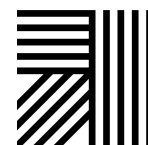


# Apparel Impact Institute's Energy and Carbon Benchmark Methodology

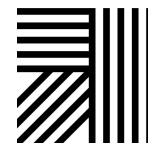


# Apparel Impact Institute’s Energy and Carbon Benchmark: Methodology

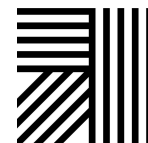
Draft v1.1 – May 2026

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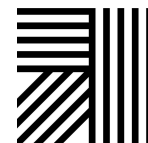
## 2. Context and Theory of Change

To date, over 600 apparel and footwear companies have approved science-based targets (SBTs) or made commitments to set them via the Science Based Targets initiative (SBTi). This is driving companies to take concrete steps to reduce greenhouse gas (GHG) emissions across the value chain. As companies develop plans to deliver on their SBTs, they are looking for robust, independent benchmarks or guidelines on “good” energy and GHG emissions performance for manufacturing processes and materials. For example, companies want to know the energy and GHG emissions profile for “better” performing textile mills versus average ones. With this information, brands can elect to source from suppliers that meet higher performance requirements, manufacturers can make operational and investment decisions to improve performance, and stakeholders will have a consistent benchmark to judge performance. Most critically, textile mills with better performance can – and should – be recognized and rewarded with increased business and engagement suitable to their advanced state of production.

Apparel Impact Institute (Aii) has initiated an open and inclusive process to develop energy and carbon performance benchmarks for the apparel sector. From discussions with various industry stakeholders, Aii understands that several brands and organizations are exploring similar performance benchmarks or would like to see one developed for the industry. Aii believes it is critical to create one independent and widely agreed-upon benchmarking tool so that the sector can focus its attention on achieving better performance rather than developing and debating different performance schemes.

The theory of change that underpins the benchmark is that facilities can use the tool to appraise their own performance and highlight opportunities for improvement – and, in due course, brands can include energy use and GHG emissions performance (judged against objective benchmarks) within their basket of sourcing metrics. This will provide the business imperative for manufacturers to make investments to improve the energy efficiency and reduce GHG emissions in their facilities. By meeting objective, tailored energy use and emission targets, brands and manufacturers can focus on improving with the most appropriate interventions. This shifts the priority to performance and away from specific, mandated interventions that may not be appropriate for all facility contexts.

While the benchmark is not intended to replace SBTs’ setting, it is designed to complement SBTi-aligned decarbonization strategies by providing a practical, process-level performance reference. Performance-based reference points can be mapped to brand-level decarbonization pathways, enabling brands to assess supplier portfolios against defined performance thresholds that support progress towards SBTs. This, in turn, supports more informed collaboration between brands and suppliers, helping to prioritize technical assistance, capacity-building, and investment



to improve energy efficiency and reduce emissions across the value chain in line with shared decarbonization objectives.

This document describes how the methodology of the Benchmark was developed and its intended use.

## **2.1. Scope & purpose**

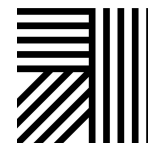
The Aii benchmarking tool provides a structured way to assess the energy use and GHG emissions performance of textile manufacturing facilities, with the current version covering spinning, weaving, knitting, wet-processing (including garment washing), and garment manufacturing. Depending on industry and stakeholder needs, Aii may include additional value chain tiers in future iterations of the Benchmark. The Benchmark will ultimately provide quantitative indicators that allow facilities and brands to understand energy use and emissions performance relative to typical industry performance.

Unlike existing tools and methodologies (e.g., Higg Facility Environmental Module (FEM), brand initiatives) that can provide figures for the total energy use and emissions for an entire factory, the Aii benchmarking tool allows the appraisal of individual facility performance against its tailored benchmark. The tool distinguishes between non-vertical facilities that focus on a single tier and vertical facilities (those that perform more than one type of processing on site, such as spinning, knitting, weaving, or dyeing), providing tier-specific indicators within a single facility. This approach builds on and complements other approaches to give a level of detail that can help both brands and facilities better understand and improve performance. The approach allows monitoring of year-on-year progress for individual facilities, and also allows objective facility-to-facility and regional comparisons.

The Benchmark enables analysis at different operational levels and can provide:

- Total energy use and emissions for a facility
- Energy and emissions profiles for individual departments within a vertical facility
- Tailored benchmark figures for facilities, based on energy sources and the exact product and processes carried out, against which performance can be assessed
- An indication of performance against those benchmarks

This level of detail makes it possible to identify specific areas of stronger or weaker performance, and to assess performance against tailored benchmarks that reflect the facility's energy sources, production mix, and process configuration.



Importantly, the Benchmark has a different scope, purpose, and intended use than other tools and frameworks used in the apparel sector, such as the Product Environmental Footprint Category Rules (PEFCR), the Facility Environmental Module (FEM), and Ecodesign for Sustainable Product Regulation (ESPR). For example, the PEFCR aims to provide a consistent and science-based approach to assessing the environmental impact of apparel across the full life cycle, from raw material extraction through production and logistics to use and end-of-life, whereas the Benchmark is focused on facility-level performance.

## **2.2. Contributors and development partners**

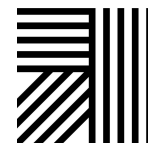
The Aii Energy and Carbon Benchmark was developed through an open and collaborative process involving a diverse group of technical experts and industry representatives. The methodology and model processes were defined by specialists across textile manufacturing disciplines, including wet and dry processing.

Technical experts provided data, reviewed model assumptions, and advised on key parameters such as fiber type, yarn structure, process configuration, and machine utilization. The Technical Review Committee (TRC) collectively reviewed the model processes and baseline parameters to ensure they reflect typical industry practice and maintain consistency across processes and materials, aligning with Aii’s broader energy and emissions datasets.

### **Contributors involved in the development of the Aii Energy and Carbon Benchmark**

<b>Role</b>	<b>Organization</b>
Project Lead	Apparel Impact Institute (Aii)
Technical Review Committee (TRC)	Artistic Milliners: Saqib Sohail <sup>1</sup> Aii: An Zhou, Kurt Kipka, Leonie Schmid Bluesign: Reinhard Umber BluWin: Dr. Siva Pariti Cascale: Joel Mertens, Jeremy Lardeau Colour Connections: Phil Patterson Elevate Textiles: Jimmy Summers H&M: Kim Hellstrom, Niklasx Johansson Inditex: Fernando Echevarria Camarero Made2Flow: Atnyel Guedj MAS Holdings: Rakith Alkegama RESET Carbon: Sophie You, Cyrus Lam, Liam Salter

<sup>1</sup> Saqib left Artistic Milliners and joined Microfibre Consortium during the development of the Benchmark



<p>Technical experts</p>	<p>BluWin: Dr. Siva Pariti          Colour Connections: Phil Patterson          Elevate Textiles: Jimmy Summers          Made2Flow: Atnyel Guedj          Niederrhein University: Prof. Dr. Marcus O. Weber          RESET Carbon: Sophie You, Cyrus Lam, Liam Salter          Rieter: Pankaj Dangra, Anna Diews &amp; Robert Wieseckl          The Idea Smith: Nimish Dave          University of Leeds: Prof. Muhammad Tausif</p>
<p>Data sources</p>	<ul style="list-style-type: none"> <li>● Research and pilot studies: Apparel Impact Institute, BluWin, Colour Connections, Elevate Textiles, RESET Carbon</li> <li>● Statistical analysis (based on a database of over 12,000 facilities in 53 countries for dry-processing operations): Made2Flow</li> <li>● Proprietary datasets and model calculations: Colour Connections</li> <li>● Factory environmental data: Worldly</li> <li>● Anonymized model process calculator software</li> <li>● MADE-BY benchmark ranges</li> </ul>

Aii would like to thank all of the members of the TRC and the technical experts for their input during the benchmark development.

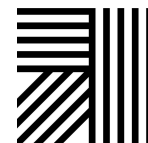
### **2.3. Definitions and key terms**

Please refer to Appendix C - Key Methodological Terms where definitions are provided to clarify terminology used throughout the Aii Energy and Carbon Benchmark methodology.

## **3. Data Governance and Stewardship**

### **3.1. Governance**

With the publication of version 1.0 of the Benchmark, Aii will form a Benchmark Advisory Committee (BAC) to provide ongoing feedback as the Benchmark is deployed. The BAC, to be composed of individuals from across the apparel ecosystem, is critical to the Benchmark’s ongoing improvement and will ensure alignment with its intended use to drive better carbon and energy performance in textile manufacturing facilities. This committee will build upon the work completed by the TRC, which supported the development of Benchmark v1.0. Apparel Impact Institute has launched an open call for nominations.



### **3.2. Data stewardship**

Aii is responsible for the stewardship of all input data, processed datasets, benchmark results, version control, and supporting documentation.

## **4. Benchmark Methodology**

This section describes Aii's approach to developing the Benchmark. A more detailed explanation of the underlying calculations - including the process-level assumptions, conversion factors, and data validation methods - can be found in Appendix A and B of this document.

### **4.1. Identify the most common textile substrates and processes**

Aii identified the most common material types used across apparel and home textiles product categories (e.g., athletic, casual, linens) by surveying a number of brands across product categories and leveraging Aii's own industry knowledge. This was followed by identifying the most common textile processes used to create those materials.

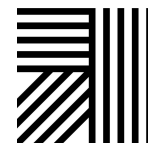
The prototype benchmark calculator contains the most common processes for fibers, yarns, and finished products (i.e., woven, knitted, knitwear) for the most common material types. The level of methodological detail varies by process type. The set of materials and processes in the Benchmark is extensive, but not exhaustive. It contains the most common:

- Fiber types, including cotton, polyester, polyamide, acrylic, viscose, lyocell, wool, silk, and common blends
- Yarn types, including continuous filament, ring, open end, woollen, and worsted
- Knitted fabric, including weft knitted, warp knitted, and flat knitted
- Woven fabrics, including those produced on rapier, air jet, projectile, and water jet looms
- Wet processing techniques, including exhaust dyeing (of fibers, yarns, fabrics, and garments), continuous dyeing of fabrics, printing of fabrics and panels, and garment laundry
- Garment and product types

The Benchmark is constructed such that new products and processes can be added in the future to ensure the tool remains comprehensive.

### **4.2. Create model processes for the most common processes**

No two facilities carry out exactly the same process, so model processes are used to describe what is typical in the industry (meaning commonly applied, not the best or worst). Included in the



benchmark calculator database are full details of the model processes and all sub-processes. For example, in the case of wet processing, the calculator covers preparation, coloration (dyeing and printing), post-coloration wash off, and finishing – as well as key assumptions. The model process detail includes the number of individual process baths and temperature details for batch processing and continuous and finishing processes.

The model processes have been agreed upon by the technical experts and reviewed by the TRC. As noted above, additional processes can be added in future revisions to the Benchmark.

### **4.3. Develop energy intensity<sup>2</sup> figures for model processes**

The goal of the Benchmark is to create baseline energy intensity data for all listed processes and sub-processes that:

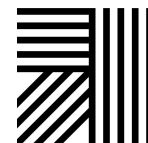
1. Reflect the energy required for each process and sub-process
2. Reflect the energy content of fuel required to provide useful energy to a typical, theoretical single-process facility (i.e., a facility that only dyes acrylic yarn on package dyeing machines or a facility that only dyes cotton using reactive dyes on jets)
3. Are adjusted to make sense relative to each other

The energy intensity is based on the energy content of the fuels used to create useful heat and electricity for the processes in a real-world scenario, and not simply the energy demand of the process. The energy intensity figures include considerations for typical inefficiencies of boilers and generators, typical machine utilization (the amount of time machines are switched on but not processing textiles), re-process rates, and energy requirements for ancillary processes, such as labs, offices, and warehouses.

The methodological approach used to develop energy intensity figures varies depending on process type, reflecting differences in process structure and data availability. From October 2025 through March 2026, a pilot phase was launched to collect facility-level data in support of Benchmark development. Data was collected from 500 participating facilities across multiple regions and process types. The results of this pilot phase are currently being analyzed and will be used to refine the energy intensity figures presented in the first iteration of the methodology, planned for publication by the end of July 2026. Additional information regarding the pilot phase can be found in section 9.

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<sup>2</sup> Energy intensity covers the full energy content of the fuel used to create useful thermal energy and electricity.



### 4.3.1 Develop energy intensity figures for wet processes

Ideally, primary data from facilities -including the actual energy demand for different processes and the energy content of the fuel used to deliver this energy, factoring in inefficiencies in energy generation, transmission, and usage - would be the foundation for the creation of benchmarks for different processes. However, very few facilities currently have verified data accurately attributed on a process-by-process basis in the form required (i.e., the energy content of the fuel used to create useful heat and electricity for those processes).

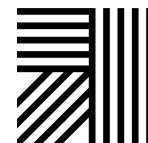
Even if fuel-content energy intensity data was obtained for single process facilities, it would need to be collected from a large number of facilities encompassing a full range of abilities to avoid outliers and create a credible average. This is simply not practical if ambitious decarbonization targets are to be achieved by 2030.

The figures in the benchmark calculator database are therefore calculated using a combination of primary data where available, modeled data from proprietary software, and structured professional judgment. The result is a provisional database of calculated process and sub-process energy intensity figures designed to reflect typical real-world operating conditions in the industry. For wet processes, these figures are developed using a stepwise approach that combines calibration to primary facility data with modeled process demand and scaling factors. The database of sub-process energy intensity figures allows us to piece them together to create new processes.

To illustrate how the calculated energy intensity figures were sense-checked - and how primary process demand data may refine them in the future - the following formula compares process demand with the energy content of the fuel required to supply useful energy to the process.

$$\text{Energy Content of Fuel kWh/kg} = \left[ \text{Process Demand kWh/kg} \div \left( \frac{\text{Electricity \%}}{\text{Thermal \%}} \right) \div \left( \frac{\text{Genset Efficiency \%}}{\text{Boiler Efficiency \%}} \right) \div \text{Machine Utilisation \%} \div \text{Process Efficiency (RFT, Machine loading) \%} \right] + \text{Ancillary processes}$$

This explains why fuel-based real-world energy intensity figures for continuous processes are higher than modeled process demand values for batch processes - mainly because continuous machines typically have lower utilization (e.g. they are switched on and are idle).



Typical boiler efficiency is roughly 65%, and typical generator efficiency is roughly 33%, which largely explains why actual energy intensities are much higher than process demand.

The energy and emissions intensity figures from the provisional benchmark calculators are what is expected from a typical facility and do not represent a pass / fail target. A detailed description of the methodology used to develop wet process energy intensity figures is provided in Appendix A.

#### 4.3.2. Develop energy intensity figures for dry processes

Technical experts in spinning, knitting, and weaving advised on the key parameters that affect the energy intensity of a particular process. For example:

- **Spinning:** Fiber type, spinning method & sub method, yarn count, post-spinning processes
- **Knitting:** Fiber type, gauge, (for weft knit) diameter of cylinder
- **Weaving:** Loom type, weaving type, fabric construction, material type
- **Product assembly:** Product type, customer age/gender, material type

Due to the lack of single-process facilities and sub-process primary data, it was not possible to create additive energy intensity figures for model processes, as was the case for wet processing.

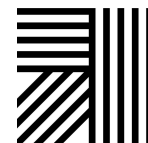
However, through collaboration with Made2Flow<sup>3</sup>, a large-scale facility dataset comprising data from over 12,000 facilities across 53 countries was available. Using statistical analysis from this data, it was possible to extract relative energy intensity factors for the key parameters highlighted by the technical experts. For example, the relative energy intensity of fine yarns compared to coarse yarns using the same machine and fiber type, or the relative energy intensity of fine gauge knits relative to coarse gauge knits.

The relative energy intensity factors for the key parameters for spinning, knitting, weaving, and product assembly were extracted by Made2Flow using a statistical, top-down approach and inserted into a calculation tool to create the prototype energy intensity figures for the listed yarns, fabrics, and final product types. These figures capture relative changes in energy intensity associated with different process parameters, rather than measured energy consumption at the process level.

For the pilot phase, the energy intensity figures created by the Made2Flow statistical analysis were adjusted to align with existing average kWh/kg figures for each tier, as indicated by Aii's report

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<sup>3</sup> Made2Flow is a data company based in Germany that specializes in collecting and validating environmental data across fashion supply chains.



series on the GHG emissions of the apparel sector (the most [recent](#) covers 2023). All results collected during the pilot phase will be analyzed, and the Benchmark data figures will be refined accordingly to ensure alignment with validated facility data and observed performance trends. A detailed description of the methodology used to develop dry process energy intensity figures is provided in Appendix B.

#### **4.4. Develop emissions intensity figures**

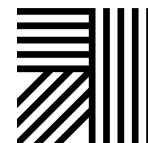
Emission intensity figures for each process and sub-process were created by multiplying the energy intensity figures by fuel-weighted average emissions factors for the fuels used in manufacturing regions.

As a result of the TRC consultation, both thermal and electrical emission factors were included to provide a full picture of performance. Emissions intensity figures, therefore, reflect the combined contribution of thermal and electrical energy use.

The estimated percentage split between the energy content of fuel required to provide thermal and electrical energy was used to create emission intensity figures for each process and subprocess. These splits are based on typical industry conditions and are intended to represent average operating profiles rather than site-specific configurations. These splits will be reviewed after analyzing the data from the pilot phase.

Emission factors for thermal energy were calculated using a weighted average based on the split of on-site fuels used for boilers and direct heating and the emission factors of those fuels. Data for on-site fuel use (including purchased steam) for seven major manufacturing nations - China, Taiwan, Vietnam, Bangladesh, India, Indonesia, and Pakistan - was provided by Worldly, and emission factors for the fuel types (and purchased steam) were provided by Cascale. The thermal emission factor will be further refined after a review of the results from the pilot phase.

Electricity emission factors were calculated using weighted average grid emission factors for textile manufacturing regions - the seven nations mentioned above and a lower figure for the EU, which is assumed to account for 20% of textile manufacturing - plus the emission factors for on-site electricity generation calculated using a weighted average based on a split of on-site fuels used for gensets.



Provisional figures for grid emission factors were taken from Institute for Global Environmental Strategies (IGES),<sup>4</sup> and estimates for major global manufacturing nations were taken from a report by Fibre to Fashion<sup>5</sup>.

The split between grid and on-site electricity generation is assumed to be 80% grid / 20% on-site, as advised by the TRC. A conversion factor of 2.4 is applied to estimate the energy content of fuel required to produce 1 kWh of useful electricity.

The electrical emission factor will be further refined during the pilot phase, by currently planning to use up-to-date information from IEA for more producing nations, and up-to-date production volume information from Worldly.

The figure of an 80:20 split between grid and on-site generation, and the conversion factor will be reviewed after the pilot phase.

#### **4.5. Data inputs and modeling approach for developing energy intensity figures**

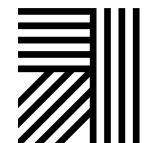
The following table summarizes the data inputs, modeling approaches, and normalization methods used to develop the energy intensity figures for both wet-processing and dry-processing pathways. It also highlights where expert judgement is required to reconcile data sources and interpret parameter-driven effects. These values were derived through a combination of available primary and secondary data sources and expert judgement to ensure methodological robustness.

The full [Benchmark Calculator](#), which may be downloaded as an Excel file, provides the complete set of values used to construct the methodology, including detailed process and sub-process configurations, machine and material combinations, and the applied normalization adjustments.

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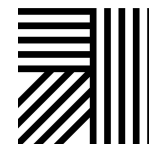
<sup>4</sup> <https://www.iges.or.jp/en/pub/list-grid-emission-factor/en>

<sup>5</sup> <https://www.fibre2fashion.com/industry-article/8471/top-10-exporting-countries-of-textile-and-apparel-industry>

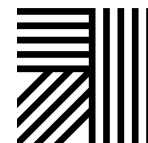


## Overview of processes used to develop the energy intensity figures

Process	Primary data source	Secondary data source	Expert judgement influence	Normalization factor	Estimated accuracy	Parameter - based modifiers
Wet-Process Calculator	Collected primary real-world data from the PACT program	<ul style="list-style-type: none"> <li>- Anonymized factory data from BluWin &amp; Colour Connections</li> <li>- Anonymized model process calculator software</li> </ul>	Yes – applied to reconcile primary and modeled data and validate final sub-process values	Normalization factors were applied to modeled process demand data and primary process demand data to align it with primary data based on the energy content of fuels	Medium	<ul style="list-style-type: none"> <li>- Process group</li> <li>- Substrate type</li> <li>- Fabric type</li> <li>- Material type</li> <li>- Process-specific type</li> <li>- Dye type</li> </ul>
Spinning	None (no single-process primary data available)	Made2Flow statistical analysis (12,000 facilities across 53 countries)	Yes – required to interpret parameter effects and validate prototype intensities	Alignment to tier-level average kWh/kg values from Aii sector GHG studies; parameter-based factorization from Made2Flow	Medium	<ul style="list-style-type: none"> <li>- Spinning type</li> <li>- Spinning sub-type</li> <li>- Material type</li> <li>- Yarn count</li> </ul>



<b>Process</b>	<b>Primary data source</b>	<b>Secondary data source</b>	<b>Expert judgement influence</b>	<b>Normalization factor</b>	<b>Estimate of accuracy</b>	<b>Parameter - Based Modifiers</b>
Knitting	None (no single-process primary data available)	Made2Flow statistical analysis (12,000 facilities across 53 countries)	Yes – required to interpret parameter effects and validate prototype intensities	Alignment to tier-level average kWh/kg values from Aii sector GHG studies; parameter-based factorization from Made2Flow	Medium	- Knitting type - Knitting gauge - Material type
Weaving						- Weaving machine - Product type - Weaving type - Material type
Garment						- Product type - Gender / size - Material type



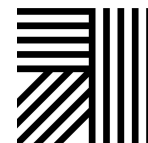
#### **4.6. Create tailored benchmarks to evaluate performance**

To develop tailored benchmarks, facilities will need to provide details of their products and processes, including production volumes (by weight) – ideally for the past 12 months. This information is used to reflect the facility’s actual production mix and process configuration.

After a facility provides details of the production volumes for each individual product and process type, a weighted average energy intensity value (in terms of kWh/kg) and emissions intensity value (in terms of g CO<sub>2</sub>e / kg) are automatically calculated. The weighted average approach is used so that benchmarks are fair and appropriate for the facility, product, and process type. The Aii Benchmark calculator provides target information in terms of:

- Weighted average emissions (gCO<sub>2</sub>e/kg): total GHG per kilogram of product, calculated as a weighted average across all reported products and processes at the facility.
- Weighted average energy (kWh/kg): total energy use, in terms of energy content of fuel used to create useful thermal energy and electricity per kilogram of product, expressed in kilowatt-hours and weighted by production volume across all products and processes.
- Weighted average energy (MJ/kg): the same weighted average total energy use expressed in megajoules, provided for compatibility.
- Thermal energy indicator (kWh/kg): the portion of total energy intensity associated with the energy content of fuel required to create useful thermal energy (e.g., boilers, direct heating, steam generation), expressed per kilogram of product.
- Electrical energy indicator (kWh/kg): the portion of total energy intensity associated with the energy content of fuel required to create useful electrical energy, including electricity generated on-site and electricity purchased from the grid, expressed per kilogram of product.
- Electrical use indicator (kWh/kg): the electrical energy delivered to process equipment per kilogram of product, excluding upstream generation inefficiencies, and intended to support assessment of electrification potential and efficiency improvements.
- Thermal emissions indicator (gCO<sub>2</sub>e/kg): GHG emissions associated with thermal energy use, calculated using a weighted average for on-site fuel types and associated emission factors
- Electrical emissions indicator (gCO<sub>2</sub>e/kg): GHG emissions associated with electricity use, calculated using a weighted combination of grid and on-site electricity emission factors.

The Benchmark performance indicator targets are derived mathematically from these generated figures. Facility performance is appraised against these targets, and in the future, once sufficient facility data has been analyzed, it is intended to introduce a structured grading methodology.



Actual emissions in terms of gCO<sub>2</sub>e/kg relative to energy use in kWh/kg will be higher for facilities in geographical regions that are more reliant on high-emission fuels such as coal. Thus, to permit appraisal of emissions performance against regional peers, it is intended to create regional emissions targets to operate alongside the initial global targets, using internationally recognized grid emission factors and on-site fuel use data provided by Worldly.

## 5. Assessment of Facilities Against the Benchmark

This assessment approach is designed to be feasible and equitable for facilities of different sizes and levels of technical maturity, including small and medium-sized enterprises (SMEs). The required information is data that facilities are expected to have access to as part of standard operational and business management. The methodology does not require detailed sub-metering, advanced monitoring systems, or additional capital investment, and is intended to minimize reporting burden while enabling meaningful benchmarking across a wide range of facility contexts.

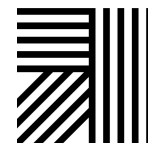
The facility assessment process can be conducted in two ways. Facilities may complete a self-appraisal using an Excel-based version of the benchmark calculator. Alternatively, the assessment can be conducted through a digital platform administered by Made2Flow. Facilities enter the required information through a structured set of online questionnaires designed to capture production and energy-related data in a consistent and standardized manner. The platform provides the interface through which facilities submit their data and receive benchmark outputs. The specific data requirements and assessment steps are described below.

Step 1: A facility develops or provides three key pieces of information and some basic factory details:

- Fuel use, on-site renewables, and grid electricity.
- Production volumes for each product/process type.
  - This provides an overview of the products and processes included in the assessment period and forms the basis for weighting energy and emissions results.
- A utility map<sup>6</sup> (For vertical facilities).
  - This describes how utilities, including electricity and thermal energy, are distributed across different processes and sub-departments within a vertical facility.

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<sup>6</sup> It is recommended that facilities complete a utility map. Although it is not necessary to create one to appraise overall facility performance (a 'black box' approach can be applied), it provides important insights into relative tier-level performance and potential areas for improvement within the facility. For example, a vertical spinning and dyeing factory may appear to have 'average' performance using a black box approach, but a utility map may show that spinning performance is excellent and the dyeing performance is poor.



- o The utility map supports indicative allocation of energy and emissions to different parts of the facility (e.g., dyeing and finishing) for internal analysis. It can also be used to inform internal decision-making and identify potential areas for targeted improvement within the facility.

Since detailed sub-metering is not common across the sector, facilities are not expected to implement additional monitoring systems for this assessment. Existing operational knowledge of on-site engineering teams is generally sufficient to provide a utility map that supports benchmarking and improvement planning, particularly for the target group of strategic suppliers identified by Cascale and Aii based on their size and reported emissions.

Step 2: A tailored energy and emissions benchmark is calculated using the Aii Benchmark Calculator.

Described in section 4.6 of this document.

Step 3: The facility is assessed

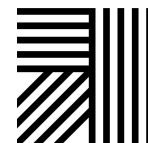
The assessment process is designed to include two stages. Objective self-appraisal is the first stage to determine performance against benchmarks and identify improvement opportunities.

An optional second stage of independent verification may be applied where appropriate:

- First, the submitted documentation and preliminary benchmark results are reviewed, and the performance level is calculated via the digital platform.
- An on-site third-party review, if requested, may then be conducted to verify the information provided in the utility and production maps. Fuel and electricity data are reviewed, and the resulting energy and emissions benchmarks and performance indicators are verified.

The weighted average approach ensures that the benchmark for a facility is appropriate to the mix of processes it carries out. To smooth out seasonal variations, information on fuel, electricity, and production over a 12-month period will be requested. Even if information is only available for a shorter period of time, it is likely to give a provisional yet very good indication of performance.

The performance indicator targets from the Benchmark Calculator are based on industry averages, but the facility will be evaluated against the emissions benchmark using the energy content of its actual fuel use and its specific grid electricity consumption, and calculating a kg CO<sub>2</sub>e / kg figure for the facility's production.



Although the  $\text{g CO}_2\text{e/kg}$  is the key indicator from this benchmarking process, a facility will assess its actual performance (and where appropriate, the performance of tiers within a vertical facility) against the following more detailed metrics:

- Weighted average emissions ( $\text{gCO}_2\text{e/Kg}$ )
- Weighted average energy ( $\text{kWh/kg}$ )
- Weighted average energy ( $\text{MJ/kg}$ )
- Thermal energy indicator ( $\text{kWh/kg}$ )
- Electrical energy indicator ( $\text{kWh/kg}$ )
- Electrical use indicator ( $\text{kWh/kg}$ )
- Thermal emissions indicator ( $\text{gCO}_2\text{e/kg}$ )
- Electrical emissions indicator ( $\text{gCO}_2\text{e/kg}$ )

Facility performance for these metrics will eventually be compared to the mathematically derived performance indicator targets described above. There will be two broad options in terms of improvement:

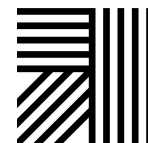
- Changes to on-site processing, which can affect fuel and grid electricity use in the short term and lead to reduced emissions.
  - Reducing process demand via process modifications, new machinery, reduced re-processing, etc., or
  - Improving utilities such as boiler/genset efficiencies or heat recovery.
- Changes in fuel type and reductions in grid emissions (which may be more challenging in the short term)

Emissions are dependent on the type of fuel used on-site and for the generation of grid electricity, so it is conceivable that facilities will be judged as very good in terms of energy use but poor in terms of emissions due to their reliance on high-emission factor fuels – and vice versa.

Emissions reductions potentially provide a much greater challenge for facilities in geographical regions that are more reliant on high-emission fuels such as coal. However, some pressure to switch fuels at the factory and grid level will need to be applied to decarbonize the industry.

### **5.1. Understanding Benchmark outcomes**

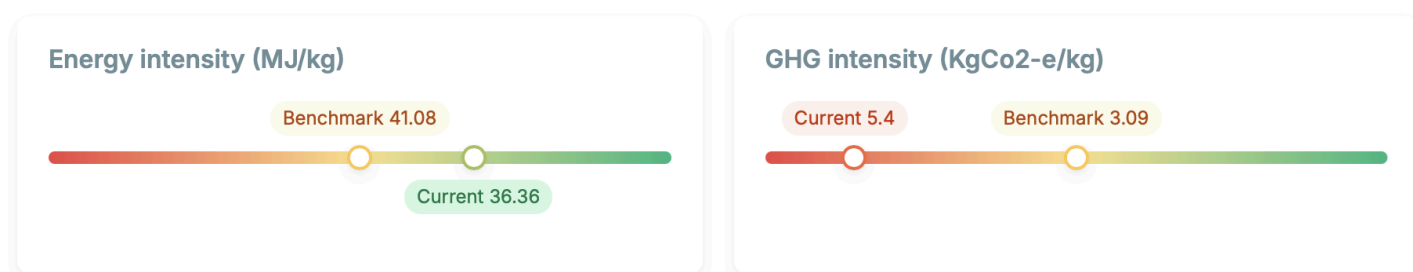
The Benchmark provides facilities with calculated energy and emissions intensity values based on their reported production mix, process configurations, and energy sources. These figures are expressed as weighted average energy intensity ( $\text{kWh/kg}$ ) and emissions intensity ( $\text{gCO}_2\text{e/kg}$ ), tailored to the specific operational profile of each facility.



If a facility conducts its assessment using the Made2Flow platform, Benchmark results are presented visually through a color-coded gauge ranging from green to red. The results act as a comparison between the facility's calculated intensity figures and the Benchmark reference values, which represent typical industry performance for comparable processes and materials.

The Benchmark output presented to facilities consists of absolute energy and emissions intensity values, calculated based on the facility's reported data and shown alongside the corresponding Benchmark reference values. The relative difference between the facility's calculated value and the benchmark reference is a key analytical result and can be calculated as a percentage difference. This percentage indicates how far current performance is above or below typical observed levels represented by the Benchmark reference. An example of the results shown in the Made2Flow platform is provided below.

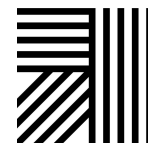
#### Main parameters



For example, a facility energy intensity of 36.36 MJ/kg compared to a benchmark reference of 41.08 MJ/kg indicates that energy use is approximately 11.5% lower than typical observed performance for that process. However, for GHG emissions, a current intensity of 5.4 kgCO<sub>2</sub>e/kg compared to a benchmark reference of 3.09 kgCO<sub>2</sub>e/kg indicates emissions approximately 75% higher than typical observed levels. This illustrates how a facility may perform below the benchmark for energy intensity while still performing above the benchmark for emissions intensity, depending on its energy sources and process configuration.

At this stage, the Benchmark does not apply categorical performance bands or grading levels. The definition of meaningful performance ranges and classifications is being informed by the analysis of data collected during the pilot phase and ongoing Benchmark use. This work aims to ensure that any future categorization supports improvement-focused engagement and reflects the diversity of facility contexts.

Benchmark outcomes are intended to support internal performance assessment, prioritization of improvement actions, and constructive dialogue between suppliers and their partners. For vertically integrated facilities, results may also be reviewed at sub-department level to help identify process stages that contribute most significantly to overall energy use and emissions.



## Data access, confidentiality, and use of results

Facility-level benchmark results are treated as confidential. Each facility has access to its own individual results through the digital platform. If a facility has been nominated by a sponsoring brand, that brand will also have access to the facility's results.

Apparel Impact Institute and Made2Flow have access to the full set of benchmark results to support data modeling, quality assurance, and continuous improvement of the benchmark methodology. Individual facility results will not be published or shared with third parties without prior consent. Any use of benchmark data for analysis, reporting, or methodological refinement will be conducted exclusively in aggregated and anonymized form, ensuring that no individual facility can be identified.

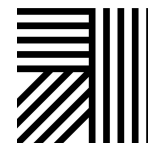
## **6. Limitations**

The Benchmark results should be interpreted with caution, as the energy and emissions intensity figures are based on the current dataset and may be refined as additional data are analyzed over time. While the emissions factors are derived from established sources, the thermal and electrical energy splits presented are estimates rather than facility-verified values, and users must therefore assess fitness for purpose when applying the data outside the intended scope of benchmarking and directional analysis.

The Benchmark represents a baseline reference and is intended to support relative performance assessment and opportunity identification, rather than absolute performance evaluation or compliance-based decision-making. The figures reflect typical operating conditions across the sector and are not intended to represent best-practice targets or guaranteed outcomes at the individual facility level.

Methodological confidence varies by process type and data availability. These differences reflect current limitations in process-level data availability, variability in process integration and utilization rates, and the voluntary nature of facility disclosures.

The Benchmark framework is designed to be iterative and to improve over time as it is applied in practice. As additional facility data is collected through ongoing use of the Benchmark and future data collection efforts, the underlying assumptions, reference values, and emission factors will be reviewed and refined to improve representativeness while preserving methodological consistency.



## 7. Intended Use

The Aii Energy and Carbon Benchmark is intended to support comparative benchmarking, performance assessment, and prioritization of energy efficiency and decarbonization opportunities across textile manufacturing facilities. It provides a consistent, process-type reference that enables facilities to understand their relative performance and supports brands and other stakeholders in identifying areas where targeted engagement, technical support, and investment can drive meaningful emissions reductions.

Benchmark results are designed to inform internal decision-making, supplier engagement, program design, and strategic planning, including actions aligned with broader climate and decarbonization objectives. The Benchmark is not intended to function as a compliance tool, certification scheme, or standalone basis for pass/fail judgments, nor should results be interpreted as substitutes for facility-specific measurements, target setting, or third-party verification.

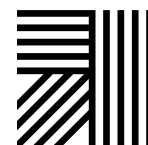
It is not recommended that these results be used for public disclosure, external reporting (e.g., impact reports or sustainability communications), or comparative claims between facilities or brands. If facilities or brands choose to reference the Benchmark, they should clearly indicate that the figures are based on version 1.0 or 1.1, and that intensity figures remain subject to refinement and may be updated on a regular basis.

## 8. Change Log & Version Control

### 8.1. Version control

Each release of the Aii Energy and Carbon Benchmark calculator and underlying energy intensity figures is assigned a unique version number. Version numbers apply to the benchmark methodology, the benchmark calculator, and any derived datasets or reference documents used within the tool. A version history log accompanies each release and documents methodological updates, data changes, corrections, and assumptions adjusted since the previous version.

- **Previous Version:** v0.9 (pilot-phase), testing phase from October 2025 to March 2026.
- **Previous Version:** v1.0 (official launch version), published after incorporating pilot-phase feedback and completing the public consultation.
- **Current Version:** v1.1, reflects a review of energy and emissions intensity benchmark values, with adjustments made to dry-process benchmarks based on analysis of primary data collected through pilot phase.



- **Future Version:** v2.0, expected to include further data iterations, the potential development of regional benchmarks, and the introduction of Energy and Carbon Benchmark performance levels to support clearer interpretation of facility performance. Anticipated Q2 2027.

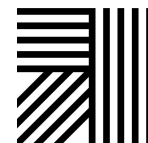
## **8.2 Review cycle and validation steps**

The Benchmark undergoes a structured expert review and validation process to ensure methodological rigor and technical accuracy. For version 0.9 (pilot phase), the TRC reviewed methodological assumptions, data processing steps, and preliminary benchmark outputs. These inputs and findings fed directly into the development of version 1.0.

The updated dry-process energy and emissions intensity figures were reviewed by the TRC before publication of v1.1. Moving forward, Aii will conduct annual consultation periods, more frequently if needed, to gather input on methodological and data updates. A dedicated Benchmark Advisory Committee will support the updates to the methodology, underlying datasets, and the Benchmark tool. This review structure ensures that the Benchmark remains technically rigorous, transparent, and responsive to new evidence and stakeholder feedback.

## **8.3. Version history**

<b>Version</b>	<b>Date</b>	<b>Description of changes</b>
v0.9	November 2025	Initial draft of the methodology framework and structure, shared for public consultation to gather feedback and inform the release of version 1.0.
v1.0	March 2026	Incorporates feedback received from the public consultation phase for the official publication of the tool.
v1.1	May 2026	Incorporates the first data iteration of energy and emissions intensity figures for dry processes, based on primary data collected during the pilot phase.



## 9. Data Iteration

Between October 2025 and March 2026, Aii conducted a pilot phase focused on gathering data from suppliers to refine energy and emissions intensity figures and inform the practical implementation of the on-site assessment process. The pilot phase included versions v0.8 and v0.9 of the Benchmark, both using the same facility questionnaires.

In total, data from 468 facilities were analyzed. Of these, 70 facilities submitted data through the digital platform supported by Made2Flow in v0.9, while the remaining facilities participated through the manual Excel-based data collection process used in v0.8.

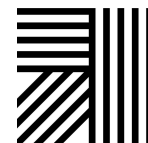
Initial statistical analysis of primary data for wet-processing facilities indicated that the Benchmark values remained broadly aligned with observed industry performance. In contrast, analysis of dry-processing facilities with more than 80% of production allocated to a single process showed a low share of facilities meeting the Benchmark values. This indicated the need to assess whether the dry-process energy and emissions intensity figures published in v1.0 remained representative of observed industry performance.

In v1.1, the dry-process analysis was based on a subset of 144 facilities allocating 100% of production to a single process. This selection reduced analytical noise from mixed-process facilities and improved the statistical comparison between facility-reported performance and process-specific Benchmark values. The subset included 70 spinning facilities, 28 weaving facilities, 25 knitting facilities, and 21 garment manufacturing facilities.

Since manufacturing energy performance typically follows a skewed distribution, arithmetic averages can be influenced by extreme values and may not represent typical operating conditions. For this reason, the wet-processing Benchmark was aligned with the statistical mode, representing the most commonly observed performance. Under typical industry conditions, this interpretation is expected to result in approximately 30% of facilities meeting or performing better than the Benchmark, meaning their energy and emissions intensity is at or below the Benchmark value.

To maintain consistency with this interpretation, the dry-process data iteration applied a 30% compliance-based approach. Energy intensity figures were adjusted so that approximately 30% of facilities in the analyzed dataset performed at or below the Benchmark value, while approximately 70% had energy intensity values above the Benchmark.

Version 1.1 reflects this conservative data iteration for dry-process energy and emissions intensity figures. No substantial methodological changes were introduced, and Aii will continue collecting and analyzing data to inform future Benchmark updates.



## Appendix A – Wet Process Energy Intensity Methodology

### A.1 Scope, purpose, and methodological foundations

This appendix describes the methodological foundations used to develop energy intensity figures for textile wet processes. This approach responds to three structural constraints commonly encountered in textile wet-processing facilities:

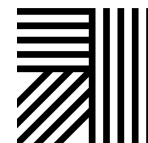
- In multi-process facilities, total factory-level energy use cannot be reliably attributed to individual processes because energy consumption is shared across utilities, equipment, and supporting infrastructure. Process-level metering is rarely available with sufficient resolution and verification.
- Very few facilities operate as dedicated single-process sites capable of providing representative, fuel-based energy intensity data. Reliance on a small number of such facilities would not yield statistically meaningful reference values or reflect sector-wide operating conditions.
- Model process-based benchmarking approaches have been applied in industry contexts to assess performance against defined reference points while accounting for typical operational conditions. The Aii Benchmark applies this approach to energy performance for the first time, building on its proven use in water-based benchmarking initiatives within the industry.

The Benchmarking tool is based on a database of the energy intensity figures of wet processes and sub-processes. To support the assessment of GHG emissions, energy intensity figures are expressed as kilowatt-hours per kilogram of product (kWh/kg), representing the fuel energy required to deliver useful energy in the form of heat, steam, or electricity.

KWh/kg figures in the database for a given process represent the energy content of fuel required to produce useful thermal energy and electricity to carry out that process in a notional single-process facility.

The energy intensity figures used in the benchmarking tool are intended to represent typical industry performance rather than best-in-class or worst-case outcomes. The database figures include inefficiencies associated with typical facilities, including re-dyes, downgrades, underutilized machines, energy losses, and inefficiencies in boilers and generators. It also includes energy used in ancillary processes such as offices and laboratories.

Empirical observations indicate that energy efficiency across wet-processing facilities is not symmetrically distributed, but characterized by a long tail of poorer performance and a smaller



number of high-performing facilities. As a result, simple arithmetic averages would disproportionately reflect extreme values and would not provide a meaningful benchmarking reference.

For this reason, the Benchmark is conceptually aligned with the statistical mode of the performance distribution for notional single-process facilities, representing the most commonly observed operating conditions in the industry.

While primary real world data can provide transparency and credibility, accurately attributing total factory-level fuel energy consumption to individual processes within multi-product, multi-process, or vertically integrated facilities is almost impossible. Therefore, in the absence of sector-wide single-process facilities, model processes provide a robust and transparent basis for defining benchmark energy intensities and enabling consistent comparison across facilities.

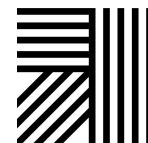
## **A.2 Definitions and conventions**

Key definitions and conventions used throughout the Energy & Carbon Benchmark methodology are provided in the consolidated definitions table in Appendix C - Key Methodological Terms. This appendix applies those definitions specifically to wet-processing pathways, including preparation, dyeing, post-dye wash-off, and finishing operations.

For wet processing, particular emphasis is placed on distinctions between process demand and real-world energy use, the treatment of ancillary processes, and the use of model processes to represent typical industry practice under defined operating conditions.

Energy intensity values in this appendix are expressed in terms of kilowatt-hours per kilogram (kWh/kg). Facility appraisals must not include re-processing (such as re-dyeing), downgrades (such as fabric that is only suitable for end uses), or waste in production volumes. The production volumes used in calculations must relate to the volumes of products released from the production department in a state that is considered fit for purpose for subsequent downstream processing or sale.

This approach avoids inadvertent lowering of kWh/kg values by including reprocessing, etc., and reflects the total fuel energy required to produce one kilogram of final output, regardless of whether it is transferred internally, stored, or delivered to a customer.



### **A.3 Stepwise development of wet process energy intensity figures**

#### **Step 1 – Creating a foundation using primary facility data**

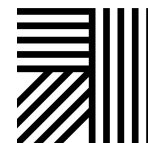
Primary real world data was used to establish a reference baseline for wet-processing energy intensity. This data was sourced from the PACT program, which focused on facilities operating as close as possible to notional single-process configurations in order to isolate dominant wet-processing energy characteristics. The objectives of this step were to obtain reliable fuel-based energy intensity values, separate energy use between wet processing and finishing, and establish representative thermal and electrical energy splits while accounting for typical system inefficiencies.

The dataset comprised assessments of more than 30 facilities, of which 13 provided data of sufficient quality and internal consistency for analysis. These facilities were primarily jet dyehouses processing weft-knitted cotton, with limited vertical integration, and were considered suitable proxies for single-process wet-processing operations.

Analysis indicated an average total fuel-based energy intensity of approximately 16 kWh/kg of delivered product, including wet processing, finishing, laboratories, and ancillary operations. The observed split between wet processing and finishing was approximately 2:1, corresponding to 10.67 kWh/kg for wet processing and 5.33 kWh/kg for finishing. Despite lower intrinsic energy demand at the individual process level, finishing accounted for approximately one-third of total fuel consumption due to low equipment utilization.

Despite wet processing's relatively small electricity demand, the dataset further indicated that approximately 65% of fuel inputs were used for thermal energy generation and 35% for electricity, reflecting the prevalence of on-site power generation and the lower efficiency of generators relative to boilers. Substantial variability in energy performance was observed across facilities, with differences of up to an order of magnitude between best- and worst-performing operations. The PACT dataset was therefore used as a calibration reference rather than as a representation of the full industry performance distribution.

All facilities carried out a 3-step finishing process of relax dry, stenter, and compact, and the energy intensity of each process was estimated in terms of energy content of fuel. Using these common processes as a reference, the energy intensity of further finishing processes was estimated.



## Step 2 – Using modeling software to create calculated energy intensity values for other batch processes

To extend coverage beyond processes with available primary fuel-based data, computed real world energy intensity values were generated using a proprietary, modeled process-impact calculator developed by a leading dye and chemical manufacturer. The tool enables comparative assessment of energy demand across wet-processing configurations under consistent modeling assumptions.

Model processes were constructed at the bath level to represent typical preparation, dyeing, and wash-off sequences, including heating, holding, and cooling phases. Key machine- and process-specific parameters (batch size, liquor ratio, fabric loading, carry-over, boiler configuration, heating and cooling rates, and incoming water temperature) were defined to reflect standard industrial practice, with targeted adjustments applied only where known technical differences existed between fiber types.

For the reference jet-dyed cotton weft-knit process, the modeled computed process demand was calculated to be 6.54 kWh/kg. Comparison with the primary real world energy intensity value of 10.67 kWh/kg derived in Step 1 yielded a scaling factor of 1.63, representing the combined effect of operational inefficiencies, utilization losses, re-processing, and ancillary energy use not captured by the process demand model.

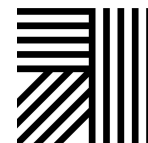
This scaling factor was applied to computed process demand data for other batch wet processes and sub-processes to derive computed real world energy intensity values. The model processes used for the calculations were based on established water-based benchmarking methodologies that have been reviewed by a large number of wet-processing facilities across the industry.

The resulting dataset was reviewed by technical specialists and, where appropriate, aligned with the model processes used in water-based benchmarking methodologies currently used within the industry. The model processes represent typical industry operating conditions and provide credible relative differentiation between wet-processing routes.

## Step 3 – Integration of MADE-BY benchmark ranges for continuous processes

For continuous wet processes, direct primary fuel-based energy data was not available. Instead, MADE-BY benchmark ranges were used as a starting point. The MADE-BY benchmark ranges were created by the collection of primary process demand measurements from multiple facilities, including both batch and continuous processes.

These benchmark ranges represent process demand energy only and therefore exclude real-world inefficiencies related to boilers, generators, machine utilization losses, and ancillary



operations. They therefore require normalising to the energy content of fuel figures via a correction factor.

As facilities capable of providing detailed process-level data tend to represent better-performing sites, midpoint values were not considered representative of typical operating conditions (as used for batch processes). Therefore, a conservative reference point located 25% below the highest value of each range was selected to avoid reliance on best-in-class performance while remaining within a plausible industrial operating envelope.

The selected MADE-BY process demand values for continuous processes were converted into computed real world energy intensity estimates via conversion factor.

Where sub-process data were unavailable, professional judgement was applied to allocate energy intensity values to sub-process stages (i.e., preparation, dyeing, and wash-off) such that they could be used for further model processes not included in the MADE-BY benchmarks. Uncertainty is higher for continuous processes due to the indirect nature of the data and greater variability in machine utilization rates across facilities.

However, the resulting calculated energy intensity values were cross-checked against independent expert datasets and confidential industry references and were confirmed to fall within a credible range for typical industrial practice and confirmed to be satisfactory in terms of relativity to batch processes.

#### Step 4 – Constructing the wet process benchmark and correction factors

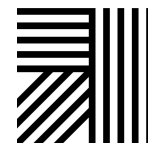
The objective of Step 4 was to consolidate the outputs from Steps 1 to 3 into a prototype wet-processing benchmark calculator.

A database of sub-processes (preparation, dyeing, printing, wash-off, finishing) and their calculated energy intensities was created for different fiber, fabric, and dyestuff types. It also included a split between thermal and electrical energy (based on the energy content of fuel).

These sub-processes were then linked together to create a database of industry-agreed full model processes with energy intensity values, a split between thermal and electrical energy, total CO<sub>2</sub> emissions/kg, and a split between emissions from thermal and electrical energy.

This Excel database was used as the prototype Benchmark calculator, where the input of relative production volumes permitted the calculation of a weighted average target for a facility.

Additional correction factors – for example, an allowance for facilities with on-site effluent treatment plants, those with zero liquid discharge facilities, water recycling, caustic recovery, and specific finishing processes – are included.



## **Appendix B – Dry Process Energy Intensity Methodology**

### **B.1 Scope, purpose, and methodological foundations**

This appendix describes the methodology used to develop energy intensity figures for textile dry processes, including spinning, knitting, weaving, and product assembly. The methodology supports comparative benchmarking across the apparel and home textiles sector under conditions where process-level, single-process primary energy data are not available.

Dry processes differ fundamentally from wet processing in terms of energy-use structure and data availability. Facilities performing dry processes are rarely single-process sites, and energy consumption is typically shared across multiple operations, product types, and production lines. As a result, it is generally not possible to derive additive, process-level energy intensity figures based on primary single-process facility data, as was done for wet processing.

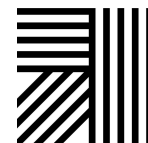
For this reason, the development of energy intensity figures for dry processes follows a statistical, top-down approach, based on large-scale facility datasets and the derivation of relative energy intensity factors associated with key technical parameters. This approach enables consistent benchmarking while acknowledging the structural and data constraints inherent to dry processing operations.

### **B.2 Definitions and conventions**

Key definitions and conventions used throughout the Energy & Carbon Benchmark methodology are provided in Appendix C – Key terms for methodology. This appendix applies those definitions to dry-processing pathways, including spinning, knitting, weaving, and product assembly.

For dry processes, energy intensity figures are derived as relative indicators, rather than absolute process-level values. Relative energy intensity factors express differences in energy use associated with specific process configurations, materials, or technical parameters, and are subsequently calibrated to sector-level average energy intensity values to generate benchmark figures.

All statistical analyses are conducted at the facility-year level and based on aggregated monthly reporting. Benchmark results are reported as single-point indicators to support comparability, recognizing that underlying variability exists but it is not published due to data confidentiality constraints.



### **B.3 Data coverage and sources**

Energy intensity factors for dry processes were derived using facility-level data collected and managed by Made2Flow, and based on a database comprising information from over 12,000 facilities across 53 countries. Data are collected directly from facilities through structured, process-specific questionnaires hosted on the Made2Flow platform. Facilities submit activity data for two primary purposes:

- facility-level environmental assessments aligned with greenhouse gas accounting frameworks; and
- product-level data, primarily used for life cycle assessment applications.

Data collection follows defined protocols and includes documentary verification, such as uploaded energy bills, as well as mathematical validation through cross-referencing with historical facility data and expected physical ranges. Data used for the dry-process benchmark cover the period from 2021 onwards and are aggregated at the facility-year level based on monthly reporting across a full calendar year. The dataset focuses on apparel and home textiles, although the broader database includes other textile segments.

### **B.4 Methodological approach and derivation of relative intensity factors**

#### **Key parameters influencing dry-process energy intensity**

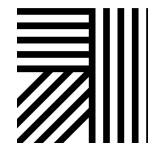
Technical experts in spinning, knitting, weaving, and product assembly were consulted to identify the primary parameters influencing energy intensity for dry processes. Key parameters include:

- **Spinning:** fiber type, spinning method, yarn count, and post-spinning processes
- **Knitting:** fiber type, machine gauge, and (for weft knitting) cylinder diameter
- **Weaving:** loom type, fabric construction, and material type
- **Product assembly:** product type, customer age or gender category, and material composition

These parameters form the basis for the statistical analysis used to derive relative energy intensity factors.

#### **Statistical analysis and factor derivation**

Due to the absence of primary single-process facility data, energy intensity figures for dry processes were derived using statistical analysis of facility-level data rather than physical process modeling.



The unit of analysis is the annual facility average, calculated from monthly reported data. Facilities lacking complete datasets are excluded. Data distributions were analyzed using clustering techniques to identify central tendencies and exclude extreme outliers, with thresholds applied to the upper and lower tails depending on sample size.

Relative energy intensity factors were derived by comparing facilities operating under otherwise similar conditions (e.g., same fiber and machine types, but different yarn counts or gauges). The resulting factors represent relative differences in energy intensity, rather than absolute process-level energy use.

Given the size of the dataset, the median value was used as the reference point for defining relative intensity factors. While variability metrics exist, these are not published due to confidentiality constraints, and Benchmark results are reported as single-point indicators only.

### **B.5 Calibration, construction, and application of dry-process benchmarks**

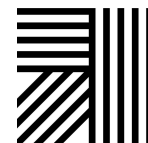
For the pilot phase, the relative energy intensity factors derived through statistical analysis were calibrated to align with average energy intensity values per tier, as reported in Apparel Impact Institute analyses of sector-level greenhouse gas emissions. This calibration ensures consistency between dry-process benchmark figures and observed industry-wide energy and emissions profiles.

The calibrated benchmark figures are intended to support comparative benchmarking, rather than to define best-practice or target performance levels. As with wet processing, this alignment reflects typical industry performance and supports facility-level performance assessment.

### **B.6 Data quality assurance, bias, and limitations**

All data used in the dry-process benchmark are based on voluntary facility disclosures and are subject to verification and validation procedures. Energy data are typically supported by documentary evidence such as energy bills, providing a relatively high level of confidence. Production quantities are more difficult to verify at scale; therefore, multiple cross-checks are applied to identify implausible values based on historical data and expected physical relationships.

The dataset exhibits a systematic bias towards larger and better-performing facilities, as these are more likely to participate in sustainability programs and possess the monitoring infrastructure required for detailed reporting. This bias is explicitly acknowledged, and conservative calibration

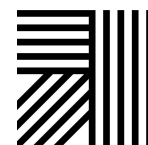


approaches—consistent with those applied for wet processing—are used to avoid underestimating typical energy intensity.

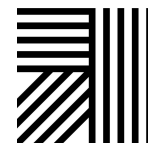
Uncertainty is higher for dry processes than for wet processes. No formal uncertainty ranges are published, and benchmark values should be interpreted accordingly.

## Appendix C – Key Methodological Terms

Term	Definition
Ancillary processes	Supporting operations required to enable production, such as laboratories, offices, warehouses, utilities, and a proportional share of general services, excluding unrelated site infrastructure.
Benchmark	A reference point used to evaluate the energy use and greenhouse gas (GHG) emissions performance of textile manufacturing processes and facilities.
Computed data	Data that is mathematically generated using a combination of primary data, modeled process data, and professional judgement.
Computed process demand data	Data that is mathematically generated to represent the theoretical energy demand of a process, excluding inefficiencies and ancillary energy use.
Computed real world data	Data that is mathematically generated to represent real-world energy content of fuel use by incorporating process and utility inefficiencies and ancillary processes into computed process demand data.
Delivered product	Final product output leaving a process or process route, inclusive of the effects of re-processing, partial rework, and operational inefficiencies.
Electrical energy	Energy used to power machinery, equipment, and auxiliary systems, supplied either from the grid or through on-site generation.



Emissions intensity	The GHG emissions associated with the energy used in a process or facility, expressed per kilogram of product (g CO <sub>2</sub> e/kg). Calculated using average emission factors for thermal and electrical energy.
Energy intensity	Energy intensity is expressed as kilowatt-hours per kilogram of product delivered from a given process or process route (kWh/kg delivered), based on the energy content of fuel inputs required to provide useful energy.
Facility-year average	Annual average energy intensity value calculated from monthly facility-level data for a full reporting year.
MADE-BY benchmarks	Benchmark ranges generated through data processing and modeling based on primary data on a process-level from multiple facilities, rather than on total factory energy measurements.
Model process	A standardized, manually constructed process representation designed to reflect typical industry practice under defined operating conditions.
Non-vertical facility	A manufacturing site dedicated to a single processing stage.
Primary data	Measured data directly collected from facilities.
Primary process demand data	Measured data that considers only the theoretical or measured energy demand of a process, excluding process and utility inefficiencies and ancillary processes.
Primary real world data	Measured facility data that takes into account process and utility inefficiencies, as well as energy use associated with ancillary processes.
Process route	A defined sequence of processes and sub-processes used to manufacture a product, including wet processing and finishing stages where applicable.



Relative energy intensity factor	A dimensionless factor expressing the relative difference in energy intensity between process configurations, derived from statistical analysis rather than absolute process-level measurement.
Thermal energy	Energy used to generate useful heat or steam for processes, such as energy supplied via boilers or direct heating systems.
Utility map	A schematic overview of where utilities (e.g., electricity, steam, thermal energy) are used within a facility, often applied to vertical sites to assess departmental performance.
Vertical facility	A manufacturing site that performs more than one processing stage on-site (e.g., spinning, knitting, and dyeing).
Weighted average	A calculation method used to aggregate performance indicators (e.g., energy or emissions) across multiple products or processes, proportionally to their production volumes.