D.2.1.1 Raw and semi-processed wool materials catalogue

Exploring the Untapped Potential of Alpine Wool

WOOLSHED ALPINE SPACE

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Abstract (for public dissemination only)	A journey through the diversity of Alpine wool fibres, showcasing their qualities, regional origins, and how they can fuel creative and sustainable innovation.
Keywords	Wool fibres, Material innovation, Alpine heritage, Sustainability

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Executive Abstract

This catalogue provides a comprehensive overview of raw and semi-processed wool materials, compiled to support a practical and effective resource-matching optimization model within the wool industry. Its primary purpose is to document, categorize, and clearly describe various wool inputs, their derived semi-products and products, enabling better decision-making and more efficient resource utilization throughout the wool value chain.

By gathering wool data from different sheep breeds, the catalogue includes key characteristics such as fibre diameter, yield percentages, staple length, mechanical properties, and environmental impacts. It also tracks the transformation of these raw materials into semi-products through various processing stages. This structured information enables the optimization model to accurately match available wool resources with suitable processes and markets, ensuring optimal outcomes.

The optimization model leverages the data in this catalogue to maximize economic benefits while minimizing environmental impacts. It accounts for real-world constraints such as resource availability, process limitations, and sustainability regulations. In essence, the catalogue serves as a foundational tool for managerial decision-making, helping stakeholders effectively manage the complex interdependencies of wool production and processing.

With future updates, the catalogue will continue to support wool producers, processors, sustainability experts, and economic analysts in making strategic decisions that enhance both profitability and sustainability across the wool industry.

Context and Objectives

The valorisation of coarse Alpine wool aligns with current EU policy priorities on bio-based materials and the development of a circular economy. The EU Bioeconomy Strategy (2018) highlights the importance of strengthening the sustainable and circular use of biomass and promoting the exploitation of underutilised biological resources. Coarse wool - much of which is currently treated as (biohazardous!) waste - represents a prime example of low-value biomass with great potential for innovative applications [11].

The EU Strategy for Sustainable and Circular Textiles addresses the entire lifecycle of textile products, setting targets for durability, repairability, recyclability, and increased use of recycled fibres. Wool, being renewable, biodegradable, and recyclable, naturally supports these objectives and can help reduce reliance on synthetic fibres [13]. Its intrinsic properties make it an ideal candidate for sustainable textile solutions, with a proven ability to displace synthetic alternatives [8].

These initiatives are part of the Circular Economy Action Plan under the European Green Deal, which identifies textiles as a priority sector for circular product design and resource-efficient production. Within this policy framework, the valorisation of Alpine wool is directly linked to the sustainable transformation of the textile and materials industries [12].

By providing a structured overview, this catalogue serves as a foundational dataset that supports both the optimisation tool developed in WP2 and the broader policy goals of Europe's transition to a circular and bio-based economy.

The overall objective of this document is to provide an overview of the software tool to be developed for the needs of optimization of the wool value chain. The concept of blocks representing material transformations performed by diverse value stakeholders allows extension of the solution to the whole sector. The innovation of the wool transformation resulting from the Design Marathons is fully compatible with the proposed modules and can be directly implemented allowing immediate simulation of the economic, social and ecological impacts of the new wood-derived products. This ensures that the catalogue and optimization model remain responsive to real-world developments and stakeholder input.

The software will serve as a dynamic interface between the catalogue (Deliverable 2.1.1), the demand portfolio (Deliverable 2.1.2), and the resource-matching engine (Deliverable 2.1.3), supporting strategic decision-making and fostering circular innovation within the wool industry.

Methodological Framework for Wool Value Chain Optimization

This chapter outlines the methodological framework used to document and characterize materials, processes, and semi-finished products across the entire wool value chain. To support the development of a comprehensive optimization model, the compiled catalogue organizes information from every stage of the value chain, starting from raw wool through various processing steps (such as scouring, carding, combing, and nonwoven fabric production), and ultimately defining diverse final wool-based products.

Each catalogue entry includes detailed descriptions of attributes essential for optimization and resource matching, such as fibre quality characteristics (diameter, staple length, yield), mechanical properties, as well as cost parameters and environmental impacts. By indexing and linking materials and processes across different stages, the framework ensures seamless integration of the collected data into the optimization model for resource allocation and matching.

Figure 1 illustrates all stages of the wool value chain where resources are used or transformed. Beginning with raw wool, materials pass through multiple stages and processes, evolving into semi-products and ultimately final products. The catalogue's purpose is to collect and characterize raw and semi-processed wool materials, providing sufficient information to serve as input data for the optimization tool.

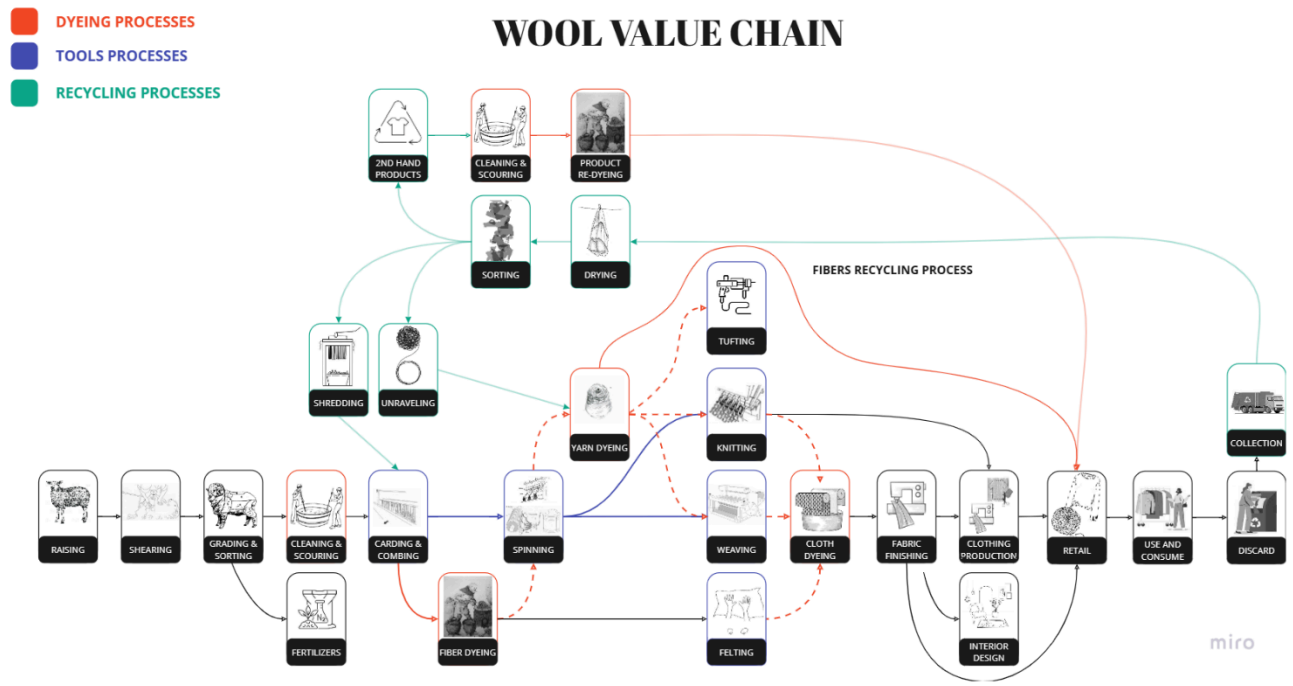


Figure 1 Wool value chain representation according to WOOLSHED project analysis

The catalogue's structured data on materials and processes is used to generate input for the optimization tool. In the original approach implement in WOOLSHED project, each element of the value chain is represented as a distinctive "block" or module.

Modular Representation of the Wool Value Chain

The wool value chain is modelled as a sequence of modular blocks, each representing a specific component or transformation step - from the sourcing of raw wool at the field or collection site to the final product ready for shipment from the factory. An example of this sequence is illustrated in Figure 2, where each pictogram corresponds to an elementary block within the system.

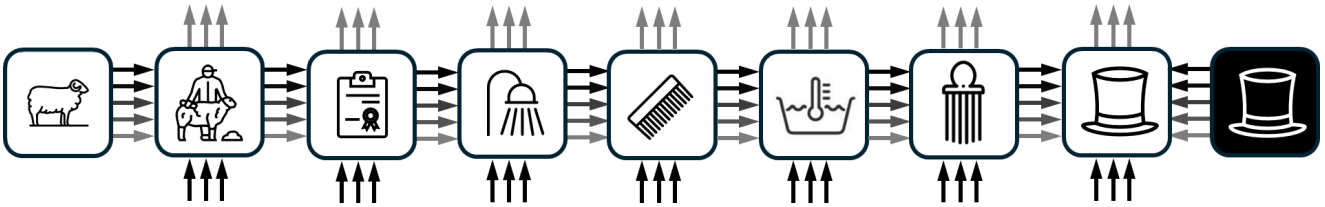


Figure 2 Example of the wool value chain representation implemented into WOOLSHED modelling software

The process begins with a quality assessment of the raw wool, resulting in a set of characteristics that describe its current state. This information is passed as input to the first block, representing the available raw resource. Each raw resource block corresponds to a real, physical batch of wool, geographically located and defined by its quantity, environmental footprint (e.g., carbon emissions), and commercial value. An example of the tabular representation of the raw wool batch is presented in Figure 3. It includes key characteristics relevant for matching to subsequent processes, along with cost and environmental impact data for procuring 1 kg of the raw material. Potential follow-up processes for each material (expressed as indexes) are also listed.

Index	Material/Breed	Fiber Diameter (µm)	Staple Length (cm)	Yield (%)	Lanolin (%)	Cost (€/kg)	Environmental Impact (kg CO2e/kg)	Next Process
RW1	Merino	18	9–11	50%	20%	9	25	Sc1,Sc2
RW2	Suffolk	30	8–10	65%	10%	1	18	Sc1
RW3	Lincoln Longwool	36	20–25	75%	8%	3	15	Sc1
RW4	Scottish Blackface	38–40	15	70%	5%	0.2	12	Sc1

Figure 3 Example input raw wool data row needed for the optimization model (filled in with placeholder/stakeholder values)

As wool undergoes various actions, such as sorting, cleaning, or dyeing, its properties change. Each of these actions is modelled as a process block, representing a transformation step within the supply chain. In most real-world scenarios, wool passes through multiple such transformations, each altering at least one of its physical, technological, or economic characteristics. These blocks are sequenced to simulate the full journey of wool from raw material to final product. It is critical that the final set of characteristics must match the requirements of downstream stakeholders. If the transformed wool meets industrial expectations, the supply chain is considered viable. If not, the chain is flagged as non-compliant and should not be executed.

Structure and Function of Process Blocks

Each process block is a core component of the modelling system and is implemented within the software tool. It simulates the transformation of wool properties based on defined process parameters (PP). Every block includes two inputs and two outputs, as shown in Figure 4.

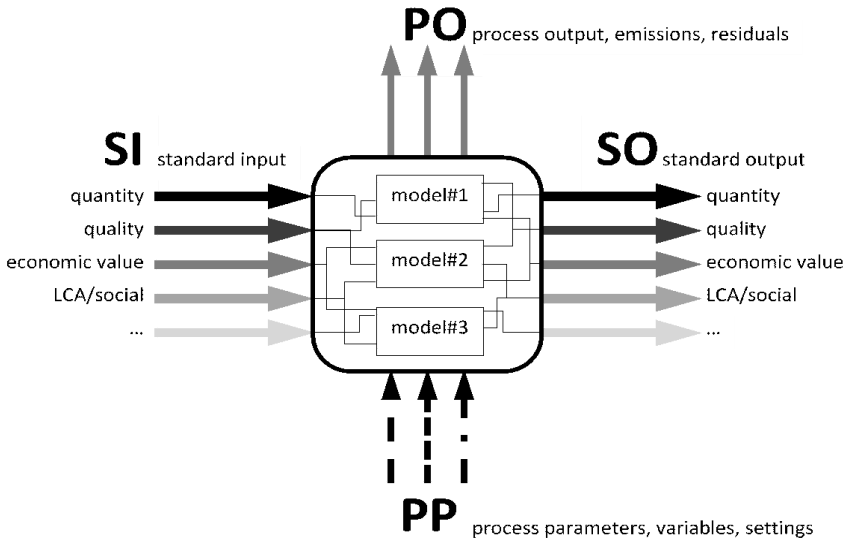


Figure 4 Elementary component of the WOOLSHED modelling system - block

Standard Input (SI) and Standard Output (SO) are consistent across all transformation blocks and include structured data on broad range of wool characteristics. Process Output (PO) captures additional outputs such as residues, emissions, or by-products not included in the SI/SO structure. The second input - Process Parameters (PP) - defines the transformation mathematically. These parameters are numerical variables used to simulate the effect of the process on the input characteristics. Stakeholders can provide detailed PP values to create digital twins of production processes. Where such data is unavailable, expert-derived approximations will be used. The SI/SO structure includes:

- Basic information: wool type, location, quantity, form, and state.
- Quality characteristics: fibre fineness, colour, staple length, and chemical composition.
- Technological characteristics: scouring yield, transformation suitability, etc.
- Economic indicators: operational costs, cumulative cost, return on investment.
- Environmental indicators: GWP, acidification, eutrophication, smog potential, energy use, ozone depletion.
- Social indicators: employment rate, livelihood impact, wealth distribution.

While complete SI/SO data enhances optimization accuracy, the system is designed to operate with partial datasets, allowing flexibility in real-world applications.

Types of Blocks and Their Roles

The general structure of process blocks is adapted to different stages of the value chain, and includes raw material, process and final product modules.

Raw Material Characterization Block

The *raw material characterization* block is used at the beginning of the supply chain to initialize wool resource data according to the SO structure (Figure 5). Inputs to this block contain useable information that may may come from inventories, measurements, databases, expert assessments, GPS data, or other sources. Deliverable D2.1.2 will define recommended wool quality measurement protocols, including sensor selection, chemometric models, and practical guidelines. Agronomists may provide this data as a contracted service, contributing to the social impact recorded in the arrow constituting the output of the block.

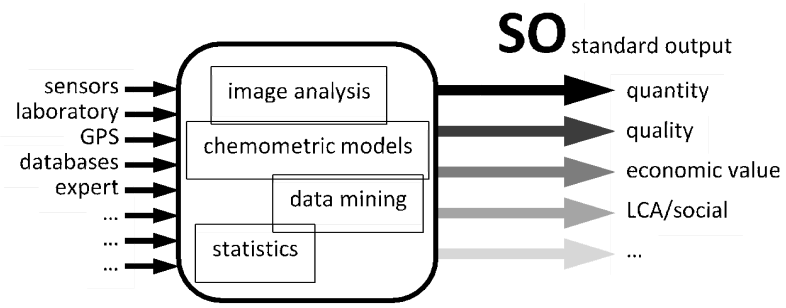


Figure 5 Raw wool characterization block.

The raw material characterization block within the WOOLSHED project digital system represents a real, physical stock of wool, defined by a specific set of characteristics, that is available for transformation. Once initialized, the software can simulate optimal value chain configurations and generate recommendations for the most suitable downstream conversion pathways of such raw resource. Moreover, this functionality enables the system to act as a traceability tool, highly valued by bio-based industries and environmentally conscious consumers.

Process and Transformation Block

The *process* block is an extension of the elementary module and its schematic is presented in Figure 6. It models the transformation of wool properties from Standard Input (SI) to Standard Output (SO), based on defined Process Parameters (PP). These transformations are mathematically described using various modelling techniques, including statistical analysis, multivariate methods, neural networks, fuzzy logic, and regression models. Process blocks represent a wide range of wool handling operations, including but not limited to:

- Shearing
- Grading
- Sorting
- Cleaning & Scouring
- Carding & Combing
- Thermo-fusion / Needle Punching
- Spinning
- Yarn Dyeing
- Weaving
- Knitting / Crochet
- Felting
- Tufting
- Fabric Dyeing

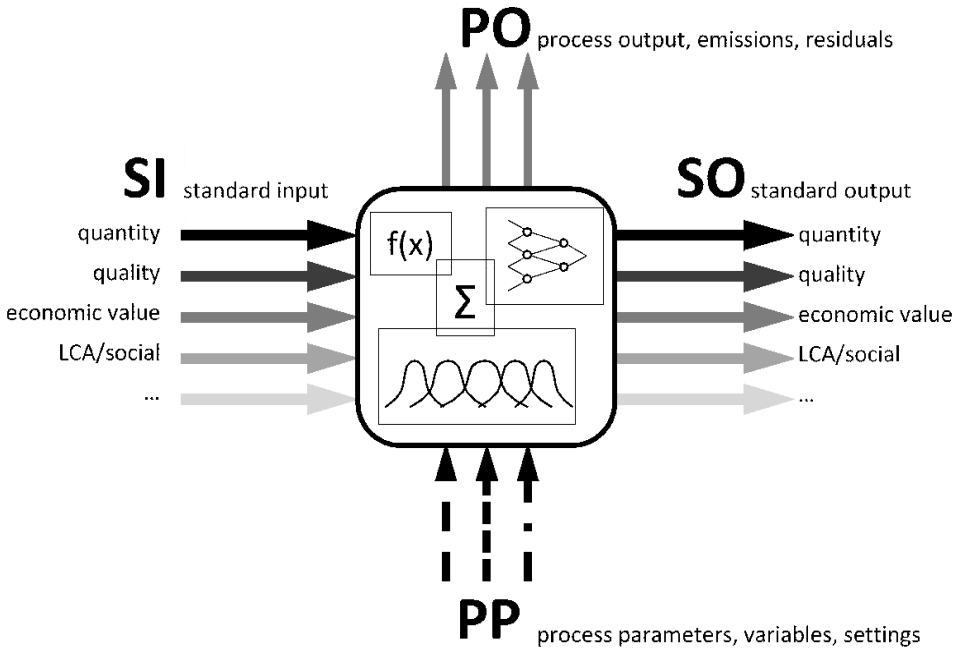


Figure 6 Process and Transformation Block

Each process block also generates a Process Output (PO), which includes additional data such as residues, emissions, or by-products not captured in the SO but having potential for further transformation as a resource for other industries. To ensure logical consistency, each block includes a set of constraints that validate the SI and prevent unrealistic or incompatible value chain sequences.

Figure 7 shows an example of input data for a processing stage - specifically carding. The data row includes essential characteristics for matching to subsequent stages, as well as cost and environmental impact data. Indexes of permissible follow-up processes for each material/semi-product are also indicated.

Index	Process	Yield (%)	Lubricant (%)	Cost (€/kg)	Environmental Impact (kg CO2e/kg)	Previous Process	Next Process
Ca1	Woollen	95%	0.5%	0.3	2	Sc1	Co2,NW1,NW2
Ca2	Worsted	95%	0.8%	0.4	2.5	Sc1,Sc2	Co1

Figure 7 Example input data row for carding stage (placeholder values)

Final Product Block

The *final product block* defines the desired characteristics - referred to as Expected Properties (EP) - required by downstream processing industries. Unlike other blocks, it does not receive an SI but instead serves as a target configuration for the value chain (Figure 8). The EP determines the architecture of the entire transformation pathway and aligns production planning with supply chain capabilities.

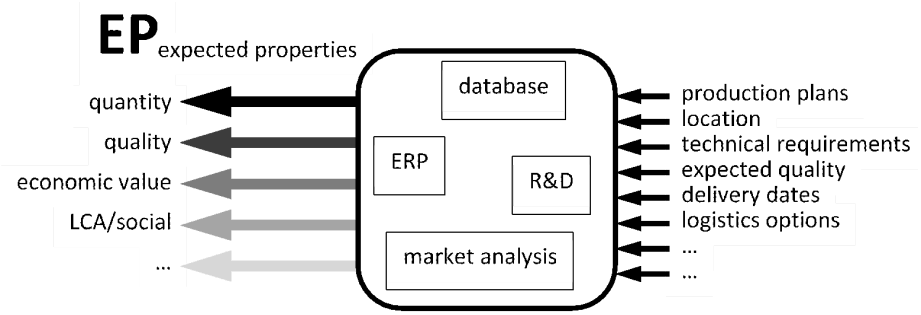


Figure 8 Final product block

Key final products identified within the project at this stage of development include (Figure 9):

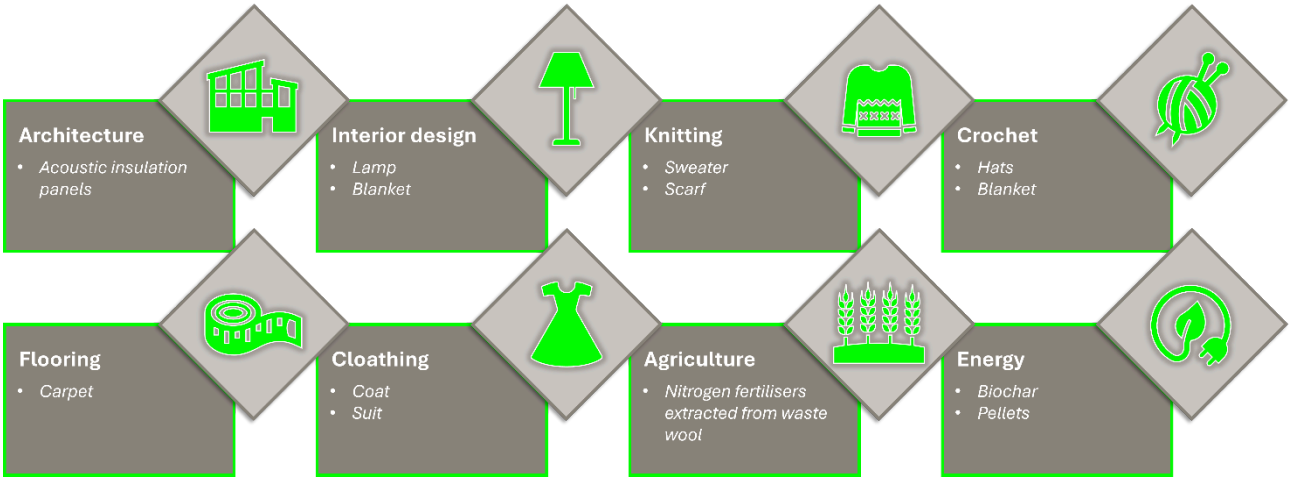


Figure 9 Final key products identified

Each product type is associated with a specific technological process or "recipe," which will be modelled as a sequence of dedicated process blocks. Not all EP attributes need to be defined - only those most relevant to the intended transformation. This flexibility allows the system to adapt to diverse industrial requirements while maintaining a consistent modelling structure. Moreover, other *final products* are expected to be defined as a result of the Design Marathons. These will be included as additional final product blocks and used for simulations.

Simplified Characterization Variant

In cases where full data set regarding raw wool characteristics is unavailable, the system allows for "expected" or "typical" values to be used, enabling continued modelling and optimization. In that case the expected yield depending on the sheep bread will be estimated together with quality characteristics typical for the same species.

Once characterized, the wool batch is treated as a digital stock, ready for transformation. The software can then simulate optimal value chains and recommend downstream conversion pathways. This functionality supports traceability and aligns with modern bio-industry standards.

Integration of Innovation and Regional Context

The modelling system is designed to evolve. Innovations from the Design Marathons will be integrated as new process blocks, reflecting emerging transformation pathways and product concepts. These additions will be analysed in collaboration with industrial partners and local authorities committed to wool valorisation in Alpine regions. Simulations will be also tailored to local conditions but designed for scalability, allowing insights and methodologies to be transferred to other regions and contexts.

Beyond traceability, the proposed modelling approach supports simulation of transformation pathways and innovation scenarios. This capability is central to the WOOLSHED project's ambition to explore future trends in wool-derived product manufacturing. Insights and know-how gathered during the Design Marathons will be integrated into the system as additional process blocks, allowing the value chain to be reconfigured based on stakeholder input and regional priorities. These simulations will be tailored to local Alpine contexts but designed for broader applicability across other regions.

Specifications for modules representing wool value chain

The WOOLSHED process blocks, as described in the preceding chapter, are implemented as core components of the optimization software. Each block corresponds to a specific transformation step within the wool value chain and is formally defined by a set of critical attributes. These attributes include default values based on average industrial operations, which can be adjusted to reflect the specific conditions and capabilities of individual stakeholders.

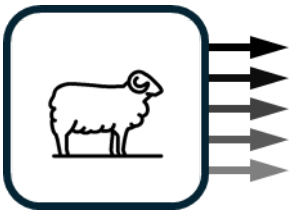
In addition to the standard data structures - Standard Input (SI), Standard Output (SO), and Process Output (PO) - each stakeholder represented in the system is assigned a unique GPS location and associated environmental and social impact indicators. These features are integrated into the WOOLSHED software to support spatial analysis and sustainability assessments.

A summary of wool characteristics for typical raw resources is provided in Appendix 1, while Appendix 2 offers detailed examples of semi-processed wool forms. These appendices serve as reference datasets for initializing and validating the simulation models within the WOOLSHED framework.

The key WOOLSHED process blocks representing the wool value chain components are listed below for raw materials, production processes of semi-products as well as production processes of final products:

Type of block: raw material

Sheep



Description: available resource of the raw and uncleaned wool.

Input (SI): ***not required***, optional quality description or historical characteristic of the breed

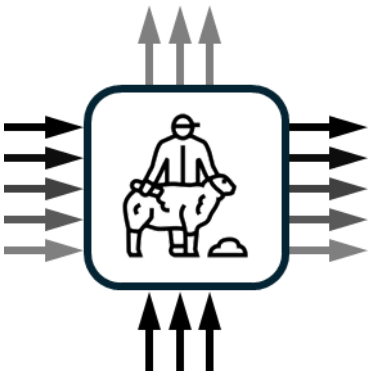
Output (SO): ***expected weight of not washed wool***, estimated wool quality, real cost of breeding animal, real use of energy for breading animal, real use of water for breeding animal, social LCA quantifiers

Optional (PP): not required

Optional (PO): not required, optional: toxic residuals, dirty water, contaminants, etc.

Type of block: process for production of semi products

Shearing



Description: activity related to cutting out hair from living animals that is performed periodically by farmers or specialized operators.

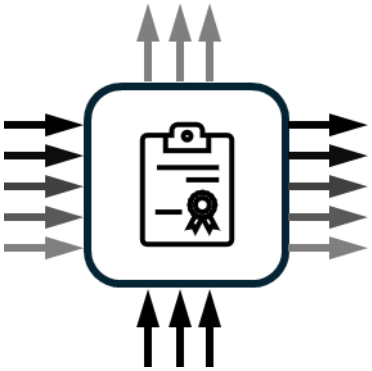
Input (SI): ***expected weight of not washed wool***, sheep bread, number of sheared sheep

Output (SO): ***not washed wool (fleece)***, weight of not washed wool, estimated wool quality, real cost of shearing operation, real use of energy, real use of water, social LCA

Optional (PP): expected cost of unite animal shaving, other costs, average time of shaving one animal

Optional (PO): toxic residuals, dirty water, contaminants

Grading



Description: activity related to determination of assured wool quality

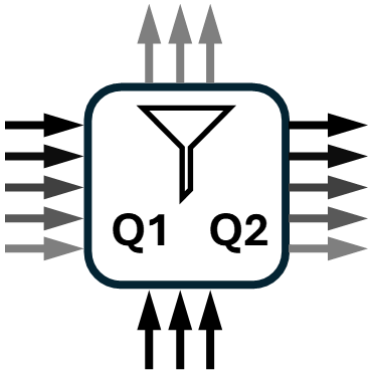
Input (SI): ***not washed wool (fleece)***, sheep bread, number of sheared sheep

Output (SO): ***not washed wool (fleece)***, weight of not washed wool, ***wool quality descriptions***, real cost of grading operation, real use of energy for grading, real use of water for grading, social LCA

Optional (PP): expected cost of grading, other costs, average time of grading 1kg of wool

Optional (PO): toxic residuals, dirty water, contaminants

Sorting



Description: activity related to separation of wool into batches of assured/defined quality and specified properties, following (or combined with) grading process

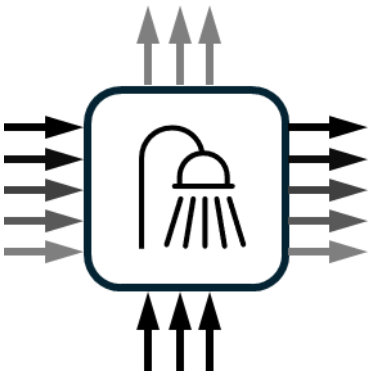
Input (SI): ***not washed wool (fleece)***, ***wool quality descriptions***

Output (SO): ***batches of sorted not washed wool (fleece)***, weight of not washed wool in each batch, ***wool quality description***, real cost of sorting operation, real use of energy for sorting, real use of water for sorting, social LCA

Optional (PP): expected cost of sorting, other costs, average time of sorting 1kg of wool

Optional (PO): toxic residuals, dirty water, contaminants

Cleaning & Scouring



Description: activity related to cleaning of not washed wool (fleece)

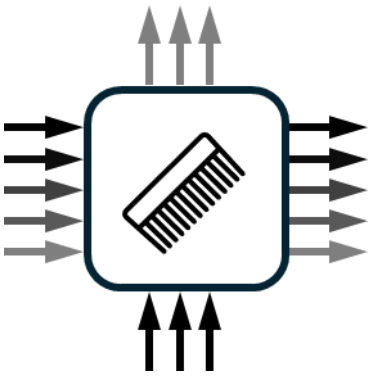
Input (SI): ***batch of not washed wool (fleece)***, wool quality description

Output (SO): ***batch of scoured/clean wool***, weight of wool after washing/scouring, ***wool quality descriptions***, real cost of washing operation, real use of energy for washing, real use of water for washing, social LCA

Optional (PP): expected cost of washing, other costs, average time of washing 1kg of wool

Optional (PO): lanoline, solid matter, toxic residuals, dirty water, contaminants

Carding & Combing



Description: activity related to carding wool to straighten and separate fibres

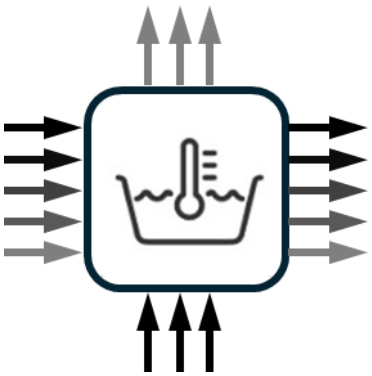
Input (SI): ***batch of scoured/clean wool***, wool quality description

Output (SO): ***batch of carded wool (silver)***, weight of wool after carding and combing, ***carded wool quality descriptions***, real cost of carding operation, real use of energy for carding, real use of water for carding, social LCA

Optional (PP): expected cost of carding, other costs, average time of carding 1kg of wool

Optional (PO): loosen fibres, toxic residuals, dirty water, contaminants

Thermo-fusion



Description: activity related to transforming wool fibres into felt or nonwoven fabric with thermo-fusion process

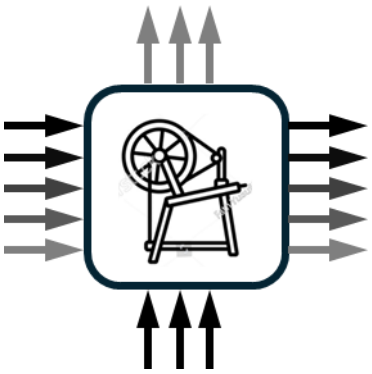
Input (SI): ***batch of carded wool***, wool quality description

Output (SO): ***nonwoven wool fabric (felt)***, weight of wool after thermo-fusion, ***wool quality (fibres) descriptions***, ***nonwoven wool fabric quality description***, real cost of thermo-fusion operation, real use of energy for thermo-fusion, real use of water for thermo-fusion, social LCA

Optional (PP): recovery rate of felt, expected cost of thermo-fusion, other costs, average time of thermo-fusion 1kg of wool

Optional (PO): loosen fibres, toxic residuals, dirty water, contaminants

Spinning



Description: activity related to transforming wool fibres into yarn

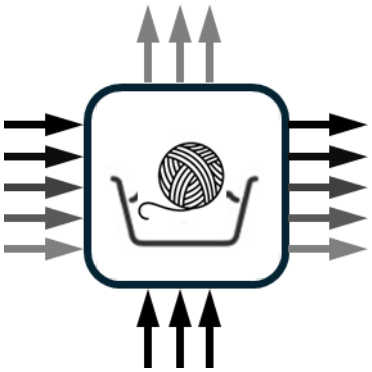
Input (SI): ***batch of carded wool***, wool quality description

Output (SO): ***batch of yarn***, weight of yarn, ***wool quality (fibres) descriptions***, ***nonwoven wool fabric quality description***, real cost of spinning operation, real use of energy for spinning, real use of water for spinning, social LCA

Optional (PP): recovery rate of yarn, expected cost of spinning, other costs, average time of spinning 1kg of wool

Optional (PO): loosen fibres, toxic residuals, dirty water, contaminants

Yarn Dyeing



Description: activity related to changing colour of yarn

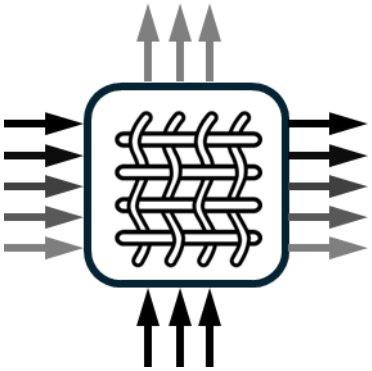
Input (SI): ***batch of yarn***, wool quality description

Output (SO): ***coloured yarn***, weight of yarn, ***wool quality (fibres) descriptions***, real cost of dying operation, real use of energy for dying, real use of chemicals for dying, real use of water for dying, social LCA

Optional (PP): recovery rate of yarn, expected cost of dying, other costs, average time of dying 1kg of wool

Optional (PO): loosen fibres, **toxic residuals**, dirty water, contaminants

Weaving



Description: activity related to changing yarn int to fabric

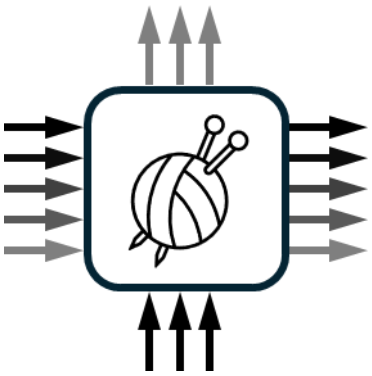
Input (SI): ***batch of yarn*** *(coloured or not)*, wool quality description, yarn characteristics

Output (SO): ***(coloured or not) fabric***, weight/surface area of fabric, ***wool quality (fibres) descriptions***, real cost of weaving operation, real use of energy for weaving, real use of chemicals for weaving, real use of water for weaving, social LCA

Optional (PP): recovery rate of yarn, expected cost of weaving, other costs, average time of weaving $1m^2$ of fabric

Optional (PO): loosen fibres/yarn, **toxic residuals**, dirty water, contaminants

Knitting / Crochet



Description: activity related to changing yarn int to textile or garment

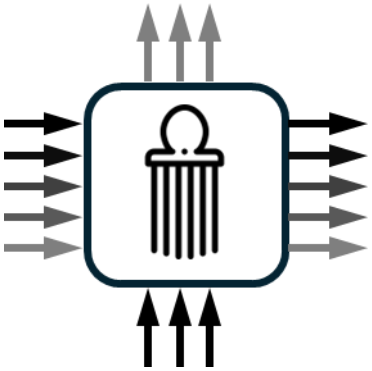
Input (SI): ***batch of yarn*** *(coloured or not)*, wool quality description, yarn characteristics

Output (SO): ***(coloured or not) textile***, weight/surface area of textile, ***wool quality (fibres) descriptions***, real cost of knitting operation, real use of energy for knitting, real use of chemicals for knitting, real use of water for knitting, social LCA

Optional (PP): recovery rate of yarn, expected cost of knitting, other costs, average time of knitting 1m^2 of fabric

Optional (PO): loosen fibres/yarn, toxic residuals, dirty water, contaminants

Felting



Description: activity related to transforming wool fibres into felt or nonwoven fabric with felting/needle punching process

Input (SI): ***batch of carded wool***, wool quality description

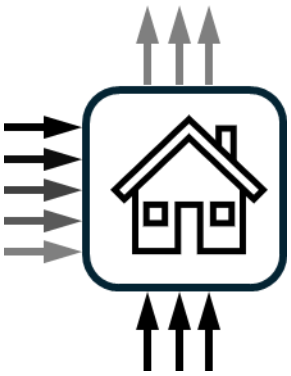
Output (SO): ***nonwoven wool fabric (felt)***, weight of wool after felting, ***wool quality (fibers) descriptions***, ***nonwoven wool fabric quality description***, real cost of felting operation, real use of energy for felting, real use of water for thermo-fusion, social LCA

Optional (PP): recovery rate of felt, expected cost of felting, other costs, average time of felting 1kg of wool

Optional (PO): loosen fibres, toxic residuals, dirty water, contaminants

Type of block: process for production of final wool-based products

Architecture



Description: production of wool-based product suitable for use in construction, such as insulation materials

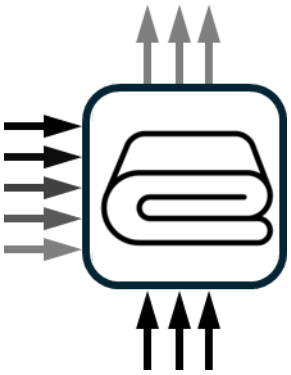
Input (SI): ***batch of carded wool***, ***batch of felt***, wool quality description

Output (SO): ***insulation material for building***, weight (or other functional unit, such as m^2 or m^3) of wool after production, ***wool quality (fibres) descriptions***, ***insulation material quality description***, real cost of production, real use of energy for production, real use of water for production, social LCA

Optional (PP): recovery rate of fibre/felt, conversion factor functional unit – 1kg od wool fibres, expected cost of production, other costs, average time of production 1 functional unit of insulation material

Optional (PO): loosen fibres, toxic residuals, dirty water, contaminants

Interior design



Description: production of wool-based product suitable for use in interior design, such as wool felt, upholstery fabric, wool carpets, curtains, dividers, and decorative objects like placemats and coasters, which are used for wall coverings, furniture, and flooring

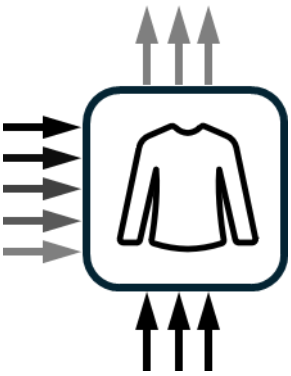
Input (SI): ***batch of carded wool***, ***batch of felt***, wool quality description

Output (SO): ***decorative product***, weight (or other functional unit, such as number of items, m^2 or m^3) of wool after production, ***wool quality (fibres) descriptions***, ***wool material quality description***, real cost of production, real use of energy for production, real use of water for production, social LCA

Optional (PP): recovery rate of fibre/felt, conversion factor functional unit – 1kg od wool fibres, expected cost of production, other costs, average time of production 1 functional unit of insulation material

Optional (PO): loosen fibres, toxic residuals, dirty water, contaminants

Knitting



Description: production of knitwear, or a specific item like a sweater, scarf, hat, or blanket

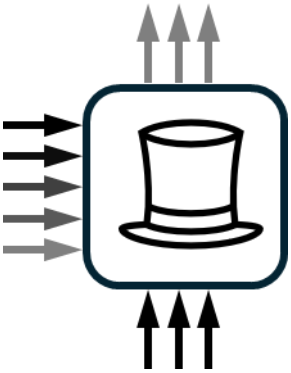
Input (SI): ***batch of (coloured or not) yarn***, ***(coloured or not) textile*** wool quality description

Output (SO): ***knitwear product***, weight (or other functional unit, such as number of items or m^2) of wool after production, ***wool quality (fibres) descriptions***, ***knitwear quality description***, real cost of production, real use of energy for production, real use of water for production, social LCA

Optional (PP): recovery rate of yarn, conversion factor functional unit – 1kg of yarn, expected cost of production, other costs, average time of production 1 functional unit of knitwear

Optional (PO): loosen yarn, toxic residuals, dirty water, contaminants

Crochet



Description: production of garments such as lacy shawls, doilies, and other decorative items, practical items like blankets, hats, scarves, and bags, and garments like classic sweaters, crop tops

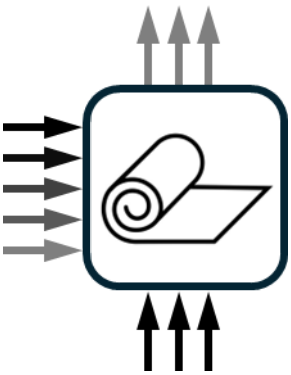
Input (SI): ***batch of (coloured or not) yarn***, wool quality description

Output (SO): ***garment product***, weight (or other functional unit, such as number of items or m^2) of wool after production, ***wool quality (fibres) descriptions***, ***garment quality description***, real cost of production, real use of energy for production, real use of water for production, social LCA

Optional (PP): recovery rate of yarn, conversion factor functional unit – 1kg of yarn, expected cost of production, other costs, average time of production 1 functional unit of garment

Optional (PO): loosen yarn, toxic residuals, dirty water, contaminants

Carpet production



Description: production of wool carpet

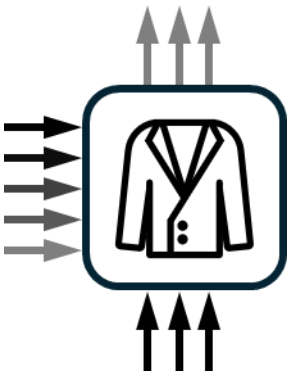
Input (SI): ***batch of (coloured or not) yarn***, wool quality description

Output (SO): ***carpet product***, weight (or other functional unit, such as number of items or m^2) of wool after production, ***wool quality (fibres) descriptions***, ***carpet quality description***, real cost of production, real use of energy for production, real use of water for production, social LCA

Optional (PP): recovery rate of yarn, conversion factor functional unit – 1kg of yarn, expected cost of production, other costs, average time of production 1 functional unit of wool carpet

Optional (PO): loosen yarn, toxic residuals, dirty water, contaminants

Clothing products



Description: production of clothing products such as outerwear, coats, jackets, sweaters, and accessories such as hats, gloves, and scarves, and tailored items like suits and pants, and direct-contact wear like underwear and socks

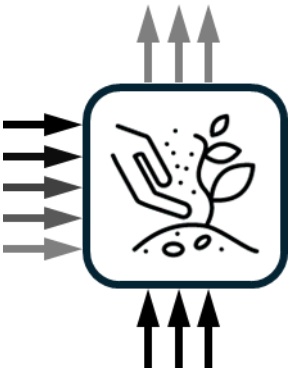
Input (SI): ***batch of (coloured or not) fabric***, wool quality description

Output (SO): ***clothing product***, number of items of wool products, ***wool quality (fibres) descriptions***, ***clothing product quality description***, real cost of production, real use of energy for production, real use of water for production, social LCA

Optional (PP): recovery rate of fabric, conversion factor functional unit – 1m2 of fabric, expected cost of production, other costs, average time of production 1 functional unit of clothing product

Optional (PO): loosen fabric, toxic residuals, dirty water, contaminants

Fertilizers



Description: production of fertilizer pellets used in agriculture

Input (SI): ***batch of not washed wool***, wool quality description

Output (SO): ***fertilizer product***, kilograms of produced pellets, ***pellet quality descriptions***, real cost of pellet production, real use of energy for pellet production, real use of water for pellet production, social LCA

Optional (PP): recovery rate of raw wool, expected cost of production, other costs, average time of production 1 kg of fertilizer pellets

Optional (PO): loosen fibres, toxic residuals, dirty water, contaminants

Cross-Sector Application Matrix

This section presents a structured and interpretive matrix that maps wool material classes to sector-specific performance requirements. In line with the methodological framework outlined in Deliverable 2.1.1, the matrix goes beyond a simple comparison of materials and applications. Instead, it evaluates their compatibility using a tripartite fuzzy assessment approach.

For each pairing of wool material and application sector, three qualitative indicators are provided:

- **Performance Match**: Assesses how well the intrinsic physical properties of the fibre - such as fineness, resilience, and moisture buffering - meet the functional demands of the target sector.
- **Circularity Score**: Evaluates the material's potential for reuse, recycling, biodegradation, and cascading use across multiple product life stages.
- **EU Policy Alignment**: Indicates the relevance of the material-application combination to current European strategies, including the European Green Deal, the Circular Economy Action Plan, the EU Strategy for Sustainable and Circular Textiles, and the EU Bioeconomy Strategy.

Each indicator is rated on a fuzzy three-point scale (3 = high, 2 = medium, 1 = low), accompanied by a concise explanatory note that justifies the score. This dual-format - combining visual clarity with narrative context - enables both quick interpretation and deeper understanding of the rationale behind each evaluation.

The resulting matrix offers a transdisciplinary and policy-aware overview of Alpine wool's cross-sectoral potential, transforming a raw inventory of fibre classes into a strategic map of innovation opportunities.

		Performance Match	Circularity Score	EU Policy Alignment
Fine wool (≤24 µm)	**Fashion & Product Design**	Excels in softness and dyeability, ideal for premium garments	Recyclable and compostable but limited cascading reuse	Aligns with EU Textiles Strategy goals on durability and premium bio-based fibres
	Interior & Acoustic	Usable in blended felts, but cost limits widespread use	Biodegradable but niche applications	Moderate link to circular textiles, niche alignment
	Constructio n & Technical	Insufficient structural resilience	Compostable, but unsuitable for long service life	Low relevance to CEAP or ESPR
	Horticulture	Too fine, decomposes rapidly in soil	Biodegradable but lacking agronomic persistence	Minimal alignment with bioeconomy cascading use
		Performance Match	**Circularity Score**	**EU Policy Alignment**
Medium wool (25 - 32 µm)	**Fashion & Product Design**	Durable for outerwear, upholstery, knitwear	Recyclable and reusable, moderate cascading potential	Aligns with Textiles Strategy emphasis on durability

	Interior & Acoustic	Strong acoustic absorption with aesthetic finish	Recyclable as felt and biodegradable at end-of-life	Supports Green Deal objectives for healthy indoor environments
	Construction & Technical	Effective insulation mats, intrinsic fire resistance	Recyclable into felts, biodegradable disposal	Matches Energy Efficiency Directive via natural insulation
	Horticulture	Feasible as mats and pots, moderate uptake	Slow biodegradation provides nutrient release	Consistent with Waste Directive's textile collection and reuse
		Performance Match	**Circularity Score**	**EU Policy Alignment**
Coarse wool (>32 µm)	**Fashion & Product Design**	Usable for rugged accessories, low apparel demand	Durable, biodegradable, recyclable into technical uses	Fits CEAP goal of replacing short-lived synthetic accessories
	Interior & Acoustic	Robust and cost-effective felts	Highly recyclable in loose-fill insulation	Supports EU construction policies on sustainable materials
	Construction & Technical	Strong candidate for insulation, erosion mats	Can be cascaded through multiple technical cycles	Exemplary Bioeconomy cascading use
	Horticulture	Proven mulch mats, long degradation period	Excellent soil-conditioning and nutrient cycling	Aligns with Bioeconomy Strategy and Waste Directive targets
		Performance Match	**Circularity Score**	**EU Policy Alignment**
Short fibres, noils & waste	**Fashion & Product Design**	Viable for chunky yarns and felt crafts	Direct upcycling of waste streams	Textbook CEAP circularity example
	Interior & Acoustic	Enhances acoustic absorption in loose-fill	Can be repeatedly reused and then composted	Supports Green Deal waste-reduction agenda
	Construction & Technical	Blown-in insulation and composites valorise residues	Closes loop by turning waste into durable products	Reinforces EU cascading use approach
	Horticulture	Pellets and plugs feed nutrients into soil	Biodegradable and fertilising	Consistent with Waste Directive textile

				collection requirements
		Performance Match	**Circularity Score**	**EU Policy Alignment**
Felts & non-wovens	**Fashion & Product Design**	Creative accessories and modular pieces	Recyclable and biodegradable	Matches ESPR push for durable, repairable design
	Interior & Acoustic	Direct substitute for synthetic acoustic panels	Recyclable and biodegradable, easy to cut and reuse	Aligned with Green Deal phase-out of petro-derived felts
	Construction & Technical	Protective linings and underlays, moderate technical performance	Recyclable and compostable	Supports CEAP through substitution of petro-based packaging
	Horticulture	Mats usable for water retention	Degrades steadily, releasing nutrients	Consistent with Bioeconomy Strategy cascading logic

Sustainability and Circularity Considerations

The environmental and circularity profile of wool-based materials must be evaluated within the framework of the European Union's core environmental policies. The European Green Deal (COM(2019) 640 final) serves as the overarching strategy to make Europe the first climate-neutral continent by 2050. It integrates decarbonisation goals with sustainable resource management across all sectors, including textiles.

Within this framework, the Circular Economy Action Plan (COM(2020) 98 final) identifies textiles as a priority value chain, emphasizing eco-design, waste reduction, and the valorisation of secondary raw materials. Building on these principles, the EU Strategy for Sustainable and Circular Textiles (COM(2022) 141 final) sets concrete targets for the industry, including durability, repairability, recyclability, and increased uptake of recycled fibres by 2030.

From a carbon intensity perspective, wool presents a distinct profile compared to petrochemical fibres such as polyester or acrylic. While sheep farming does contribute to greenhouse gas emissions, particularly methane, Life Cycle Assessments (LCAs) conducted by the International Wool Textile Organisation and independent research institutes show that wool's extended product lifespan, reusability, and composability help offset its initial environmental footprint. Unlike synthetic fibres, wool does not rely on fossil extraction and avoids releasing persistent microplastics during laundering, a concern highlighted in Joint Research Centre (JRC) reports on microfibre pollution.

Wool's biodegradability is a key environmental advantage. As a keratin-based fibre, untreated wool naturally decomposes in soil and aquatic environments, releasing nitrogen and sulphur compounds that enhance soil fertility. This contrasts sharply with synthetic polymers, which fragment into microplastics and contribute to long-term pollution. Pilot applications in agriculture and horticulture, such as mulching mats and soil-conditioning substrates, demonstrate wool's practical biodegradability benefits. It aligns with the Waste Framework Directive (2008/98/EC, as amended) and its upcoming revision mandating separate textile collection by 2025.

The substitution potential of wool for petrochemical materials is significant. In construction, non-woven wool felts can replace polyurethane foams or polyester batts in insulation, offering acoustic and thermal performance with lower embodied carbon. In horticulture, coarse wool substrates compete with synthetic geotextiles and plastic foams, providing water retention and nutrient release. In protective textiles and absorbent pads, wool's natural hydrophilicity and fire resistance offer a sustainable alternative to chemically treated synthetics. These cascading applications reflect the EU Bioeconomy Strategy (2018, updated 2022) principle of "cascaded use," where biological resources are diverted into secondary value chains before returning to the biosphere.

The material pathways documented in Deliverable 2.1.1 demonstrate strong alignment with the EU Strategy for Sustainable and Circular Textiles. They show how Alpine coarse wools - currently undervalued and often discarded - can contribute to circular product design, reduced environmental impact, and increased availability of bio-based and biodegradable textiles. Wool's inherent fire resistance, acoustic absorption, and moisture regulation also reduce the need for chemical finishing agents, supporting the goals of the Eco-design for Sustainable Products Regulation (ESPR, COM(2022) 142 final, pending adoption), which will set product-level requirements for sustainability, durability, and recyclability.

From a compliance standpoint, all sustainability considerations presented here are consistent with the *Do No Significant Harm* (DNSH) principle outlined in Article 17 of the EU Taxonomy Regulation (Reg. (EU) 2020/852), and with the Alpine Space Programme's commitment to promoting sustainable development and climate objectives. By embedding wool valorisation within these frameworks, Deliverable 2.1.1 ensures that the catalogue functions not only as a technical repository but also as a regulatory-aligned foundation

for future exploitation. Its outputs directly inform Deliverable 2.1.2 (Portfolio of Demands) and Deliverable 2.1.3 (Software for Resource Allocation), enabling the practical substitution of fossil-derived textiles with renewable alternatives in full coherence with EU policy.

Data Management and Accessibility

This chapter outlines the structure, governance, and accessibility of the wool materials database, developed in alignment with FAIR data principles and Alpine Space programme requirements. All evidence and catalogue entries are maintained in a reproducible, version-controlled workspace and submitted via JEMS, the official platform for reporting and archiving under Alpine Space procedures.

Within the partnership, a single “working” repository preserves the live dataset and its provenance. For reporting purposes, the Lead Partner generates a read-only snapshot and uploads the deliverable and annexes to JEMS, ensuring audit trails and timestamps are preserved. This approach satisfies programme compliance requirements for submission integrity and traceability, while avoiding the need for additional infrastructure or costs.

The dataset is intentionally designed to be simple and pragmatic, enabling partners to contribute with minimal effort. Material entries are stored in a normalized tabular format using SI units and controlled field names. Supporting artefacts - such as laboratory sheets and images - are linked via persistent internal identifiers. Each release is accompanied by a human-readable codebook that explains field definitions, test methods, and units. Data curation is managed through a secure web form with role-based access, and the system automatically records attribution and change history to support verification without duplicating files.

Public access follows a two-tier logic that balances openness with programme compliance. During implementation, only project partners have write access, while the Joint Secretariat is granted read access to immutable reporting snapshots. Upon acceptance, all non-confidential records are mirrored on the project website in a browsable format, with downloadable CSV exports and the accompanying codebook. This enables external reuse without registration. No personal data are published; any contact details collected for internal curation remain in a restricted-access register and are excluded from public releases.

All public-facing interfaces and files adhere to Alpine Space communication and visibility requirements. The ERDF acknowledgement, programme logo, and project references are consistently displayed on the catalogue PDF, export packages, and the project website. These measures are mandatory, cost-neutral, and ensure compliance with dissemination and capitalisation guidelines.

Retention and audit readiness are built into the system design. Partners retain primary evidence and underlying records for the statutory period defined by the Programme Manual and relevant EU regulations. The Lead Partner preserves the JEMS submission receipt and the exact dataset snapshot and codebook that underpin the approved deliverable. Because each record and file is version-pinned, any figure cited in the deliverable can be reconstructed without reprocessing, ensuring verification while keeping administrative overhead low.

To facilitate legal reuse, the catalogue’s tabular data and metadata are released under a standard open data licence (e.g., CC BY), clearly indicated in the codebook and on the download page. This licensing model supports the software matching engine to be delivered under Deliverable 2.1.3, which will be released as open source along with its input-format specification. The current catalogue provides the canonical input, enabling the tool to operate transparently on project data and future third-party contributions.

To lower the barrier to contribution, the partnership adopts a “FAIR-lite” approach—focusing on essential practices that improve usability without incurring additional costs. These include persistent identifiers for each record, minimal mandatory metadata for findability, machine-readable CSV formats alongside narrative PDFs for accessibility and interoperability, and explicit versioned provenance for reusability. These modest but effective steps ensure functional diffusion and uptake of Action 2.1 deliverables and enable a seamless transition to Deliverable 2.1.3.

Conclusions and Next Steps

This deliverable establishes a foundational dataset and methodological framework for resource optimization in the wool value chain. By systematically documenting raw and semi-processed wool materials, their properties, processing stages, and cross-sectoral applications, the catalogue provides a robust basis for both technical modelling and strategic decision-making.

The catalogue highlights the wide variability in wool characteristics across breeds and processing stages, revealing untapped potential for non-apparel applications in sectors such as construction, horticulture, and protective textiles.

The documented and modelled material pathways demonstrate strong coherence with EU sustainability strategies, including the European Green Deal, Circular Economy Action Plan, and the EU Strategy for Sustainable and Circular Textiles.

The structured data format, combined with environmental, social and economic indicators, enables immediate integration into the resource-matching tool developed under Deliverable 2.1.3.

While the catalogue provides a comprehensive starting point, several areas require further exploration:

- Some processing stages lack detailed data related to cost or environmental impact metrics, which may affect optimization accuracy.
- The cross-sector matrix relies on qualitative assessments; empirical testing in target applications would strengthen confidence in substitution potential.
- More precise indicators for reuse, recyclability, and biodegradability - especially in mixed-material contexts - would enhance lifecycle modelling. This is not considered in the optimization software developed within frame of WOOLSHED project

To address these gaps and expand the catalogue's utility, the upcoming Design Marathons will serve as collaborative, hands-on sessions for validating and refining data entries with input from producers, processors, and end-users. It will also lead to mapping new application pathways, informed by real-world use cases and innovation opportunities identified during the workshops. Each Design Marathon will generate a versioned update to the catalogue, ensuring that the dataset remains dynamic, stakeholder-driven, and policy-relevant. These updates will feed directly into the optimization tool and support broader dissemination and uptake across the wool ecosystem. Particularly, adding innovative material/products classes and process variants, especially those emerging from marathon activities enriches the presented portfolio. Continuous stakeholder feedback is another desired solution for refinement of the catalogue's processes descriptions by proposing alternative documentation, test protocols, and sector-specific performance benchmarks.

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Appendix 1: specification for most common raw Wool Materials

Breed / Material	Description	Key Characteristics	Possible Applications	Source
Foza (uncerned)	Coarse Alpine wool from PE2020 sample (F3 C-C3). Laboratory washed.	Clean yield: 63.4%; Lanolin: 7.0%; COD: 8520 mg/L; BOD_5: 3530 mg/L; COD/BOD_5: 2.4; Industrial yield ~10% lower; sorting improves quality.	Carpet yarns, coarse textiles, insulation; potential lanolin recovery in large-scale operations.	[10]
Brogna (uncerned)	Traditional Alpine breed, PE2019 & PE2020 samples (F1 B-C8, F2 B-C9).	Yields: 64.5% & 75.2% (avg 69.8%); Lanolin: 5.8% avg; COD: 8320–9960 mg/L; BOD_5: 1200–3210 mg/L; COD/BOD_5: 2.6–8.3; industrial yield ~10% lower.	Outerwear, rugs, upholstery; lanolin recovery impractical at current scale.	[10]
Transumante (uncerned)	Grazing-adapted wool from Spring & Autumn 2020 (F10 E-C11, F11 E-C7).	Yields: 64.9% & 76.0% (avg 70.4%); Lanolin: 5.3%; COD: 5520–6550 mg/L; BOD_5: 1762–2450 mg/L; COD/BOD_5: 2.7–3.1; industrial yield ~10% lower.	Rustic fabrics, insulation; quality benefits from sorting; free-range grazing improves cleanliness.	[10]
Lamon (cerned / uncerned)	Mixed cerned & uncerned PE2020 samples (F6 D-C6, F8 D-C5, F7 D-C4).	Clean yield: 70.9–75.1% (mean 73.0%); Lanolin: 5.7–7.8% (mean 7.0%); COD: 5540–9230 mg/L; BOD_5: 2480–3360 mg/L; COD/BOD_5: 2.2–2.7.	Knitting yarns, blankets, insulation; high lanolin content of cosmetic interest at large scale.	[10]
NZ Strong Wool (market data)	Auction data from 36,904 lots (28–42 µm) sold Jan 2022–Jun 2024.	Price drivers: Colour (48%), micron, length, exchange rate, vegetable matter; price prediction accuracy ±$0.15/kg clean; Model R^2 = 0.91.	Market value optimisation through breeding, fleece preparation, and timing of sale.	[2]
Polish Mountain Sheep – Acoustic Felts	*Wool of mountain sheep, treated nowadays as a waste…* (CC BY 4.0 verbatim).	High-porosity felts: NRC up to 0.4; tufted fabrics: NRC 0.4–0.42; comparable to commercial acoustic panels.	Acoustic screens, panels, carpets.	[5]
Oplemenjena Jezersko–Solčavska (JSR)	Improved JS breed wool (samples JSR1, JSR2).	Finer mean fibre diameter; higher comfort factor; more uniform crimp; staple length suitable for spinning.	Apparel yarns, woven cloth for garments, higher-value textiles.	[1], [7]
Jezersko–Solčavska (JS)	Native Slovenian mountain breed wool.	Coarser average fibre (vs JSR); lower comfort factor; rustic crimp; adapted to harsh conditions.	Rugs, felts, insulation panels, rustic cloth.	[1], [3]
Oplemenjena Bovška	Improved Bovška breed wool analysed for fibre diameter (BF1, BF2).	Fine–medium wool; measured fibre diameters; mixed-use textile quality.	Hand-knitting yarns, traditional weft, felt.	[7]

		teristics	Possible Applications	Source
Istrska Pramenka	Coarse Mediterranean wool (I1–I3) with strong medullation.	Coarse (>35 µm), long staple; low elasticity; resistant to felting.	Rugs, tapestries, insulation panels.	[7]
Waste Wool – Adsorbent Form	Coarse wool processed for oil adsorption.	Capacity: 15 ml/g for diesel; optimal diesel:water 1:10; >90% removal with washed wool.	Oil spill clean-up.	[9]
Wool Insulation (Fire Safety Tested)	Scoured, carded wool batts tested for insulation/PPE.	Naturally flame-retardant; self-extinguishing; meets EN standards.	Building insulation, firefighting clothing.	[6]
Jezersko-solčavska (Slovenia)	Traditional Slovenian sheep breed	Medium fiber thickness (~32.5 µm); good yield; very low vegetable impurities; good color; resistant	Felting, clothing, footwear, fashion accessories, carpets	[4]
Oplemenjena jezersko-solčavska (Slovenia, crossbred)	Crossbred improved Jezersko-solčavska	Finer fibers (~28.4 µm, thinnest of breeds studied); low yield; moderate impurities	Felting, knitwear, clothing, carpets, scarves, hats	[4]
Bovška (white, Slovenia)	Milk-focused Slovenian breed	Coarse fibers (~37.2 µm); good yield; few impurities; less attractive color	Felting, knitwear, jackets, shoes, accessories	[4]
Bovška (black, Slovenia)	Dark variant of Bovška	Coarse fibers (~37.3 µm); higher yield and more impurities than white; natural dark color	Carpets, knitwear, clothing, footwear	[4]
Istrska pramenka (Slovenia)	Coarse-wooled pramenka breed	Coarse fibers (~39.8 µm); low yield; high impurities	Carpets; decorative effects due to natural color	[4]
Belokranjska pramenka (Slovenia)	Local pramenka breed	Average fiber thickness (~35.6 µm); good yield; few impurities	Carpets, tapestry yarn, felting, knitwear	[4]
Plezzana (Italy)	Friuli breed	Good yield; high impurities	Carpets, blankets, scarves	[4]
Sarda (Italy)	Sardinian origin breed	High yield; many impurities; medium fibers (~39.7 µm)	Carpets	[1]
Alpagota (Italy)	Breed from Alpine region	Good yield; few impurities; raw wool felted and needs combing; many dead fibers; variable length	Carpets	[1]
Massese (Italy)	Tuscan origin breed	Good yield; few impurities; coarse fibers (~42.9 µm); dark grey color	Carpets, moquettes, decorative uses	[1]

Appendix 2: Semi-Processed Wool Forms

Stage / Form	Input Material	Process (key steps & parameters)	Output Properties (key metrics)	Env./Safety Notes	Typical Applications	Source
Scoured wool (lab scale)	Foza, Brogna, Lamon, Transumante	Laboratory scouring of ≈500 g greasy wool; UNI/ISO/"Libro blu FLI" methods; retain ~2–2.5% lanolin in industrial scouring to reduce fibre damage.	Clean yields: Foza 63.4%; Brogna avg 69.8%; Lamon avg 73.0%; Transumante avg 70.4%.	Effluent COD/BOD_5 requires treatment: Foza 8520/3530; Brogna 8320–9960/1200–3210; Lamon 5540–9230/2480–3360; Transumante 5520–6550/1762–2450 mg/L.	Feedstock for carding, combing, felting, spinning.	[10]
Carded sliver (trial)	Scoured Foza, Brogna, Lamon, Transumante	Opening–carding into sliver; pre-sorting before scouring improves cleanliness.	Slivers from cleaner fleeces more uniform, spinnable; dirtier samples yield more waste.	Pre-sorting reduces non-wool material load.	Yarn production (woollen/semi-worsted).	[10]
Ring-spun yarn (trial)	Coarse local mountain wool (scoured)	Carding then ring spinning; also core-rug yarn variant.	Yarn from coarse wool suitable for tufting; adequate tensile strength.	Coarse grade best for interior/technical uses.	Tufted rugs/carpets, weft yarns.	[5]
Needle-punched felt batts (acoustic)	Coarse mountain wool (loose fibres)	Needle-punch felting; thickness primary driver of absorption.	NRC up to 0.4 for thicker felts (comparable to ceiling tiles).	Renewable, inherently fire-resistant.	Acoustic panels/screens, wall/ceiling tiles.	[5]
Tufted fabric (acoustic pile)	Ring-spun & core-rug yarns from coarse wool	Tufting with cut & loop piles; pile height 12 → 16 mm.	NRC 0.4 → 0.42 with increased pile height.	Wool buffers humidity, absorbs VOCs.	Acoustic carpets/rugs, wall panels.	[5]
Insulation batts (building)	Scoured, carded wool batts	Needle-punched batts; compared vs polystyrene/mineral wool.	Thermal/acoustic performance suitable for eco-builds; naturally	Safer fire behaviour than polystyrene; renewable content.	Wall/roof insulation, retrofits.	[6]

Stage / Form	Input Material	Process (key steps & parameters)	Output Properties (key metrics)	Env./Safety Notes	Typical Applications	Source
			flame-retardant, self-extinguishing.			
Protective textiles (PPE)	Wool fabrics (woven/knit/felt)	Garment design for flame/heat resistance; standard tests.	Higher fire resistance vs common fibres; no melt-drip.	Inherent FR; fewer toxic emissions.	Firefighting/protective clothing.	[6]
Oil-adsorbent pads / loose fill	Coarse waste wool (raw/washed)	Washed with soap/detergent; deployed in diesel-contaminated water.	Adsorption: ~15 ml/g diesel; optimal diesel:water 1:10; >90% removal efficiency with washed wool.	Upcycles low-value wool; requires safe disposal after use.	Spill response, marina maintenance.	[9]
Agricultural mulch mats / horticulture	Mixed-breed wools	Needle-punched mats & lanolin-rich plugs.	Improves soil moisture retention; suppresses weeds; slow-release nutrients.	Fully biodegradable; soil-enriching.	Orchard mulch, seedling collars.	[4]