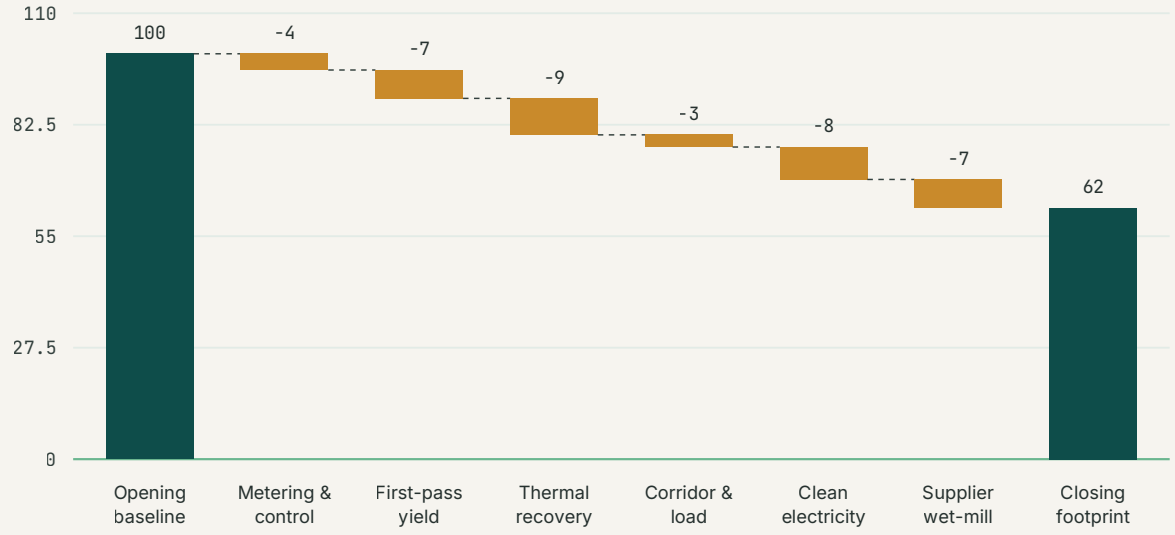
Focusing on carbon hotspots also requires testing whether a proposed action shifts environmental or greenhouse gas burdens to another life cycle stage, Scope 3 category, or impact category. [S01] [S05] [S24] ISO 14067:2018 addresses climate change alone. [S05] Because ISO 14040 and ISO 14044 warn that single-issue optimisation can mask trade-offs in water scarcity, ecotoxicity, or land use, every candidate abatement measure must pass a boundary-wide check before approval. [S24] [S25]

For instance, lowering a dyeing temperature cuts boiler fuel in Scope 1 or steam in Scope 2, but if the modified recipe requires a higher-impact chemical or lowers fabric tear strength so garment service life falls by 20 percent (illustrative sensitivity test), cradle-to-grave CO2e per wear can rise even as factory-gate emissions fall. [S03] [S04] [S31] Similarly, switching a marine freight corridor to a biofuel blend without evaluating well-to-wake pathways under International Maritime Organization (IMO) guidelines can shift emissions from shipboard combustion into upstream feedstock production. [S19]

To make the order of work visible, **Exhibit 47**, p. 168 presents an illustrative waterfall sequencing interventions from metering and process control through yield improvement, thermal recovery, logistics consolidation, clean electricity, and supplier wet-mill upgrades. [S08] [S13] [S23] [S1002]

EXHIBIT 47 / ILLUSTRATIVE INDEX (BASE = 100)

An illustrative abatement sequence moves from measurement to supply



ILLUSTRATIVE [S08] [S13] [S23] [S1002] Illustrative sequence modelled on the intervention hierarchy in S08, S13, S23 and S1002. Values are an illustrative index (opening = 100, closing = 62) to show why demand, yield and efficiency steps precede supply-side energy sizing; they are not measured results from a GFT facility.

As **Exhibit 47**, p. 168 shows, the sequence starts at an illustrative index of 100 units and applies demand cuts before capital-intensive energy supply replacements, closing at 62 units. [S08] [S13] [S1002] Sub-metering and control (4 illustrative points) and first-pass yield gains (7 illustrative points) cut the fabric, steam, and electricity needed per accepted garment before thermal recovery (9 illustrative points), corridor load optimisation (3 illustrative points), clean electricity (8 illustrative points), and supplier wet-mill actions (7 illustrative points) are sized. [S13] [S23] [S1002] What **Exhibit 47**, p. 168 cannot establish is the actual saving at any specific mill; those values require site meters, batch logs, and dated regional factors. [S14] [S20]

10.4

Efficiency links carbon to factory economics

Resource efficiency bridges cost control and carbon abatement because every wasted kilowatt-hour of electricity, tonne of leaked steam, or cubic metre of over-heated water is paid for on both the utility invoice and the carbon ledger. [S13] [S20] The International Finance Corporation (IFC) demonstrated this link through its Partnership for Cleaner Textiles (PaCT) in Bangladesh, which began in wet dyeing and finishing before expanding across the entire textile value chain. [S13] Efficiency programmes work when engineers treat carbon as the physical result of thermodynamic and mechanical losses across boilers, compressors, stenter frames, dye jiggers, spinning frames, and sewing lines. [S13] [S20]

In Cameroon, linking efficiency to unit economics is vital. Public reporting on CICAM recorded capacity utilisation in July 2023 at 33.7 percent for Garoua, 48.9 percent for CICAM 1, and 10.83 percent for CICAM 2, with underutilisation costing about CFAF 2

billion in 2020. [R12] Announced third-party plans such as the Camtext SA project (reported in November 2025 at US$300 million, or 180 billion XAF, targeting 12,000 tonnes a year of processed fibre and optimal capacity around 2033) show the capital scale involved in pursuing the SND30 target of 50 percent local processing by 2030. [R07] [R09] [R10] These records describe third-party sector conditions and announcements, not GFT operating results. [R09] [R12] Low utilisation, uninsulated steam lines, and air leaks spread baseload overheads across fewer good units, raising CFA franc cost and CO2e per garment together. [R12] [S20] [S23]

10.5 PHYSICAL ACTIVITY SAVINGS MUST BE SEPARATED FROM TARIFF FLUCTUATIONS

Never infer a greenhouse gas reduction from a lower utility bill in CFA francs or US dollars. [S20] [S23] Under UK Department for Energy Security and Net Zero (DESNZ) conversion factor rules and the GHG Protocol Corporate Standard, emissions are calculated from physical activity data (litres of fuel, cubic metres of gas, or kilowatt-hours of electricity) multiplied by the corresponding factor. [S04] [S20]

A spend drop can arise from a tariff change, currency shift, or subsidy while physical kilowatt-hours or fuel litres per unit rise. [S23] Conversely, when a factory returns condensate, cleans heat exchangers, seals air leaks, or cuts sewing-line idle running, the proof of abatement is the drop in metered kilowatt-hours or fuel litres per standard minute and per accepted garment. [S13] [S20]

10.6 CO-BENEFITS ACROSS WATER, STEAM, AND CHEMISTRY REQUIRE DISTINCT FACTORS

In wet processing and washing, water conservation and thermal abatement are coupled in physics but separate in factor accounting. [S13] [S31] Pumping, heating, and treating process water consumes electricity and boiler fuel, so lowering the dyeing liquor ratio cuts water mass, steam demand, and effluent load simultaneously. [S13] [S31]

However, thermal savings must not be counted twice: once via a water-heating proxy and again via the boiler fuel meter. [S04] [S20] [S23] When boiler fuel is metered in Scope 1 (or steam in Scope 2), the thermal gain from heating less water is already captured in the fuel or steam reading. [S03] [S04] Water supply and effluent factors then apply only to upstream supply and downstream treatment energy outside the boiler boundary. [S20] [S23]

> **GFT NOTE**
>
> In GFT's Cameroon textile programme, energy, water, and waste per unit sit beside Overall Equipment Effectiveness (OEE) and quality in the six core key performance indicator (KPI) families. [S20] [S23] GFT recommends evaluating every efficiency proposal on two parallel ledgers: a financial ledger in XAF and US dollars using metered physical savings multiplied by the site tariff, and a carbon ledger in kg CO2e using the same physical savings multiplied by the versioned IEA or national factor. [R32] [S14] [S20] If a saving is not visible on a physical sub-meter or fuel log, it is not verified abatement. [S20] [S23]

10.7

Yield improvement avoids repeated production burdens

Improving first-pass yield and cutting waste across spinning, knitting or weaving, dyeing, cutting, and sewing is one of the strongest abatement levers available, yet it is missed by audits that stop at Scope 1 and Scope 2 meters. [S08] [S23] [S1002] The WRI and Apparel Impact Institute roadmap ranks maximising material efficiency first among its six interventions because every kilogramme of lint, yarn, or fabric lost to scrap or defects carries the entire upstream cradle-to-gate burden invested up to that stage. [S31] [S1002]

In the 2026 T-shirt assessment by Forfora et al., producing a 0.25 kg cotton T-shirt involves cumulative cotton losses of 31 percent across the cradle-to-gate chain. [S31] By direct arithmetic from that 31 percent loss, delivering 0.25 kg of finished garment mass requires `0.25 / 0.69 = 0.3623 kg` of input cotton fibre per accepted shirt. [S31] Rejecting a finished shirt or scrapping a dyed panel forces the chain to cultivate, gin, spin, knit, and dye another 0.3623 kg of raw cotton input and dispose of the reject. [S23] [S31]

10.8 STARTED UNITS AND ACCEPTED UNITS TELL DIFFERENT CARBON STORIES

Dividing monthly Scope 1 and Scope 2 emissions by total units started hides the carbon cost of defects and rework. [S23] [S26] If a line starts 10,000 shirts in an illustrative month, rejects 800 shirts, and reworks 1,200 shirts, dividing energy by 10,000 started units makes the line look artificially efficient (illustrative example). [S23]

Locking the denominator to accepted first-quality garments (9,200 accepted units in that illustrative month) exposes wasted facility utilities and excess fabric in Scope 3 Category 1 and Category 5. [S02] [S23] GFT tracks carbon per started garment beside carbon per accepted garment on every line so supervisors see the CO2e penalty of quality failures. [S23]

10.9 AUTOMATED DEFECT DETECTION PREVENTS DOWNSTREAM CARBON LOCK-IN

Catching a defect on the greige frame before wet processing diverts the faulty roll before it consumes dyehouse steam, dyes, stenter gas, freight, and sewing labour. [R29] [S31] Shared evidence shows that manual visual inspection is 60 to 70 percent accurate and misses 20 to 30 percent of defects, whereas computer-vision inspection exceeds 90 percent accuracy across more than 40 defect types at speeds up to 60 metres a minute. [R29] The global fabric-defect-detection AI market was valued at US$523.4 million in 2024 and projected to reach US$6,522.1 million by 2033 at 33.8 percent a year, with Asia-Pacific at about 46 percent in 2024. [R28]

To show how reject rates amplify upstream burdens, **Exhibit 48**, p. 171 links final reject shares to required raw cotton lint and the upstream multiplier per 1,000 accepted 0.25 kg shirts. [R29] [S23] [S31]

EXHIBIT 48 / KG LINT PER 1,000 GOOD SHIRTS

First-pass yield improvements avoid upstream material and processing burdens

Operating quality regime	Unrecovered reject share (%)	Started shirts per 1,000 accepted	Raw lint required (kg)	Upstream CO2e multiplier
Reference zero-reject boundary (S31 basis)	0	1,000	362	1
High-scrap manual regime (illustrative)	12	1,136	412	1.14
Controlled line regime (illustrative)	6	1,064	385	1.06
Vision-assisted target regime (illustrative)	2	1,020	370	1.02

DERIVED [S23] [S31] [R29] Derived from the 0.25 kg cotton T-shirt mass and 31 percent cumulative cradle-to-gate cotton loss in S31 (0.25 / 0.69 = 0.3623 kg lint per finished shirt), combined with Scope 3 waste accounting in S23 and inspection accuracy benchmarks in R29. Illustrative factory unrecovered reject scenarios (12 percent, 6 percent and 2 percent) multiply upstream inputs by 1 / (1 - reject share).

As **Exhibit 48**, p. 171 shows, under the zero-reject boundary from Forfora et al., 1,000 accepted 0.25 kg cotton shirts require 1,000 started shirts and 362.3 kg of raw cotton lint after the cited 31 percent upstream loss. [S31] In an illustrative high-scrap manual regime with a 12.0 percent unrecovered reject rate, delivering 1,000 accepted shirts requires starting 1,136 shirts (1,000 / 0.88) and pulling 411.7 kg of raw lint, multiplying upstream Scope 3 Category 1 and Category 4 emissions by 1.136. [R29] [S02] [S23] [S31] Moving to a 6.0 percent illustrative reject rate cuts started units to 1,064 and lint to 385.4 kg, while a 2.0 percent illustrative reject regime via inline vision inspection cuts started units to 1,020 and lint to 369.7 kg, saving 42.0 kg of lint and 10.2 percent of upstream embodied emissions per 1,000 accepted shirts. [R29] [S23] [S31] What **Exhibit 48**, p. 171 cannot establish is any net credit from selling seconds or recycling scraps; such credits require verified displacement evidence. [S26] [S30]

WORKED EXAMPLE

Quantifying the full-scope carbon saving of an illustrative first-pass yield and rework intervention

Consider an illustrative line producing 100,000 accepted 0.25 kg cotton T-shirts per quarter. In baseline Quarter 1, the line has an illustrative unrecovered reject rate of 8.0 percent and rework rate of 15.0 percent. Assume three illustrative inputs: (1) incoming finished fabric carries a verified cradle-to-gate footprint of 3.20 kg CO2e per started shirt (reflecting the 0.25 kg garment mass and 31 percent upstream loss in S31); (2) factory Scope 1 and Scope 2 energy is 0.35 kg CO2e per standard pass plus 0.20 kg CO2e per reworked shirt; and (3) Scope 3 Category 5 reject disposal adds 0.05 kg CO2e per reject. [S02] [S03] [S04] [S20] [S23] [S31]

- **Baseline Quarter 1 (illustrative):** Delivering 100,000 accepted shirts at an 8.0 percent reject rate requires `100,000 / 0.92 = 108,696` started shirts, with `8,696` rejects and `16,304` reworked units. [S23] Upstream fabric is `347,827 kg CO2e`, standard-pass energy `38,044 kg CO2e`, rework energy `3,261 kg CO2e`, and disposal `435 kg CO2e`, totalling `389,567 kg CO2e`, or **3.896 kg CO2e per accepted shirt** (illustrative). [S02] [S03] [S04] [S20] [S23]
- **Post-intervention Quarter 2 (illustrative):** Inline inspection (informed by R29) and quality gates cut rejects to 2.5 percent and rework to 4.0 percent at 100,000 accepted shirts and constant factors. [R29] [S23] Started shirts drop to `102,564` (`2,564` rejects and `4,103` reworked units), cutting upstream fabric to `328,205 kg CO2e`, standard energy to `35,897 kg CO2e`, rework energy to `821 kg CO2e`, and disposal to `128 kg CO2e`, totalling `365,051 kg CO2e`, or **3.651 kg CO2e per accepted shirt** (illustrative). [S03] [S04] [S20] [S23]
- **Result:** Quarterly emissions fall by `24,516 kg CO2e` (24.52 tonnes CO2e, or 6.3 percent), with `19,622 kg CO2e` (80.0 percent in this illustrative case) from avoided Scope 3 Category 1 fabric and `4,587 kg CO2e` from factory Scopes 1 and 2. [S02] [S23]

10.10

Supplier engagement scales beyond one site

Even when an assembly plant achieves near-zero rework and clean power, it controls only a small fraction of cradle-to-grave emissions when spinning, knitting, weaving, and wet processing sit at upstream suppliers. [S08] [S31] Because Scope 3 dominates apparel footprints, abatement must extend beyond the fence line through supplier engagement, technical assistance, and harmonised data exchange. [S08] [S10] [S13] [S21]

Shifting orders using desktop grid averages does not build low-carbon chains. The United Nations Industrial Development Organization (UNIDO) warned that developing-country suppliers face rising pressure to limit their footprints due to buyer commitments, and that without capability building and fair incentives, private standards act as market barriers. [S21] In Cameroon, where SODECOTON supports more than 220,000 cotton producers and operates nine ginning plants and two oil mills, decarbonising from field to garment requires investing in local metering and thermal efficiency alongside producers and mills rather than imposing unpriced checklists. [R03] [S21]

10.11 CAPABILITY BUILDING BEATS UNPRICED COMPLIANCE QUESTIONNAIRES

Sending an annual spreadsheet to a Tier 2 dyehouse or Tier 3 spinning mill without specifying process boundaries, allocation rules, or metering methods yields unusable data. [S23] As GHG Protocol and Carbon Trust Scope 3 guidance notes, supplier data can be less accurate than industry averages if allocation rules, boundaries, or factors are weak. [S23]

To protect the baseline, supplier engagement follows three rules: 1. **Joint engineering diagnostics:** Following IFC's PaCT model in Bangladesh, buyers and lead manufacturers co-fund on-site energy, water, and chemical audits at wet-processing and spinning mills to execute boiler, steam-trap, heat-recovery, and motor retrofits. [S13] 2. **Harmonised product carbon exchange:** Supplier footprints use WBCSD Partnership for Carbon Transparency (PACT) Version 3 and GHG Protocol Scope 3 supplier-specific rules, declaring cradle-to-gate boundaries, periods, primary-data shares, allocation drivers, and verification. [S10] [S23] 3. **Multimodal logistics alignment:** Carriers report transport work in tonne-kilometres, load factors, empty running, and well-to-wake fuel pathways under the Global Logistics Emissions Council (GLEC) Framework and IMO marine fuel guidelines. [S18] [S19]

10.12 COMMERCIAL CONTRACTING ALIGNS BUYER COMMITMENTS WITH MILL CAPITAL

A supplier cannot finance a boiler conversion, solar array, or heat exchanger paying back over four to seven years (illustrative window) on 60-day spot orders. [S13] [S21] Under SBTi supplier rules, the register tracks contracted engineering actions, financing terms, and metered post-project intensities at each tier, not merely target pledges. [S08] [S13] [S21]

10.13

An abatement curve compares more than tonnes

Once hotspots are mapped across operations and suppliers, management needs a structured method to rank projects. A marginal abatement cost curve (MACC) plots cost per tonne of CO2e saved against annual abatement volume (illustrative convention), but two variables hide capital limits, lead times, proof readiness, and project interactions. [S13] [S15] [S1001]

In GFT's method, candidate measures are ranked across seven criteria:

- **Expected CO2e effect:** Annual tonnes of CO2e and grammes of CO2e per accepted garment across Scopes 1, 2, and 3. [S04] [S23] [S1001]
- **Capital expenditure (capex):** Installed cost in XAF and US dollars, including duties and grid works. [R32] [S15]
- **Operating cost effect (opex):** Annual fuel, electricity, water, chemical, maintenance, and scrap savings at site tariffs. [S13] [S15]
- **Technical feasibility:** Lead time, downtime, skill requirements, and local grid fit. [S13] [S28]

- **Proof readiness:** Whether savings are metered directly or rely on modelled counterfactuals. [S20] [S23] [S1001]
- **Sequence dependency:** Which demand or yield measures precede supply sizing to avoid double counting. [S1001] [S1003]
- **Co-benefits and burden-shift check:** Effects on water, effluent, defects, and durability. [S05] [S13] [S24]

10.14 RENEWABLE ENERGY COST BENCHMARKS INFORM CAPEX BUT DO NOT REPLACE SITE FACTORS

Global cost evidence supports the financial case for renewable power. The International Renewable Energy Agency (IRENA) reports in *Renewable Power Generation Costs in 2025* (published July 2026) that global weighted average levelised cost of electricity (LCOE) for solar photovoltaics (PV) stayed at USD 44/MWh in 2025, while onshore wind fell to USD 33/MWh and offshore wind stood at USD 78/MWh. [S15] The World Bank notes in January 2025 that Cameroon is embracing hydropower and solar energy to lower costs and cut carbon emissions while improving grid reliability. [S28]

However, cost evidence and carbon accounting remain separate. [S03] [S14] [S15] IRENA's USD 44/MWh solar figure is a global cost benchmark, not a Cameroonian emission factor. [S15] Calculating CO2e abated by on-site solar PV and storage requires comparing metered solar use against displaced grid power (using the dated IEA factor for Cameroon [^S14]) and displaced diesel backup fuel (using metered fuel litres and DESNZ factors [^S20]), while recording Scope 3 capital-goods emissions for panels and batteries. [S02] [S03] [S14] [S20]

10.15 SEQUENCE DEPENDENCIES PREVENT DOUBLE COUNTING ACROSS INTERACTING MEASURES

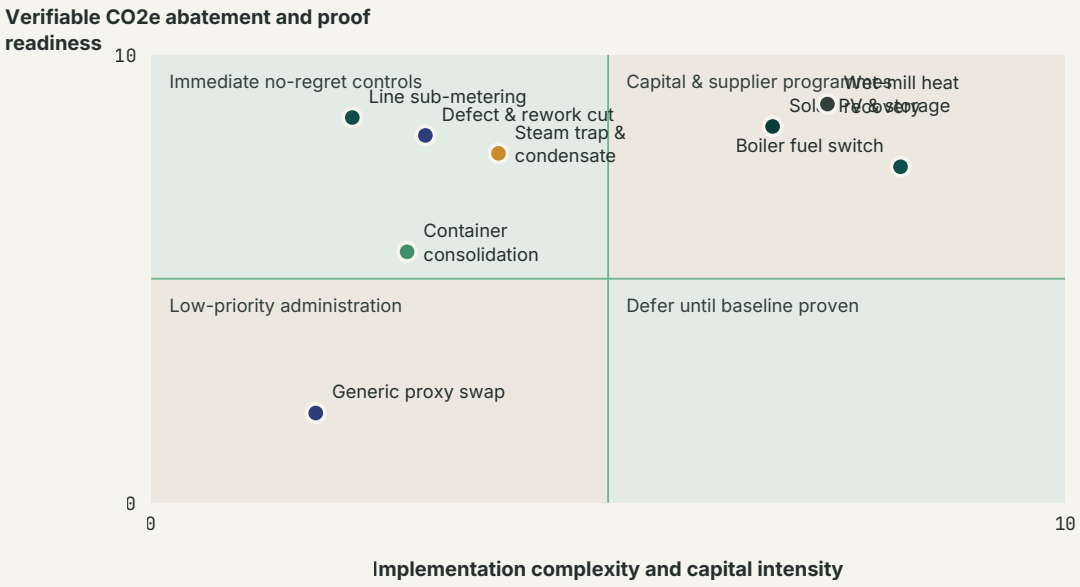
Summing standalone savings of interacting projects as if each acted on the untouched baseline overstates abatement. [S1001] [S1003] Under the GHG Protocol for Project Accounting and the Policy and Action Standard, interventions on the same process chain combine multiplicatively. [S1001] [S1003]

Consider three sequential measures on an illustrative opening thermal footprint of 100.0 t CO2e per 100,000 accepted garments: Measure A (first-pass yield) cuts required dyed fabric by 8.0 percent; Measure B (dyehouse heat recovery) cuts steam per kilogramme of fabric by 20.0 percent; and Measure C (boiler fuel switch) cuts the steam factor by 35.0 percent (all illustrative). [S04] [S13] [S20] [S23] [S31] Evaluated naively in isolation, the three steps appear to save `8.0 + 20.0 + 35.0 = 63.0 t CO2e` (illustrative error). [S1001] [S1003] Evaluated in physical sequence: Measure A lowers emissions to `92.0 t CO2e` (`-8.0 t CO2e`); Measure B acts on `92.0` to reach `73.6 t CO2e` (`-18.4 t CO2e`); and Measure C acts on `73.6` to reach `47.84 t CO2e` (`-25.76 t CO2e`), giving a combined abatement of `52.16 t CO2e` (`10.84 t CO2e` below the naive sum, illustrative) while letting the new boiler be sized 26.4 percent smaller. [S13] [S1001] [S1003]

To show how candidate interventions are organised before capital commitment, **Exhibit 49**, p. 175 plots eight representative actions by implementation complexity and capital intensity on the horizontal axis against verifiable CO2e abatement and proof readiness on the vertical axis. [S13] [S15] [S23] [S1001]

EXHIBIT 49 / ILLUSTRATIVE SCORE (0 TO 10 SCALE)

A measure register ranks carbon, cost, feasibility and proof



ILLUSTRATIVE [S13] [S15] [S23] [S1001] Illustrative decision matrix using the evaluation dimensions in S13, S15, S23 and S1001. Horizontal axis scores implementation complexity and capital intensity (0 = low barrier, 10 = high barrier); vertical axis scores verifiable abatement potential and data readiness (0 = low, 10 = high). Positions are illustrative planning examples, not site measurements.

In **Exhibit 49**, p. 175, the upper-left quadrant ("Immediate no-regret controls") holds low-barrier, high-proof actions: line sub-metering (x = 2.2, y = 8.6), defect and rework reduction (x = 3.0, y = 8.2), steam trap and condensate recovery (x = 3.8, y = 7.8), and freight consolidation (x = 2.8, y = 5.6) on an illustrative 0 to 10 scale. [S13] [S18] [S23] The upper-right quadrant ("Capital & supplier programmes") holds structural investments executed after demand control: solar PV and storage (x = 6.8, y = 8.4), supplier wet-mill heat recovery (x = 7.4, y = 8.9), and boiler fuel switching (x = 8.2, y = 7.5) on the same illustrative scale. [S13] [S15] [S1002] "Generic proxy swap" (x = 1.8, y = 2.0) sits in the lower-left quadrant because swapping database proxies changes paper estimates without cutting physical emissions. [S16] [S23] What **Exhibit 49**, p. 175 cannot establish is the site-specific financial return, which requires local quotes and tariffs. [S15] [S28]

10.16

Realised reduction requires a stable counterfactual

Claiming that a project or supplier programme cut emissions requires comparing measured results against a counterfactual baseline or a recalculated base year. [S04] [S23] [S1001] [S1003] Three illusions corrupt reduction reports: 1. **The volume drop illusion:** Total Scope 1 and Scope 2 emissions fall by 15 percent because orders dropped, while energy per accepted garment worsened. [R12] [S04] [S23] 2. **The growth erasure illusion:** Carbon per garment falls by 10 percent through efficiency, but output grows by 25 percent, raising absolute emissions (seen globally as fibre production rose from 125 million tonnes in 2023 to 132 million tonnes in 2024). [S07]

[S08] 3. **The methodological shift illusion:** Replacing a conservative ecoinvent proxy with a lower supplier PACT record or updated grid factor is misreported as operational abatement without recalculating the base year. [S04] [S10] [S16] [S23]

10.17 STRUCTURAL DECOMPOSITION ISOLATES VOLUME, ACTIVITY INTENSITY, AND FACTOR CHANGES

To prevent these illusions, GFT decomposes changes between base period `0` and reporting period `t` across every process activity `i`. [S04] [S23] [S1003]

> METHOD
>
> **Stepwise decomposition of corporate and product emission changes**
>
> Let total greenhouse gas emissions in period `p` (base period `0` or reporting period `t` under consistent methods) across activities `i = 1 ... n` be `E_p = Q_p * sum_i ( a_{i,p} * f_{i,p} )`, where `Q_p` is accepted garments, `a_{i,p} = A_{i,p} / Q_p` is metered activity per accepted garment, `f_{i,p}` is the versioned factor, and `I_p = E_p / Q_p` is carbon per accepted garment. [S01] [S14] [S20] [S23] [S26]
>
> To reconcile opening base-year emissions `E_0` with closing emissions `E_t`, compute three sequential states: [S04] [S23] [S1001] [S1003] 1. **Volume counterfactual (`E_vol`):** Hold base intensities `a_{i,0}` and factors `f_{i,0}` constant at reporting output `Q_t`, giving `E_vol = Q_t * I_0`. The **output volume effect (`Delta E_vol = E_vol - E_0`)** isolates absolute change from scaling output. [S04] [S07] [S23] 2. **Activity-efficiency state (`E_act`):** Apply reporting intensities `a_{i,t}` at output `Q_t` with base factors `f_{i,0}`, giving `E_act = Q_t * sum_i ( a_{i,t} * f_{i,0} )`. The **physical activity-intensity effect (`Delta E_act = E_act - E_vol`)** isolates engineering abatement from sub-metering, yield gains, heat recovery, and modal shifts. [S13] [S20] [S1001] 3. **Closing factor state (`E_t`):** Apply reporting verified factors `f_{i,t}` to `Q_t * a_{i,t}`, giving `E_t = Q_t * sum_i ( a_{i,t} * f_{i,t} )`. The **emission-factor effect (`Delta E_fac = E_t - E_act`)** isolates fuel switching, solar self-consumption, market instruments, or grid factor changes. [S03] [S14] [S20]
>
> **Identity check:** `E_t - E_0 = Delta E_vol + Delta E_act + Delta E_fac`, and `I_t - I_0 = (Delta E_act + Delta E_fac) / Q_t`. [S04] [S23] [S1003]

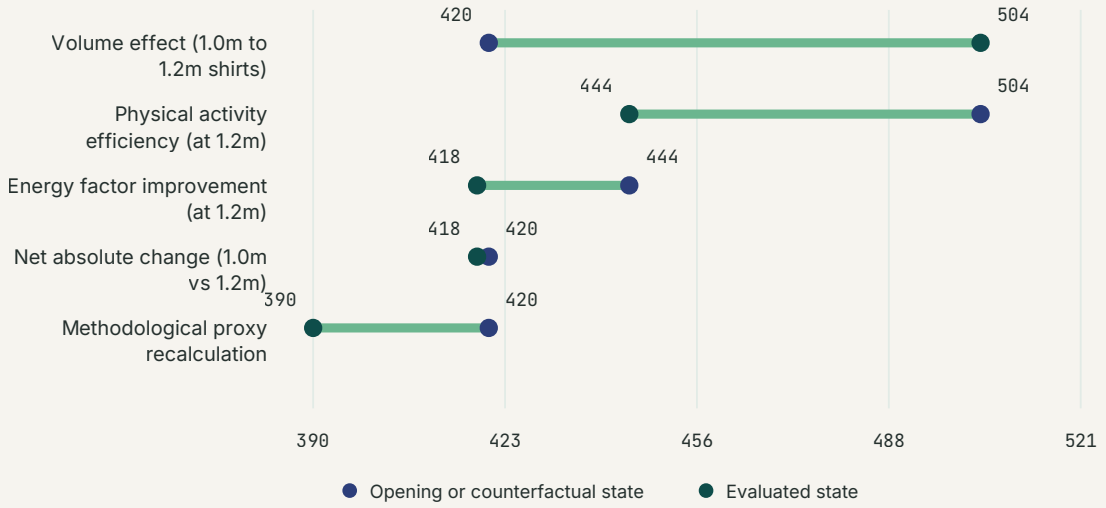
10.18 BASE-YEAR RECALCULATION SEPARATES DATA UPGRADES FROM OPERATIONAL ABATEMENT

When a manufacturer replaces an ecoinvent spinning proxy ([^S16]) with an audited PACT Version 3 record from its existing yarn supplier ([^S10]) showing a 30 percent lower footprint (illustrative example), the GHG Protocol Corporate Standard and Scope 3 guidance require recalculating the base-year inventory `E_0` rather than claiming an operational cut. [S04] [S23] Only if the company switched to a verified lower-carbon supplier between period `0` and period `t`, or co-invested in new supplier efficiency or renewable plant during that window, does the change count as abatement. [S08] [S23] [S1001]

To show this separation numerically, **Exhibit 50**, p. 177 plots a derived dumbbell comparison for an illustrative facility scaling from 1.0 million to 1.2 million accepted shirts. [S04] [S20] [S23] [S1001] [S1003]

EXHIBIT 50 / T CO2E PER REPORTING PERIOD

Baseline against verified result separates activity from factor change



DERIVED [S04] [S20] [S23] [S1001] [S1003] Derived decomposition applying the tracking and recalculation rules in S04, S20, S23, S1001 and S1003 to an illustrative facility scaling from 1.0 million to 1.2 million accepted shirts. Base intensity is 0.420 kg CO2e/shirt (420 t CO2e); volume counterfactual at 1.2m units is 504 t CO2e; physical efficiency cuts 60 t CO2e to 444 t CO2e (0.370 kg/shirt); energy factor change cuts 26 t CO2e to 418 t CO2e (0.3483 kg/shirt). Separate methodological proxy revision (420 to 390 t CO2e) is isolated as a base-year recalculation.

In **Exhibit 50**, p. 177, five paired rows illustrate the decomposition on an illustrative dataset. [S04] [S23] [S1003] First, growing output by 20 percent from 1.0 million to 1.2 million accepted shirts at 0.420 kg CO2e per shirt moves emissions from 420 t CO2e to a volume counterfactual (E_vol) of 504 t CO2e (+84 t CO2e volume effect, illustrative). [S04] [S23] Second, metered yield and thermal gains cut physical intensity to 0.370 kg CO2e per shirt at constant factors, lowering emissions from 504 t CO2e to 444 t CO2e (-60 t CO2e activity abatement, illustrative). [S13] [S20] [S1001] Third, verified solar self-consumption and fuel switching cut the energy factor, pulling emissions from 444 t CO2e to 418 t CO2e (-26 t CO2e factor abatement, illustrative, or 0.3483 kg CO2e per shirt). [S03] [S14] [S15] Fourth, because combined physical and factor abatement (-86 t CO2e) exceeds the volume addition (+84 t CO2e), net absolute emissions edge down from 420 t CO2e to 418 t CO2e (-2 t CO2e) despite 20 percent growth (illustrative). [S07] [S08] [S23] Fifth, the proxy revision (420 t CO2e to 390 t CO2e) is isolated as a base-year recalculation rather than mixed into the -86 t CO2e operational saving. [S04] [S16] [S23] What **Exhibit 50**, p. 177 cannot establish is that efficiency always outpaces growth; when volume growth exceeds intensity cuts, absolute emissions rise. [S07] [S08]

> **WARNING**
>
> **Never report a proxy replacement or an external carbon offset as product abatement**
>
> Two practices invalidate a reduction claim under accounting and consumer-protection rules: 1. **Claiming data refinement as physical reduction:** Replacing an ecoinvent proxy with a lower primary supplier factor without a physical process or procurement change improves accuracy but does not cut emissions; it belongs in base-year recalculation. [S04] [S16] [S23] 2. **Substituting external offsets for value-chain abatement:** Under Directive (EU) 2024/825 (28 February 2024), claims that a product has a neutral, reduced, or positive greenhouse gas impact are prohibited when based on offsetting outside the product's value chain, as lifecycle cuts and offsets are not equivalent. [S32] Every GFT reduction must occur inside the declared value chain. [S01] [S23] [S32]

10.19 VERIFICATION GATES LOCK EACH PROJECT BEFORE CLAIMS ARE RELEASED

To embed this discipline into daily management, GFT links every abatement project to four verification gates:

- **Gate 1 (Baseline freeze):** Record the process boundary, 90 days (illustrative window) of metered physical activity per unit, versioned IEA or DESNZ factors, and the burden-shift check. [S14] [S20] [S24] [S1001]
- **Gate 2 (Meter validation):** Confirm that line meters, steam flowmeters, and quality logs capture post-intervention activity without gaps or unrecorded backup fuel. [S04] [S20]
- **Gate 3 (Counterfactual reconciliation):** Run the decomposition equations to separate volume (`Delta E_vol`), physical activity (`Delta E_act`), and factor (`Delta E_fac`) effects, deducting upstream interactions. [S23] [S1001] [S1003]
- **Gate 4 (Claim clearance):** Clear the reconciled saving for buyer exchange via PACT Version 3 or public reporting only after internal audit and, for comparative claims, review under ISO 14044 and Directive 2024/825. [S10] [S25] [S32]

A factory proves what changed only when the meter, the baseline and the good garment tell the same story.

CHAPTER SOURCE NOTES

S01 GHG Protocol. 2011.

S23 GHG Protocol and Carbon Trust. 2013.

S1001 GHG Protocol. 2005.

S04 GHG Protocol. 2004.

S20 UK Department for Energy Security and Net Zero. 2026-06-11.

S1003 GHG Protocol. 2014-11.

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

S16 ecoinvent. 2025-11-05.

S13 International Finance Corporation. 2018-01-29.
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S1002 World Resources Institute and Apparel Impact Institute. 2021-11-05.
S32 European Parliament and Council of the European Union. 2024-02-28.
S31 Forfora et al., Sustainability. 2026-04-20.
S05 International Organization for Standardization. 2018-08.
S24 International Organization for Standardization. 2006-07.
S25 International Organization for Standardization. 2006-07.
S03 GHG Protocol. 2015.
S19 International Maritime Organization. 2024.
S14 International Energy Agency. 2026-09-25.
R12 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.
R32 Wise; XE. Publication date unrecorded; inherited source-text check.
S26 Watson and Wiedemann, Sustainability. 2019-07-15.
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R29 MDPI; industry inspection literature. Publication date unrecorded; inherited source-text check.
R28 DataIntelo. Publication date unrecorded; inherited source-text check.
S30 European Environment Agency. 2022.
S10 World Business Council for Sustainable Development. 2025-04-30.
S21 United Nations Industrial Development Organization. 2010.
R03 SODECOTON. Publication date unrecorded; inherited source-text check.
S18 Smart Freight Centre. 2024.
S15 International Renewable Energy Agency. 2026-07-02.
S28 World Bank. 2025-01-16.
S07 Textile Exchange. 2025-09-18.

GREEN FUTURE TECH

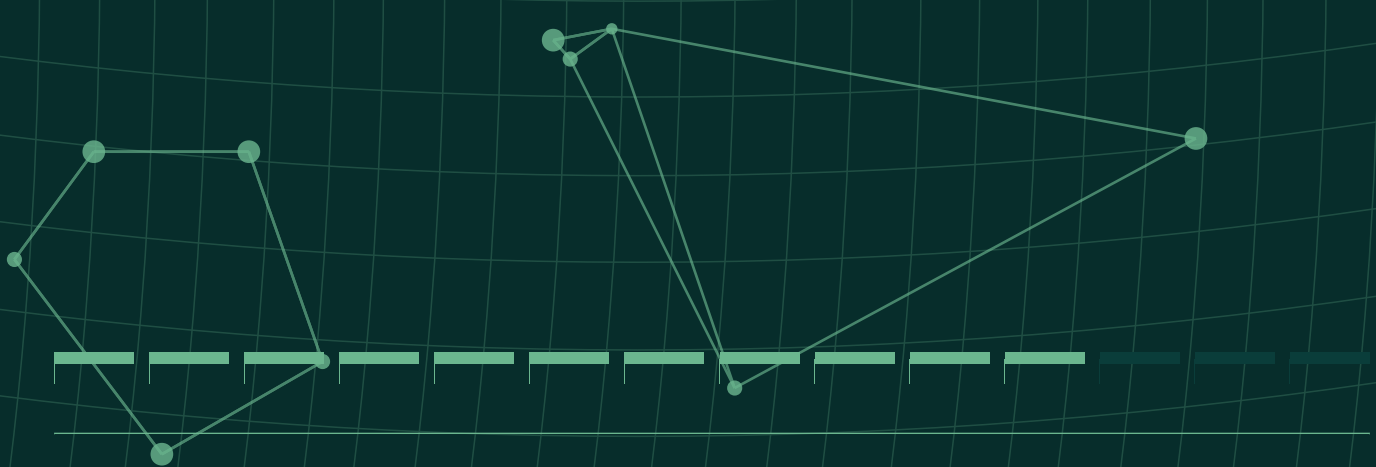
LIMITED / HONG KONG SAR

11

PART III: REDUCE CARBON WITHOUT MOVING THE PROBLEM / ENERGY TRANSITION

Clean electricity is necessary but not a complete garment strategy

Electricity and heat decarbonisation require meter data, contractual evidence and a separate solution for thermal demand.



CHAPTER 11
DECISION TEST

Electricity and heat decarbonisation require meter data, contractual evidence and a separate solution for thermal demand.

Clean electricity is a necessary condition for low-carbon garment production, but purchasing renewable power or installing rooftop solar panels does not by itself decarbonise a textile supply chain. [S03] [S08] An apparel manufacturer consumes energy in two distinct physical forms: electrical power that drives spinning frames, looms, cutting tables, sewing lines, compressors and chillers, and thermal energy that heats water, generates steam and dries fabric across dyeing, washing, finishing and pressing. [S08] [S31] Treating energy transition as a single procurement exercise in which renewable electricity certificates or annual solar totals are subtracted from a combined utility bill violates greenhouse gas accounting standards and conceals the boilers and backup diesel generators that often dominate industrial emissions. [S03] [S20] Green Future Tech Limited (GFT), Hong Kong SAR, structures factory energy transition around three rules: report Scope 2 purchased energy under both location-based and market-based methods with verified contractual instruments, reduce process electricity and heat demand through metered efficiency before sizing generation assets, and engineer separate, auditable pathways for thermal steam, grid losses, upstream fuel cycles and outage backup power. [S03] [S13] [S14] What follows in this chapter is an operational accounting and engineering method, not investment, legal or tax advice.

11.1

Scope 2 claims begin with dual accounting

A garment manufacturer cannot claim a zero-carbon electricity footprint simply by signing a green tariff or buying unbundled certificates while ignoring the physical grid to which its machinery is connected. [S03] The GHG Protocol Scope 2 Guidance standardises how corporations measure emissions from purchased or acquired electricity, steam, heat and cooling. [S03] Organisations operating in markets with contractual energy products must report their Scope 2 inventory using two methods: the location-based method and the market-based method. [S03] The location-based method reflects the average emissions intensity of the grids on which consumption physically occurs, using grid-average emission factors for defined geographic boundaries and periods. [S03] [S14] The market-based method reflects emissions from electricity purposefully chosen through contractual instruments, or, where no qualifying contract is held, the residual mix factor representing untracked power on the grid. [S03] Both figures must travel into the corporate inventory and into any product carbon footprint compiled under ISO 14067 or the GHG Protocol Product Standard. [S01] [S03] [S05]

11.2 EIGHT QUALITY CRITERIA GOVERN MARKET-BASED INSTRUMENTS

Under the market-based method, a contractual instrument can set an electricity emission factor only when it satisfies all eight Scope 2 Quality Criteria established by the GHG Protocol. [S03] The instrument must convey the direct greenhouse gas emission rate attribute associated with the unit of electricity produced, be the only instrument carrying that attribute claim, and be tracked, redeemed, retired or cancelled by or on behalf of the reporting entity. [S03] It must also be issued and redeemed as close as possible to the period of energy consumption to which it is applied, and be sourced from the same market boundary in which the reporting entity's electricity-consuming operations are located, or from a physically interconnected market where applicable. [S03] When a supplier or factory presents a certificate from an unconnected grid

region, or fails to retire the certificate for the reporting year in which the yarn was spun or the shirt was sewn, the instrument fails the quality test and the market-based account reverts to the residual mix or the location-based grid average. [S03] [S23]

Utility-specific or supplier-specific emission factors must also be disclosed cleanly, and residual mix factors are required so that when one buyer claims tracked low-carbon power, other consumers on the same grid do not claim the same renewable generation through an unadjusted grid average. [S03] The GHG Protocol held a public consultation on updates to the 2015 Scope 2 Guidance between October 2025 and January 2026, signalling closer scrutiny of temporal matching, deliverability and market boundaries. [S03] A garment programme built for multi-year durability must therefore capture interval meter data and contract retirement records at the time of consumption. [S03] [S10]

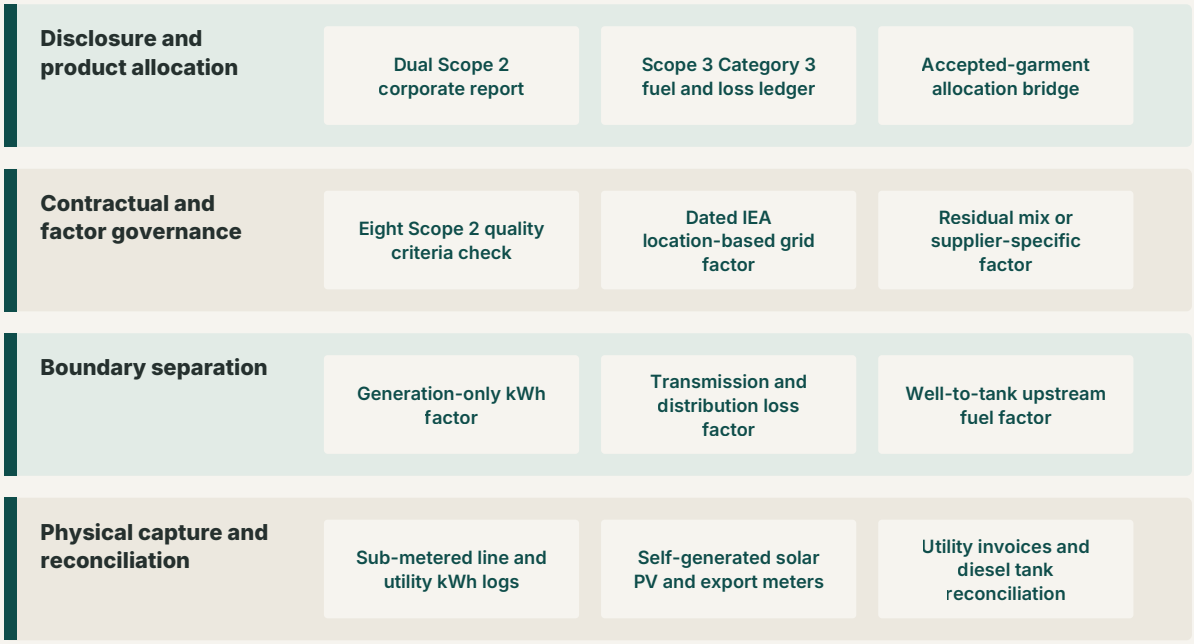
11.3 DUAL NUMBERS PREVENT SILENT BLENDING IN GARMENT FOOTPRINTS

When corporate Scope 2 emissions are allocated to garments or fabric batches under the GHG Protocol Product Standard, PACT Methodology Version 3 or European apparel product environmental footprint category rules, blending location-based and market-based figures into one undocumented number hides whether a lower footprint came from physical grid decarbonisation, on-site generation or paper certificates. [S01] [S06] [S10] In a comparative life cycle assessment of T-shirts made from viscose, Lyocell, cotton and polyester published in April 2026, Forfora and colleagues showed that regional energy mixes materially shift cradle-to-gate warming impacts. [S31] In their model, Lyocell exhibited the highest carbon footprint at 21.6 kg CO2e per kilogram of fabric unless produced in regions with cleaner electricity and heat supplies, and shifting production from China to Brazil lowered global warming impact by up to 38 percent in the modelled scenario. [S31] That geographic sensitivity reflects physical grid mixes and process steam configurations, not unbundled offsets purchased outside the production chain. [S31] [S32]

Under European Union Directive 2024/825, environmental claims about a product must be grounded in actual lifecycle impacts rather than offsetting outside the product's value chain. [S32] A garment maker that communicates a product footprint to buyers or regulators must state whether the electricity factor applied is location-based or market-based, record the factor vintage and boundary, and preserve the alternative figure alongside it. [S03] [S10] [S32] **Exhibit 51**, p. 183 organises this chain of custody into four operational layers, linking physical sub-meters on the factory floor to boundary separation, factor governance and dual disclosure. [S03] [S14] [S20]

EXHIBIT 51 /

An electricity evidence stack runs from meter to contractual instrument



SOURCED [S03] [S14] [S20] [S23] Accounting architecture synthesised from GHG Protocol Scope 2 Guidance (S03), IEA Emissions Factors 2026 (S14), UK DESNZ conversion factors 2026 (S20) and Scope 3 calculation guidance (S23). Separates physical metering, grid generation factors, transmission and distribution losses, upstream fuel-cycle burdens and market-based contractual quality criteria.

As **Exhibit 51**, p. 183 illustrates, the accounting architecture separates physical measurement at the bottom layer from contractual and factor rules in the middle layers before any figure reaches the product allocation bridge. [S03] [S20] [S23] What this diagram cannot establish on its own is whether a specific utility contract in Cameroon satisfies the eight Scope 2 quality criteria, or what the numerical residual mix is when national tracking registries are absent; when no verified residual mix exists, the Scope 2 Guidance requires disclosing that absence and using grid-average location-based factors. [S03]

GFT NOTE

In GFT's Cameroon textile programme (prepared 31 January 2024, with sources refreshed in 2026), factory performance management records kilowatt-hours per unit alongside water and waste per unit from the first shift. GFT recommends configuring the carbon ledger so that every sub-metered kilowatt-hour carries two factor slots: a dated national location-based factor from the International Energy Agency register and a market-based slot that remains equal to the location-based factor unless an audited, retired, market-matched generation record or on-site meter reading is attached. [S03] [S14]

11.4

Efficiency precedes renewable procurement

Replacing grid power with solar panels or low-carbon contracts before fixing compressed-air leaks, idle motor draw, uninsulated steam pipes and garment rework inflates capital expenditure and wastes clean generation capacity on avoidable losses. [S08] [S13] [S1102] Both the Science Based Targets initiative guidance for the apparel and footwear sector and the International Energy Agency analysis of renewables in industry identify energy efficiency as the foundational first step in industrial decarbonisation, paired with but preceding renewable energy supply. [S08] [S1102] In the International Finance Corporation's Partnership for Cleaner Textiles (PaCT) in Bangladesh, factory interventions began in dyeing and finishing and then expanded across the textile value chain because resource-efficiency measures cut fuel, electricity and water use simultaneously. [S13]

11.5 METERED KILOWATT-HOURS PER ACCEPTED GARMENT GOVERN MACHINE EFFICIENCY

In a spinning, weaving, knitting or cut-make-trim facility, electrical demand divides between direct production machinery and site utilities. [S08] [S20] Production machinery includes spinning frames, looms, spreaders, cutters, sewing motors and pressing stations, while site utilities cover air compressors, chillers, heating, ventilation and air-conditioning (HVAC) systems, lighting and conveyors. [S08] [S20] If electricity is read only once a month at the main revenue meter, engineers cannot separate base-load HVAC and compressor leakage during non-productive hours from active energy used to make garments. [S20] [S23]

The denominator attached to sub-metered electricity also determines whether quality discipline is rewarded in the carbon account. [S23] [S26] In GFT's Cameroon textile programme, line logs capture started units, defects, rework and first-pass yield, while industry literature shows that manual fabric inspection achieves 60 to 70 percent accuracy and misses 20 to 30 percent of defects, whereas computer-vision line-scan systems exceed 90 percent accuracy across more than 40 defect types at speeds up to 60 metres a minute. [R29] When defective fabric is dyed, dried, cut and sewn before a fault is caught, every kilowatt-hour of electricity and kilogram of steam is spread across fewer accepted garments. [R29] [S23] Lowering defect rates and idle run-time cuts kilowatt-hours per accepted garment directly. [R29] [S13]

11.6 THERMAL INSULATION AND HEAT RECOVERY SHRINK DOWNSTREAM EQUIPMENT

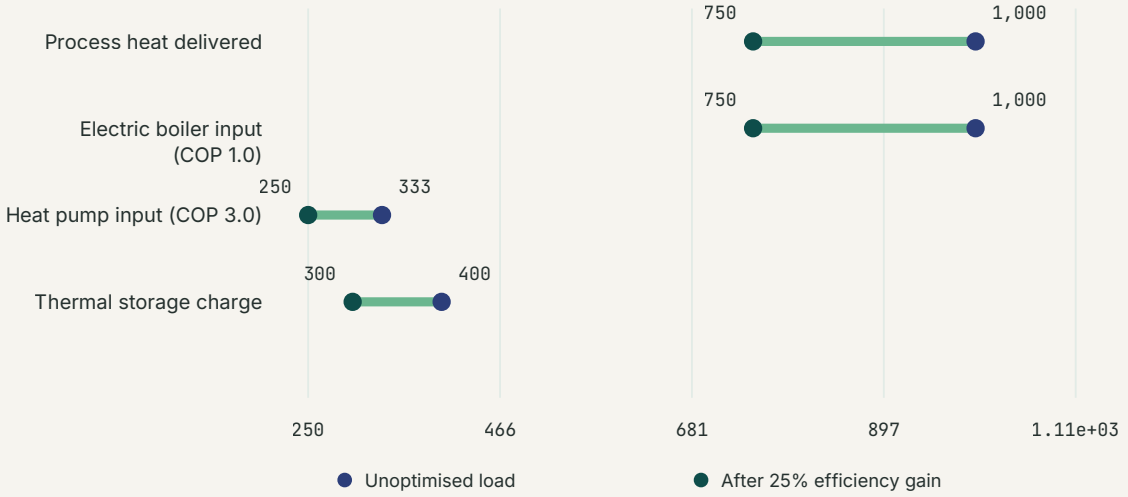
The case for efficiency before supply substitution is even stronger in thermal systems. [S1102] In its December 2025 report on renewables for industry, the International Energy Agency notes that energy efficiency measures lower overall heat demand, reduce thermal losses and enable smaller, more cost-effective electrification equipment. [S1102] Basic thermal optimisation, including recovering waste heat from hot dye-bath effluent and dryer exhausts, insulating steam headers and condensate return lines, maintaining steam traps, and tightening temperature control, delivers immediate fuel reductions at low capital cost. [S13] [S1102]

Because industrial heat pumps and electric boilers have higher upfront capital costs per kilowatt of capacity than fossil-fuel boilers, shrinking thermal load by 20 to 30 percent through heat recovery and liquor-ratio reduction directly cuts the nameplate

capacity of electric heating, transformers and storage that the factory must finance. [S13] [S15] [S1102] **Exhibit 52**, p. 185 demonstrates this coupling using a derived batch model before and after a 25 percent thermal efficiency gain. [S13] [S1101] [S1102]

EXHIBIT 52 / KWH PER ILLUSTRATIVE BATCH

Efficiency before electrification cuts the required heat and power input



DERIVED [S13] [S1101] [S1102] Derived from an illustrative baseline of 1,000 kWh process heat per batch. An illustrative 25 percent demand reduction from insulation and heat recovery cuts heat to 750 kWh (S13, S1102). Supplying that heat via an industrial heat pump at an illustrative COP of 3.0 up to 150 C (S1102) cuts electrical input from 333 kWh to 250 kWh, versus 1,000 kWh to 750 kWh for an electric boiler at COP 1.0.

In **Exhibit 52**, p. 185, an illustrative unoptimised batch requires 1,000 kWh of process heat. [S1101] [S1102] When insulation and effluent heat recovery cut that requirement by an illustrative 25 percent to 750 kWh, an electric resistance boiler at an illustrative coefficient of performance of 1.0 sees its electrical input fall from 1,000 kWh to 750 kWh, whereas an industrial heat pump at an illustrative coefficient of performance of 3.0 sees its electrical input drop from 333 kWh to 250 kWh, and an illustrative four-hour thermal storage buffer shrinks from 400 kWh to 300 kWh. [S13] [S1102] What **Exhibit 52**, p. 185 cannot establish is the exact saving or coefficient of performance at a specific Cameroon mill, because actual heat-pump performance depends on the temperature lift between the effluent heat source and the dye-bath sink, which must be measured on site. [S1102]

11.7

Solar and storage must be sized against the actual load

Once mechanical, electrical and thermal demand efficiency have been engineered into the plant baseline, on-site solar photovoltaic generation and energy storage can be evaluated against the remaining hourly load profile. [S15] [S28] A common error in industrial feasibility studies is to multiply a nameplate solar capacity by a generic regional irradiation figure, compare the resulting annual megawatt-hours with annual factory electricity use, and declare the site self-sufficient. [S03] [S15] Electricity cannot be dispatched on an annual average; unless solar generation coincides hour by hour

with machine demand, or is shifted across hours through battery or thermal storage, midday solar peaks are curtailed or exported while evening shifts draw grid power or burn diesel in backup generators. [S15] [S28] [S1103]

11.8 COST BENCHMARKS ARE NOT SITE YIELDS OR CARBON FACTORS

Global cost benchmarks confirm that solar photovoltaic power is a competitive electricity source, but cost statistics must not be confused with site yields or emission factors. [S14] [S15] According to the International Renewable Energy Agency's *Renewable Power Generation Costs in 2025*, published in July 2026, the global weighted average levelised cost of electricity for utility-scale solar photovoltaic plants remained at its 2024 level of US$44 per MWh in 2025, while onshore wind fell to US$33 per MWh and offshore wind to US$78 per MWh. [S15] Those figures show global cost progress, yet a sponsor in Cameroon cannot plug US$44 per MWh or a generic capacity factor into a factory budget without adjusting for local cloud cover, harmattan dust soiling, roof load limits, import duties, financing costs and grid rules. [S15] [S28]

In Cameroon, the national energy mix is shifting toward renewable generation across both the Southern and Northern Interconnected Networks. [S09] [S28] The International Energy Agency country profile notes that 54 percent of Cameroon's population has access to electricity while consumption remains low. [S09] A January 2025 World Bank feature reports electricity access at 71 percent nationally but highlights that 75 percent of the rural population remains without electricity, reflecting differences in survey vintages and definitions. [S09] [S28] On the supply side, the 420 MW Nachtigal run-of-the-river hydropower plant on the Sanaga River, about 65 kilometres north-east of Yaoundé, was injecting 360 MW from six of its seven turbines by mid-January 2025, designed to increase national generation capacity by 30 percent. [S28] [S1104] Alongside hydropower, Cameroon is developing solar photovoltaic plants toward a target of 250 MW of installed capacity, including expansions at Maroua and Guider in the northern cotton belt and modular solar containers paired with battery storage to replace diesel generation. [S28]

These investments matter to Cameroon's textile sector, where about 95 percent of cotton fibre has historically been exported raw and about 5 percent processed locally, against a National Development Strategy 2020 to 2030 (SND30) target of 50 percent local processing by 2030. [R06] [R07] Third-party announcements, such as the proposed SODECOTON and CICAM merger by 2030 and the Camtext SA integrated cotton-to-textile project announced on 12 November 2025 at US$300 million (180 billion XAF) to process 12,000 tonnes a year across hubs at Dibamba and Garoua, indicate the scale of planned power and steam loads. [R08] [R09] [R10] None of those announcements or national grid additions, however, is a measured operating result or relieves an individual garment factory from metering its own hourly load. [R09] [S28]

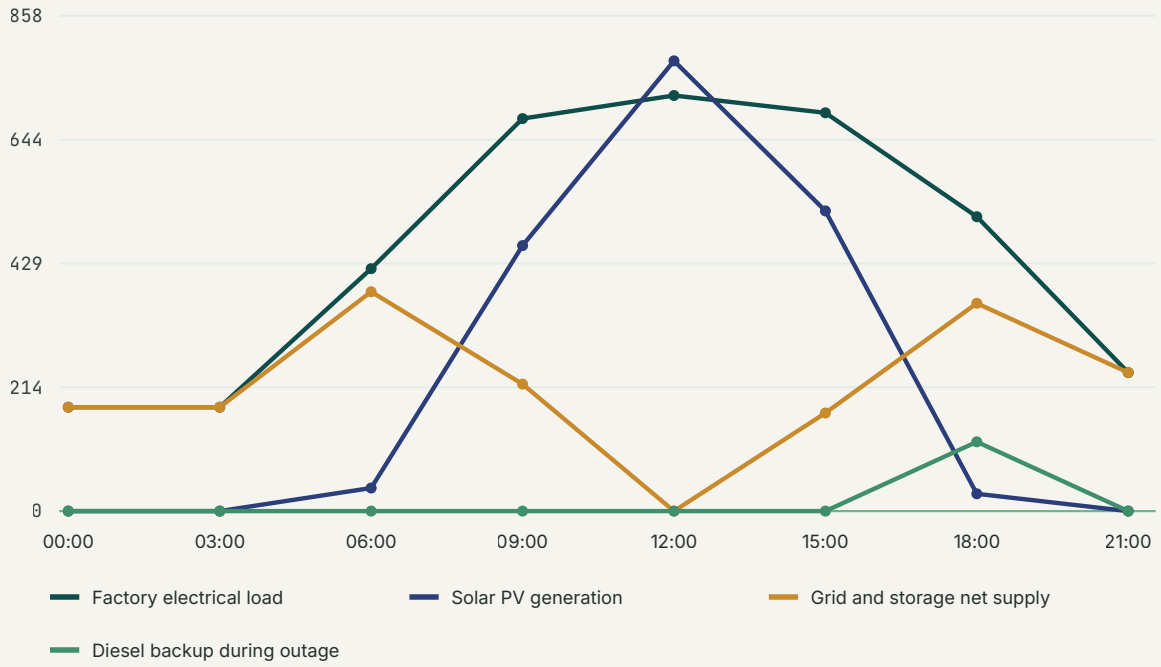
11.9 HOURLY DISPATCH SEPARATES SELF-CONSUMPTION FROM GRID IMPORTS

To account accurately for on-site solar photovoltaic generation and storage, the factory energy model must track four hourly flows: direct solar self-consumption by factory loads, solar charging and discharging of on-site storage net of conversion losses, solar electricity exported to the grid, and electricity imported from the grid or gener-

ated by diesel sets during low-irradiance hours, night shifts or outages. [S03] [S20] [S1103] **Exhibit 53**, p. 187 presents an illustrative 24-hour dispatch profile sampled at three-hour intervals to show how these four flows interact. [S15] [S28] [S1103] [S1104]

EXHIBIT 53 / ILLUSTRATIVE KW ACROSS 24 HOURS

An hourly load matches solar, storage, grid and backup



ILLUSTRATIVE [S15] [S28] [S1103] [S1104] Illustrative 24-hour dispatch profile sampled at three-hour intervals for a hypothetical textile facility. Demonstrates why annual energy totals cannot size solar photovoltaic arrays or battery and thermal storage, and why grid outages require metered backup tracking (S15, S28, S1103, S1104). Values are illustrative design inputs, not measured site data.

In the illustrative profile in **Exhibit 53**, p. 187, factory electrical demand rises from an overnight base load of 180 kW to 420 kW at the 06:00 shift start, peaks at 720 kW at 12:00 when cutting, sewing, cooling and heat pumps run simultaneously, and steps down in the evening. [S1103] Illustrative solar generation reaches 780 kW at 12:00, exceeding instantaneous demand by 60 kW to charge on-site storage; at 18:00, as solar drops to 30 kW and an illustrative grid outage occurs against a 510 kW load, stored energy and partial grid supply cover 360 kW while a diesel generator supplies the remaining 120 kW. [S28] [S1103] [S1104] What **Exhibit 53**, p. 187 cannot establish is the actual solar yield or optimal storage capacity for an unbuilt plant; sizing requires site irradiance logs and sub-metered shift schedules, which GFT's solar-storage sizing tool and resilient power design paper (wp07) address. [S15] [S28]

Under the GHG Protocol Scope 2 Guidance, self-generated renewable electricity consumed on site reduces purchased grid power, lowering both location-based and market-based Scope 2 emissions, provided that any energy attribute certificates associated with that generation are retained and retired by the factory. [S03] If the factory sells the renewable attributes of its rooftop solar output to a third party, it cannot claim zero-emission solar electricity in its market-based inventory and must apply the residual mix or grid average factor. [S03] Solar power exported to the grid

cannot be netted against evening grid imports in a location-based Scope 2 inventory; physical grid imports take the grid emission factor, while exports are recorded separately. [S03] [S20]

11.10

Thermal demand needs its own decarbonisation route

Even if a textile mill or garment factory procures 100 percent verified renewable electricity for its motors and lighting, thermal demand for washing, bleaching, dyeing, drying, printing and steam pressing remains a separate physical and accounting problem. [S08] [S31] [S1102] According to the International Energy Agency's *Renewables for Industry* report published in December 2025, industry accounts for 30 percent of global energy consumption, mostly supplied by fossil fuels, and industries relying primarily on low-temperature heat and steam processes, including textiles, food, chemicals and paper, represent roughly 70 percent of global industrial energy consumption. [S1101] [S1102] In 2023, those sectors emitted nearly 3 gigatonnes of direct energy-related CO2, half of all direct industrial emissions, and across major economies the electricity share in industrial heat had reached only 4 to 5 percent. [S1102]

11.11 WET PROCESSING AND GARMENT FINISHING RUN ON STEAM AND HOT WATER

In the apparel value chain, thermal intensity varies sharply by stage. [S08] [S31] A standalone cut-make-trim factory uses thermal energy mainly for steam irons, garment finishers and fusing presses, whereas an integrated mill or wet-processing plant consumes hot water (60 to 98 degrees Celsius) and saturated steam (100 to 180 degrees Celsius) for desizing, scouring, bleaching, dyeing, washing-off and drying. [S08] [S31] [S1102] In the April 2026 T-shirt life cycle assessment by Forfora and colleagues, dyeing, finishing and regional steam assumptions are primary drivers of cradle-to-gate warming impact across cotton, viscose, Lyocell and polyester garments. [S31]

In greenhouse gas accounting, the boundary of thermal energy depends on asset ownership and fuel type: [S03] [S04] [S20]

- **On-site fossil-fuel boilers** burning heavy fuel oil, diesel, liquefied petroleum gas, natural gas or coal belong in Scope 1 direct emissions, calculated from metered fuel consumption and combustion factors covering carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O). [S04] [S14] [S20]
- **Purchased steam, hot water or chilled water** delivered from an industrial park utility or cogeneration plant belongs in Scope 2 under the GHG Protocol Scope 2 Guidance, calculated from metered thermal energy delivered multiplied by the supplier's emission factor or a dated regional heat factor. [S03] [S14]
- **On-site biomass boilers** burning agricultural residues require separate reporting of biogenic CO2 outside Scopes 1, 2 and 3 in the corporate inventory, while CH4 and N2O combustion emissions remain in Scope 1, and upstream cultivation, processing and transport burdens sit in Scope 3 and enter product footprints under ISO 14067. [S04] [S05] [S20]

- **Electrified thermal equipment** such as industrial heat pumps, mechanical vapour recompression units and electric boilers shifts thermal demand out of Scope 1 fuel combustion and into Scope 2 electricity (or on-site solar self-consumption), where its carbon burden depends on equipment coefficient of performance and electricity emission factors. [S03] [S1102] [S1103]

11.12 HEAT PUMPS, ELECTRIC BOILERS AND THERMAL STORAGE ADDRESS DIFFERENT TEMPERATURE BANDS

Decarbonising textile heat requires matching each process temperature band to the appropriate thermodynamic technology rather than replacing every boiler with direct resistance heating. [S1102] As the International Energy Agency documents in its December 2025 analysis, large-scale industrial heat pumps are established to deliver process heat up to 150 degrees Celsius, while electric boilers generate steam up to 350 degrees Celsius and pressures of around 70 bar. [S1102] Because textile dye baths, washing stages and drying pre-heat operate largely below 150 degrees Celsius, industrial heat pumps that recover waste heat from warm dye-house effluent and lift it to process temperatures can deliver roughly three units of thermal energy per unit of electricity consumed. [S13] [S1102]

Where higher-temperature steam or rapid peak ramping is needed, electric boilers can operate alongside heat pumps and thermal storage. [S1102] [S1103] In its December 2025 *Renewables for Industry* report and July 2026 *Heat Pump Monitor 2026*, the International Energy Agency highlights that thermal storage systems built from simple materials such as sand, cement, bricks or water can store heat up to 1,000 degrees Celsius at costs of around US$15 to US$20 per kWh, far cheaper than chemical batteries and free of critical-mineral bottlenecks. [S1102] [S1103] Coupling heat pumps and electric boilers with thermal storage lets factories charge thermal stores during midday solar peaks and discharge heat across shifts. [S1102] [S1103] In China, the International Energy Agency found that connecting industrial plants to captive solar or wind generators paired with thermal storage could cut electrified steam costs from US$70 to US$100 per MWh (grid-connected) to around US$50 per MWh in examined provinces. [S1102]

METHOD

To reconcile garment thermal and electrical energy without double counting, GFT applies a five-step protocol across every batch: [S03] [S14] [S20] [S23]

1. **Separate metered streams:** Log imported grid electricity (`E_grid`), on-site solar self-consumption (`E_pv`), imported steam (`H_imp`), boiler fuel (`F_boil`) and generator fuel (`F_gen`). [S03] [S20]
2. **Compute Scope 1 emissions:** Multiply `F_boil` and `F_gen` by dated fuel combustion factors (`EF_comb`, covering CO2, CH4 and N2O under IPCC AR6 GWP-100). [S11] [S14] [S20]
3. **Compute dual Scope 2 emissions:** Multiply `E_grid` by the dated IEA location-based factor (`EF_loc`) and by the verified market-based or residual-mix factor (`EF_mkt`); add `H_imp` multiplied by `EF_steam` to both accounts. [S03] [S14]
4. **Compute Scope 3 Category 3 burdens:** Multiply `F_boil` and `F_gen` by well-to-tank fuel factors (`EF_wtt_fuel`), and multiply `E_grid` and `H_imp` by generation well-to-tank (`EF_wtt_grid`), grid loss (`EF_td`) and loss well-to-tank (`EF_wtt_td`) factors. [S14] [S20] [S23]
5. **Allocate and check conservation:** Sum batch Scope 1, dual Scope 2 and Scope 3 Category 3 emissions, divide by accepted garments (`N_good`), and verify that product allocations sum to 100 percent of the period inventory. [S01] [S20] [S23]

11.13

Grid losses and upstream energy remain visible

A frequent error in corporate inventories and product carbon footprints is to apply a single electricity or fuel emission factor without checking whether that factor covers only power-plant stack emissions or also includes electricity lost in transmission and distribution grids and the upstream emissions of extracting, refining and transporting fuels. [S14] [S20] [S23] Omitting those upstream and grid-loss components truncates the product life cycle boundary required by ISO 14067 and the GHG Protocol Product Standard, while lumping them into Scope 1 or Scope 2 violates the GHG Protocol Corporate Standard and Scope 2 Guidance. [S01] [S03] [S04] [S05]

11.14 GENERATION FACTORS, GRID LOSSES AND WELL-TO-TANK BURDENS OCCUPY SEPARATE SLOTS

The International Energy Agency's *Emissions Factors 2026* database (published September 2026) and the UK Department for Energy Security and Net Zero *Greenhouse gas reporting conversion factors 2026* (published June 2026) disaggregate energy conversion factors so practitioners can assign each physical emission source to its proper scope and life cycle stage. [S14] [S20] The IEA database provides annual greenhouse gas emission factors across world countries for electricity and heat generation, separating direct generation factors, electricity trade and transmission and distribution loss adjustments, and upstream fuel-cycle factors, with breakouts for carbon dioxide, methane and nitrous oxide. [S14] Similarly, the UK conversion factors separate Scope 1 direct fuel combustion, Scope 2 electricity generation, and Scope 3 Category 3 fuel- and energy-related activities, including transmission and distribution losses and well-to-tank upstream fuel burdens. [S20] [S23]

These components remain separate because the operational lever that reduces each one is distinct: [S03] [S14] [S20] [S23]

- **Scope 2 generation emissions** represent greenhouse gases released at the power station per kilowatt-hour delivered to the grid; they change when national generation shifts toward hydro or solar, or when the factory cuts grid imports. [S03] [S14]
- **Scope 3 Category 3 transmission and distribution (T&D) loss emissions** represent greenhouse gases generated at power stations to produce the electricity dissipated in transformers and lines before reaching the factory meter; in grids with long radial feeders or high technical losses, T&D loss factors add a material burden to every imported kilowatt-hour. [S14] [S20] [S23] [S28]
- **Scope 3 Category 3 well-to-tank (WTT) upstream emissions** represent emissions from extracting, refining and transporting fuels before combustion in utility power plants or the factory's own boilers and generators, belonging inside the cradle-to-gate product footprint. [S01] [S14] [S20] [S23]

Exhibit 54, p. 191 summarises how each energy stream in a textile and garment operation maps across organisational scopes, physical activity meters and emission-factor rules. [S03] [S14] [S20] [S23] [S31] [S1102]

EXHIBIT 54 /

Purchased power, steam and backup fuel sit in distinct accounting registers

Energy stream	Organisational scope	Primary activity record	Factor and Scope 3 Category 3 rule
Grid electricity	Scope 2 (dual report)	Calibrated feeder kWh and utility bill	Generation factor in Scope 2; grid losses and upstream fuel in Category 3
On-site solar PV	Scope 1 and 2 zero generation	Inverter kWh and export meter	Retained attributes support market-based claim; embodied capex in Scope 3
Purchased steam	Scope 2 purchased heat	Condensate and steam flow meter	Supplier boiler fuel mix and efficiency factor; upstream fuel in Category 3
On-site boiler fuel	Scope 1 direct combustion	Fuel mass or volume log and pressure	Direct CO2, CH4 and N2O in Scope 1; well-to-tank fuel burden in Category 3
Backup diesel generator	Scope 1 direct combustion	Run-hour log, fuel litres and kWh output	Direct combustion in Scope 1; never hidden inside annual grid average

SOURCED [S03] [S14] [S20] [S23] [S31] [S1102] Compiled from GHG Protocol Scope 2 Guidance (S03), IEA Emissions Factors 2026 (S14), UK DESNZ conversion factors 2026 (S20), Scope 3 calculation guidance (S23), T-shirt LCA steam sensitivity (S31) and IEA industrial heat electrification analysis (S1102).

As **Exhibit 54**, p. 191 makes explicit, no single conversion factor covers all rows, and moving from an on-site fuel boiler to a heat pump or from grid imports to on-site solar shifts entries across Scope 1, Scope 2 and Scope 3 Category 3 simultaneously. [S03] [S20] [S23] What **Exhibit 54**, p. 191 cannot establish by itself is the numerical value of the national grid factor or T&D loss rate for a given operating year; those parameters must be drawn from the IEA annual release or national grid disclosures for the exact production year and locked into the versioned factor register described in Chapter 4. [S14] [S20]

11.15 EMBODIED CAPITAL GOODS AND REFRIGERANT LEAKAGE PREVENT HIDDEN BURDEN SHIFTING

When a factory replaces fuel boilers with industrial heat pumps and installs solar panels paired with battery storage, two further boundary questions arise: the embodied carbon of the new equipment and the fugitive emissions of heat-pump and chiller refrigerants. [S02] [S04] [S23] Under the GHG Protocol Scope 3 Standard, the cradle-to-gate emissions of manufacturing solar modules, inverters, batteries, transformers and heat pumps sit in Scope 3 Category 2 (Capital goods) in the year of acquisition, while in a product life cycle assessment under ISO 14040, ISO 14044 and ISO 14067, capital equipment burdens are amortised over lifetime production output or excluded only where product category rules demonstrate immateriality. [S02] [S05] [S23] [S25]

By contrast, refrigerant leakage from industrial heat pumps, chillers and air-conditioning units is a direct Scope 1 fugitive emission in the corporate inventory and a direct manufacturing emission in the product footprint. [S04] [S20] Because hydrofluorocarbon refrigerants can carry global warming potentials hundreds or thousands of times higher than carbon dioxide over a 100-year horizon under IPCC Sixth Assessment Report metrics, an unmaintained heat pump or chiller loop that leaks refrigerant can offset a substantial share of its electrical carbon savings. [S11] [S20] GFT's specification therefore pairs heat pumps using low-GWP or natural refrigerants with quarterly refrigerant weigh-ins in the Scope 1 fugitive register. [S04] [S11] [S20]

11.16

Resilience and carbon are designed together

In emerging industrial economies, power quality and grid availability are core operational constraints. [S28] [S1104] According to the Multilateral Investment Guarantee Agency project summary for the Nachtigal Hydropower IPP in Cameroon, power availability, reliability and cost have historically constrained economic growth, with dry-season supply deficits of 80 to 100 MW and power outages averaging 160 hours annually. [S1104] Similarly, Cameroon's incumbent textile manufacturer CICAM experienced severe operational strain, with a July 2023 report recording capacity utilisation of 33.7 percent at Garoua, 48.9 percent at CICAM 1 and 10.83 percent at CICAM 2, and underutilisation costing about CFAF 2 billion in 2020. [R12] When voltage sags or feeder outages strike a spinning frame, dye beck or cutting line without ride-through protection, yarn breaks, dye batches shade-shift and require re-dyeing, and standby diesel generators fire up. [R12] [S20] [S1104]

11.17 BACKUP DIESEL GENERATION MUST BE METERED, NOT HIDDEN IN GRID AVERAGES

In many desktop life cycle assessments compiled from background databases such as ecoinvent, a factory in a hydroelectric-dominant country is assigned the national grid-average electricity factor for 100 percent of its electrical demand. [S16] As ecoinvent's documentation states, database processes represent average production conditions within a geography rather than site-specific conditions. [S16] If a garment factory in Cameroon draws 85 percent of its electricity from a hydro-rich grid but generates the remaining 15 percent on site using diesel generators during dry-season rationing or feeder trips, applying the national grid-average factor to 100 percent of factory kilowatt-hours hides the Scope 1 diesel combustion and understates carbon per garment. [S14] [S16] [S20]

To prevent this distortion, GFT's accounting architecture requires dedicated fuel flow meters (reconciled monthly against tank dip readings and delivery invoices) and dedicated kilowatt-hour output meters on every standby diesel generator. [S04] [S20] Diesel burned in on-site generators is recorded in Scope 1 (with its well-to-tank burden in Scope 3 Category 3), while only the kilowatt-hours drawn through the utility revenue meter take the Scope 2 grid factor. [S03] [S20] [S23] When hybrid solar and battery or thermal storage systems are installed, their carbon benefit separates into two distinct calculations: the displacement of Scope 1 diesel fuel during outages, and the displacement of Scope 2 grid electricity during normal grid-connected hours. [S03] [S20] [S28]

WORKED EXAMPLE

Consider an illustrative garment and wet-processing facility producing 250,000 accepted cotton shirts in a reporting quarter; all figures in this box are illustrative assumptions constructed to demonstrate the accounting arithmetic and are not measured results from any GFT site. [S20] [S23]

1. **Assumed baseline:** The plant uses 300,000 kWh of electricity and 450,000 kWh of process heat. [S1102] Outages force 15 percent of electricity (45,000 kWh) onto diesel generators burning 0.30 litres per kWh (13,500 litres), while 85 percent (255,000 kWh) comes from the grid. [S20] [S1104] A fuel-oil boiler at 75 percent efficiency supplies process heat using 600,000 kWh of fuel input. [S1102]
2. **Assumed illustrative factors:** Let the grid generation factor be 0.22 kg CO2e per kWh, grid T&D losses be 0.03 kg CO2e per kWh, and grid WTT be 0.04 kg CO2e per kWh. [S14] [S20] Let diesel emit 2.68 kg CO2e per litre in Scope 1 plus 0.62 kg CO2e per litre WTT in Scope 3 Category 3, and boiler fuel emit 0.28 kg CO2e per kWh in Scope 1 plus 0.06 kg CO2e per kWh WTT in Scope 3 Category 3. [S20]
3. **Baseline calculation:** Scope 1 equals boiler fuel (168,000 kg CO2e) plus diesel backup (36,180 kg CO2e), giving 204,180 kg CO2e. [S04] [S20] Scope 2 equals 255,000 kWh multiplied by 0.22, giving 56,100 kg CO2e under both location-based and market-based methods. [S03] [S14] Scope 3 Category 3 equals boiler WTT (36,000 kg CO2e) plus diesel WTT (8,370 kg CO2e) plus grid T&D and WTT (17,850 kg CO2e), giving 62,220 kg CO2e. [S20] [S23] The total is **322,500 kg CO2e**, or **1.290 kg CO2e per accepted shirt** across 250,000 units (hiding diesel backup inside the grid factor would understate the total by 31,500 kg CO2e). [S20] [S23]
4. **Illustrative intervention:** Efficiency and quality gains cut machine electricity by 10 percent (to 270,000 kWh) and lift accepted output to 260,000 shirts; heat recovery cuts thermal demand by 25 percent (to 337,500 kWh); a heat pump at an illustrative COP of 3.0 supplies 225,000 kWh thermal using 75,000 kWh of electricity (bringing total electricity to 345,000 kWh), while the boiler supplies 112,500 kWh thermal at 80 percent efficiency (140,625 kWh fuel input); and on-site solar PV with storage supplies 180,000 kWh on site and cuts diesel backup to 4,500 litres (15,000 kWh), leaving 150,000 kWh of grid imports. [S03] [S13] [S1102] [S1103]
5. **Post-intervention calculation:** Scope 1 falls to boiler fuel (39,375 kg CO2e) plus diesel backup (12,060 kg CO2e), giving 51,435 kg CO2e. [S04] [S20] Scope 2 falls to 150,000 kWh multiplied by 0.22, giving 33,000 kg CO2e. [S03] [S14] Scope 3 Category 3 falls to boiler WTT (8,437.5 kg CO2e) plus diesel WTT (2,790 kg CO2e) plus grid T&D and WTT (10,500 kg CO2e), giving 21,727.5 kg CO2e. [S20] [S23] The total is **106,162.5 kg CO2e**, or **0.408 kg CO2e per accepted shirt** across 260,000 units, a 67.1 percent absolute reduction and a 68.4 percent reduction per accepted shirt. [S20] [S23]

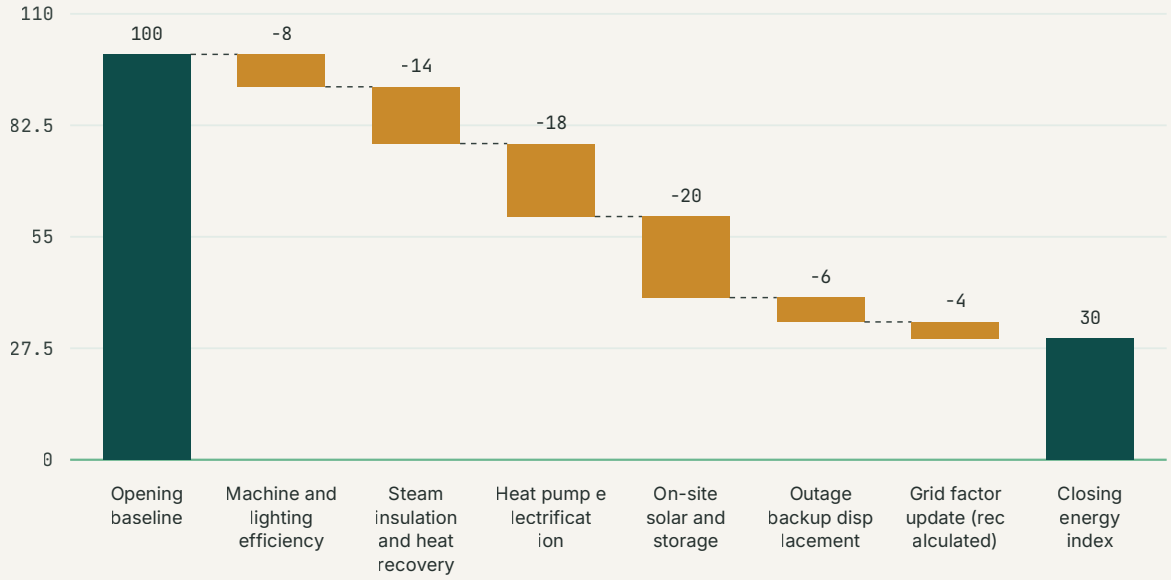
11.18 SEQUENCE THE ENERGY LEDGER SO EVERY REDUCTION STEP IS AUDITABLE

When an industrial sponsor presents an energy transition roadmap to lenders, development-finance institutions or brand buyers, collapsing all energy improvements into a single before-and-after bar obscures which engineering actions worked and which depended on external grid changes. [S04] [S13] [S23] **Exhibit 55**, p. 195 illustrates how GFT structures the energy abatement ledger as an ordered waterfall that separates

internal demand reductions from thermal electrification, on-site solar and storage dispatch, backup diesel displacement and external grid-factor updates. [S03] [S08] [S13] [S14] [S1102]

EXHIBIT 55 / ILLUSTRATIVE INDEX (OPENING ENERGY BURDEN = 100)

A heat and electricity sequence separates distinct reduction routes



ILLUSTRATIVE [S03] [S08] [S13] [S14] [S1102] Illustrative decomposition index (opening balance = 100 units) showing how an engineering ledger isolates demand efficiency, waste-heat recovery, thermal electrification, on-site solar dispatch, backup diesel displacement and grid-factor updates (S03, S08, S13, S14, S1102). Step magnitudes are illustrative placeholders to demonstrate accounting separation, not a claimed or forecast GFT factory reduction.

In **Exhibit 55**, p. 195, the illustrative opening balance of 100 index units steps down through six distinct mechanisms to a closing index of 30 units: machine and lighting efficiency (-8), steam insulation and waste-heat recovery (-14), heat-pump thermal electrification (-18), on-site solar photovoltaic and storage self-consumption (-20), outage backup diesel displacement (-6) and an external national grid-factor update (-4). [S03] [S13] [S14] [S1102] The final step (-4 from a cleaner national grid factor) is flagged for base-year recalculation evaluation under Scope 3 and corporate accounting rules rather than claimed as an internal factory achievement. [S04] [S20] [S23] What **Exhibit 55**, p. 195 cannot establish is the empirical magnitude of each step before a factory is metered; real step values emerge only after Phase 1 baseline capture and Phase 2 post-implementation metering are completed. [S13] [S23]

WARNING

National electricity statistics and contractual green-power claims face three unresolved constraints in Cameroon and comparable garment-manufacturing regions: first, national electrification and grid-mix publications carry reporting lags and differing survey boundaries (for example, the 54 percent access rate in the IEA country profile versus the 71 percent national and 25 percent rural access rates in the January 2025 World Bank report); second, formal residual-mix emission factors required for market-based Scope 2 accounting are not yet published for most Central and West African grids; and third, shifting wet-processing heat to electric boilers or heat pumps on a constrained feeder without on-site solar and thermal storage can trigger local transformer overloading and increase standby diesel consumption. [S03] [S09] [S28] [S1102] Resolving these constraints requires installing interval sub-meters on grid incomers, solar inverters, steam headers and backup diesel sets from day one, defaulting market-based Scope 2 factors to the dated IEA location-based factor unless a physically connected, retired contractual instrument exists, and sizing thermal storage alongside heat pumps before connecting new electrical loads. [S03] [S14] [S1103]

By linking sub-metered kilowatt-hours, fuel litres and steam enthalpy to dual Scope 2 accounting, Scope 3 Category 3 upstream and loss registers, and separate engineering pathways for thermal demand and outage resilience, a garment manufacturer turns energy from an opaque overhead into a verifiable product input. [S03] [S14] [S20] Yet even the cleanest kilowatt-hour and the most efficient heat pump cannot guarantee that a growing factory's total climate impact will decline if rising garment volumes, material substitutions or lower garment utilisation outpace unit efficiency gains, which is the subject of Chapter 12. [S07] [S08] [S31]

A kilowatt-hour on a certificate never heated a dye bath or rode through a grid outage; meter the wire, the pipe and the tank before claiming the garment is clean.

CHAPTER SOURCE NOTES

S03 GHG Protocol. 2015.

S08 Science Based Targets initiative and World Resources Institute. 2019.

S31 Forfora et al., Sustainability. 2026-04-20.

S20 UK Department for Energy Security and Net Zero. 2026-06-11.

S13 International Finance Corporation. 2018-01-29.

S14 International Energy Agency. 2026-09-25.

S01 GHG Protocol. 2011.

S05 International Organization for Standardization. 2018-08.

S23 GHG Protocol and Carbon Trust. 2013.

S10 World Business Council for Sustainable Development. 2025-04-30.

S06 European Commission. 2025-06-25.

S32 European Parliament and Council of the European Union. 2024-02-28.

S1102 International Energy Agency. 2025-12-23.

S26 Watson and Wiedemann, Sustainability. 2019-07-15.

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

S15 International Renewable Energy Agency. 2026-07-02.

S1101 International Energy Agency. 2025-12-23.

S28 World Bank. 2025-01-16.

S1103 International Energy Agency. 2026-07-28.

S09 International Energy Agency. 2026.

S1104 Multilateral Investment Guarantee Agency. 2018-12-21.

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

R07 Ecofin Agency. 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.

S04 GHG Protocol. 2004.

S11 Intergovernmental Panel on Climate Change. 2021-08-06.

S02 GHG Protocol. 2011.

S25 International Organization for Standardization. 2006-07.

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

S16 ecoinvent. 2025-11-05.

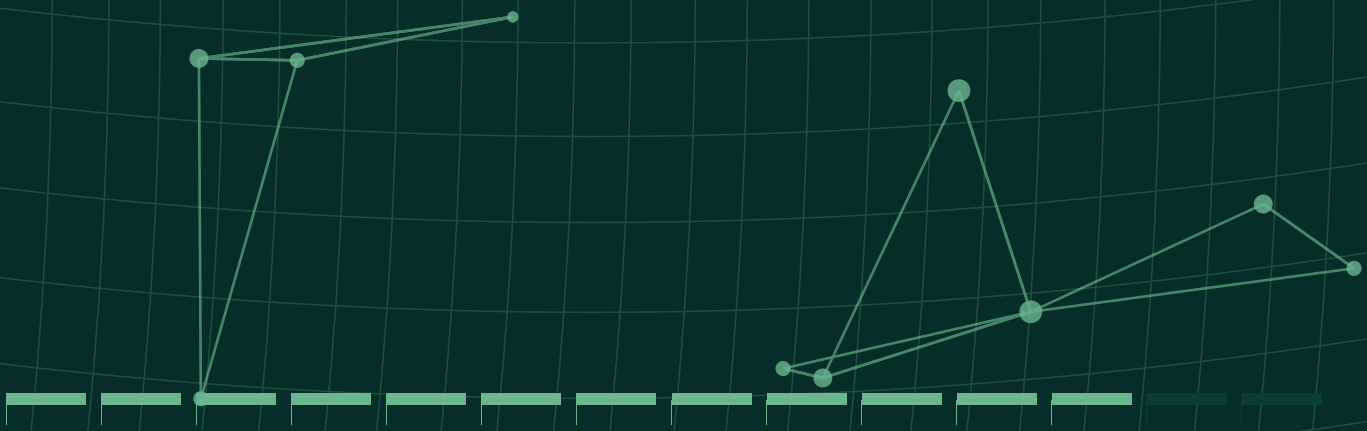
S07 Textile Exchange. 2025-09-18.

12

PART III: REDUCE CARBON WITHOUT MOVING THE PROBLEM / TARGETS AND CHOICES

Absolute carbon must fall even as production grows

A lower footprint per garment is not enough when volume, substitution or rebound raises the total.



CHAPTER 12
DECISION TEST

A lower footprint per garment is not enough when volume, substitution or rebound raises the total.

An apparel manufacturer cannot claim climate progress on the strength of a falling footprint per garment if expanding production volume, unverified material switches or consumer rebound cause total greenhouse gas emissions to rise. [S07] [S08] The governing rule for Part III of this paper is that product intensity and organisational totals must be managed as one algebraic system, where total emissions equal accepted output multiplied by emissions per accepted unit. [S04] [S23] When output grows, intensity must fall faster than physical expansion simply to hold absolute emissions flat, and faster still to deliver an absolute contraction. [S08] [S1202] Green Future Tech Limited (GFT), Hong Kong SAR, designs its Cameroon textile programme (prepared 31 January 2024, with sources refreshed in 2026) around this dual constraint so that industrialisation and decarbonisation are engineered together from the first shift. [R06] [S04] Because industrial expansion involves capital allocation, energy contracting and regulatory compliance across jurisdictions, the analytical methods and target structures in this chapter are engineering and accounting frameworks, not investment, legal or tax advice. [S04] [S32]

For a raw-material economy seeking to process its own fibre, the tension between industrial growth and absolute carbon limits is immediate. [R06] [R07] In the inherited sector baseline for Cameroon, approximately 95 percent of cotton fibre is exported raw while about 5 percent is processed locally, and the national industrialisation strategy (restated under SND30) targets 50 percent domestic processing by 2030. [R06] [R07] Moving from a 5 percent local-processing share toward 50 percent requires commissioning new spinning, weaving, knitting, wet-processing and garment-assembly capacity inside the country. [R06] [S08] That build-out will increase local site activity data, electricity consumed and steam generated within Cameroon, even when the resulting garments displace higher-carbon processing elsewhere. [S08] [S31] A credible carbon accounting system budgets both absolute tonnes of CO2e and intensity per accepted garment across separated corporate and product accounts. [S01] [S04] [S23]

12.1

Intensity and absolute emissions can diverge

Unit efficiency gains fail to reduce atmospheric greenhouse gas concentrations whenever physical production volume expands faster than per-unit emissions decline. [S07] [S08] According to Textile Exchange's Materials Market Report 2025, global fibre production across apparel, home textiles, footwear and other applications rose from 125 million tonnes in 2023 to 132 million tonnes in 2024, a derived single-year volume increase of 5.6 percent (7 million tonnes divided by 125 million tonnes). [S07] Over a longer horizon, the Ellen MacArthur Foundation reported that greenhouse gas emissions from global textiles production totalled 1.2 billion tonnes of CO2 equivalent in 2015, exceeding the combined emissions of all international flights and maritime shipping in that baseline year. [S27] When the Science Based Targets initiative (SBTi) notes that the apparel and footwear sector accounts for up to 8 percent of global greenhouse gas emissions, the driver is the multiplication of unit process burdens by a rising annual volume of finished goods. [S08] [S1202]

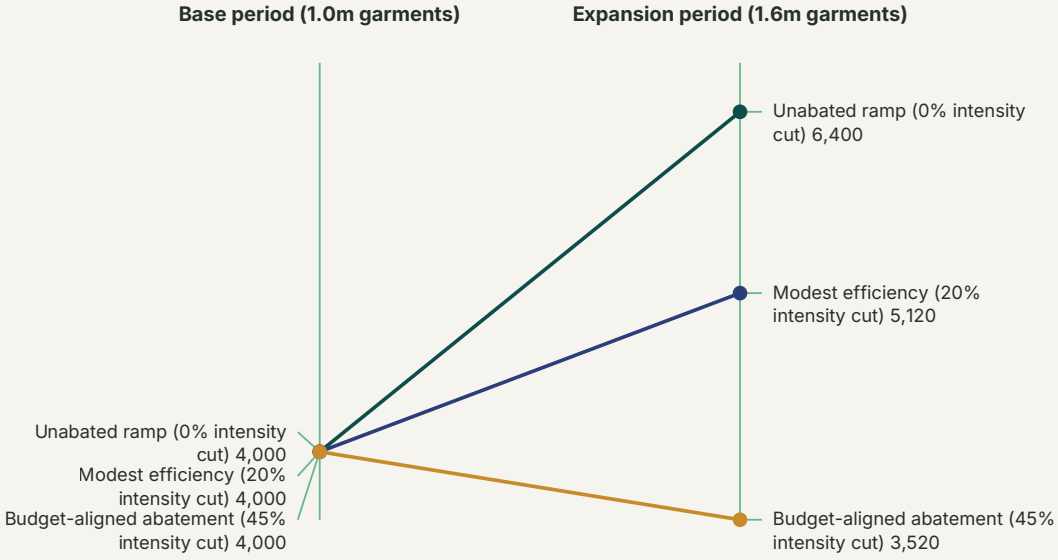
12.2 THE ALGEBRAIC IDENTITY LINKING VOLUME AND INTENSITY LEAVES NOWHERE TO HIDE

At any organisational or product-system boundary, total absolute emissions in period `t` (`E_t`, in tonnes of CO2e) equal physical output of accepted garments (`Q_t`) multiplied by physical carbon intensity (`i_t`, in kilograms of CO2e per accepted unit), expressed as `E_t = Q_t * i_t`. [S04] [S23] Moving from a base period `0` to a reporting period `t`, where output changes by a relative growth rate `g = (Q_t - Q_0) / Q_0` and unit intensity falls by a relative reduction fraction `r = (i_0 - i_t) / i_0`, the ratio of reporting-period absolute emissions to base-period absolute emissions is `E_t / E_0 = (1 + g) * (1 - r)`. [S08] [S23] For total absolute emissions to remain at or below the base-period level (`E_t ⩽ E_0`), the unit intensity reduction fraction `r` must satisfy the break-even condition `r ⩾ g / (1 + g)`. [S08] [S23]

This relationship is non-linear for growing manufacturers, as shown in **Exhibit 56**, p. 200. [S08] [S23] In an illustrative scenario where a factory expands accepted garment output by 60 percent (`g = 0.60`, moving from 1.0 million to 1.6 million accepted garments per year), holding absolute emissions constant requires cutting carbon per accepted garment by 37.5 percent (`0.60 / 1.60 = 0.375`). [S08] [S23] An illustrative 20 percent intensity reduction lowers the product footprint from 4.00 kg CO2e to 3.20 kg CO2e per garment, yet total annual emissions climb from 4,000 tonnes CO2e to 5,120 tonnes CO2e (+28 percent). [S08] [S23] Achieving an illustrative 12 percent absolute reduction (to 3,520 tonnes CO2e) while expanding output by 60 percent requires a 45 percent cut in per-garment intensity (to 2.20 kg CO2e per accepted garment). [S08] [S23]

EXHIBIT 56 / TONNES CO2E PER YEAR (ILLUSTRATIVE)

Production growth can erase an intensity improvement



ILLUSTRATIVE [S07] [S08] [S23] Illustrative scenarios applying E = Q * i from S08 and S23. Base output is 1.0m accepted garments at an illustrative 4.00 kg CO2e per garment (4,000 t CO2e). Expansion output is 1.6m accepted garments (+60%). A 20% intensity cut (to 3.20 kg CO2e) raises absolute emissions to 5,120 t CO2e (+28%). A 45% intensity cut (to 2.20 kg CO2e) cuts absolute emissions to 3,520 t CO2e (-12%). Values are illustrative method demonstrations, not measured site data.

What **Exhibit 56**, p. 200 proves is the arithmetic divergence between intensity and absolute totals under volume growth. [S08] [S23] What the exhibit cannot establish on its own is what share of a Cameroonian factory's expansion represents new global apparel volume versus the geographical relocation of processing that previously occurred in overseas mills importing raw Cameroonian lint. [R06] [S26] Answering that question requires separating attributional inventory accounting from consequential system analysis under GHG Protocol and ISO life cycle rules. [S01] [S24] [S26]

12.3 INDUSTRIALISATION IN RAW-MATERIAL ECONOMIES SEPARATES LOCAL RAMP FROM GLOBAL DISPLACEMENT

In Cameroon, the agricultural cotton base operates at commercial scale: inherited programme evidence records seed-cotton production of 330,000 tonnes in 2022, 314,455 tonnes in 2023, about 340,000 tonnes in 2024, and a 2025 projection above 350,000 tonnes, supported by more than 220,000 producers, nine ginning plants and two oil mills operated by SODECOTON. [R01] [R02] [R03] Across the CFA franc zone, cotton output reached 2.3 million tonnes in 2024/25 (down 11.5 percent). [R05] Alongside the national target to process 50 percent of fibre locally by 2030, third-party announcements such as the Camtext SA project (announced 12 November 2025 at US$300 million or 180 billion XAF, targeting 12,000 tonnes processed a year and optimal capacity around 2033) and the announced SODECOTON-CICAM industrial pole show the scale of planned capacity. [R07] [R08] [R09] [R10]

When a Cameroonian mill spins, dyes and assembles garments from lint previously exported raw, its organisational Scope 1 and Scope 2 emissions rise from zero to its active operating load and belong unconditionally to the company's inventory under the GHG Protocol Corporate Standard. [R06] [S04] At the product level, however, a cradle-to-gate or cradle-to-grave footprint under the GHG Protocol Product Standard and ISO 14067 follows the garment across its life cycle, allowing direct comparison between a locally integrated pathway and an export-and-reimport pathway once site meters and regional electricity factors are in place. [S01] [S05] [S14]

12.4

Targets distinguish operations from the value chain

A single headline reduction percentage that blends factory boilers, grid electricity, cotton farming and consumer washing into one undifferentiated promise is operationally unusable and impossible to audit. [S04] [S08] [S23] Because engineering control, data precision and commercial authority differ between owned equipment and value-chain partners, the GHG Protocol and the Science Based Targets initiative require targets to separate direct operations and purchased energy (Scopes 1 and 2) from upstream and downstream value-chain activities (Scope 3). [S02] [S08] [S1202]

12.5 SCOPE 1 AND SCOPE 2 TARGETS GOVERN DIRECT ENGINEERING AND UTILITY PROCUREMENT

Within the organisational boundary defined under the GHG Protocol Corporate Standard, Scope 1 covers direct emissions from owned or controlled sources (boilers, thermal-oil heaters, backup diesel generators, vehicles and refrigerants), while Scope 2 covers indirect emissions from purchased electricity, steam, heat and cooling accounted under the GHG Protocol Scope 2 Guidance using location-based grid

factors and market-based instruments meeting quality criteria. [S03] [S04] [S14] [S20] Because plant management holds direct authority to repair steam traps, insulate condensate lines, right-size motors, install solar photovoltaics with storage to displace diesel runtime, and sign power purchase agreements, SBTi apparel guidance and the Corporate Net-Zero Standard treat absolute contraction across Scopes 1 and 2 as the primary operational benchmark, requiring total direct and purchased-energy emissions to fall against a fixed base year regardless of throughput growth. [S03] [S08] [S13] [S1202] Where a factory also tracks a Scope 1 and 2 physical intensity metric (kilograms of CO2e per accepted garment), that ratio must be translated into implied absolute tonnes using the disclosed production schedule. [S08] [S23]

12.6 SCOPE 3 TARGETS REQUIRE CATEGORY COVERAGE, SUPPLIER ENGAGEMENT AND PHYSICAL DENOMINATORS

Outside the factory fence, the 15 categories of the GHG Protocol Corporate Value Chain (Scope 3) Standard represent the majority of an apparel company's footprint, led by purchased yarn or fabric, trims, chemicals and packaging (Category 1), inbound and outbound freight (Categories 4 and 9), production waste (Category 5), consumer laundering (Category 11), and end-of-life disposal (Category 12). [S02] [S08] [S23] Because the garment maker does not control the spinning mill's meter or the household's washing machine, SBTi apparel guidance provides three target structures for Scope 3: absolute reduction targets across significant categories, physical or economic intensity targets, and supplier engagement targets committing a defined share of suppliers to set science-based targets. [S08] [S1202]

TARGET BOUNDARY AND DENOMINATOR SPECIFICATION PROTOCOL

Every corporate or facility carbon target used for governance or capital approval within GFT's performance-management system must declare six fields before any reduction is evaluated. [S04] [S08] [S23] First, **scope and category coverage** states the exact percentage of Scope 1 and Scope 2 emissions covered and lists each included Scope 3 category (1 to 15) with its share of screened Scope 3 emissions. [S02] [S08] Second, **base year and recalculation threshold** records the base year, its primary-data share, and the significance threshold (such as an illustrative 5 percent structural or method change threshold) triggering mandatory base-year recalculation. [S04] [S23] Third, **target year and horizon** separates near-term operational milestones (5 to 10 years under SBTi criteria) from long-term net-zero targets (no later than 2050 under the SBTi Corporate Net-Zero Standard). [S08] [S1202] Fourth, **target formulation and denominator** specifies whether the target is an absolute contraction or a physical intensity reduction, defining a physical denominator (accepted garments or tonnes of net finished fabric) rather than monetary revenue. [S08] [S23] Fifth, **implied absolute emissions path** publishes the annual volume path (`Q_t`) alongside any intensity target and calculates the resulting absolute envelope (`E_t = Q_t * i_t`). [S07] [S08] Sixth, **separation of external credits** excludes purchased carbon credits and offsets outside the value chain from target progress, following the GHG Protocol, SBTi criteria and Directive (EU) 2024/825. [S04] [S32] [S1202]

12.7 PHYSICAL INTENSITY DENOMINATORS BEAT MONETARY DENOMINATORS IN VOLATILE APPAREL MARKETS

When pairing an intensity metric with absolute tracking, engineers must choose between physical denominators (kilograms of CO2e per accepted garment, per kilogram of fabric, or per wear) and economic denominators (kilograms of CO2e per US

dollar of revenue or per million XAF of value added). [S08] [S23] Economic denominators distort engineering reality whenever prices, margins or exchange rates move. [S23] If a factory shifts from basic T-shirts to higher-priced workwear, experiences cotton price inflation, or sees currency movements against the CFA franc (pegged to the euro at 655.957 XAF per euro in the shared register), revenue per piece rises and emissions per unit of revenue fall even when boiler fuel and fabric mass per garment are unchanged. [R32] [S23]

Physical denominators anchored to accepted output avoid price noise, provided functional equivalence is maintained. [S23] [S26] Reducing fabric weight lowers emissions per garment at constant emissions per kilogram, but if the lighter fabric fails in half as many washes, emissions per wear rise and replacement purchases increase absolute sector emissions. [S26] [S30] [S31] GFT therefore tracks total tonnes of CO2e alongside three physical denominators: CO2e per kilogram of processed output (for mill control), CO2e per accepted garment (for assembly and buyer exchange under WBCSD PACT Version 3), and CO2e per wear under sensitivity-tested use scenarios. [S10] [S23] [S31]

12.8

Material substitution needs an equivalent reference

Switching from one fibre or fabric construction to another is a common proposal in apparel reduction plans because raw materials, spinning and wet processing are major hotspots. [S08] [S30] The European Environment Agency's 2022 briefing on textiles in Europe's circular economy reports that about 80 percent of the total climate change impact of textiles consumed in Europe occurs in the production phase (with 3 percent in distribution and retail, 14 percent in use, and 3 percent at end-of-life). [S30] Both Textile Exchange (2026) and Watson and Wiedemann (2019) warn that static cradle-to-gate fibre rankings mislead when underlying studies differ in boundary, energy grid, co-product allocation, functional equivalence or uncertainty. [S22] [S26]

12.9 GEOGRAPHY, ENERGY MIX AND PROCESS CONFIGURATION REORDER FIBRE COMPARISONS

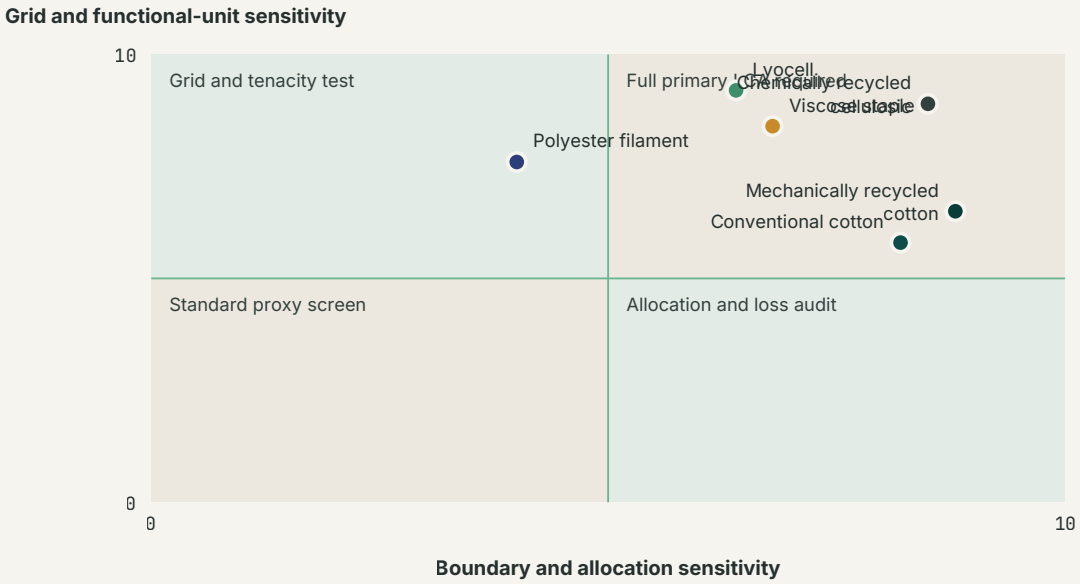
The 2026 comparative life cycle assessment of T-shirt production by Forfora et al. (published in *Sustainability* on 20 April 2026) shows why fibre names never determine a garment's footprint. [S31] Assessing T-shirts made from cotton, polyester, viscose and Lyocell under ISO 14040 and ISO 14044 rules, the study found that Lyocell had the highest cradle-to-gate carbon footprint at 21.6 kg CO2eq per kilogram of fibre under its baseline regional energy mix, unless produced in regions with cleaner power and thermal energy. [S24] [S25] [S31] Shifting production from China to Brazil in the study's scenario lowered global warming impact by up to 38 percent due to cleaner electricity and biomass heat. [S31] Replacing locally grown cotton with imported cellulosic or synthetic yarn based on a generic `ecoinvent` location average can increase absolute product emissions if the actual supplier mill runs on coal steam and a carbon-intensive grid; generic proxies must be replaced with supplier-specific records verified under WBCSD PACT Version 3 and GHG Protocol Scope 3 guidance. [S10] [S16] [S23]

12.10 FUNCTIONAL EQUIVALENCE AND PROCESSING LOSSES ALTER THE MASS REQUIRED PER GARMENT

Comparing one kilogram of fibre A with one kilogram of fibre B also ignores processing losses and garment mechanics. [S26] [S31] In Forfora et al. (2026), cumulative material losses across the cradle-to-gate cotton chain reached 31 percent, meaning that a finished 0.250 kg cotton T-shirt requires about 0.362 kg of upstream lint input (`0.250 / (1 - 0.31) = 0.3623 kg`). [S31] Moreover, when Forfora et al. (2026) replaced an equal-mass baseline (250 g per shirt) with an equivalent-tenacity functional scenario, the garment mass required for equal strength shifted to 250 g for cotton, 250 g for viscose, 153 g for Lyocell and 115 g for polyester. [S31] Watson and Wiedemann (2019) note that tensile strength is only one aspect of garment function: moisture management in warm climates, pilling resistance, odour retention (which alters washing frequency), and microplastic shedding from synthetics (which account for 60 to 70 percent of textiles according to the European Environment Agency) must also be checked so that a carbon switch does not degrade service life or shift burdens. [S26] [S31] [S1201] [S1203]

EXHIBIT 57 / STRUCTURED EVIDENCE INDEX (0 TO 10)

A material decision tests function, boundary and uncertainty



SOURCED [S22] [S26] [S31] Decision matrix synthesised from sensitivity findings in Textile Exchange (S22), Watson and Wiedemann (S26) and Forfora et al. (S31). The horizontal axis scores sensitivity to boundary, co-product allocation (cottonseed vs lint) and processing loss (31% for cotton in S31). The vertical axis scores sensitivity to regional energy mix (up to 38% GWP shift in S31) and functional mass equivalence (115 g to 250 g in S31). Scores (0 to 10) guide evidence priority and are not emission factors.

As **Exhibit 57**, p. 204 shows, no major fibre sits in the lower-left quadrant where secondary proxies suffice for procurement claims. [S22] [S26] [S31] Cotton pathways score high on boundary and allocation sensitivity due to nitrogen fertiliser, lint-versus-cottonseed partitioning, 31 percent processing losses, and waste cut-off rules, while cellulosic and chemically recycled pathways score high on grid and thermal sensitivity and polyester is sensitive to tenacity mass scaling and end-of-life incineration. [S26] [S31] Furthermore, Forfora et al. (2026) ran a 1,000-iteration Monte Carlo analysis showing overlapping uncertainty distributions across fibres. [S31] Under ISO 14044 and the EU Product Environmental Footprint Category Rules (PEFCR) for

apparel and footwear (welcomed by the European Commission on 25 June 2025), material comparisons require aligned boundaries, common allocation rules and uncertainty checks before any saving is claimed. [S06] [S25] [S26]

12.11

Recycled content is not an automatic carbon credit

Incorporating mechanically or chemically recycled fibres into yarns and fabrics is central to circular strategies, including the EU Strategy for Sustainable and Circular Textiles, yet treating recycled content as an automatic deduction violates accounting rules when collection, sorting, reprocessing energy, yield loss, virgin blending and displacement are ignored. [S22] [S27] [S30] [S1203]

12.12 PHYSICAL CONSTRAINTS GOVERN WHAT TEXTILE RECYCLING ACTUALLY REPLACES

Closed-loop textile-to-textile feedstock remains scarce. [S27] [S1201] The Ellen MacArthur Foundation (2017) estimated that less than 1 percent of material used to produce clothing globally is recycled into new clothing. [S27] [S1201] [S1203] In the European Union, European Environment Agency data (updated 10 April 2026) show that in 2020 each person consumed an average of 16 kg of textiles (causing a life cycle carbon footprint of about 270 kg CO2e, 9 cubic metres of water, 400 square metres of land and 391 kg of raw materials), with only 4.4 kg per person collected separately for reuse and recycling and 11.6 kg per person entering mixed household waste, while around 5 million tonnes of clothing are discarded each year across the EU (about 12 kg per person). [S1201] [S1203]

The physical reprocessing route determines both the energy load of recycled fibre and its ability to replace virgin input. [S27] [S30] In **mechanical cotton recycling**, shredding and carding fabric waste back into fibre uses primarily electricity and avoids cultivation, but mechanical tearing shortens staple length and lowers yarn tenacity, requiring blending with virgin cotton or polyester carrier fibres; if the blend requires a heavier fabric weight or shortens service life, the carbon saving per wear can disappear. [S26] [S27] [S30] In **mechanical polyester recycling (rPET)**, most apparel rPET comes from open-loop diversion of post-consumer PET beverage bottles rather than closed-loop garments, requiring accounting for collection, washing and extrusion energy and testing whether diverting bottle rPET increases virgin fossil PET demand in packaging. [S22] [S26] [S27] [S30] In **chemical and regenerated recycling**, dissolving cellulosic waste into pulp for viscose or Lyocell, or depolymerising polyester into monomers, restores virgin-like tenacity but demands substantial steam, electricity and solvent recovery; as Forfora et al. (2026) showed for Lyocell (21.6 kg CO2eq/kg in a high-carbon energy mix), chemically regenerated fibre from a coal-powered mill can emit more CO2e than virgin cotton lint. [S30] [S31]

12.13 CUT-OFF AND CLOSED-LOOP ALLOCATION RULES MUST NEVER BE MIXED TO DOUBLE COUNT CREDITS

To prevent double counting between upstream recycled content and downstream recyclability, the GHG Protocol Product Standard, ISO 14044 and the EU PEFCR require strict allocation consistency. [S01] [S06] [S25] Under the **cut-off (100:0) method**, recycled input enters free of prior virgin burdens, carrying only collection,

sorting, transport and reprocessing emissions (plus any virgin blend burden), while zero credit is granted at end-of-life for potential future recycling. [S01] [S23] Under **closed-loop avoided-burden (0:100) and PEFCR Circular Footprint Formula methods**, burdens and credits are partitioned across recycled input and verified end-of-life recovery, adjusted for quality loss and displaced virgin factors so total credit across life cycles never exceeds 100 percent of the physical saving. [S01] [S06] [S25] Double counting occurs when a manufacturer uses a low cut-off factor for incoming recycled yarn and also subtracts an end-of-life recyclability credit, or claims a virgin-displacement credit for internal cutting waste re-fed within the same boundary. [S01] [S23] [S25] Under Directive (EU) 2024/825, recycled-content and circularity claims must reflect actual lifecycle impact and cannot rely on external offsets. [S22] [S32]

EXHIBIT 58 / VERIFICATION GATE CRITERIA

Material and circularity switches require six equivalence checks before any saving is booked

Candidate intervention	Primary accounting failure mode	Mandatory equivalence check	Governing evidence
Switch fibre family (e.g. cotton to polyester or Lyocell)	Comparing 1 kg of raw fibre without adjusting for garment mass, tenacity or processing loss	Test per accepted garment and per wear; reconcile 31% cotton loss and tenacity masses (250 g vs 115 g to 153 g)	S22, S26, S31
Shift sourcing geography across countries	Applying a global secondary average factor that hides coal steam or high-carbon grid power	Require dated regional electricity and steam factors; S31 shows up to 38% GWP shift across regions	S14, S16, S31
Substitute mechanically recycled cotton for virgin lint	Ignoring staple shortening, higher spinning waste, virgin carrier blending and shorter garment life	Apply cut-off reprocessing energy, measure actual blend yield, and test fabric durability per wear	S01, S26, S30
Substitute chemically recycled or regenerated fibre	Assuming recycled feedstock equals low carbon despite high thermal and solvent-recovery energy	Audit supplier mill steam and power mix; Lyocell reaches 21.6 kg CO2eq/kg in high-carbon grids	S27, S30, S31
Extend garment durability or launch reuse model	Dividing cradle-to-gate CO2e by an assumed wear multiplier when new purchases are not displaced	Model actual displacement rate d in [0, 1], plus added washing (14% to 24% share) and reverse logistics	S12, S26, S30
Retire external carbon credits against product total	Presenting outside-value-chain offsets as an intrinsic reduction in carbon per garment	Report value-chain lifecycle CO2e separately; external offsets cannot support product neutrality claims	S04, S32, S1202

SOURCED [S22] [S26] [S27] [S30] [S31] [S32] Synthesised from methodological rules and empirical findings in S22, S26, S27, S30, S31 and S32. Each row defines a verification gate that GFT's chart of accounts applies before a procurement, circularity or durability change is credited in corporate Scope 3 or product footprints.

The six gates in **Exhibit 58**, p. 206 ensure that no procurement or design switch is booked as an emission reduction on the basis of a material label alone. [S22] [S26] While **Exhibit 58**, p. 206 defines the verification rules from the literature, it cannot replace primary supplier PACT declarations and laboratory testing of yarn tenacity, shrinkage and pilling on actual factory styles. [S10] [S23] [S31]

12.14

Reuse and durability require a displacement test

Extending the service life of clothing through physical durability, repair or reuse is a central circular-economy measure. [S12] [S27] [S30] Yet an accounting gap separates *carbon per wear* from *absolute sector emissions*. [S26] [S30] Wearing a garment more times lowers its amortised production footprint per wear only if the extended use prevents the manufacture and purchase of a replacement garment. [S12] [S26] [S30]

12.15 THE DISPLACEMENT RATE GOVERNS WHETHER DURABILITY CUTS ABSOLUTE EMISSIONS

Consider a garment with production and end-of-life footprint `F_prod` (kg CO2e) and laundering burden `c_wear` (kg CO2e per wear). [S12] [S30] Worn `W_0` times in the baseline, its intensity per wear is `i_wear,0 = (F_prod / W_0) + c_wear`; when reinforced construction adds `dF_mfg ⩾ 0` and extends life to `W_1` wears (`W_1` above `W_0`), single-garment intensity per wear becomes `i_wear,1 = ((F_prod + dF_mfg) / W_1) + c_wear`. [S26] [S30] Across `W_1` total wears, the absolute carbon saving depends on the **displacement rate** `d` (from `0` to `1`), the fraction of the `(W_1 - W_0)` extra wears that replace a new purchase: `dE_abs = d * ((W_1 - W_0) / W_0) * F_prod - dF_mfg - dE_rebound`, where `dE_rebound` covers extra repair, resale shipping or cleaning energy. [S26] [S30] At **full displacement (`d = 1.0`)**, doubling wear life (`W_1 = 2 * W_0`) with a 5 percent manufacturing penalty (`dF_mfg = 0.05 * F_prod`) and zero extra logistics cuts absolute production emissions by 47.5 percent across two baseline garment lives. [S26] [S30] At **partial displacement (`d = 0.30`)** with resale shipping and cleaning consuming 15 percent of `F_prod`, the net absolute saving falls below one-third of the naive 1:1 credit. [S26] [S30] At **zero displacement (`d = 0.0`)**, selling the same annual volume of heavier garments (`dF_mfg` above zero) *increases* absolute emissions by `dF_mfg` per garment despite a lower theoretical footprint per potential wear. [S07] [S26] [S30]

12.16 USE-PHASE ENERGY AND EXPORT WASTE FLOWS CONSTRAIN DOWNSTREAM ASSUMPTIONS

The United Nations Environment Programme (2021) cites a sector LCA (2016 baseline) attributing 24 percent of fashion greenhouse gas emissions to the use phase, while the European Environment Agency (2022) reports a 14 percent use-phase share in its European consumption model; extending life lowers `F_prod / W` but leaves per-wear laundering (`c_wear`) unchanged unless paired with lower-temperature care. [S12] [S30] European Environment Agency data (2026) show EU used-textile exports tripled from slightly over 550,000 tonnes in 2000 to almost 1.7 million tonnes in 2019, while 4 to 9 percent of textile products placed on the European market are destroyed unused (with EU bans taking effect in July 2026 for large enterprises and July 2030 for medium-sized enterprises). [S1201] [S1203] In Cameroon (where Statista estimates clothing and footwear spend at about US$94.70 and 8.0 pieces per person in 2024), imported used clothing and low-cost imports compete

with local mills. [R26] [S1201] A Cameroonian manufacturer supplying institutional workwear, uniforms or hospital linens under multi-year contracts can verify displacement directly from reduced annual replacement orders, whereas open-market consumer durability claims must be reported as sensitivity scenarios across d rather than deducted from cradle-to-gate footprints. [S01] [S23] [S26] [S32]

> **UNVERIFIED DURABILITY MULTIPLIERS VIOLATE PRODUCT CLAIM STANDARDS**
>
> A manufacturer must never divide its cradle-to-gate carbon footprint by an assumed durability multiplier and report the quotient as cradle-to-gate CO_2e. [S26] [S32] Under the GHG Protocol Product Standard, ISO 14067 and Directive (EU) 2024/825, cradle-to-gate emissions per garment and cradle-to-grave emissions per wear have distinct boundaries. [S01] [S05] [S32] Public durability claims require physical testing under recognised rules (such as the EU PEFCR welcomed in June 2025), explicit disclosure of assumed wears (W) and care profiles, and sensitivity checks for displacement rates d below one. [S06] [S26] [S32]

12.17

The growth plan carries a carbon budget

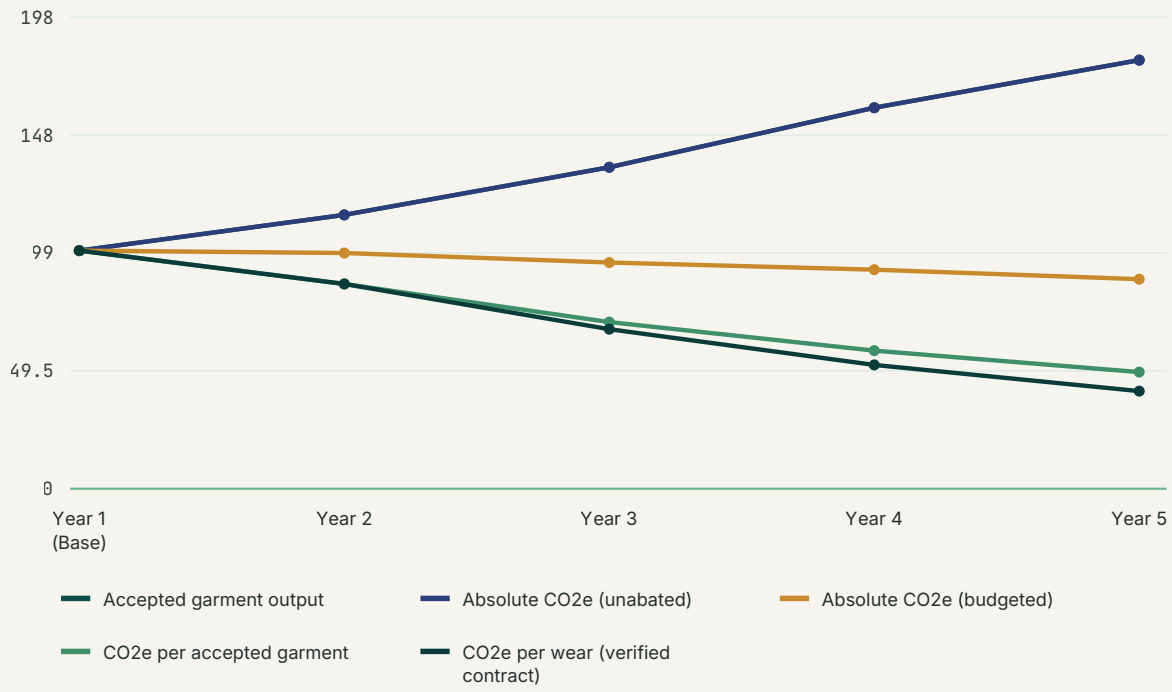
To reconcile rising output with absolute reductions, an expanding factory must govern its multi-year ramp through an explicit carbon budget, tracking absolute tonnes of CO_2e alongside kilograms of CO_2e per accepted garment and per wear in the monthly plant cadence. [S04] [S07] [S08] [S23]

12.18 CAPACITY UTILISATION AND FIRST-PASS YIELD DETERMINE THE CARBON COST OF GROWTH

Factory emissions do not scale from zero with output because every facility carries a fixed utility baseload (lighting, ventilation, compressed air, wastewater aeration and boiler standby heat) and a defect loss rate. [R12] [S13] [S20] In Cameroon, a July 2023 report on CICAM recorded capacity utilisation of 33.7 percent at Garoua, 48.9 percent at CICAM 1 and 10.83 percent at CICAM 2, with underutilisation costing about CFAF 2 billion in 2020 (restructuring estimates ranged from CFAF 30.7 to 48.2 billion, with one relaunch plan at CFAF 70.2 billion, and market share falling from about 85 percent three decades ago to about 5 percent). [R11] [R12] [R13] Raising utilisation spreads baseload energy across more units, cutting Scope 1 and 2 intensity, yet absolute site emissions rise unless specific energy consumption, thermal efficiency, solar generation and material yield improve simultaneously. [S08] [S13] [S23] First-pass yield is equally decisive: every rejected garment carries the full upstream burden of its materials plus wasted utilities while adding zero accepted units. [S23] [S31] Manual fabric inspection is 60 to 70 percent accurate (missing 20 to 30 percent of defects), whereas computer-vision inspection exceeds 90 percent accuracy across more than 40 defect types at speeds up to 60 metres a minute (and McKinsey's *The State of Fashion 2025* reports AI at scale can cut inventory costs by 35 to 40 percent and forecast errors by 20 to 50 percent). [R27] [R29]

EXHIBIT 59 / INDEX (BASE YEAR Y1 = 100, ILLUSTRATIVE)

A target glidepath shows absolute and per-garment measures



ILLUSTRATIVE [S07] [S08] [S23] Illustrative five-year ramp (Base Year 1 = 100) from the worked example below (S07, S08, S23). Output rises from index 100 (1.0m units) to 180 (1.8m units). Unabated absolute CO2e rises to 180. Under the budgeted programme, CO2e per accepted garment falls from 100 (4.50 kg) to 49 (2.20 kg), cutting absolute CO2e to 88 (-12%). With verified contract durability (+20% wears at d = 1.0), CO2e per wear reaches 41. Live targets require a metered base year first.

The indexed paths in **Exhibit 59**, p. 209 show how output, absolute emissions, per-garment intensity and per-wear intensity move together under a binding budget. [S07] [S08] [S23] What **Exhibit 59**, p. 209 cannot establish is a pre-committed target before Year 1 meters operate: setting a live glidepath requires a verified base-year inventory first. [S04] [S23]

WORKED EXAMPLE: BUDGETING AN 80 PERCENT PRODUCTION EXPANSION UNDER A 12 PERCENT ABSOLUTE CARBON CAP

Consider an illustrative five-year expansion plan for an integrated garment programme, presented solely to demonstrate the carbon-budget method and not as a forecast or measured GFT result. [S08] [S23] In Year 1 (Base Year), the plant produces `Q_1 = 1,000,000` accepted cotton workwear shirts (0.250 kg finished mass, matching Forfora et al.). [S31] Cradle-to-gate intensity is `i_1 = 4.50 kg CO2e` per shirt (`0.90 kg` Factory Scope 1 and 2, or `900 tonnes CO2e`; plus `3.60 kg` Upstream Scope 3 Categories 1 and 4, or `3,600 tonnes CO2e`), giving `E_1 = 4,500 tonnes CO2e` (Index 100 in **Exhibit 59**, p. 209). [S02] [S03] [S04] [S23] At `W_1 = 50` contract wears per shirt, baseline production carbon per wear is `0.090 kg CO2e` (90 g, Index 100). [S23] [S26]

By Year 5, output grows 80 percent to `Q_5 = 1,800,000` accepted shirts (`g = +0.80`), which would push unabated emissions to `8,100 tonnes CO2e` (Index 180). [S08] [S23] The board caps Year 5 cradle-to-gate emissions at `E_5 = 3,960 tonnes CO2e` (Index 88, a 12.0 percent absolute cut), including a 36.0 percent cut in Factory Scope 1 and 2 to `576 tonnes CO2e`. [S08] [S1202] Meeting `E_5 = 3,960 tonnes CO2e` at `1,800,000` shirts requires cutting combined intensity by 51.1 percent to `i_5 = 3,960,000 / 1,800,000 = 2.20 kg CO2e` per shirt (Index 49). [S08] [S23] Factory intensity drops 64.4 percent from `0.90` to `0.32 kg CO2e` per shirt (`576 tonnes CO2e` via two-shift utilisation, vision inspection, steam-trap maintenance and solar PV with battery storage), while upstream Scope 3 intensity drops 47.8 percent from `3.60` to `1.88 kg CO2e` per shirt (`3,384 tonnes CO2e` by cutting cotton processing and cutting losses from 31 percent toward 18 percent and shifting supplier process heat from coal to biomass verified via PACT Version 3 records). [R29] [S03] [S10] [S13] [S31] Reinforced seams extend verified institutional life by 20 percent from `50` to `60` wears (`d = 1.0`), reducing production carbon per wear to `2.20 / 60 = 0.0367 kg CO2e` (36.7 g, Index 41). [S26] [S30]

12.19 BASE-YEAR RECALCULATION SEPARATES REAL OPERATIONAL REDUCTIONS FROM ACCOUNTING DRIFT

As a plant progresses from initial screening to primary data exchange, engineers execute physical abatement while data teams replace `ecoinvent` proxies with metered activity data, updated conversion factors (`IEA Emissions Factors 2026` or `UK conversion factors 2026`) and supplier PACT records. [S10] [S14] [S16] [S20] Under the GHG Protocol Corporate Standard and Scope 3 Technical Guidance, whenever a change in methodology, factor vintage, data provenance (replacing a secondary proxy with primary supplier data when no physical process change occurred) or structure alters base-year emissions beyond the significance threshold, the base year is restated on the same basis as the current period. [S04] [S20] [S23] Period-to-period reporting separates four variances: **volume variance** (`dQ * i_0`), **verified physical abatement** (`Q_t * di_physical`), **external grid and factor-vintage updates**, and **base-year proxy restatements** paired with primary-data coverage scores. [S13] [S14] [S20] [S23]

GFT NOTE

In GFT's Cameroon textile programme, no capacity expansion or shift extension should be approved without a carbon budget variance check. [S04] [S08] [S23] Set up the monthly review ledger with four parallel metrics: total absolute emissions (tonnes CO2e across Scopes 1, 2 and screened Scope 3), operational intensity (kg CO2e per accepted garment for Scopes 1 and 2), cradle-to-gate product intensity (kg CO2e per accepted garment), and primary-data share (percentage of CO2e backed by site meters and audited supplier PACT records). [S10] [S20] [S23] Require every expansion capital request to specify the exact efficiency, yield, solar, thermal and supplier measures that keep absolute tonnes inside the multi-year budget. [R07] [S08] [S13]

Binding production growth to a carbon budget, testing material and circularity switches for functional equivalence, and separating physical abatement from proxy restatements ensure that lower carbon per garment delivers lower carbon in the atmosphere. [S07] [S08] [S23] Chapter 13 now examines the evidence chain, assurance standards and legal disclosure rules required to defend these numbers in supplier exchange and public claims. [S10] [S32]

Efficiency lowers the cost of growth, but only a binding budget lowers total carbon.

CHAPTER SOURCE NOTES

S07 Textile Exchange. 2025-09-18.

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S04 GHG Protocol. 2004.

S23 GHG Protocol and Carbon Trust. 2013.

S1202 Science Based Targets initiative. 2026.

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

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

S31 Forfora et al., Sustainability. 2026-04-20.

S01 GHG Protocol. 2011.

S27 Ellen MacArthur Foundation. 2017.

S26 Watson and Wiedemann, Sustainability. 2019-07-15.

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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.

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.

S05 International Organization for Standardization. 2018-08.

S14 International Energy Agency. 2026-09-25.

S02 GHG Protocol. 2011.

S03 GHG Protocol. 2015.

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

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S10 World Business Council for Sustainable Development. 2025-04-30.

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R13 Business in Cameroon; MMI News. 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.

13

PART IV: MAKE THE ACCOUNT OPERABLE / PROOF AND DISCLOSURE

Assurance and claims require a chain of custody for numbers

Every published footprint needs reproducible arithmetic, proportionate review and wording bounded by the evidence.

CHAPTER 13
DECISION TEST

Every published footprint needs reproducible arithmetic, proportionate review and wording bounded by the evidence.

A garment carbon figure is defensible only when a versioned chain of custody links the published number back to its declared system boundary, functional unit, dated emission factor, allocation rule and activity record. [S01] [S23] Without that lineage, a footprint is an orphan numeral detached from the factory conditions that produced it. [S22] In apparel supply chains, where cotton cultivation, spinning, wet processing, garment assembly, freight, care and disposal cross multiple entities, numerical provenance is as essential as physical traceability. [S01] [S08] Green Future Tech Limited (GFT), Hong Kong SAR, designs industrial systems on the principle that production is the warp and measurement is the weft: the factory that makes the garment must simultaneously generate the evidence record that substantiates its environmental performance. [S04] [S23] This chapter defines the engineering, assurance and disclosure controls required to move from meter logs and supplier declarations to audited footprints and lawful claims, noting that this governance model is an operational framework rather than legal, tax or investment advice. [S32] [S1301]

Across the textile sector, regulatory scrutiny has closed the gap between internal carbon screening and public-grade evidence. [S06] [S32] Global fibre production rose from 125 million tonnes in 2023 to 132 million tonnes in 2024, shifting buyer expectations toward verifiable product and value-chain accounting. [S07] [S10] In Cameroon, where the inherited baseline records roughly 95 percent of cotton fibre exported raw and about 5 percent processed locally against a 50 percent local-processing target by 2030, a new mill cannot rely on generic green labels or imported database averages. [R06] [R07] [S16] GFT's Cameroon textile programme (prepared 31 January 2024, sources refreshed 2026) embeds data capture from the first shift so that every kilogram of carbon dioxide equivalent (CO2e) reported per garment can be rebuilt by an independent reviewer from primary logs, documented secondary proxies and explicit arithmetic. [S20] [S23]

13.1

The evidence pack preserves every methodological choice

An auditable carbon calculation begins with a structured evidence pack that freezes every methodological parameter alongside the raw data used to compute the footprint. [S01] [S23] Under the GHG Protocol Product Standard and ISO 14067, a product carbon footprint addresses a single impact category, climate change, across a defined life cycle boundary. [S01] [S05] Because life cycle assessment (LCA) results are sensitive to boundaries, co-product allocation and background datasets, a figure published without its metadata cannot be verified. [S22] [S26] Each evidence pack records eight mandatory fields: study goal and audience, system boundary (cradle-to-gate or cradle-to-grave), functional or reference unit, primary and secondary activity streams, factor identifiers and vintages, selected global warming potential (GWP) metric and time horizon from the Intergovernmental Panel on Climate Change (IPCC), allocation rules for shared processes and co-products, and uncertainty bounds. [S01] [S11] [S23]

Assembling this record after year-end invites reconstruction errors, missing invoices and unlogged spreadsheet edits. [S04] [S23] GFT's digital strategy and performance-management system treat the evidence pack as a live, immutable data object

generated alongside production lots. [S10] [S20] Just as physical chain-of-custody systems track lint bales from northern Cameroon where SODECOTON supports more than 220,000 producers across nine ginning plants and two oil mills, the numerical chain of custody tracks how energy, water, chemical and waste quantities become emissions ledger entries. [R03] [S20] As shown in **Exhibit 60**, p. 215, each layer of the product carbon record references version keys from the layer beneath it, keeping every external claim tied to its calculation graph. [S10] [S18] [S23]

EXHIBIT 60 / SYSTEM LAYERS

A product carbon record links every figure to its evidence graph



ILLUSTRATIVE [S10] [S18] [S23] Illustrative system architecture based on PACT Version 3 product footprint fields (S10), GLEC logistics reporting elements (S18) and GHG Protocol Scope 3 data quality and assurance rules (S23).

Exhibit 60, p. 215 shows the four layers that maintain numerical custody from factory floor to external disclosure. [S10] [S23] The base layer stores metered electricity, steam, fuel and defect logs alongside a versioned registry of emission factors and IPCC GWP values. [S11] [S14] [S20] The second layer packages reconciled quantities into standardised business-to-business envelopes for manufacturing and freight. [S10] [S18] The third layer runs automated reconciliation checks between the corporate GHG inventory (Scopes 1, 2 and 3) and the product ledger, storing audit logs and critical review statements. [S04] [S25] The top layer blocks any external statement whose wording exceeds the verified boundary or whose evidence pack has expired. [S32] While **Exhibit 60**, p. 215 defines the control hierarchy, software structure alone cannot prove meter calibration or proxy fit; those require physical inspection and data-quality scoring. [S16] [S23]

13.2 VERSIONED FACTOR REGISTERS PREVENT SILENT DRIFT ACROSS REPORTING PERIODS

Unrecorded substitution of emission factors between reporting periods frequently distorts carbon time series. [S20] [S23] Reference databases update their coefficients regularly as grid mixes, fuel pathways and farm models change. [S14] [S20] The International Energy Agency (IEA) publishes annual emission factors for world electricity and heat generation, while the UK Department for Energy Security and Net Zero issues annual conversion factors covering fuel volumes, kilowatt-hours (kWh) of electricity and freight tonne-kilometres across Scopes 1, 2 and 3. [S14] [S20] Background life cycle inventory databases such as ecoinvent and the World Apparel and Footwear Life Cycle Assessment Database (WALDB) also release periodic updates that shift upstream intensities for cotton, synthetic fibres and textile chemicals. [S16] [S17]

Updating a factor library without locking the base-year vintage confuses operational improvement with administrative factor drift. [S20] [S23] The evidence pack must store every factor as an immutable record containing publisher, title, release date, geography, life cycle boundary (separating direct combustion from upstream fuel-cycle or grid losses), gas split (CO_2, CH_4, N_2O) and IPCC GWP horizon. [S11] [S14] [S20] When a factor revision or primary-data replacement shifts the base-year footprint beyond a defined significance threshold, GHG Protocol rules require a formal base-year recalculation and reconciliation note. [S04] [S23]

13.3 CONSISTENCY CHECKS SEPARATE REAL PROCESS CHANGE FROM MODELLING ARTEFACTS

ISO 14040 and ISO 14044 require life cycle interpretation to include completeness, sensitivity and consistency checks. [S24] [S25] A completeness check verifies that all relevant mass, energy and waste flows within the boundary are captured or tested against a cut-off rule. [S01] [S25] Because Forfora et al. (2026) report cumulative cotton losses of 31 percent across cradle-to-gate stages, omitting spinning, knitting or cutting waste understates upstream farm and energy burdens by nearly one third. [S31]

A consistency check verifies that assumptions, allocation rules, data quality and boundaries are applied uniformly across the system and across compared products. [S25] [S26] Watson and Wiedemann (2019) show that inconsistent co-product allocation (such as mixing mass and economic allocation between cotton lint and cottonseed) or incompatible functional units can invert fibre rankings even with identical background databases. [S26] GFT's calculation engine runs automated balance checks on every batch: input fibre mass must equal accepted garment mass plus rework and waste mass, and metered site energy must equal the energy allocated across lines and site services, blocking external reporting if any discrepancy exceeds an illustrative 0.5 percent tolerance. [S20] [S23] [S25]

13.4

Supplier exchange needs a common product language

No garment factory controls its entire footprint within its own gates. [S02] [S08] Even an integrated project such as the announced Camtext SA venture in Cameroon, reported at US$300 million (180 billion XAF) to process 12,000 tonnes of fibre a year across

Dibamba and Garoua, relies on external chemical, machinery, packaging, utility and freight suppliers. [R09] [R10] [S08] Purchased yarn, fabric, trims and zippers sit in corporate Scope 3 Category 1 and form the cradle-to-gate base of every garment footprint. [S02] [S23] UNIDO notes that developing-country suppliers face growing pressure to quantify and limit their carbon footprints for international buyers, yet bespoke buyer spreadsheets create high administrative costs and irreconcilable numbers. [S10] [S21]

To solve this interoperability problem, the World Business Council for Sustainable Development (WBCSD) developed the Partnership for Carbon Transparency (PACT) Methodology Version 3, providing a harmonised framework for calculating and exchanging cradle-to-gate product carbon footprints. [S10] A PACT exchange transmits a structured payload that preserves upstream metadata so the receiving manufacturer can integrate supplier records into its product and Scope 3 accounts without double counting. [S10] [S23]

13.5 PACT ENVELOPES ATTACH DATA QUALITY AND PRIMARY SHARES TO EVERY EXCHANGED VALUE

A supplier-specific emission factor is useful only if the buyer can inspect its composition. [S10] [S23] Scope 3 technical guidance from the GHG Protocol and Carbon Trust warns that data collected from a supplier may actually be less accurate than industry-average data if the supplier relies on weak measurement, poor granularity or arbitrary facility allocation. [S23] Provenance is therefore never a substitute for data-quality evaluation. [S16] [S23] Under PACT Version 3 and GHG Protocol Scope 3 rules, every exchanged supplier footprint record must carry five metadata groups: [S10] [S23]

1. **Product and batch identity**: unique product code, physical specification, declared unit (such as 1 kg of combed cotton yarn at stated moisture regain), and shipping lot reference. [S10] [S26]
2. **Temporal and geographic scope**: manufacturing period of activity capture, country and facility identifier, and record expiry date. [S10] [S23]
3. **Boundary and gas disaggregation**: cradle-to-gate boundary confirmation, separate reporting of fossil CO_2e, biogenic carbon content and removals, and explicit exclusion of carbon offsets. [S05] [S10] [S32]
4. **Primary Data Share (PDS) and Data Quality Ratings (DQR)**: share of the footprint derived from site-specific primary data versus secondary databases, plus scores across the five GHG Protocol indicators: technology, time, geography, completeness and reliability. [S10] [S23]
5. **Allocation and assurance metadata**: allocation method for shared utilities and co-products, calculation standard used, and verification status. [S10] [S23] [S25]

With these five metadata groups attached, a garment maker can combine upstream records rigorously, propagating primary-data shares and uncertainty ranges into the finished garment's evidence pack. [S10] [S16] [S17]

13.6 UPSTREAM COTTON AND WET-PROCESSING SUPPLIERS REQUIRE TIERED ONBOARDING

In an emerging industrial corridor such as Cameroon's cotton-to-garment chain, demanding full primary PACT payloads from every farmer group, ginnery, chemical supplier and packaging vendor on day one is impractical. [R03] [S21] [S23] GFT's digital strategy instead applies a tiered supplier onboarding protocol governed by materiality screening. [S21] [S23] During initial screening, the manufacturer uses secondary data-sets from ecoinvent and WALDB, alongside IEA and UK government conversion factors, to rank upstream inputs by their share of garment CO2e and uncertainty. [S14] [S16] [S17] [S20]

Where screening confirms that cotton lint production, spinning power and wet-processing heat dominate the cradle-to-gate footprint, onboarding focuses engineering support on those hotspots first. [S08] [S23] [S31] In cotton farming and ginning, where synthetic nitrogen fertiliser manufacture and application drive nitrous oxide (N2O) and CO2 emissions and ginning separates lint from cottonseed co-products, the onboarding template captures physical farm and ginnery metrics (seed-cotton yield per hectare, fertiliser mass by type, ginning kWh per tonne of lint, and lint-to-seed ratios) rather than expecting rural co-operatives to run standalone LCA software. [R03] [S26] [S29] Low-share ancillary items such as carton staples remain on documented secondary proxies with their status flagged in the evidence pack. [S16] [S23]

13.7

Logistics data follow their own compatible standard

Transport links every stage of the garment life cycle, moving seed cotton to ginneries, baled lint to spinning mills, fabric to garment lines, and finished clothes through ports and warehouses to customers. [S01] [S18] In corporate accounting, third-party inbound and outbound freight sit in Scope 3 Categories 4 and 9 (or Scopes 1 and 2 for owned fleets), while in product accounting all transport legs within the system boundary belong to the garment inventory. [S01] [S02] [S04] Because freight chains involve road hauliers, rail operators, container shipping lines and port terminals, logistics data require a compatible standard that connects cleanly with PACT and the GHG Protocol. [S10] [S18]

The Global Logistics Emissions Council (GLEC) Framework, developed by the Smart Freight Centre, harmonises logistics greenhouse gas calculation and reporting across multimodal chains and supports ISO 14083 implementation. [S18] In a GFT carbon account, no freight leg enters a verified garment footprint on straight-line distance alone. [S18] [S20] Each logistics record must capture transport work in tonne-kilometres (tkm), recording gross consignment mass (including packaging), route distance, vehicle or vessel class, load factor, empty running share and hub energy use. [S18] [S20]

13.8 WELL-TO-WAKE ACCOUNTING KEEPS FUEL PRODUCTION INSIDE THE FREIGHT LEDGER

Both the GLEC Framework and the International Maritime Organization (IMO) life cycle GHG intensity framework require full fuel life cycle accounting, termed well-to-wake (WTW) for shipping and aviation or well-to-wheel for surface transport. [S18] [S19] As

the IMO notes, candidate low-carbon and zero-carbon marine fuels such as biofuels and hydrogen-derived fuels have diverse production pathways with large differences in overall footprint. [S19] Evaluating a shipping leg only on tank-to-wake (TTW) exhaust emissions would treat a high-upstream-emission fuel as zero-carbon at the stack, shifting the burden upstream without cutting atmospheric warming. [S19] [S23]

Every logistics record in the garment chain of custody therefore splits transport emissions into two auditable components: [S18] [S19] [S20]

- **Well-to-tank (WTT) upstream fuel emissions**: emissions from extraction, cultivation, refining, power generation and distribution of the fuel or energy carrier up to the vehicle or vessel tank. [S18] [S19] [S20]
- **Tank-to-wake (TTW) direct operational emissions**: emissions (CO_2, CH_4, N_2O) from fuel combustion, slip or leakage during vehicle, vessel or hub operation. [S18] [S19] [S20]

Separating WTT and TTW also preserves corporate-to-product reconciliation: for owned factory trucks, TTW fuel burn sits in corporate Scope 1 while WTT upstream fuel sits in Scope 3 Category 3, yet both sum into the product footprint of the shipped garments. [S02] [S04] [S20]

13.9 MULTIMODAL HANDOVERS RECONCILE CONSIGNMENT MASS WITH CONTAINER ALLOCATION

When lint or finished garments move along a multimodal corridor, such as road haulage from northern Cameroon to Douala or Kribi followed by ocean shipping, consignment mass crosses several consolidation nodes. [R03] [R10] [S18] At each handover, the numerical chain of custody reconciles packing lists and bills of lading with carrier emissions statements, allocating shared container and truck loads by physical mass (or volume where volume-constrained) rather than invoice value, and including warehouse and port terminal energy per tonne handled in accordance with the GLEC Framework. [S03] [S18] [S23]

13.10

Assurance is proportionate to decision and risk

Verification and assurance test whether an inventory or product footprint is complete, accurate, consistent and transparent, but the GHG Protocol Corporate Standard distinguishes inventory preparation from verification. [S04] Applying the same external audit burden to an exploratory internal screen as to a public comparative marketing claim wastes engineering effort on rough proxies while under-controlling public disclosures. [S23] [S25] Conversely, publishing a consumer footprint or fibre comparison from an unreviewed internal worksheet violates ISO 14044 critical review rules and consumer protection law. [S25] [S32] [S1301]

GFT structures assurance around a five-tier proportionality schedule governed by the intended application of the result, as shown in **Exhibit 61**, p. 220. [S04] [S24] [S25] ISO 14040 places intended application inside goal and scope definition precisely because the decision context determines required data quality, boundary completeness and review depth. [S24]

EXHIBIT 61 / GOVERNANCE TIERS

Assurance depth follows the intended use of the result

Intended application	Minimum data basis	Required review mechanism	Permitted external wording	Validity window (months)
Tier 1: Internal hotspot screening	Secondary LCI proxies and spend or mass screen	Internal calculation and boundary check	None; internal engineering use only	24
Tier 2: B2B supplier PACT exchange	Metered gate energy plus documented upstream proxies	Second-party or internal audit of ledger reconciliation	Contractual B2B footprint payload with DQR score	12
Tier 3: Capital allocation and abatement case	Metered baseline and engineering counterfactual	Independent technical review of baseline and savings	Financing dossier disclosure with sensitivity bounds	12
Tier 4: Public single-garment footprint	Primary factory data and PEFCR-compliant lifecycle model	Independent third-party verification of evidence pack	Quantified lifecycle CO2e with boundary and wear basis	12
Tier 5: Public comparative assertion	Equivalent functional unit, PCR/PEFCR and Monte Carlo bounds	ISO 14044 critical review panel plus legal claim sign-off	Compared products, method and update schedule disclosed	12

ILLUSTRATIVE [S04] [S10] [S25] [S26] [S32] Illustrative governance tiers synthesised from GHG Protocol verification principles (S04), PACT Version 3 assurance rules (S10), ISO 14044 critical review requirements (S25), textile LCA review literature (S26) and EU consumer-claim rules (S32).

As **Exhibit 61**, p. 220 sets out, internal hotspot screening (Tier 1) uses secondary databases such as ecoinvent and WALDB and requires only internal checks on units and boundaries. [S16] [S17] [S23] Transmitting a cradle-to-gate footprint to a buyer via PACT Version 3 (Tier 2) or presenting an abatement investment case (Tier 3) requires metered site energy, reconciled denominators and audited ledger arithmetic. [S10] [S13] [S20] Public single-garment footprints (Tier 4) and public comparative assertions (Tier 5) require independent third-party verification and, for comparisons, an ISO 14044 critical review panel plus legal sign-off. [S25] [S32] **Exhibit 61**, p. 220 is an operational governance schedule rather than a statutory safe harbour: passing a Tier 2 B2B check never authorises reusing that partial cradle-to-gate figure in a Tier 4 or Tier 5 consumer campaign. [S01] [S32]

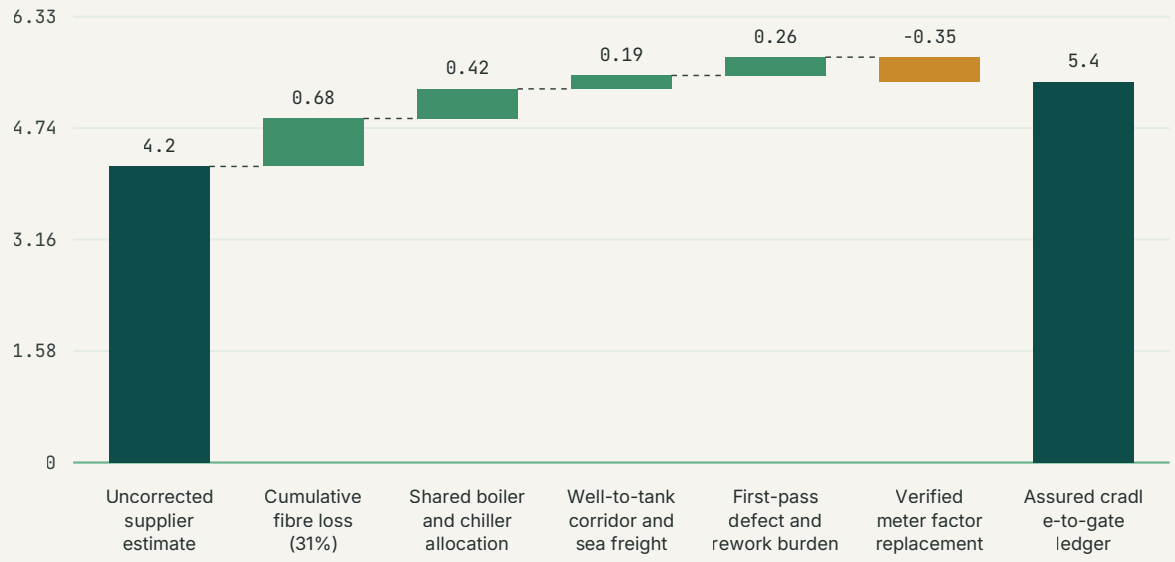
13.11 INTERNAL SCREENING AND SUPPLIER EXCHANGE NEED REPEATABLE CALCULATION CHECKS

Before an external verifier inspects a factory's carbon ledger, internal controls must eliminate boundary and allocation errors. [S04] [S23] In supplier audits, the largest corrections rarely stem from radiative physics; they arise from omitted processing waste, unallocated auxiliary loads (boilers, chillers, compressed air), missing well-to-tank freight, and dividing emissions by started pieces rather than accepted units. [S18] [S20] [S23] [S31]

Exhibit 62, p. 221 traces how pre-assurance reconciliation corrects an illustrative cradle-to-gate estimate for a 0.25 kg cotton T-shirt, using the reference garment mass and 31 percent cumulative cotton loss reported in the 2026 comparative LCA by Forfora et al. [S31]

EXHIBIT 62 / KG CO2E PER SHIRT

Reconciling an unverified screening figure to an assured cradle-to-gate ledger



DERIVED [S10] [S18] [S23] [S31] Derived arithmetic walkthrough using the 0.25 kg cotton T-shirt reference mass and 31 percent cumulative cotton loss from S31 (implying 0.362 kg input lint), combined with illustrative adjustments for unallocated utility meters, well-to-tank freight omissions (S18) and first-pass yield losses under PACT (S10) and Scope 3 (S23) rules. Values illustrate reconciliation mechanics, not a measured GFT factory result.

In **Exhibit 62**, p. 221, an uncorrected worksheet figure of 4.20 kg CO2e per shirt (illustrative) understates the cradle-to-gate footprint because it multiplies finished garment weight (0.25 kg) by a lint factor without accounting for the 31 percent cumulative processing loss reported in S31. [S31] Adding upstream fibre loss (+0.68 kg CO2e illustrative), shared steam and HVAC loads (+0.42 kg CO2e illustrative), well-to-tank freight (+0.19 kg CO2e illustrative) and first-pass yield adjustments (+0.26 kg CO2e illustrative), then substituting verified meter factors for conservative proxies (-0.35 kg CO2e illustrative), yields an assured ledger value of 5.40 kg CO2e per accepted shirt. [S10] [S18] [S23] [S31] These step values illustrate the accounting bridge and are not a measured Cameroonian factory benchmark. [S23]

METHOD

Pre-assurance reconciliation protocol for garment batch footprints

Before submitting any batch footprint to an external verifier or a PACT exchange, the performance-management system runs five verification equations across reporting period t: [S10] [S20] [S23]

1. **Mass balance closure across stages**: Confirm through $M_{\text{input}} = M_{\text{finished}} / \prod (1 - l_s)$ that stage loss rates l_s reconcile physical bale receipts M_{input} with accepted garment mass M_{finished} plus weighed scrap and rework. [S23] [S31]
2. **Corporate-to-product utility conservation**: Confirm through $\sum E_{p,t} = E_{\text{metered, main},t} + E_{\text{metered, backup},t}$ that power, steam and fuel allocated across all product lots p equal 100 percent of utility invoices and calibrated main plus backup generator meters for period t. [S03] [S04] [S20]
3. **Accepted-unit denominator enforcement**: Confirm through $I_{\text{accepted}} = C_{\text{batch, total}} / (N_{\text{started}} \times Y_{\text{FPY}})$ that batch emissions $C_{\text{batch, total}}$ are divided by accepted units meeting quality specification, never by uninspected started pieces. [R29] [S23]
4. **Well-to-wake freight completeness**: Confirm through $C_{\text{freight}} = \sum (M_{\text{gross},r} \times D_r \times (EF_{\text{WTT},r} + EF_{\text{TTW},r})) + C_{\text{hubs}}$ that every leg r includes packaging mass and pairs tank-to-wake factors with well-to-tank fuel factors and hub energy. [S18] [S19] [S20]
5. **Factor vintage and GWP lock**: Confirm that every emission factor ID resolves to a dated entry in the locked register with a declared IPCC AR6 GWP horizon and zero embedded offsets. [S11] [S14] [S32]

WORKED EXAMPLE

Auditing an illustrative 10,000-unit cotton T-shirt batch from worksheet to PACT exchange

Consider an illustrative order of 10,000 accepted cotton T-shirts weighing 0.25 kg each (2,500 kg net accepted fabric mass), using the cited 31 percent cumulative loss rate from S31 and assumed utility logs to demonstrate pre-assurance reconciliation: [S23] [S31]

- **Step 1: Reconcile fibre mass against stage losses.** A worksheet multiplying 2,500 kg of finished shirts by an illustrative lint factor of 2.20 kg CO2e/kg reports 5,500 kg CO2e (0.55 kg CO2e per shirt). Applying the 31 percent cumulative loss from S31 requires $2,500 / (1 - 0.31) = 3,623.19\text{ kg}$ of input lint (0.3623 kg per shirt), giving an illustrative lint burden of 7,971.0 kg CO2e (0.797 kg CO2e per shirt) and exposing 2,471.0 kg CO2e (+0.247 kg CO2e per shirt) of omitted upstream lint emissions. [S23] [S31]
- **Step 2: Reconcile inspection and rework denominators.** Suppose 10,800 pieces were started to deliver 10,000 accepted shirts. Manual inspection is 60 to 70 per-cent accurate and misses 20 to 30 percent of defects, whereas computer vision exceeds 90 percent accuracy across more than 40 defect types at up to 60 metres a minute. [R29] With 500 pieces reworked (adding an illustrative 120 kWh) and 300 rejected, assigning batch emissions to 10,000 accepted shirts rather than 10,800 started pieces raises per-unit assembly intensity by 8 percent. [R29] [S23] [S26]
- **Step 3: Reconcile sub-meters and backup diesel.** Adding 1,000 kWh of shared HVAC and compressed air to 3,200 kWh of line sub-meters, plus 180 litres of backup diesel (482.4 kg CO2e illustrative combustion and WTT burden using UK conversion methods), brings the reconciled batch total to 54,000 kg CO2e, or 5.40 kg CO2e per accepted shirt in **Exhibit 62**, p. 221, linked to meter IDs, bills of lading and factor vintages. [S10] [S18] [S20] [S28]

13.12 PUBLIC COMPARATIVE ASSERTIONS REQUIRE CRITICAL REVIEW AND UNCERTAINTY TESTING

When an organisation asserts that its garment has a lower footprint than a competing product or fibre, ISO 14044 requires a formal critical review by independent experts or an interested-party panel, alongside uncertainty and sensitivity analysis. [S25] [S26] The 2026 comparative T-shirt study by Forfora et al. demonstrates why deterministic point rankings fail without uncertainty bounds. [S31] Running 1,000 Monte Carlo itera-tions across cotton, polyester, viscose and Lyocell T-shirts, the authors found that while Lyocell had the highest baseline point footprint (21.6 kg CO2eq/kg) unless pro-duced with cleaner regional energy (where shifting from China to Brazil cut impact by up to 38 percent in the modelled scenario), probability distributions overlapped sub-stantially once parameter uncertainty and equivalent-strength garment mass (250 g for cotton and viscose versus 115 g for polyester and 153 g for Lyocell) were included. [S31] A Tier 5 reviewer must therefore block any comparative claim where confidence intervals overlap or where functional durability and regional energy mixes are omitted. [S22] [S25] [S26] [S31]

13.13

Neutrality cannot be manufactured with offsets

A common commercial practice in apparel has been to estimate a rough product footprint, retire voluntary carbon credits from projects outside the garment supply chain, and label the item "carbon neutral" or "climate neutral". [S32] [S1302] Both physical accounting standards and consumer law reject that practice. [S01] [S32] [S1303]

In physical accounting, the GHG Protocol Product Standard and ISO 14067 quantify emissions and removals inside the product system's life cycle stages. [S01] [S05] External carbon credits represent projects outside the garment's boundary; subtracting them from a product inventory mixes an internal physical account with an external counterfactual. [S01] [S10] [S26] In the European Union, Directive (EU) 2024/825 on consumer protection for the green transition prohibits claims, based on the offsetting of greenhouse gas emissions, that a product has a neutral, reduced or positive impact on the environment in terms of greenhouse gas emissions. [S32] As the directive states, such claims are permitted only when based on the actual lifecycle impact of the product in question, and not on offsetting outside the product's value chain, because the two are not equivalent. [S32]

13.14 LIFECYCLE INVENTORY ACCOUNTING EXCLUDES EXTERNAL COMPENSATION CREDITS

To enforce this rule structurally, GFT's chart of carbon accounts and PACT Version 3 schemas forbid negative offset rows inside any product footprint or corporate Scope 1, 2 or 3 inventory table. [S04] [S10] [S32] This aligns with the United Nations High-Level Expert Group on the Net Zero Emissions Commitments of Non-State Entities (reviewed at the COP29 stocktake on 14 November 2024), which requires non-state actors to prioritise direct value-chain abatement over external credits. [S1303] Where removals occur inside the product boundary, such as biogenic carbon uptake in cotton plants or verified soil carbon changes, ISO 14067 and PACT Version 3 require separate disclosure of fossil and biogenic flows alongside permanence and end-of-life release modelling, preventing farm-stage uptake from being claimed as a net reduction when the carbon returns to the air at disposal. [S05] [S10] [S29] [S30] [S31]

13.15 SEPARATE DISCLOSURE GOVERNS CLIMATE CONTRIBUTIONS OUTSIDE THE PRODUCT BOUNDARY

Directive (EU) 2024/825 clarifies that banning offset-based product neutrality claims does not stop companies from reporting investments in external environmental initiatives, provided the communication is not misleading and stays separate from product claims. [S32] Similarly, UK Competition and Markets Authority (CMA) guidance requires businesses to distinguish intrinsic product impacts from corporate funding actions. [S1301] In GFT's architecture, external climate contributions sit in a separate corporate financial note, never netted against product or Scope 1 to 3 tonnes and never placed on garment swing-tags or PACT certificates. [S04] [S10] [S32]

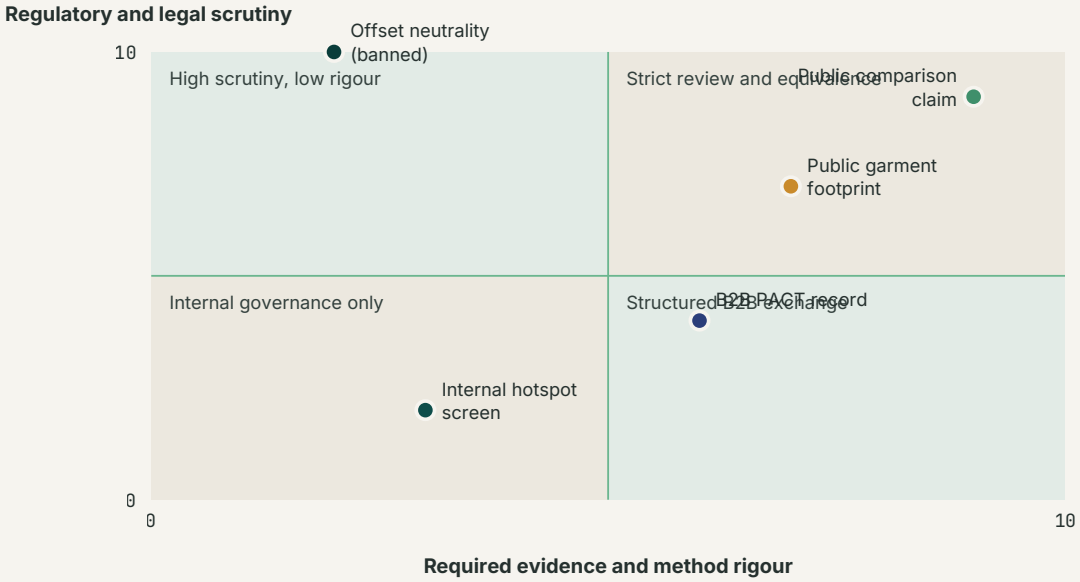
13.16

Public comparisons need common methods and current evidence

Even without offsets, a public claim can mislead buyers if its wording exceeds the evidence boundary or compares studies built on incompatible rules. [S22] [S32] [S1301] As the European Commission notes, ensuring environmental claims are credible and trustworthy protects both consumers and fair competition. [S1302] Every proposed external statement must therefore pass through a claim review matrix that maps wording against required technical rigour and legal scrutiny, as shown in **Exhibit 63**, p. 225. [S06] [S22] [S32]

EXHIBIT 63 / SCORE (0 TO 10 SCALE)

A claim review traces each sentence to evidence and scope



SOURCED [S06] [S22] [S32] Regulatory exposure and evidence strictness across five apparel statement classes, structured from EU PEFCR lifecycle rules (S06), Textile Exchange LCA comparability guidance (S22) and Directive 2024/825 substantiation rules (S32). Numerical coordinates (0 to 10) are an illustrative analytical encoding of those requirements.

Exhibit 63, p. 225 positions five statement classes across methodological rigour (x) and regulatory scrutiny (y). [S06] [S22] [S32] An internal hotspot screen (x: 3, y: 2 illustrative score) remains inside engineering governance. [S23] A B2B PACT record (x: 6, y: 4 illustrative score) demands metered gate data and quality scores for professional buyers. [S10] [S23] Public single-garment footprints (x: 7, y: 7 illustrative score) and public comparisons (x: 9, y: 9 illustrative score) sit in the upper-right quadrant, requiring full lifecycle coverage (or explicit boundary naming), common category rules and independent review. [S06] [S25] [S32] Offset-based product neutrality (x: 2, y: 10 illustrative score) faces prohibition under Directive 2024/825 regardless of credit volume. [S32] These coordinates are an analytical classification rather than legal advice; actual publication requires jurisdiction-specific legal review. [S32] [S1301]

13.17 PRODUCT CATEGORY RULES CONSTRAIN BOUNDARY AND FUNCTIONAL-UNIT DIVERGENCE

Textile Exchange and Watson and Wiedemann (2019) warn that LCA rankings flip when studies use different boundaries, wash scenarios or cottonseed allocation rules. [S12] [S22] [S26] [S30] To harmonise lifecycle comparisons, the European Commission welcomed the Product Environmental Footprint Category Rules (PEFCR) for apparel and footwear on 25 June 2025, developed over five years to assess clothing and shoes across extraction, production, logistics, use and end-of-life without favouring any fibre. [S06] Under Directive (EU) 2024/825, comparative claims must disclose the comparison method, the products and suppliers compared, and updating arrangements. [S32] GFT blocks any comparative assertion unless both garments follow the same category rules, share an equivalent functional unit per garment and per wear, and show non-overlapping uncertainty bounds under critical review. [S06] [S25] [S26] [S32]

13.18 CLAIM RELEASE GATES BIND MARKETING COPY TO EXPIRING EVIDENCE RECORDS

Sound LCA studies still fail if marketing copy turns a bounded operational metric ("14 percent lower Scope 1 and 2 sewing electricity per accepted shirt in Q2 2026 versus Q2 2025" illustrative) into an unqualified headline ("14 percent lower carbon shirts" illustrative). [S01] [S32] [S1301] GFT requires every external carbon sentence to pass a seven-field release gate: verbatim text, covered SKU and batch IDs, declared boundary and functional unit, locked evidence pack and PACT/GLEC hashes, verified transition-plan commitments for any future target under Directive 2024/825, assurance tier sign-off from **Exhibit 61**, p. 220, and a 12-month expiry date that withdraws stale claims until refreshed with current meter data and updated IEA or national factors. [S10] [S14] [S18] [S20] [S32] [S1303]

> **GFT NOTE**
>
> **Practical recommendation for Cameroon textile programme sponsors**
>
> Build the numerical chain of custody during factory commissioning rather than retrofitting it after buyers ask for audits: [S04] [S20] [S23]
>
> 1. Assign every power sub-meter, steam meter, fuel gauge and inspection station a permanent asset ID in the factory database before commercial production starts. [S20] [S23]
> 2. Write PACT Version 3 and GLEC data fields into lint, yarn, chemical and freight procurement contracts from day one, even where suppliers initially report secondary proxies with declared quality scores. [S10] [S18] [S21]
> 3. Block terms such as "carbon neutral", "climate positive" or unqualified "low carbon" on samples and catalogues unless a verified Tier 4 or Tier 5 evidence pack is linked to that exact style. [S25] [S32] [S1301]

WARNING

Unresolved verification constraints in emerging apparel corridors

Three structural constraints in Central and West African textile corridors must be disclosed openly: [R03] [S16] [S23]

- **Regional LCI gaps**: Databases such as ecoinvent and WALDB have sparser primary coverage for Central African farm inputs, chemicals and road freight than for European or Asian nodes, widening proxy uncertainty until local primary campaigns are completed. [S16] [S17] [S22]
- **Verifier scheduling**: Accredited bodies audit ISO 14067 and PACT footprints globally, but on-site meter and ginning-corridor verification in Cameroon requires advance scheduling and pooled industrial-zone budgeting. [R10] [S21] [S25]
- **Evolving templates**: While Directive (EU) 2024/825 and the June 2025 apparel PEFCR set clear lifecycle and anti-offsetting rules, digital product passport templates continue to evolve, requiring annual review of export disclosures. [S06] [S32] [S1302]

Binding every published figure to a reproducible evidence graph, proportionate assurance and bounded wording turns carbon accounting into an operational asset. [S01] [S10] [S32] Chapter 14 integrates these accounting, abatement and assurance rules into GFT's four-phase, 18-month roadmap. [S10] [S13] [S23]

A claim is only as durable as the ledger that can rebuild its number from the factory floor.

CHAPTER SOURCE NOTES

S01 GHG Protocol. 2011.

S23 GHG Protocol and Carbon Trust. 2013.

S22 Textile Exchange. 2026-07-16.

S08 Science Based Targets initiative and World Resources Institute. 2019.

S04 GHG Protocol. 2004.

S32 European Parliament and Council of the European Union. 2024-02-28.

S1301 UK Competition and Markets Authority. 2021-09-20.

S06 European Commission. 2025-06-25.

S07 Textile Exchange. 2025-09-18.

S10 World Business Council for Sustainable Development. 2025-04-30.

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

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

S16 ecoinvent. 2025-11-05.

S20 UK Department for Energy Security and Net Zero. 2026-06-11.

S05 International Organization for Standardization. 2018-08.

S26 Watson and Wiedemann, Sustainability. 2019-07-15.

S11 Intergovernmental Panel on Climate Change. 2021-08-06.

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

S18 Smart Freight Centre. 2024.
S14 International Energy Agency. 2026-09-25.
S25 International Organization for Standardization. 2006-07.
S17 Quantis. 2026-10-09.
S24 International Organization for Standardization. 2006-07.
S31 Forfora et al., Sustainability. 2026-04-20.
S02 GHG Protocol. 2011.
R09 Ecofin Agency. Publication date unrecorded; inherited source-text check.
R10 Ecofin Agency. Publication date unrecorded; inherited source-text check.
S21 United Nations Industrial Development Organization. 2010.
S29 Food and Agriculture Organization of the United Nations. 2017.
S19 International Maritime Organization. 2024.
S03 GHG Protocol. 2015.
S13 International Finance Corporation. 2018-01-29.
R29 MDPI; industry inspection literature. Publication date unrecorded; inherited source-text check.
S28 World Bank. 2025-01-16.
S1302 European Commission. 2026-09-15.
S1303 United Nations. 2024-11-14.
S30 European Environment Agency. 2022.
S12 United Nations Environment Programme. 2021-11-08.

GREEN FUTURE TECH

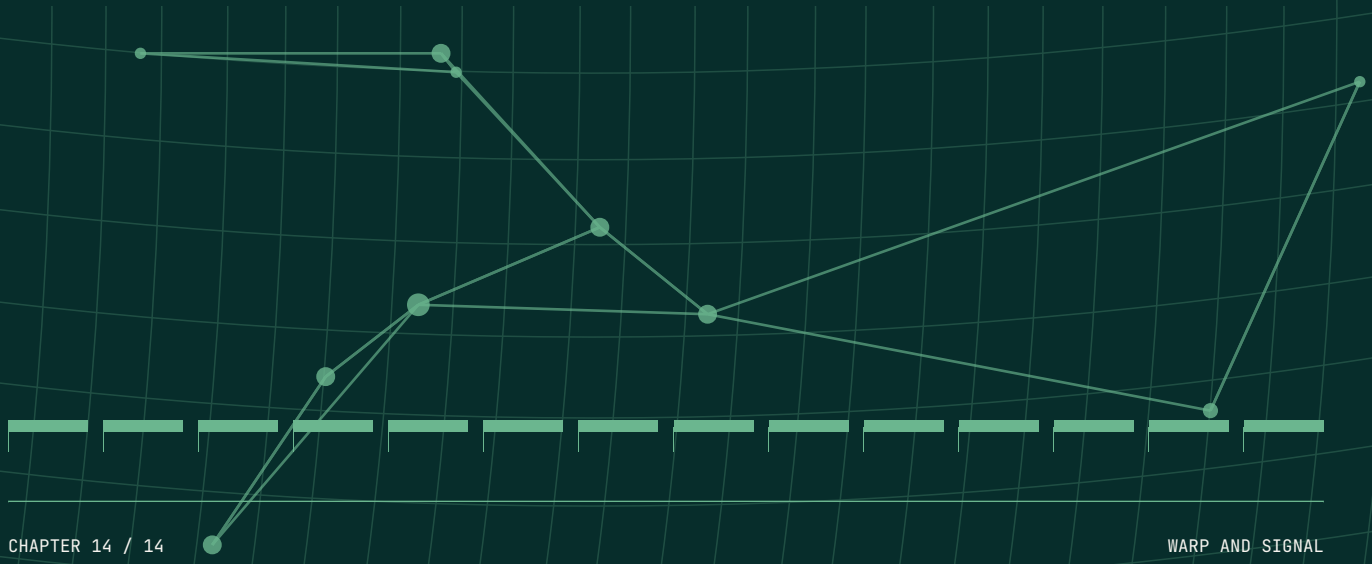
LIMITED / HONG KONG SAR

14

PART IV: MAKE THE ACCOUNT OPERABLE / RECOMMENDATIONS

GFT's roadmap makes every garment traceable to evidence

The first shift should produce a controlled carbon record that improves with each phase of the factory's operating system.



CHAPTER 14
DECISION TEST

The first shift should produce a controlled carbon record that improves with each phase of the factory's operating system.

A garment carbon footprint becomes an operational asset rather than a compliance liability only when the factory captures activity data, emission factors, allocation rules and quality yields inside a single phased management system from the first production shift. [S01] [S04] [S23] Across the preceding thirteen chapters, this paper has shown that carbon per garment is not a static constant attached to a fibre name or a country of origin, but the output of an explicit accounting architecture reconciling corporate inventories under the GHG Protocol Corporate Standard, Scope 2 Guidance and Scope 3 Standard with product life cycle accounts under the GHG Protocol Product Standard, ISO 14040, ISO 14044 and ISO 14067. [S01] [S02] [S03] [S04] [S05] [S24] [S25] Green Future Tech Limited (GFT), Hong Kong SAR, translates those rules into an executable 18-month roadmap that joins the three workstreams of GFT's Cameroon textile programme (feasibility study, performance-management system design and digital strategy, prepared 31 January 2024 with source-refresh notes retained in 2026) into one governed carbon operating system. [R06] [S20] [S23] Rather than waiting until full scale to hire an external consultant or buy carbon credits, the roadmap sequences work through four gated phases (Phase 0 pre-commissioning governance, Phase 1 line metering and baseline locking, Phase 2 hotspot proxy replacement and verified abatement, and Phase 3 automated supplier exchange and proportionate assurance) over four windows: Months 1 to 3, Months 4 to 8, Months 9 to 12 and Months 13 to 18. [S10] [S18] [S23] [S32]

The condition for advancing between phases is verifiable exit evidence, never elapsed calendar time alone. [S04] [S23] In Cameroon, where the inherited sector baseline records roughly 95 percent of cotton fibre exported raw and about 5 percent processed locally against a national target of 50 percent local processing by 2030 under SND30, new domestic spinning, weaving, dyeing and cut-make-trim capacity must be built with embedded measurement from day one. [R06] [R07] Third-party announcements in the register, including the planned SODECOTON and CICAM cotton-textile pole targeted by 2030 and the Camtext SA integrated project announced on 12 November 2025 at US$300 million (180 billion XAF) to process 12,000 tonnes of cotton per year with optimal capacity around 2033, show the scale of planned capacity alongside legacy utilisation challenges at CICAM (reported in July 2023 at 33.7 percent at Garoua, 48.9 percent at CICAM 1 and 10.83 percent at CICAM 2, with underutilisation costing about 2 billion XAF in 2020 and restructuring estimates of 30.7 billion to 70.2 billion XAF). [R08] [R09] [R10] [R12] [R13] None of those third-party announcements or sector baselines is a measured GFT factory footprint. [R06] [S04] GFT asserts no garment carbon figure before site meters and production logs operate. [S04] [S20] Because industrial commissioning, energy contracting and environmental claims carry project-specific financial and statutory obligations, the roadmap, gates and illustrative calculations in this chapter are engineering and accounting frameworks, not investment, legal or tax advice. [S04] [S32]

14.1

Phase 0 defines governance before machinery starts

A factory that energises its main switchgear and cutting tables before defining its carbon chart of accounts guarantees months of unallocable utility bills and incompatible spreadsheets. [S04] [S20] [S23] Phase 0 executes during the pre-commis-

sioning window (the 90 days before the first shift, bridging into Months 1 to 3) to lock the institutional and mathematical rules of the carbon account before any lint or fabric enters the line. [S01] [S04] [S23] Under ISO 14040, the intended application of any life cycle study belongs inside the initial definition of goal and scope. [S24] Equally, the GHG Protocol Corporate Standard requires an organisation to fix its consolidation boundary and operational scopes before compiling activity records. [S04]

14.2 SIX PRE-COMMISSIONING CHARTERS LOCK THE CHART OF ACCOUNTS AND FACTOR REGISTER BEFORE THE FIRST SHIFT

Phase 0 requires management to sign off six linked technical specifications prior to line start-up. [S01] [S04] [S23] First, the **organisational boundary charter** defines which facilities, boilers, backup diesel generators, effluent plants and vehicles fall under operational control for Scope 1 and Scope 2 reporting under the GHG Protocol Corporate Standard and Scope 2 Guidance. [S03] [S04] Second, the **product-family and functional-unit register** classifies planned styles into product families and assigns the three mandatory functional units from Chapter 3: per kilogram of intermediate textile for mill control, per accepted finished garment at the factory gate for buyer exchange, and per wear across declared consumer care and durability scenarios. [S01] [S26] [S31]

Third, the **reconciled carbon chart of accounts** maps every physical cost centre to both its organisational category (Scope 1 direct emissions, Scope 2 purchased energy, and the 15 Scope 3 categories) and its product life cycle stage (raw materials, upstream processing, assembly, logistics, use and end-of-life), ensuring that direct combustion factors, upstream fuel-cycle factors, grid generation factors, transmission loss factors and cradle-to-gate material factors occupy distinct account codes that are never summed twice. [S01] [S02] [S03] [S14] [S20] [S23] Fourth, the **versioned emission-factor and GWP register** locks the initial factor library, recording publisher, publication date, activity year, geography, gas coverage and the selected IPCC AR6 Global Warming Potential horizon (such as GWP100 under IPCC AR6 Working Group I Chapter 7), drawing on IEA Emissions Factors 2026 for national power and heat grids, UK DESNZ 2026 conversion factors for fuels and freight, and `ecoinvent` and Quantis WALDB for secondary screening proxies. [S11] [S14] [S16] [S17] [S20]

Fifth, the **allocation and base-year recalculation rulebook** sets the physical allocation hierarchy for shared utilities (sub-metered line kilowatt-hours and steam mass first, followed by machine hours or standard allowed minutes, barring revenue splits) and fixes the significance threshold (such as an illustrative 5 percent structural or methodological change threshold) that triggers mandatory base-year recalculation. [S04] [S23] [S24] Sixth, the **claims and sign-off matrix** designates a single claim owner (the performance and sustainability lead) who holds veto authority over any external carbon statement, barring unverified proxies or offset-based neutrality labels prohibited by Directive (EU) 2024/825. [S04] [S32]

14.3 DRY-RUNNING ONE REPRESENTATIVE GARMENT EXPOSES MISSING DENOMINATORS AND PROXY RISK BEFORE PRODUCTION BEGINS

Before commercial shifts begin, Phase 0 requires an end-to-end methodological pilot on one representative garment (such as a 0.250 kg finished cotton T-shirt, matching the reference mass in Forfora et al., 2026) using synthetic shift logs and secondary screening factors. [S22] [S23] [S31] This dry run does not estimate the factory's eventual

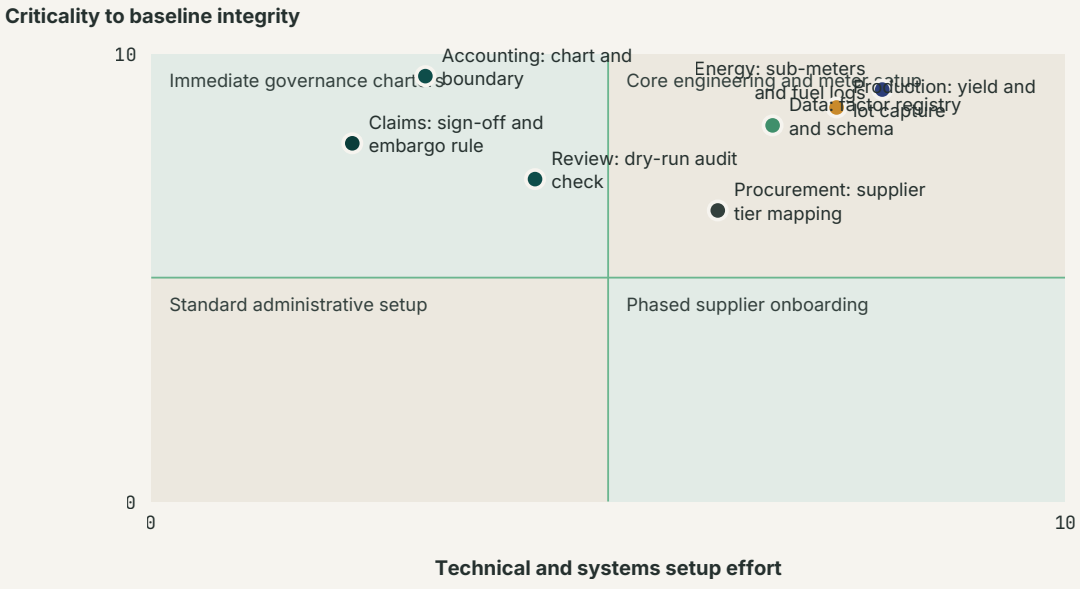
footprint, which remains unknown until meters run; it verifies that every calculation joint resolves cleanly and that every secondary proxy is tagged for replacement. [S16] [S22] [S23]

In the dry run, the bill of materials traces cumulative losses stage by stage: as Forfora et al. (2026) show, a 31 percent cumulative cradle-to-gate cotton loss means a 0.250 kg finished shirt requires approximately 0.362 kg of upstream cotton fibre input (`0.250 / (1 - 0.31) = 0.3623 kg`), with waste routed to documented recovery or disposal processes. [S25] [S31] Every background factor pulled from `ecoinvent` or literature during Phase 0 enters a **proxy replacement log** scored across the five quality dimensions in GHG Protocol Scope 3 Technical Guidance (technology, time, geography, completeness and reliability) so the team knows before the first shift which upstream inputs (synthetic nitrogen fertiliser manufacturing and field nitrous oxide emissions noted by FAO, cottonseed co-product allocation highlighted by Watson and Wiedemann, or regional spinning electricity) dominate screening uncertainty. [S16] [S22] [S23] [S26] [S29]

Exhibit 64, p. 232 maps the seven functional roles in the factory start-up team by their technical setup effort and their criticality to baseline integrity. [S04] [S20] [S23]

EXHIBIT 64 / ILLUSTRATIVE READINESS INDEX (0 TO 10)

The first 90 days assign owners, evidence and decisions



ILLUSTRATIVE [S04] [S20] [S23] Illustrative 90-day pre-commissioning and start-up matrix derived from inventory governance and activity-data requirements in the GHG Protocol Corporate Standard (S04), UK DESNZ conversion factor activity rules (S20) and Scope 3 Technical Guidance (S23). Horizontal position scores setup effort across hardware and IT integration (0 to 10); vertical position scores criticality for locking a valid Phase 1 baseline (0 to 10). Coordinates are illustrative management-planning indices, not measured site performance.

As **Exhibit 64**, p. 232 illustrates, the accounting boundary charter and claims embargo rule require low hardware effort (`x = 2.2` to `3.0` on the illustrative 0 to 10 scale) but carry high criticality (`y = 8.0` to `9.5`) because they prevent premature external statements and double counting from day one. [S04] [S23] [S32] Installing and calibrating sub-meters alongside lot and yield capture requires higher engineering effort (`x = 7.5` to `8.0`) and must be scheduled early so physical capture is live when

Phase 1 begins. [S20] [S23] What **Exhibit 64**, p. 232 cannot establish is the exact capital cost or lead time of metering hardware for a specific mill, which depends on switchboard and boiler layouts verified during site engineering. [S13] [S20]

14.4

Phase 1 meters the first lines and fixes the baseline

Once commercial lines start running (Months 1 to 3 for clean capture, extending through Months 4 to 8 for active baseline management), Phase 1 replaces synthetic dry-run templates with metered operational activity data. [S04] [S20] [S23] The central rule of Phase 1 is that **carbon capture is not a separate reporting workflow**: fuel volumes, electricity kilowatt-hours, steam mass, raw materials, started garments, accepted garments, rework and solid waste are recorded in the same daily shift log and relational database that run production and quality management. [S20] [S23] In GFT's Cameroon textile programme, the performance-management system specifies daily line logs and a plant sustainability log tracking energy, water and waste per unit alongside Overall Equipment Effectiveness (OEE) and first-pass yield. [R06] [S20] Phase 1 connects those physical fields directly to the Phase 0 factor register. [S14] [S20] [S23]

14.5 JOINING PHYSICAL UTILITY LOGS TO ACCEPTED-UNIT PRODUCTION RECORDS PREVENTS DENOMINATOR DRIFT

A carbon intensity figure (`kg CO2e per accepted garment`) has a greenhouse gas numerator and a physical output denominator. [S20] [S23] [S26] If utility meters are read monthly from grid invoices while garment output is logged daily using uncalibrated tally sheets that mix started pieces, reworked pieces and seconds, the ratio drifts every week. [S04] [S20] [S23] Phase 1 eliminates that mismatch by synchronising the time window and batch identity of utility and production capture. [S20] [S23]

On the utility side, main grid electricity meters, solar photovoltaic inverters, battery storage meters, backup diesel generator fuel flowmeters (cross-checked against tank dip readings and fuel receipts), boiler fuel meters (in litres, cubic metres or kilograms), and header steam flowmeters are logged at shift boundaries, while refrigerant top-ups in chillers and HVAC units are logged from maintenance certificates in kilograms by gas blend. [S03] [S04] [S11] [S14] [S20] On the production side, every order records fabric roll mass issued to cutting (`kg`), marker offcuts (`kg`), trims and packaging (`kg`), started units entering sewing, first-pass accepted units passing final inspection, reworked units, and rejected scrap (`kg` and pieces). [S20] [S23] [S31] In Cameroon and comparable hubs, inspection accuracy governs the validity of the accepted-unit denominator: manual fabric defect inspection achieves only 60 to 70 percent accuracy and misses 20 to 30 percent of defects, whereas automated computer-vision line-scan inspection reaches above 90 percent accuracy across more than 40 defect types at speeds up to 60 metres a minute (within a fabric-defect-detection AI market valued at US$523.4 million in 2024 and projected to reach US$6,522.1 million by 2033 at 33.8 percent a year). [R28] [R29] Catching fabric defects before cutting avoids investing sewing and finishing energy into garments that will be rejected, and the European Commission's Ecodesign for Sustainable Products Regulation ban on des-

troying unsold clothes and shoes (applying from 19 July 2026 for large companies and 2030 for medium-sized companies) reinforces why preventing unsaleable output is both an operational and a climate imperative. [R29] [S1403]

PHASE 1 DAILY CAPTURE AND MONTHLY RECONCILIATION PROTOCOL

Phase 1 enforces a five-step capture and reconciliation sequence across all operating lines: [S04] [S20] [S23]

1. **Shift-level physical logging (every 8-hour or 12-hour shift):** Supervisors and gateways record electrical energy (`kWh`) by board, backup diesel (`litres`), boiler fuel (`kg` or `litres`), steam (`kg`), fabric issued (`kg`), offcuts and waste (`kg` by route), units started, units reworked, and net accepted garments packed. [S20] [S23]
2. **Batch and style allocation (daily close):** Direct line electricity is assigned to orders by metered line kilowatt-hours or standard allowed minutes; shared utilities (compressed air, HVAC, lighting, effluent) are allocated using the Phase 0 physical hierarchy, keeping sum-allocated kilowatt-hours equal to metered plant kilowatt-hours. [S20] [S23] [S24]
3. **Purchased-input and inbound-freight matching (per goods-received note):** Every inbound batch of lint, yarn, fabric, chemicals, trims and packaging is logged with net mass (`kg`), supplier location, mode, distance (`km`), vehicle or vessel class, and load factor for Scope 3 Category 1 and Category 4 calculations under GHG Protocol and GLEC rules. [S02] [S18] [S20] [S23]
4. **Monthly invoice-to-meter reconciliation (within 5 working days of month-end):** Energy and accounting leads reconcile shift electricity sums against utility invoices, diesel flowmeters against tank stock balances, and fabric issues plus offcuts against warehouse stock and shipped garment mass, auditing any variance above an illustrative 2.0 percent tolerance before locking the monthly ledger. [S04] [S20]
5. **Dual Scope 2 and factor-vintage application (monthly ledger lock):** Validated quantities are multiplied by locked Phase 0 factors, generating parallel location-based and market-based Scope 2 accounts and keeping direct combustion (`Scope 1`), generation (`Scope 2`), and upstream fuel-and-loss (`Scope 3 Category 3`) emissions separate. [S03] [S14] [S20] [S23]

14.6 RECONCILING THE FIRST CORPORATE INVENTORY AGAINST THE CRADLE-TO-GATE PILOT ESTABLISHES THE AUDITABLE BASE YEAR

Phase 1 culminates at Month 8 by delivering two reconciled outputs before any garment figure is published externally: a complete organisational greenhouse gas inventory across Scopes 1, 2 and relevant Scope 3 categories, and a cradle-to-gate product footprint pilot for core garment families. [S01] [S02] [S04] [S23] Keeping external garment claims under embargo during Phase 1 is essential because early commissioning shifts exhibit elevated scrap and baseload energy per unit while lines stabilise. [R12] [S04] [S23]

During Phase 1, the corporate-to-product reconciliation bridge from Chapter 2 is executed on real records. [S01] [S04] [S23] Total Scope 1 and Scope 2 factory emissions for the period must equal the sum of factory-stage emissions allocated across all accepted garments produced, plus any separated commissioning loads. [S04] [S23] Upstream Scope 3 Category 1 and Category 4 totals must reconcile with the cradle-

to-gate material and inbound-freight burdens summed across all garment lots, adjusted for stock changes. [S02] [S18] [S23] Downstream scenarios for distribution (Category 9), consumer laundering (Category 11) and end-of-life (Category 12) are stored in separate database columns from the measured cradle-to-gate record so measured factory performance and assumed consumer behaviour are never conflated. [S01] [S12] [S23] [S30]

14.7

Phase 2 replaces hotspots with supplier evidence and abatement

Once Phase 1 locks a reconciled baseline, Phase 2 (Months 4 to 8 for active hotspot management and Months 9 to 12 for proven improvements) replaces the highest-uncertainty secondary proxies with primary supplier evidence and sub-metering while implementing physical abatement verified against the stable baseline. [S08] [S10] [S13] [S23]

14.8 RANKING PROXY CONTRIBUTIONS DIRECTS SUPPLIER REQUESTS AND SUB-METERING TO THE LARGEST UNCERTAINTIES

As Chapter 4 established, the GHG Protocol Scope 3 Technical Guidance warns that supplier data are not automatically more accurate than industry averages if supplier boundaries or allocation rules are weak, and directs primary collection to the activities with the largest emissions, uncertainty and abatement potential. [S23] Both SBTi sector guidance and empirical life cycle studies (including the European Environment Agency's finding that about 80 percent of textile climate impact occurs in production, and Forfora et al.'s 2026 T-shirt assessment) show that upstream fibre cultivation, yarn spinning and wet processing dominate cradle-to-gate burdens. [S08] [S30] [S31]

In Phase 2, procurement ranks every proxy in the Phase 1 inventory by its share of cradle-to-gate emissions multiplied by its uncertainty range and targets the top three to five upstream hotspots (cotton ginning and lint supply, spinning, knitting or weaving, wet processing, and main freight corridors). [S08] [S18] [S23] [S31] For those priority suppliers, GFT replaces generic `ecoinvent` or WALDB averages with primary product footprints exchanged under WBCSD PACT Methodology Version 3 (published 30 April 2025), requiring each supplier record to declare its period, boundary, primary-data share, electricity basis, co-product allocation rule and verification status. [S10] [S16] [S17] [S26] Following UNIDO's supplier capability findings, GFT works directly with domestic ginning and mill partners to standardise meter logging and activity templates rather than passing down unpriced compliance demands. [R03] [S21] [S29]

14.9 SEPARATING OPERATIONAL ABATEMENT FROM FACTOR UPDATES PROVES WHAT ENGINEERING CHANGED

Alongside proxy upgrades, Phase 2 executes physical efficiency and decarbonisation projects inside the factory and across freight routes, following the IFC Partnership for Cleaner Textiles (PaCT) sequence from wet processing to the wider value chain. [S08] [S13] To evaluate those interventions rigorously, GFT applies the decomposition rules of the GHG Protocol Corporate Standard, Scope 3 Technical Guidance and Policy and Action Standard (S1402, published November 2014). [S04] [S23] [S1402]

Between base period `0` and reporting period `t`, unit emissions change through three distinct mechanisms: [S04] [S23] [S1402] 1. **Physical activity and yield improvement (`Delta_activity`):** Fewer kilowatt-hours, kilograms of steam or litres of diesel per kilogram of fabric, or higher first-pass inspection yield reducing the scrap-and-rework multiplier per accepted garment. [S13] [S20] [S23] 2. **Energy-supply and procurement decarbonisation (`Delta_supply`):** Commissioning on-site solar photovoltaics and battery storage (evaluated with IRENA renewable cost benchmarks, where solar PV stood at USD 44/MWh in 2024 and 2025, alongside Cameroon grid and outage profiles noted by the World Bank and IEA) to displace backup diesel, switching boiler fuels, or consolidating sea-and-rail freight under the GLEC Framework and IMO marine fuel life cycle rules. [S09] [S15] [S18] [S19] [S28] 3. **Methodological or emission-factor updates (`Delta_method`):** Replacing a background database proxy with a supplier PACT record, or updating national grid factors across IEA editions. [S10] [S14] [S16] [S23]

Phase 2 governance forbids counting `Delta_method` as operational abatement: whenever replacing a proxy shifts the baseline beyond the significance threshold, the base year is restated on the same basis so reported savings reflect only verified physical actions (`Delta_activity + Delta_supply`). [S04] [S23]

WORKED EXAMPLE: PHASED PROXY REPLACEMENT AND VERIFIED ABATEMENT ACROSS AN 18-MONTH FACTORY RAMP

Consider an **illustrative** worked example for a Cameroonian cut-make-trim and finishing line producing a 0.250 kg cotton crew-neck T-shirt (`functional unit = 1 accepted garment at the factory gate`, cradle-to-gate boundary). [S01] [S23] [S31] All figures are **illustrative** method demonstrations constructed to show accounting reconciliation, not measured results of a GFT facility. [S04] [S23]

Step 1: Phase 1 baseline lock (Month 8 annualised run-rate). At an illustrative baseline output of `Q_0 = 1,000,000` accepted shirts per year and a `92.0 percent` first-pass yield (`5.0 percent` reworked, `3.0 percent` rejected scrap, requiring `1,030,928` started shirts), the initial Phase 1 account records: [R29] [S04] [S23]

- **Factory Scope 1 and Scope 2 (metered primary data):** `420,000 kg CO2e` per year, or `0.420 kg CO2e` per accepted shirt. [S03] [S04] [S20]
- **Inbound freight and cutting waste (Scope 3 Categories 4 and 5, metered mass/distance with DESNZ/GLEC factors):** `180,000 kg CO2e` per year, or `0.180 kg CO2e` per accepted shirt. [S18] [S20] [S23]
- **Purchased knitted dyed cotton fabric and trims (Scope 3 Category 1, secondary proxy):** Using a conservative regional proxy for `0.362 kg` gross cotton input per shirt (reflecting the 31 percent cumulative cotton loss in Forfora et al., 2026), upstream materials screen at an illustrative `3.400 kg CO2e` per shirt (`3,400,000 kg CO2e` per year). [S16] [S23] [S31]
- **Phase 1 initial total:** `4.000 kg CO2e` per accepted shirt (`4,000 tonnes CO2e` per year), with a **primary-data share of 15.0 percent** (`(0.420 + 0.180) / 4.000 = 15.0%`). [S10] [S23]

Step 2: Phase 2 proxy replacement and base-year restatement (Month 10). Onboarding the domestic cotton ginning, spinning and wet-processing chain onto WBCSD PACT Version 3 primary records replaces the `3.400 kg CO2e` regional proxy with a verified supplier footprint of `2.700 kg CO2e` per accepted shirt (`-0.700 kg CO2e`), reflecting hydropower-dominant grid electricity and biomass steam. [R03] [S10] [S28] [S31]

- Because this `17.5 percent` shift (`0.700 / 4.000`) exceeds the illustrative `5.0 percent` recalculation threshold, the `-0.700 kg CO2e` change is booked strictly as `Delta_method`, restating the Phase 1 base year to `3.300 kg CO2e` **per accepted shirt** (`3,300 tonnes CO2e` per year at `Q_0 = 1,000,000`) and raising primary-data coverage to an illustrative `90.9 percent` (`(0.420 + 0.180 + 2.400 primary supplier share) / 3.300 = 90.9%`). [S04] [S10] [S23]

Step 3: Phase 2 verified abatement and ramp check (Month 12). Between Months 8 and 12, output expands by `25.0 percent` to an illustrative `Q_1 = 1,250,000` accepted shirts per year while four measured actions take effect: [S13] [S23] 1. **Computer-vision fabric inspection and marker optimisation:** Cutting final rejection from `3.0 percent` to `1.0 percent` saves an illustrative `0.060 kg CO2e` per shirt (`Delta_activity_yield = -0.060 kg CO2e`). [R29] [S23] [S1403] 2. **Motor right-sizing, steam-trap repair and condensate return:** Thermal and electrical efficiency cuts factory energy by an illustrative `0.090 kg CO2e` per shirt (`Delta_activity_energy = -0.090 kg CO2e`). [S13] [S20] 3. **On-site solar PV with storage displacing backup diesel:** Cuts factory Scope 1, Scope 2 and fuel-cycle burdens by an illustrative `0.150 kg CO2e` per shirt (`Delta_supply_power = -0.150 kg CO2e`). [S03] [S15] [S28] 4. **Sup-**

plier dye-bath heat recovery and container consolidation: Verified supplier PACT and GLEC improvements cut upstream burdens by an illustrative `0.290 kg CO2e` per shirt (`-0.250` wet processing and `-0.040` freight). [S10] [S13] [S18]

Step 4: Reconciled Month 12 illustrative check against intensity and absolute gates. [S04] [S08] [S23]

- Verified physical abatement totals `0.060 + 0.090 + 0.150 + 0.290 = 0.590 kg CO2e` per accepted shirt, lowering restated cradle-to-gate intensity from `3.300` to `2.710 kg CO2e` **per shirt** (a `17.88 percent` **physical intensity cut**). [S04] [S23] [S1402]
- At `Q_1 = 1,250,000` shirts, total cradle-to-gate emissions are `3,387.5 tonnes CO2e` **per year** (`1,250,000 * 2.710 kg`), sitting `87.5 tonnes CO2e` (`+2.65 percent`) above the restated `3,300.0 tonnes CO2e` base year because a `25.0 percent` volume expansion requires a `20.0 percent` intensity cut (`0.25 / 1.25`) to hold absolute tonnes flat. [S07] [S08] [S23]
- Inside the factory fence, direct and purchased-energy intensity fell from `0.420` to `0.180 kg CO2e` per shirt (`-57.14 percent`), cutting absolute Factory Scope 1 and 2 emissions from `420.0 tonnes` **to** `225.0 tonnes CO2e` **per year** (`-46.43 percent` absolute reduction despite `+25.0 percent` output growth). [S04] [S08]
- **Gate 2 decision:** Approve the verified `46.43 percent` absolute factory cut and `17.88 percent` unit product cut, while requiring an additional `0.070 kg CO2e` per shirt of upstream supplier abatement (`to reach 2.640 kg CO2e`) in Phase 3 to bring cradle-to-gate absolute tonnes below `3,300 tonnes CO2e`. [S08] [S23]

14.10

Phase 3 automates exchange and verifies selected claims

By Month 13 (Months 13 to 18), the factory holds a metered daily operating record, a reconciled base year and primary supplier coverage across major hotspots. [S10] [S20] [S23] Phase 3 converts that workflow into repeatable digital exchange and applies proportionate independent review before external publication. [S10] [S18] [S25] [S32]

14.11 MACHINE-READABLE PRODUCT AND FREIGHT PACKETS CONNECT FACTORY RECORDS TO BUYER AND REGULATORY REGISTRIES

Manually re-keying spreadsheets for each customer portal creates transcription errors and version drift. [S10] [S21] [S23] Phase 3 standardises exchange across three digital interfaces: [S10] [S18] [S1401] 1. **WBCSD PACT Methodology Version 3 API packets (`S10`):** Every garment family exports a PACT-compliant JSON record carrying product identifiers, period, cradle-to-gate boundary, functional units (`1 accepted garment` and `1 kg net garment`), total `kg CO2e`, separated fossil and biogenic carbon flows under ISO 14067, primary-data share, quality scores and verification metadata. [S05] [S10] 2. **Smart Freight Centre GLEC Framework and ISO 14083 logistics packets (`S18`, `S19`):** Inbound and outbound shipments append GLEC records separating well-to-tank and tank-to-wake emissions across road, rail, hub and maritime legs under IMO marine fuel life cycle guidelines. [S18] [S19] 3. **European Union Digital Product Passport (DPP) Registry integration (`S1401`):** Under the Ecodesign for Sustainable Products Regulation (ESPR, Regulation (EU) 2024/1781), textiles are a priority group for Digital Product Passports, and on 20 July 2026 the European Com-

mission launched the live Digital Product Passport Registry and API, enabling operators to register unique product identifiers, decentralised data pointers and B2B compliance proofs directly from existing digital systems alongside EU Apparel PEFCR lifecycle records (S06, published 25 June 2025). [S06] [S1401]

14.12 PROPORTIONATE CRITICAL REVIEW AND STRICT OFFSET SEPARATION PROTECT EXTERNAL CLAIMS FROM REGULATORY FAILURE

As Chapter 13 established, assurance depth follows intended use: internal line control relies on automated mass-balance and meter-to-invoice checks, B2B PACT exchange uses third-party verification of the facility calculation engine and primary-data share, and public comparative claims require a critical review panel under ISO 14040 and ISO 14044 plus EU Apparel PEFCR equivalence. [S04] [S06] [S10] [S24] [S25] [S26]

Above all, Phase 3 maintains a strict firewall between the product inventory and external carbon credits. [S01] [S05] [S32] Under Directive (EU) 2024/825 on consumer protection for the green transition (adopted 28 February 2024), claiming based on greenhouse gas offsetting that a product has a neutral, reduced or positive impact on the environment in terms of greenhouse gas emissions is prohibited; claims must reflect actual lifecycle impact. [S32] GFT's Phase 3 claims control therefore releases only bounded, evidence-backed statements: verified cradle-to-gate `kg CO2e per accepted garment` for a named period, verified Factory Scope 1 and 2 reductions against a stated base year, or full cradle-to-grave footprints with disclosed care and durability parameters. [S01] [S06] [S32]

14.13

GFT measures carbon beside production, quality, delivery and cost

A carbon accounting system endures only when executives and line supervisors review carbon metrics inside the same weekly and monthly meetings where they govern throughput, defects, delivery and cost. [S04] [S13] [S23] In GFT's Cameroon textile programme, the performance-management system organises factory governance around six KPI families (throughput and OEE, quality and first-pass yield, maintenance, supply chain and inventory, workforce and safety, and sustainability) across four cadences (shift handover, daily huddle, weekly operational review and monthly board review). [R06] [S20]

14.14 THE BOARD GOVERNANCE CADENCE PAIRS ABSOLUTE EMISSIONS, UNIT INTENSITIES AND DATA-QUALITY COVERAGE

As Textile Exchange's 2025 report on global fibre volume growth (`125 million tonnes` in 2023 to `132 million tonnes` in 2024) and SBTi's apparel guidance demonstrate, watching unit intensity alone hides volume-driven absolute increases, while watching emissions without data-quality coverage lets secondary proxies masquerade as precision. [S07] [S08] [S23] GFT structures the monthly board view around six linked tiles, shown in **Exhibit 65**, `p. 240`. [S04] [S07] [S10] [S23]

EXHIBIT 65 / ILLUSTRATIVE MONTHLY BOARD GOVERNANCE INDICATORS

The board dashboard tracks carbon, activity, quality and proof

225 t / 3,388 t **Absolute CO2e (Scopes 1+2 / Cradle-to-gate)** Illustrative annualised run-rate vs 420 t / 3,300 t restated base year	**2.71 kg CO2e** **CO2e per accepted garment (Cradle-to-gate)** Illustrative 0.250 kg cotton shirt; down from 3.30 kg restated base	**0.072 kg CO2e** **CO2e per wear (Cradle-to-grave scenario)** Illustrative 50-wear scenario including 0.90 kg use/end-of-life block
90.9% **Primary-data share (Cradle-to-gate)** Illustrative share of footprint from metered site and PACT supplier logs	**1 stage** **Unresolved proxy hotspots (>5% share)** Illustrative remaining proxy: farm-level fertiliser N2O field factor	**-0.59 kg / unit** **Verified physical abatement (vs base)** Illustrative -17.9% physical cut separated from -0.70 kg method restatement

ILLUSTRATIVE [S04] [S07] [S10] [S23] [S32] Illustrative board dashboard schema reflecting the Month 12 worked-example state to demonstrate GFT's six-metric executive cadence. Values shown (225 t CO2e Factory Scopes 1+2, 3,388 t CO2e cradle-to-gate total, 2.71 kg CO2e per accepted shirt, 0.072 kg CO2e per wear at 50 illustrative wears, 90.9% primary-data share, and -17.9% verified unit abatement) are illustrative method outputs from the worked case, not measured operating results of a GFT facility.

In **Exhibit 65**, p. 240, Tile 1 pairs direct operational emissions (Scopes 1 and 2) with cradle-to-gate product totals so the board sees immediately when volume expansion (+25 percent in the illustrative case) pushes total cradle-to-gate emissions (3,388 tonnes CO2e) above the restated base year (3,300 tonnes CO2e) even while direct factory emissions fell by 46.4 percent (225 tonnes vs 420 tonnes). [S04] [S07] [S08] Tile 2 tracks the commercial PACT metric (kg CO2e per accepted garment), while Tile 3 tracks kg CO2e per wear across a declared 50-wear scenario (adding an illustrative 0.900 kg CO2e downstream block to 2.710 kg CO2e cradle-to-gate to yield 3.610 / 50 = 0.0722 kg CO2e per wear) so lightweighting never passes if it degrades durability. [S10] [S12] [S26] [S30] Tiles 4, 5 and 6 track primary-data coverage (90.9 percent), remaining material proxies, and verified physical abatement (-0.590 kg CO2e per unit) separated from method restatement (-0.700 kg CO2e). [S10] [S23] [S1402] What **Exhibit 65**, p. 240 cannot replace is the underlying parameter uncertainty distribution or non-climate PEFCR indicators (water, toxicity, land use), which must be checked alongside carbon before approving process changes. [S05] [S06] [S31]

14.15 SHIFT AND LINE LOGS TRANSLATE CARBON TARGETS INTO PHYSICAL LEVERS OPERATORS CAN CONTROL

Line supervisors and maintenance technicians manage kilowatt-hours, diesel litres, steam kilograms, marker efficiency and defect rework rather than abstract tonnes of CO2e. [S13] [S20] In GFT's operating design, the daily shift handover and weekly line review display the six physical drivers that feed the carbon calculation: [S20] [S23]

- **Electricity intensity (`kWh per 100 accepted garments`):** Split between direct line boards and shared HVAC/lighting baseload to expose idle equipment left energised between shifts. [S14] [S20]
- **Backup generator fuel ratio (`litres of diesel per MWh` and `% of hours on backup`):** Tracking grid outage impact and solar-plus-storage dispatch efficiency. [S15] [S20] [S28]
- **Thermal intensity (`kg of steam or MJ of boiler fuel per kg of finished fabric`):** Exposing steam-trap blow-through, insulation loss or under-loaded wet batches. [S13] [S20] [S31]
- **Material utilisation (`gross kg of fabric issued per net kg of accepted garments`):** Tracking cutting and sewing waste against the 31 percent cumulative cotton loss benchmark in Forfora et al. (2026). [S23] [S31]
- **First-pass quality yield (`% of started units accepted without rework or rejection`):** Quantifying the energy and fabric penalty of defects. [R29] [S23]
- **Solid waste routing (`kg of offcuts sent to verified recycling vs incineration or landfill`):** Supporting Scope 3 Category 5 and EU ESPR compliance. [S20] [S27] [S30] [S1403]

> **GFT NOTE**
>
> **Embed carbon calculation inside the factory's edge-to-cloud production ledger rather than purchasing a standalone sustainability reporting silo.** In GFT's three-part Cameroon textile programme (feasibility study, performance-management system design and digital strategy), the digital architecture uses shop-floor edge capture (local industrial gateways buffering meter pulses, bundle scans and inspection tallies during power or internet interruptions) synchronised to a central relational database. [R06] [S20] GFT recommends adding the emission-factor register and allocation rules directly as a calculation view on top of those production, utility and warehouse tables so every garment lot inherits the exact energy and material quantities recorded during the shifts that made it. [S04] [S10] [S20] [S23]

14.16

An 18-month sequence turns recommendations into gates

To make the carbon operating system executable alongside factory commissioning and ramp-up, GFT organises the roadmap across an 18-month numeric planning window divided into the four operational windows of GFT's programme cadence: **Months 1 to 3 (Clean Capture)**, **Months 4 to 8 (Active Management and Baseline**

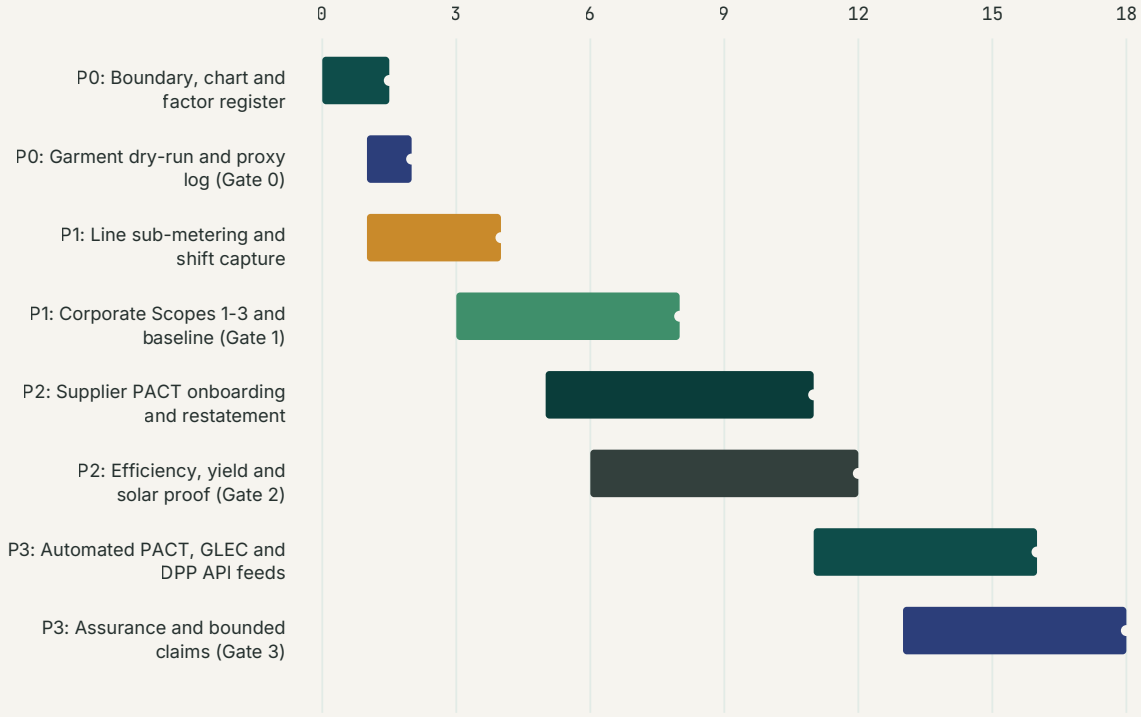
Lock), **Months 9 to 12 (Proven Improvements and Hotspot Replacement)**, and **Months 13 to 18 (Automated Supplier Exchange and Selected Assurance)**, preceded by Phase 0 pre-start governance. [S01] [S10] [S13] [S23]

14.17 FOUR SEQUENTIAL PHASE WINDOWS ALIGN CARBON MATURITY WITH INDUSTRIAL RAMP-UP

Exhibit 66, p. 242 sets out the eight core workstreams across the 18-month horizon (Month 0 to Month 18), derived from GFT's programme sequence and the requirements of the GHG Protocol (S01, S02, S03, S04, S23), IFC PaCT (S13), WBCSD PACT Version 3 (S10), Smart Freight Centre GLEC (S18), and EU claims and product-passport rules (S06, S32, S1401). [S01] [S04] [S10] [S13] [S18] [S23] [S32] [S1401]

EXHIBIT 66 / MONTHS FROM PROGRAMME START (0 TO 18)

An 18-month roadmap moves from manual evidence to verified exchange



DERIVED [S01] [S04] [S10] [S13] [S18] [S20] [S23] [S32] Derived 18-month implementation schedule joining GFT's four programme windows (Months 1 to 3 clean capture, Months 4 to 8 active management, Months 9 to 12 proven improvements, and Months 13 to 18 automated exchange and assurance, with pre-start governance in Months 0 to 1) to the accounting steps in GHG Protocol (S01, S04, S23), UK DESNZ activity rules (S20), IFC PaCT efficiency sequencing (S13), WBCSD PACT v3 (S10), GLEC freight (S18) and EU Directive 2024/825 (S32). Numeric positions represent planning months from programme approval, not achieved historical dates.

As **Exhibit 66**, p. 242 shows, Phase 0 governance and dry-run testing complete inside Months 0 to 2, overlapping with line sub-metering and shift capture in the Clean Capture window (Months 1 to 3). [S20] [S23] Across Months 3 to 8 (Active Management), the factory accumulates continuous shift records, reconciles meters against invoices, and locks its corporate Scope 1 to 3 inventory and cradle-to-gate pilot at Gate 1 (Month 8). [S02] [S04] [S23] Supplier PACT onboarding (Months 5 to 11) and engineering efficiency projects (Months 6 to 12) run through the Proven Improvements window so that at Gate 2 (Month 12) the factory restates its base year with primary supplier records and verifies physical abatement. [S10] [S13] [S23] In

Months 11 to 18, the programme automates PACT, GLEC and EU DPP API feeds and completes proportionate review for selected claims (Gate 3 at Month 18). [S10] [S25] [S32] What **Exhibit 66**, p. 242 cannot predict is customs or utility connection delays, which require holding the gate criteria firm even if calendar dates shift. [R01] [S28]

14.18 HARD EXIT GATES PREVENT PREMATURE CLAIMS AND LOCK IN BASE-YEAR INTEGRITY

Each phase ends with a hard governance gate (Gate 0, Gate 1, Gate 2 and Gate 3) rather than an automatic calendar rollover. [S04] [S23] [S32] If a factory reaches Month 8 with an 8 percent meter-to-invoice gap or unseparated rework counts, it fails Gate 1 and remains under external claims embargo until reconciliation passes. [S04] [S20] [S23] **Exhibit 67**, p. 243 defines the exit evidence, verification checks and permitted claim scope for all four gates. [S01] [S04] [S10] [S18] [S20] [S23] [S25] [S32] [S1401]

EXHIBIT 67 / GOVERNANCE GATE CRITERIA AND VERIFICATION RULES

Four phase gates require verifiable exit evidence before advancing

Gate and window	Mandatory exit evidence	Quantitative verification check	Permitted external claim scope
Gate 0 (Month 2: Pre-start)	Signed boundary charter, Scope 1-3 chart of accounts, AR6 factor register, 1-garment dry run and proxy log	100% of BOM and utility flows mapped without double counting; all proxies scored on 5 quality dimensions	Zero quantitative claims; methodological design disclosure only
Gate 1 (Month 8: Baseline lock)	Continuous shift utility, yield and waste logs; reconciled corporate Scopes 1-3 and cradle-to-gate pilot	Meter-to-invoice and mass balance variance within illustrative 2% tolerance; Scope 1+2 equals allocated product sum	Internal governance and confidential B2B screening under NDA; no public garment footprint
Gate 2 (Month 12: Proven abatement)	Top upstream proxies replaced by PACT v3 supplier records; base year restated; efficiency and energy actions metered	Primary-data share above target threshold; physical abatement separated from factor restatement and volume growth	Verified B2B PACT product footprints and audited facility Scope 1+2 reductions; no offset neutrality claims
Gate 3 (Month 18: Verified exchange)	Automated PACT v3, GLEC and EU DPP API feeds; ISO 14044/14067 critical review for selected public lines	Zero unresolved material proxies; full provenance from source meter to published wording; EU 2024/825 compliance check	Public cradle-to-gate or full lifecycle footprints with stated bounds; PEFCR-compliant comparisons only

SOURCED [S01] [S04] [S10] [S18] [S20] [S23] [S25] [S32] [S1401] Synthesised phase-gate control table combining inventory boundary and recalculation rules from GHG Protocol (S01, S04, S23), activity reconciliation from UK DESNZ (S20), supplier exchange from WBCSD PACT v3 (S10) and GLEC (S18), critical review from ISO 14044 (S25), digital registry integration from the European Commission DPP Registry (S1401), and anti-greenwashing claim rules from Directive (EU) 2024/825 (S32).

Inspecting **Exhibit 67**, p. 243 shows how the four gates protect both capital allocation and reputation: Gate 0 tests structural completeness, Gate 1 tests physical conservation between meters and invoices, Gate 2 tests analytical separation between method restatements and physical savings, and Gate 3 tests external defensibility under ISO critical review and Directive (EU) 2024/825. [S04] [S10] [S20] [S23] [S25] [S32]

UNRESOLVED SECTOR CONSTRAINTS REQUIRE SITE-SPECIFIC VALIDATION BEFORE GATE 2 AND GATE 3 SIGN-OFF

Four external constraints in the Cameroon and international evidence base cannot be solved by software alone and must be addressed before `Gate 2` and `Gate 3` sign-off: [R03] [S23] [S28]

1. **Farm-level nitrous oxide and soil-carbon factors for Cameroonian cotton (R03, S29, S31):** While the shared register documents more than 220,000 producers, nine ginning plants and two oil mills operated by SODECOTON producing roughly 314,455 to 350,000+ tonnes of seed cotton a year (R01, R02, R03), neither the register nor global LCA databases provide a verified field-level emission factor for Cameroonian nitrogen fertiliser application, soil carbon flux and ginning co-product allocation. [R01] [R02] [R03] [S16] [S29] Resolving this requires field-sampling and agronomic templates with ginning and producer organisations in Phase 2, keeping soil carbon separate from lint biogenic carbon under ISO 14067. [R03] [S05] [S29]
2. **Grid emission-factor vintage and outage volatility (S09, S14, S28):** Cameroon's grid is evolving as hydropower and solar expand while industrial users still experience outages requiring backup diesel. [S09] [S28] Resolving this requires continuous dual logging of grid kWh and generator fuel alongside annual updates from IEA Emissions Factors (S14). [S14] [S20] [S28]
3. **Informal labour and trade-regime uncertainty (R14, R16, R18, R23):** With roughly 90 percent informal employment (R16), a statutory minimum wage (SMIG) of 43,969 XAF a month from 23 February 2024 (R14), Cameroon's continued AGOA ineligibility as of 2025 (R18), and unresolved AfCFTA textile tariff lines (R23), order batch sizes can fluctuate during ramp-up, requiring sensitivity tests across 35 to 85 percent capacity utilisation (R12, S23). [R12] [R14] [R16] [R18] [R23] [S23]
4. **Missing annex references (R19 to R22):** References R19 to R22 remain absent from the verified register and are never cited in this paper; any assumption touching those topics must be independently sourced from primary publications before use. [R18] [R23]

14.19 CLOSING SYNTHESIS: ONE SYSTEM FROM FIBRE TO PROOF

Across all fourteen chapters of White Paper 16, GFT's argument has remained constant: **value is made where it is measured, and carbon can be reduced and defended only where it is accounted as rigorously as cash and physical mass.** [R06] [S01] [S04] [S23] Part I built the accounting architecture reconciling organisational Scopes 1, 2 and 3 with product footprints across explicit functional units (`per kilogram`, `per accepted garment` and `per wear`). [S01] [S02] [S04] [S23] [S26] [S31] Part II followed carbon through cotton farming, 31 percent cumulative processing losses and cotton-seed co-products, spinning and wet-processing energy, cut-make-trim denominators, GLEC and well-to-wake freight, and consumer care and end-of-life displacement. [S08] [S12] [S18] [S19] [S29] [S30] [S31] Part III linked hotspot abatement, clean power and thermal solutions to an absolute carbon budget (`E = Q * i`). [S07] [S08] [S13] [S15] [S28] Part IV has made the account operable through numerical provenance, EU-compliant claims control, and this 18-month gated roadmap. [S10] [S20] [S25] [S32] [S1401] When a factory builds this roadmap into its operating system

from shift one, every garment leaving the packing line carries a versioned, auditable link to the cotton field, the spinning frame, the dye bath, the boiler meter, the sewing line and the freight corridor that made it. [S01] [S10] [S18] [S1401]

A garment footprint earns trust only when the factory that weaves the cloth also weaves the proof.

CHAPTER SOURCE NOTES

S01 GHG Protocol. 2011.

S04 GHG Protocol. 2004.

S23 GHG Protocol and Carbon Trust. 2013.

S02 GHG Protocol. 2011.

S03 GHG Protocol. 2015.

S05 International Organization for Standardization. 2018-08.

S24 International Organization for Standardization. 2006-07.

S25 International Organization for Standardization. 2006-07.

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

S20 UK Department for Energy Security and Net Zero. 2026-06-11.

S10 World Business Council for Sustainable Development. 2025-04-30.

S18 Smart Freight Centre. 2024.

S32 European Parliament and Council of the European Union. 2024-02-28.

R07 Ecofin Agency. 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.

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

R13 Business in Cameroon; MMI News. Publication date unrecorded; inherited source-text check.

S26 Watson and Wiedemann, Sustainability. 2019-07-15.

S31 Forfora et al., Sustainability. 2026-04-20.

S14 International Energy Agency. 2026-09-25.

S11 Intergovernmental Panel on Climate Change. 2021-08-06.

S16 ecoinvent. 2025-11-05.

S17 Quantis. 2026-10-09.

S22 Textile Exchange. 2026-07-16.

S29 Food and Agriculture Organization of the United Nations. 2017.

S13 International Finance Corporation. 2018-01-29.

R28 DataIntelo. Publication date unrecorded; inherited source-text check.

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

S1403 European Commission. 2026-07-17.

S12 United Nations Environment Programme. 2021-11-08.

S30 European Environment Agency. 2022.

S08 Science Based Targets initiative and World Resources Institute. 2019.

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

S21 United Nations Industrial Development Organization. 2010.

S1402 GHG Protocol. 2014-11.

S09 International Energy Agency. 2026.

S15 International Renewable Energy Agency. 2026-07-02.

S19 International Maritime Organization. 2024.

S28 World Bank. 2025-01-16.

S07 Textile Exchange. 2025-09-18.

S1401 European Commission. 2026-07-20.

S06 European Commission. 2025-06-25.

S27 Ellen MacArthur Foundation. 2017.

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

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

R14 WageIndicator. Publication date unrecorded; inherited source-text check.

R16 WageIndicator. Publication date unrecorded; inherited source-text check.

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

R23 MacMap; AfCFTA. Publication date unrecorded; inherited source-text check.

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.

Inherited source-text check; original source not independently re-opened for this edition.

R15 Inherited evidence R15 GRADE C

wage.is. Publication date unrecorded. wage.is/cameroon

Source metadata retained for traceability. This entry is not cited in the chapter text.

Inherited source-text check; original source not independently re-opened for this edition.

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.

Inherited source-text check; original source not independently re-opened for this edition.

R17 Inherited evidence R17 GRADE C

just-style. Publication date unrecorded. just-style.com

Source metadata retained for traceability. This entry is not cited in the chapter text.

Inherited source-text check; original source not independently re-opened for this edition.

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.

Inherited source-text check; original source not independently re-opened for this edition.

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.

Inherited source-text check; original source not independently re-opened for this edition.

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.

Inherited source-text check; original source not independently re-opened for this edition.

R25 Inherited evidence R25 GRADE C

Market.us. Publication date unrecorded. market.us

Source metadata retained for traceability. This entry is not cited in the chapter text.

Inherited source-text check; original source not independently re-opened for this edition.

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).

Inherited source-text check; original source not independently re-opened for this edition.

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.

Inherited source-text check; original source not independently re-opened for this edition.

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.

Inherited source-text check; original source not independently re-opened for this edition.

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.

Inherited source-text check; original source not independently re-opened for this edition.

R30 Inherited evidence R30 GRADE C

Design Journal (Taylor and Francis). Publication date unrecorded. tandfonline.com

Source metadata retained for traceability. This entry is not cited in the chapter text.

Inherited source-text check; original source not independently re-opened for this edition.

R31 Inherited evidence R31 GRADE C

arXiv 2509.04705. Publication date unrecorded. arxiv.org/abs/2509.04705

Source metadata retained for traceability. This entry is not cited in the chapter text.

Inherited source-text check; original source not independently re-opened for this edition.

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.

Inherited source-text check; original source not independently re-opened for this edition.

c01-S01 Product Life Cycle Accounting and Reporting Standard GRADE A

GHG Protocol. 2011. https://ghgprotocol.org/product-standard

Opened source record.

Accessed 2026-10-30. Quote retained in the machine-readable source record.

c01-S02 Corporate Value Chain Scope 3 Accounting and Reporting Standard GRADE A

GHG Protocol. 2011. https://ghgprotocol.org/corporate-value-chain-scope-3-standard

Opened source record.

Accessed 2026-10-30. Quote retained in the machine-readable source record.

c01-S04 Corporate Accounting and Reporting Standard GRADE A

GHG Protocol. 2004. https://ghgprotocol.org/corporate-standard

Opened source record.

Accessed 2026-10-30. Quote retained in the machine-readable source record.

c01-S05 **ISO 14067:2018 Carbon footprint of products** GRADE A

International Organization for Standardization. 2018-08. https://www.iso.org/standard/71206.html

Opened source record.

Accessed 2026-10-30. Quote retained in the machine-readable source record.

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c01-S07 **Materials Market Report 2025** GRADE B

Textile Exchange. 2025-09-18. https://textileexchange.org/knowledge-center/reports/materials-market-report-2025/

Opened source record.

Accessed 2026-10-30. Quote retained in the machine-readable source record.

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c01-S08 **Apparel and Footwear Sector Science-Based Targets Guidance** GRADE B

Science Based Targets initiative and World Resources Institute. 2019. https://sciencebasedtargets.org/resources/legacy/2019/06/SBT_App_Guide_final_0718.pdf

Opened source record.

Accessed 2026-10-30. Quote retained in the machine-readable source record.

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c01-S09 **Cameroon country energy profile** GRADE A

International Energy Agency. 2026. https://www.iea.org/countries/cameroon

Opened source record.

Accessed 2026-10-30. Quote retained in the machine-readable source record.

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Stable definitions make comparisons useful.

Absolute emissions

The total greenhouse gas emissions within a declared boundary and period, before normalisation by output or another denominator.

Activity data

A quantitative measure of an activity that causes emissions, such as litres of fuel, kWh of electricity or kilograms of material.

Allocation

The assignment of shared inputs, outputs or emissions among products, processes or reporting entities using a documented rule.

Attributional LCA

A life cycle model that describes the average share of environmental burdens associated with a product system.

Base year

The reference period against which later emissions and reductions are compared.

Biogenic carbon

Carbon contained in biomass, whose uptake, storage and release must be represented separately from fossil carbon where relevant.

Carbon dioxide equivalent

A common unit that converts greenhouse gases using their selected global warming potentials, abbreviated CO2e.

Carbon footprint of a product

The sum of greenhouse gas emissions and removals for a product system, expressed as CO2e under a declared method.

Chain of custody

The documented path through which a material, product or item of evidence passes between owners and processes.

Co-product

Another valuable output produced alongside the principal product within the same system, such as cottonseed with lint.

Consequential LCA

A life cycle model that estimates how environmental burdens change in response to a decision, including market or substitution effects.

Cradle-to-gate

A boundary covering raw-material acquisition and production up to the point where a product leaves the supplier's gate.

Cradle-to-grave

A boundary covering raw materials, production, distribution, use and final disposal or recovery.

Critical review

A structured check that an LCA is consistent with the applicable standards, methods and evidence.

Data quality

The fitness of data for a stated use, assessed through dimensions such as technology, time, geography, completeness and reliability.

Emission factor

A coefficient that converts activity data into greenhouse gas emissions for a specified gas, boundary, geography and period.

Environmental Product Declaration

A standardised document reporting life cycle environmental information for a product under applicable product category rules.

Environmentally extended input-output model

A top-down model that estimates environmental flows from economic transactions between sectors, often used for screening.

Functional unit

The quantified function of a product system used as the reference for inputs, outputs and results.

Global warming potential

A metric that expresses the relative radiative effect of a greenhouse gas compared with carbon dioxide over a selected time horizon.

Greenhouse gas inventory

A structured account of greenhouse gas emissions and, where applicable, removals within a defined boundary and period.

Life cycle

The consecutive and interlinked stages of a product system, from raw-material acquisition to final disposition.

Life cycle assessment

The compilation and evaluation of inputs, outputs and potential environmental impacts throughout a product's life cycle.

Life cycle inventory analysis

The phase that compiles and quantifies the inputs and outputs belonging to a product system.

Life cycle impact assessment

The phase that evaluates the magnitude and significance of potential environmental impacts from inventory results.

Location-based method

A Scope 2 method that uses the average emissions intensity of the grids where electricity consumption occurs.

Market-based method

A Scope 2 method that uses emissions associated with electricity specifically chosen through contracts or instruments that meet quality criteria.

Primary data

Data collected for the specific activity, process, site or product under study.

Product category rules

Detailed rules that make life cycle studies within a product category consistent in areas such as boundary, allocation and reporting.

Product Environmental Footprint

A European Commission method for assessing life cycle environmental impacts across multiple impact categories.

PEFCR

Product Environmental Footprint Category Rules, the product-specific rules used within the PEF method.

Proxy data

Secondary data from a similar activity used to fill a gap for the activity under study.

Reference flow

The quantity of product required to deliver the functional unit within the studied system.

Scope 1

Direct greenhouse gas emissions from sources owned or controlled by the reporting organisation.

Scope 2

Indirect emissions from the generation of purchased or acquired electricity, steam, heat and cooling.

Scope 3

Other indirect emissions occurring in the reporting organisation's value chain, divided into 15 upstream and downstream categories.

Screening

An initial estimate used to identify significant activities, evidence gaps and priorities for more precise work.

Secondary data

Industry-average, database, literature, financial, proxy or other data not collected for the specific activity under study.

Sensitivity analysis

A test of how results change when an assumption, method, activity value or emission factor is varied.

System boundary

The set of criteria determining which processes and flows belong to the product system or inventory.

System expansion

A way of handling multi-functionality by adding the functions or displaced products associated with co-products rather than allocating between them.

Tank-to-wake

Emissions from fuel or energy already in a ship's tank through its use on board, excluding upstream production.

Tonne-kilometre

A freight activity unit equal to one tonne of goods transported for one kilometre.

Uncertainty analysis

The evaluation of how data, models and assumptions affect the reliability and range of a result.

Upstream emissions

Emissions occurring before a reporting organisation or process, including raw-material and fuel production.

Use phase

The life cycle stage in which a product is used and maintained, including washing, drying and ironing for apparel.

Well-to-wake

The complete fuel pathway from primary production through use on board a ship, combining well-to-tank and tank-to-wake.

Follow the terms back to their context.

Page references point to occurrences in chapter prose. When a term does not occur in a chapter, its glossary definition is indexed.

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