RĪGAS STRADIŅA UNIVERSITĀTES
DARBA DROŠĪBAS UN VIDES VESELĪBAS INSTITŪTS

RIGA TECHNICAL UNIVERSITY

Tekstila un klimata aspekti IAL, darba apģērbu un uniformu izvēlē

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RIGA, 2024

ABOUT PPELab

Personal Protective Equipment Laboratory

Accreditation scope:
Physical, chemical, microbiological, and mechanical testing of fiber materials and textiles

- **15 methods** in accreditation scope
- More than **60 other testing methods**
- **80 equipment items**

Testing of textile materials and products and PPE:

- Fibre composition of textile products
- Physical characteristics
- Mechanical properties
- Protection against heat and flames
- Water resistance
- Thermal resistance and water-vapour permeability
- Resistance to biological hazards
- Testing microclimate conditions (thermal mannequin)
- Testing of respiratory protective equipment
- Anthropometry and ergonomics tests and research

RTU
PPE Lab

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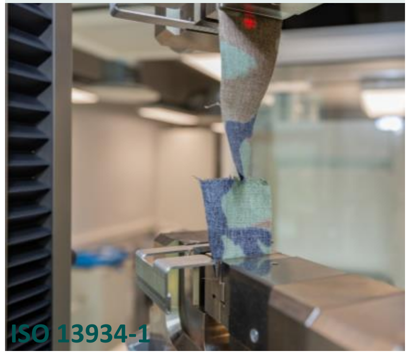
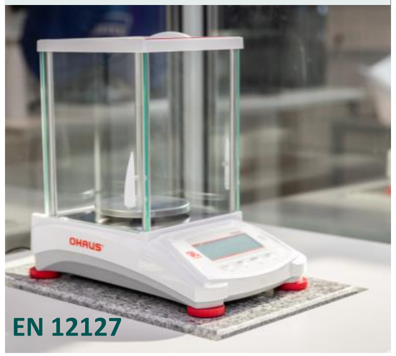
ACCREDITED METHODS*

Tensile properties



Abrasion resistance

Mass per unit area



Air permeability

Water resistance

Dimensional changes

Colour fastness

Thermal and water-vapour resistance

Population of Microorganisms

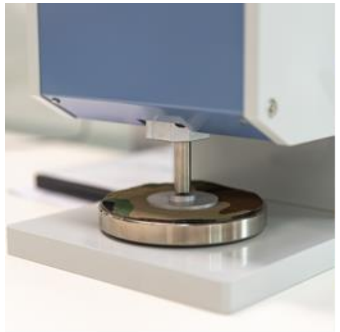
Fibre composition of textile products

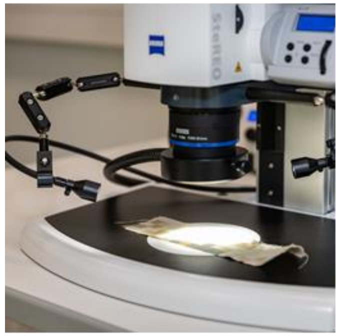
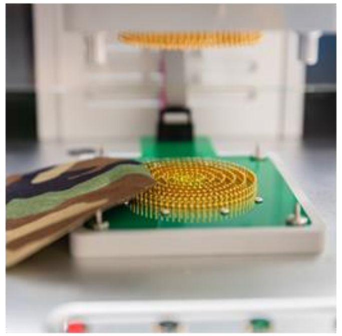
Flammability

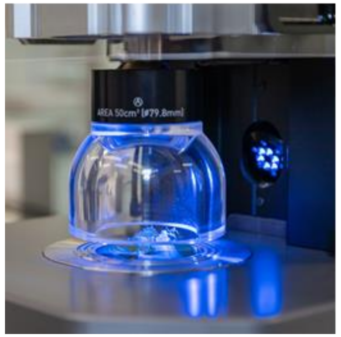
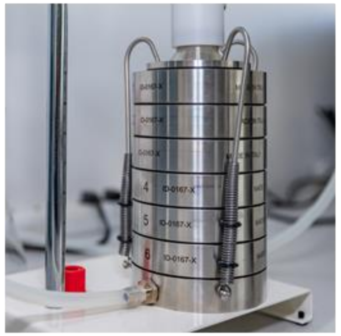
RTU
PPE Lab

** Methods and equipment functions can be adapted to other/specific testing and research purposes - contact the lab for options!*

OTHER TESTING* & RESEARCH

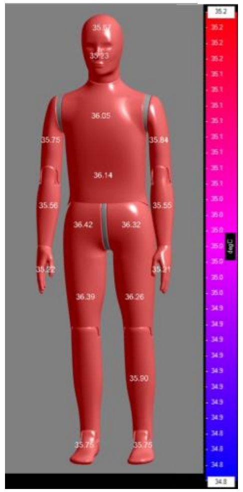


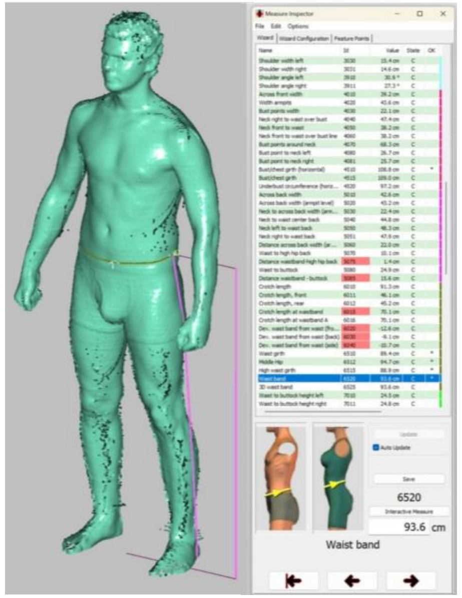




- Thickness
- Colour
- Weave
- Colour fastness
- Tensile properties
- Elasticity
- Water resistance
- Pilling, Fuzzing, Matting
- Washing and drying
- Thermal properties
- Oil
- Blood
- pH
- Bacteria
- Heat and flames
- Leather
- Furniture textile
- Respiratory protection

Thermal manikin Andi
(Thermetrics)

Human body 3D scanner
VitusSmartXXL



** Methods and equipment functions can be adapted to other/specific testing and research purposes - contact the lab for options!*

Introduction to textiles

ETYMOLOGY

TEXTILE – *latin textilis, meaning «woven»* - diverse range or fiber based materials, including filaments, fibers, yarns that can be made into fabric or cloth, and the resulting material itself (*Enciclopedia Britannica*) – so called umbrella term

FABRIC – any thin, flexible material bound together (woven, knitted, braided, sewn etc.) of fibers, filaments, yarns, film, foam, or any combination of these techniques

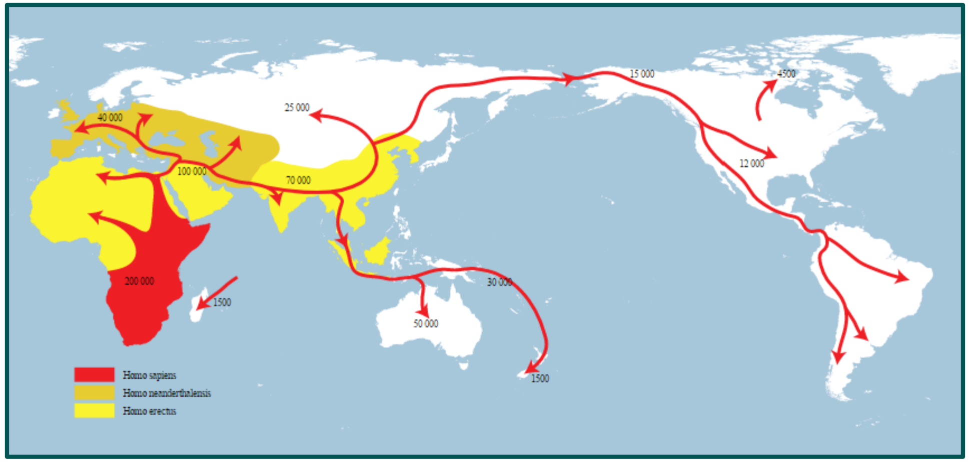
CLOTH – *old english clað, meaning «a cloth, woven, or felted material to wrap around one's body»* - a pliable material made usually by weaving, felting, or knitting natural or synthetic fibers and filaments (*Merriam-Webster Dictionary*)

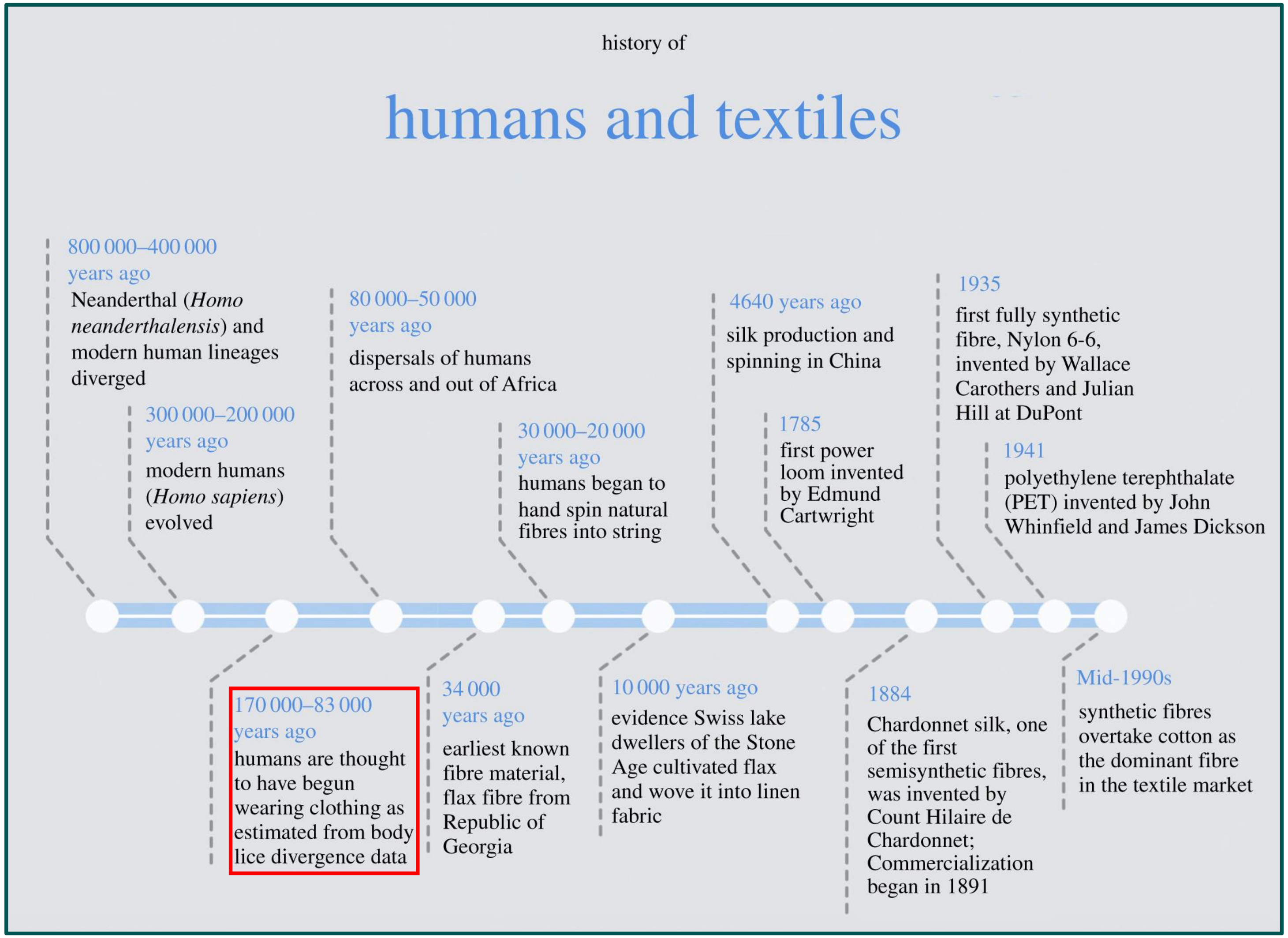
TEXTILE PRODUCT – any raw, semi-worked, worked, semi-manufactured, manufactured, semi-made-up or made-up product which is exclusively composed of textile fibres, regardless of the mixing or assembly process employed, as well as a product containing at least 80% textile fibres in weight (*Law Insider Dictionary*)

BRIEF HISTORY

Evolution of textiles:

- Animal skins
- First plant fiber materials – flax (Georgia)
- Natural fiber spinning – wool
- Weaving from cultivated plant fibers – flax, cotton
- Silk production (China)
- Invention of semisynthetic fibers – rayon
- Invention of synthetics
- Smart textiles, nanomaterials





Sources:
Sanders, D., Grunden, A., Dunn, R.R. A review of clothing microbiology: the history of clothing and the role of microbes in textiles. Biol. Lett.17:20200700, (2021) http://doi.org/10.1098/rsbl.2020.0700
Map of Homo Sapiens Migration. https://www.worldhistory.org/image/6605/map-of-homo-sapiens-migration/

FIBER CLASSIFICATION IN RELATION TO THEIR ORIGIN

***Fiber** or **fibre** – (noun) a natural or artificial substance that is significantly longer than it is wide (Kadolph, S., Marcketti, S. Textiles)*

TEXTILE FIBERS

NATURAL FIBERS

ANIMAL FIBERS (PROTEIN)

ANIMAL HAIRS

Wool (sheep wool, virgin wool)
Fine hair (Alpaca, Llama, Vicuna, Guanaco, Camel, Rabbit, Angora, Mohair, Cashmere, Cashgora, Yak)
Coarse hair (Cattle, Horse, Goat)
Other fibers

SECRETION FIBERS

Silk (Cultivated, Wild (Tussah)
Byssuss (from molluscs)

VEGETABLE FIBERS (CELLULOSE)

FROM SEED

Cotton
Kapok
Akund

FROM STEM

Flax
Hemp
Jute
Ramie
Other fibers

FROM LEAF

Sisal
Manila
Other fibers

FROM FRUIT

Coir
Other fibers

MINERAL FIBERS

ROCK FIBERS

Asbestos

MAN-MADE FIBERS

FROM ORGANIC CHEMISTRY

NATURAL POLYMERS (ARTIFICIAL)

Cellulosic (Viscose, Modal, Lyocell, Cupro, Acetate, Triacetate, Other fibers)
Alginate
Rubber
Protein fibers
Other fibers

SYNTHETIC POLYMERS

Elastomeric (Elastane, Elastodiene, Elastolefin, Elastomultiester)
Fluorofibers
Polyacrylics (Acrylic, Modacrylic)
Polyamides (Nylon, Aramid)
Chlorofibers (Vinyl chloride, Vinylidene chloride)
Polyesters
Polyolefines (Polyethulene, Polypropylene)
Vinylal (Polyvinyl alcohol)
Other fibers

FROM INORGANIC CHEMISTRY

INORGANICS

Glass
Metal
Carbon
Ceramics
Other fibers

Source:
ISO/TR 11827:2012 Textiles – Composition testing – Identification of fibers
ISO 2076:2021 Textiles – Man-made fibers – Generic names
ISO 6938:2012 Textiles – Natural fibers – Generic names and definitions

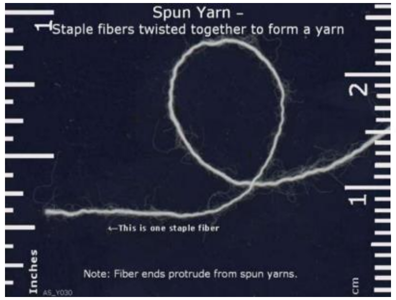
YARN CLASSIFICATION IN RELATION TO THEIR STRUCTURE

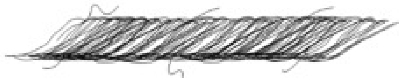
***Yarn** – (noun) a continuous often plied strand composed of either natural or man-made fibers or filaments and used in weaving and knitting to form cloth (Merriam-Webster Dictionary)*

YARN TYPES

STAPLE/SINGLE/SPUN YARN

Made from staple fibers (natural fibers and/or cut man-made fibers) by mechanically assembling and twisting (spinning) them

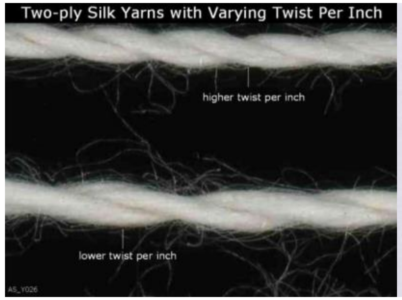


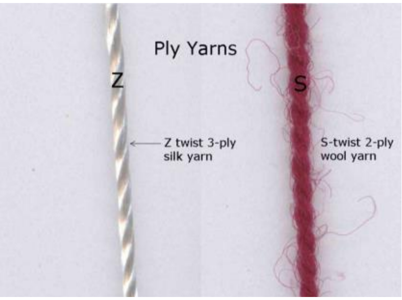


Spun yarn (or staple-fiber yarn)

PLY YARN

Made using one or more staple yarns by mechanically assembling and twisting (spinning) them





FILAMENT YARN

Made by assembling continuous filaments (silk or man-made fibers)

MONOFILAMENT YARN

Consists of a single, untwisted continuous filament

MULTI-FILAMENT YARN

Made from multiple filaments with or without twist

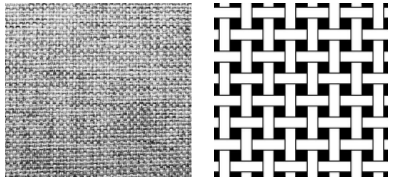
✚ SPECIAL YARNS

Photo Source:
https://courseware.cutm.ac.in/wp-content/uploads/2020/06/L-4-CLASSIFICATION-OF-YARN.pdf
https://www.sciencedirect.com/topics/engineering/textile-yarn

FABRIC TYPES IN RELATION TO MANUFACTURING TECHNOLOGY

FABRIC TYPES

WOVEN FABRIC

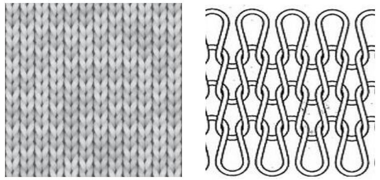


Produced by interlacing (weaving on a loom or a weaving machine) a set of warp (longitudinal) threads and a set of weft (transverse) threads normally at right angles to each other

BASIC WEAVES

Plain weave
Twill weave
Satin weave

KNITTED FABRIC



Textile fabrics in which at least one system of threads is formed into knitted loops and the knitted loops are intermeshed into stitches

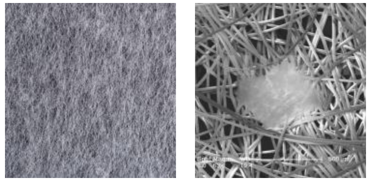
WARP-KNITTED FABRIC

Knitted fabrics in which the stitches made from each warp thread are formed substancially along the length of the fabric

WEFT-KNITTED FABRIC

Knitted fabrics in which the stitches made by each thread are formed substancially across the width of the fabric

NON-WOVEN FABRIC



Fibrous assembly (staple fibers or filaments), primarily planar, which has been given a designed level of structural integrity by mechanical, chemical, heat or solvent treatment, excluding weaving, knitting, papermaking

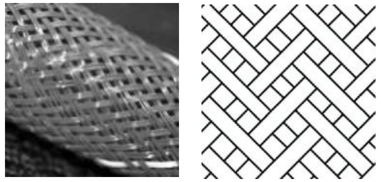
FELTS

Wool felt
Needle felt

BONDED WEBS

Dry laid
Wet laid
Direct spun

BRAIDED FABRIC



Produced by interlacing three or more yarns or narrow strips of textiles in such a way that they cross one another diagonally forming a narrow flat or tubular fabric with multidirectional nature

CIRCULAR BRAIDS

Tubular with or without a center core, used mostly for manufacturing ropes, cables, and various industrial applications

FLAT BRAIDS

Narrow fabrics – strips or tapes used for trimmings and elastic components

COMPOSITES

Produced by traditional and hybrid methods by combining two or more dissimilar materials, 2D and 3D, used for specific performance, functional, and industrial applications

✚ SPECIAL FABRICS

Source:
ISO 3572:1976 Textiles – Weaves – Definitions of general terms and basic weaves
ISO 8388:2003 Knitted Fabrics – Types – Vocabulary
ISO 9092:2019 Nonwovens - Vocabulary

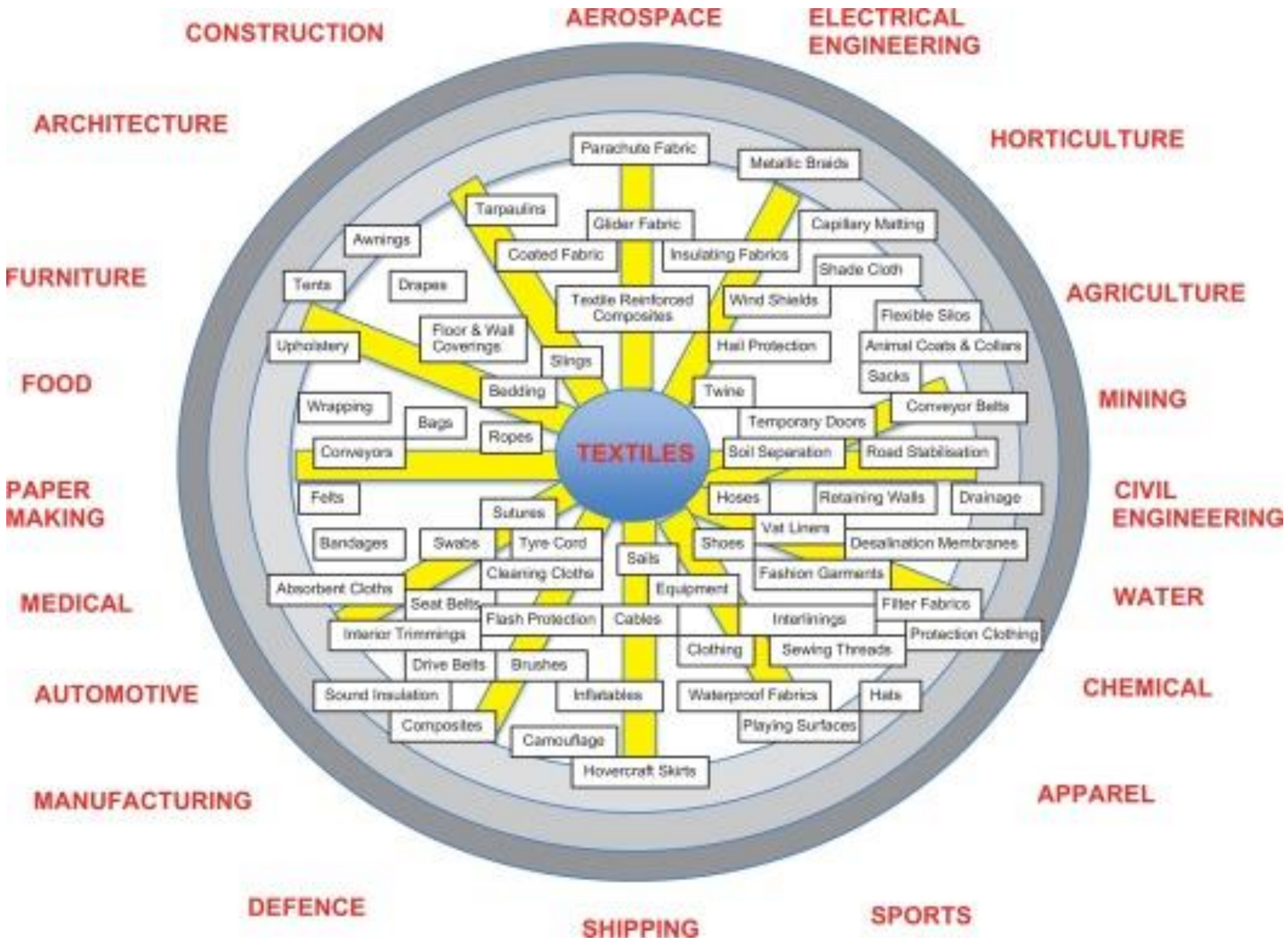
APPLICATIONS

Conventional textiles
- Clothing and fashion

Home textiles

Technical textiles
- Medical
- Aerospace
- Agriculture
- Automotive
- Filtration
- Protective Gear
- Electrical Engineering
- Construction
- Sports
- Food
- etc.

Textiles in art and design



Source:
Horrocks, A.R., Anand, S.C. Handbook of Technical Textiles. Volume 1: Technical Textile Processes. Woodhead Publishing, 2016. https://doi.org/10.1016/C2015-0-01011-5

Introduction to textile testing

INTRODUCTION (1/2)

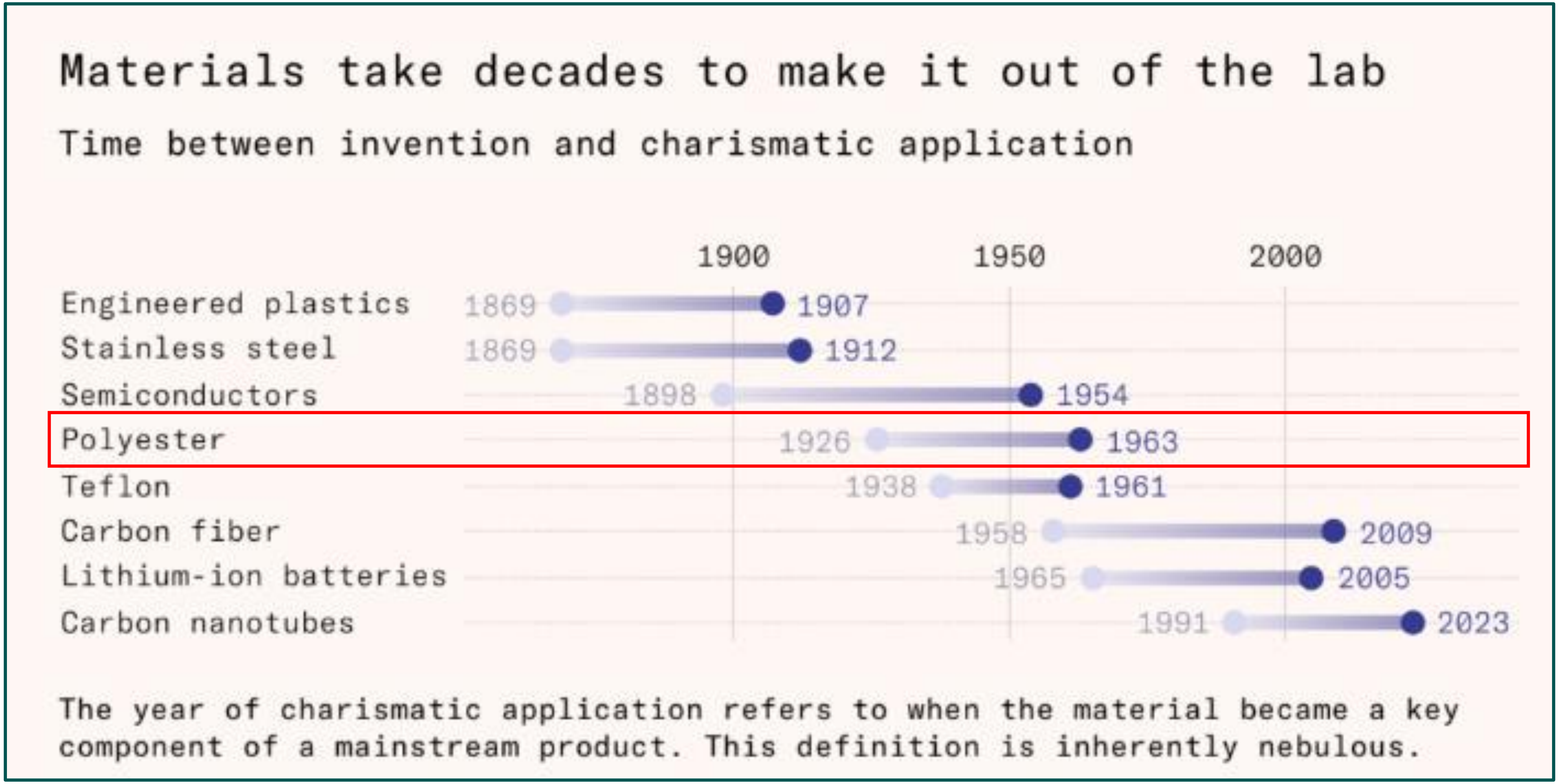
INVENTION

↓

MASS PRODUCTION

↓

USE



Source:
Reinhardt, B. Getting materials out of the lab (2024) https://worksinprogress.co/issue/getting-materials-out-of-the-lab/

INTRODUCTION (2/2)

Textile testing – a (*standard*) method or a set of methods performed to determine the quality (properties and performance) of the raw textile material or the final product or to assess compliance with certain requirements before large-scale production.

Importance of testing – DATA:

- Product quality assurance;
- Regulatory compliance assurance;
- Manufacturing process and cost control;
- Consumer satisfaction;
- Gaining/maintaining market share;
- Reputation.

Textile testing is costly and time-consuming → it needs to add some benefit to the final product and optimize the production process!

Key factors contributing to the development of textile testing:

- Advances in textile technology;
- Increase in consumer quality requirements;
- The development of new innovative materials and new fields of application;
- Regulatory compliance requirements (for example, safety requirements);
- Globalization, increased competition;
- Sustainability requirements and ecological considerations.

The key outcome of textile testing → data interpretation in a systematic and scientific way to provide an objective assessment of the properties and performance of a textile product!

LEVELS OF TEXTILE TESTING
- FIBER
- YARN
- FABRIC
- TEXTILE PRODUCT

NATURE OF TEXTILE TESTING
- DESTRUCTIVE
- NON-DESTRUCTIVE

LOCATIONS FOR TEXTILE TESTING
- LABORATORY
- FIELD TESTS

SCOPE OF TEXTILE TESTING (1/2)

Physical and mechanical testing:

- Physical agents and influences affecting the performance of textiles;
- Structural characteristics of textiles (density, thickness, mass per unit area, etc.)
- Mechanical deformation and degradation (tensile behaviour, compression, bending, shrinkage, abrasion resistance, frictional rubbing, torsion, shear, etc.);
- Tactile and visual properties (wrinkling, buckling, drape, fabric hand, etc.);
- Response to heat, flame, liquids, static charge;
- Bonding integrity (for coated textiles and composites);
- Specific tests for high-performance textiles (impact resistance, thermal resistance, wear resistance)

Chemical testing:

- Determination of chemical composition;
- Chemical agents and influences affecting the performance of textiles;
- Chemical contamination of textiles;
- Resistance to water, acids, bases, bleaches, pollutants, UV light, etc.
- Specific tests for chemically resistant protective textiles.

Biological testing:

- Biological agents (microorganisms, insects) and influences affecting the performance of textiles;
- Hygenic and medical properties of textiles;
- Resistance to degradation by fungi and insects for effective textile storage and transportation;
- Specific tests for protective textiles against biological attacks.

SCOPE OF TEXTILE TESTING – END USE PERFORMANCE

- PHYSICAL AND MECHANICAL TESTING
- CHEMICAL TESTING
- BIOLOGICAL TESTING
- PHYSIOLOGICAL TESTING
- INTELLIGENCE TESTING
- VISUAL EXAMINATION

SCOPE OF TEXTILE TESTING (2/2)

Physiological testing:

- Assessment of properties influencing the well-being, performance, health of the wearer – testing of comfort properties (heat transmission, moisture management, air permeability).
- Assesment of microclimate.

Intelligence testing:

- Testing of smart/intelligent textiles (wearable electronics, phase change materials, shape-memory materials, chromic and conductive materials);
- Development of new testing methods

Visual examination:

- Evaluation of texture, surface characteristics, structure, color, and design manually or using equipment such as microscopes, spectrometers, computer vision etc.
- Evaluation of textile product quality, defect analysis.
- Tests for assessing surface modifications, treatments, coatings.

SCOPE OF TEXTILE TESTING – END USE PERFORMANCE

- PHYSICAL AND MECHANICAL TESTING
- CHEMICAL TESTING
- BIOLOGICAL TESTING
- PHYSIOLOGICAL TESTING
- INTELLIGENCE TESTING
- VISUAL EXAMINATION

OBJECTIVES OF TEXTILE TESTING (1/10)

*Quality control – (noun) a system of maintaining standards in manufactured products **by testing** a sample of the output against the specification (Oxford Dictionary)*

Quality control:

- Continuous and periodic control (performance assessment) at every manufacturing stage;
- Assessment plan based on the final application of the product;
- Control measures (testing) vary from product to product and from process to process.

PLANNING → **DATA COMPILATION** → **INVESTIGATION** → **IMPLEMENTATION**

The definition and indicators of quality may vary depending on the final application of the product → need for defined quality criteria for a specific product to determine its compliance or non-compliance with set requirements!

Quality dimensions:

- Perceived quality – supports the corporate image, initiates the purchase;
- Functional quality – quality guaranteed by the manufacturer, compliance with standard regulations, and expected performance.

TESTING OBJECTIVES – QUALITY CONTROL

- MATERIAL SELECTION
- PROCESS CONTROL
- FINAL PRODUCT CONTROL
- INVESTIGATION OF FAULTY MATERIAL
- R & D
- SETTING STANDARDS
- CONFORMITY TO SPECIFICATION
- ECOLOGICAL CONSIDERATIONS

OBJECTIVES OF TEXTILE TESTING (2/10)

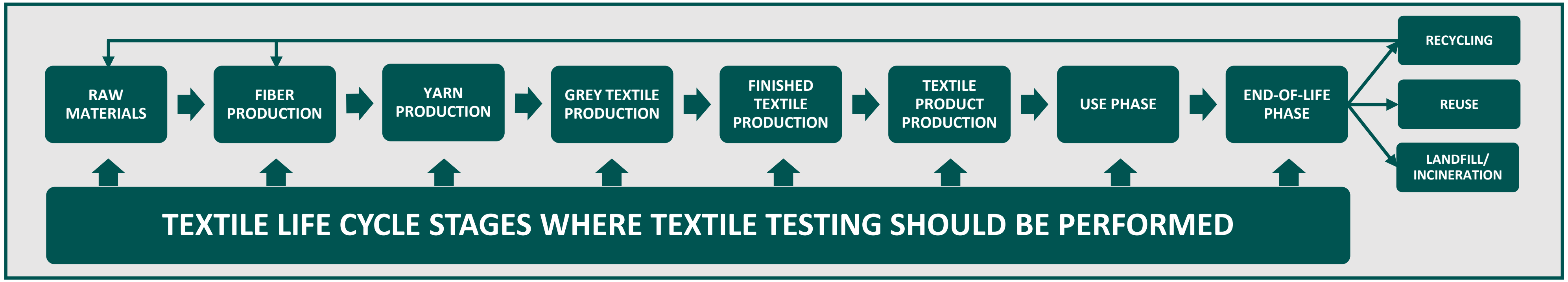
Objectives of quality control:

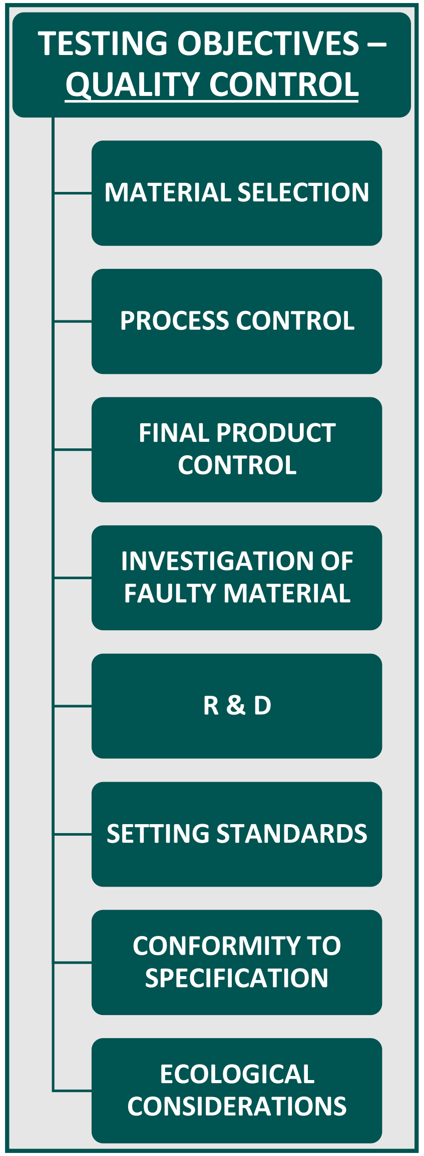
- Selection of raw materials suitable for final application;
- Production of the required quality product;
- Compliance with standard requirements and costumer's expectations;
- Reduction of manufacturing cost;
- Reduction of the amount of production waste;
- Maximum profit at the minimum cost!

Quality product = product with properties that meet or exceed the set specifications!

Quality control (testing strategy) should conform with:

- Inter-organizational standards (specifications);
- International standards, established scientific specifications (ISO, ASTM, AATCC, DIT, etc.);
- Market requirements;
- Consumer requirements for satisfactory performance.





OBJECTIVES OF TEXTILE TESTING (3/10)

RAW MATERIAL SELECTION

FIBERS ➔ SPINNING	YARNS ➔ FABRIC PRODUCTION	FABRICS ➔ FINAL PRODUCT

Material selection:

- Raw materials tend to vary in quality and their properties ➔ need for testing as preventive measure to ensure efficient running of the production process;
- The selection of materials is made based on the quality criteria set for the intended final application of textile product. Quality requirements (*minimum values*) are determined not only by the purpose of use of the product but also by the target audience (*market, price category*) for which this product is intended;
- Quality standards that material needs to meet should be realistic, any rejection of material should be justified;
- Putting sub-standard faulty material or unsuitable material into production will result in large financial losses and loss of reputation and valuable resources;
- Raw material testing prior to production is especially important for natural fibers, the quality and properties of man made materials is determined and controlled during manufacture.

KEY CRITERIA FOR MATERIAL SELECTION

SUITABILITY FOR INTENDED APPLICATION	COMPLIANCE WITH REALISTIC QUALITY CRITERIA	COMPLIANCE WITH STANDARD REQUIREMENTS

TESTING OBJECTIVES – QUALITY CONTROL

- MATERIAL SELECTION
- PROCESS CONTROL
- FINAL PRODUCT CONTROL
- INVESTIGATION OF FAULTY MATERIAL
- R & D
- SETTING STANDARDS
- CONFORMITY TO SPECIFICATION
- ECOLOGICAL CONSIDERATIONS

OBJECTIVES OF TEXTILE TESTING (4/10)

<u>Process control (production monitoring):</u>

- Testing of samples from the production line throughout all manufacturing stages to assess their compliance with set performance/quality requirements (*within previously defined tolerances*);
- Appropriate sampling strategy is essential for the test results to be representative for the whole lot/batch;
- Regular testing throughout all the manufacturing stages is necessary to timely prevent low-quality products from reaching the next stage of the production cycle, thus reducing financial risks and waste of resources;
- The key purpose of testing throughout all the manufacturing stages is to ensure the efficiency of the manufacturing process by ensuring that the raw material is of adequate quality for each subsequent step of production.

RAW MATERIALS → FIBER PRODUCTION → YARN PRODUCTION → TEXTILE PRODUCTION → WET TREATMENT → TEXTILE PRODUCT PRODUCTION

TEXTILE MANUFACTURING STAGES WHERE TEXTILE TESTING SHOULD BE PERFORMED

TESTING OBJECTIVES – <u>QUALITY CONTROL</u>

- MATERIAL SELECTION
- PROCESS CONTROL
- FINAL PRODUCT CONTROL
- INVESTIGATION OF FAULTY MATERIAL
- R & D
- SETTING STANDARDS
- CONFORMITY TO SPECIFICATION
- ECOLOGICAL CONSIDERATIONS

OBJECTIVES OF TEXTILE TESTING (5/10)

Final product control (product testing):

- Textile products are examined, tested to assess their overall quality and compliance with set requirements before delivering to the customer;
- The performance of a finished product is tested – compliance with its intended purpose of use, for example, by simulating certain wearing conditions, durability, service life, etc.
- Imitating everyday use conditions and combinations of influencing factors and loads is a complicated problem since they are inconsistent and obtained results are unrepeatable and incomparable; therefore, imitative laboratory tests are carried out to assess one property at a time;
- In the case of sub-standard products steps are taken to rectify faults, for example, product mending.

TESTING OBJECTIVES – QUALITY CONTROL

- MATERIAL SELECTION
- PROCESS CONTROL
- FINAL PRODUCT CONTROL
- INVESTIGATION OF FAULTY MATERIAL
- R & D
- SETTING STANDARDS
- CONFORMITY TO SPECIFICATION
- ECOLOGICAL CONSIDERATIONS

OBJECTIVES OF TEXTILE TESTING (6/10)

Investigation of faulty material:

- If discovered during production, at the final product assessment stage, or through a customer complaint, testing is necessary to identify the root cause of the problem to eliminate further production of low-quality and/or faulty products;
- Testing helps to understand in which of the stages of product development the nonconformity occurred;
- In case of dispute it is possible to determine the responsible party ➔ it is recommended to have an independent laboratory/experts carry out the testing to ensure the objectivity of results.

TESTING OBJECTIVES – QUALITY CONTROL

- MATERIAL SELECTION
- PROCESS CONTROL
- FINAL PRODUCT CONTROL
- INVESTIGATION OF FAULTY MATERIAL
- R & D
- SETTING STANDARDS
- CONFORMITY TO SPECIFICATION
- ECOLOGICAL CONSIDERATIONS

OBJECTIVES OF TEXTILE TESTING (7/10)

Research and development:

- Converts ideas into products ➔ testing required throughout the development process;
- Testing helps with further decision making;
- Different/new production methods ➔ need for product assessment before any claims;
- R & D could be as a separate department or as a part of testing department;
- Could include development of new testing methods for specific research applications, research of textile innovation behaviour ➔ as a result could be adopted as industry-wide standards

NEW TEXTILE PRODUCT DEVELOPMENT CYCLE

IDEA/ CONCEPT ➔ FEASIBILITY STUDY ➔ DESIGN DEVELOPMENT ➔ PROTOTYPING ➔ VALIDATION ➔ PILOT PRODUCTION ➔ PRODUCTION

TESTING

TESTING OBJECTIVES – QUALITY CONTROL

- MATERIAL SELECTION
- PROCESS CONTROL
- FINAL PRODUCT CONTROL
- INVESTIGATION OF FAULTY MATERIAL
- R & D
- SETTING STANDARDS
- CONFORMITY TO SPECIFICATION
- ECOLOGICAL CONSIDERATIONS

OBJECTIVES OF TEXTILE TESTING (8/10)

Setting standards:

- Guidelines for the quality, performance, and safety of textile products by providing objective, measurable data;
- Systematic way to evaluate, and validate textile products;
- Ensurance that products meet:
  - regulatory requirements;
  - consumer expectations;
  - global market demands.
- Determining minimum quality requirements;
- Creating unified methodology – comparability, repeatability, transparency

TESTING OBJECTIVES – QUALITY CONTROL

- MATERIAL SELECTION
- PROCESS CONTROL
- FINAL PRODUCT CONTROL
- INVESTIGATION OF FAULTY MATERIAL
- R & D
- SETTING STANDARDS
- CONFORMITY TO SPECIFICATION
- ECOLOGICAL CONSIDERATIONS

OBJECTIVES OF TEXTILE TESTING (9/10)

Conformity to specification:

- Important for textile products that are subjects to procurement procedure:
  - Uniforms
  - Workwear
  - PPE
  - Interior textiles
  - etc.
- EU Green Public Procurement for Textile Products and Services (soon to be mandatory) – textiles with a reduced environmental impact
- Testing to assess the conformity to predefined characteristics (minimum quality criteria)

TESTING OBJECTIVES – QUALITY CONTROL

- MATERIAL SELECTION
- PROCESS CONTROL
- FINAL PRODUCT CONTROL
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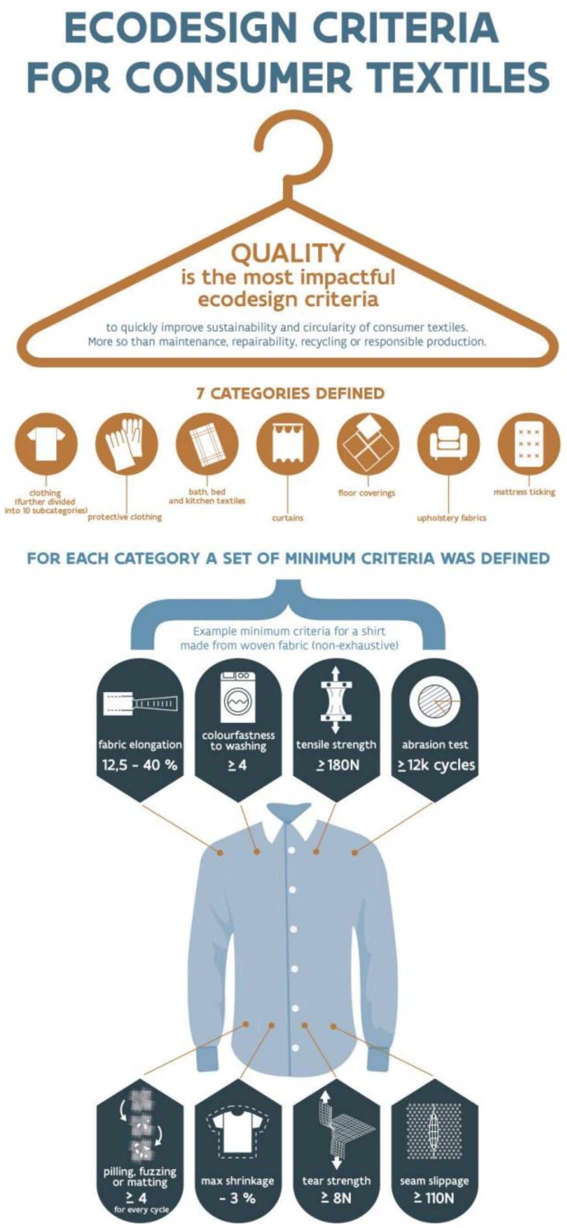
OBJECTIVES OF TEXTILE TESTING (10/10)



Ecological considerations:

- Focus on the sustainability of textile products (environmental footprint, harmful effect on human health, social injustice, etc.), changes in legislation ➔ extra demand for testing, conformity assessment, and product certification;
- To assure the sustainability of textiles products testing covers all production stages, as well as the use and disposal phase

TESTING OBJECTIVES – QUALITY CONTROL

- MATERIAL SELECTION
- PROCESS CONTROL
- FINAL PRODUCT CONTROL
- INVESTIGATION OF FAULTY MATERIAL
- R & D
- SETTING STANDARDS
- CONFORMITY TO SPECIFICATION
- ECOLOGICAL CONSIDERATIONS

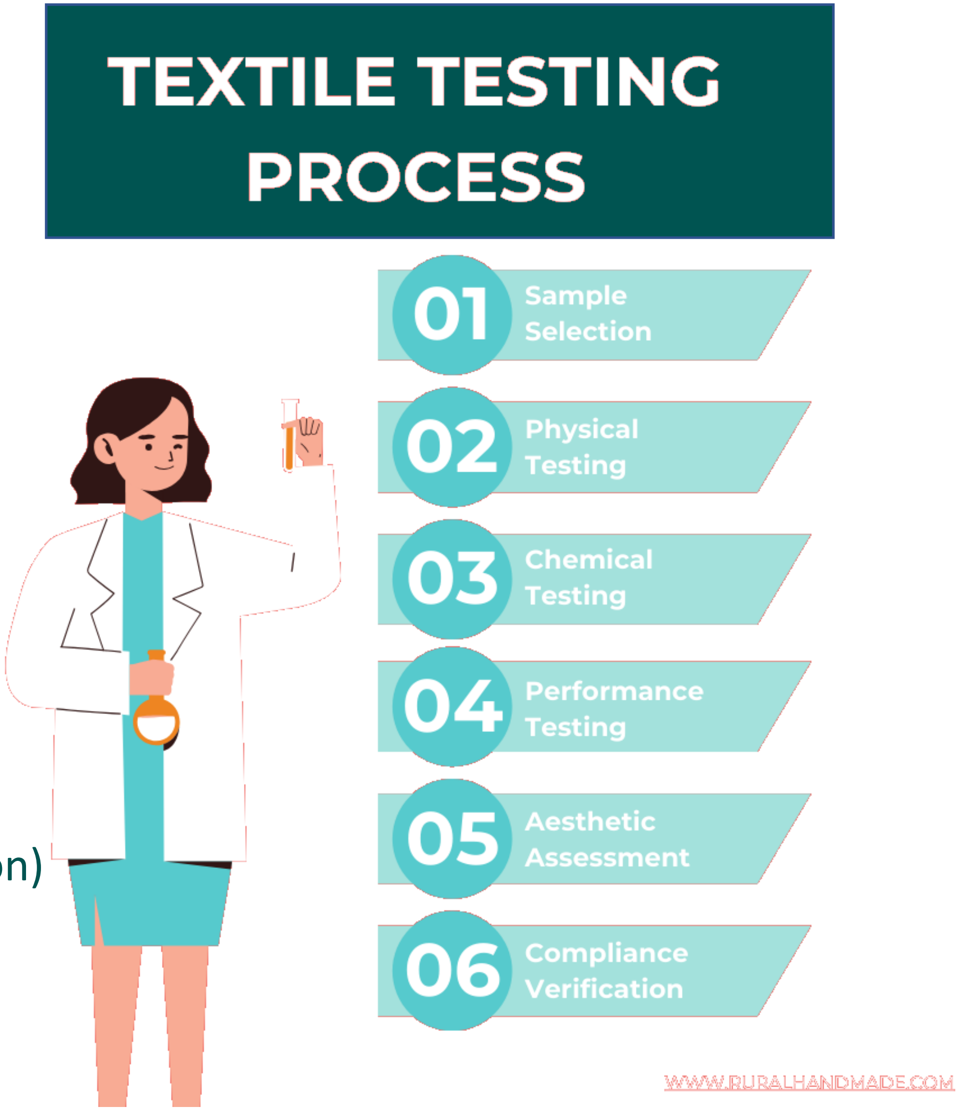
CURRENT STATE OF TEXTILE TESTING AND FUTURE TRENDS

Different types of testing laboratories:

- In-house laboratories
- Commercial laboratories
  - The American Association of Textile Chemists and Colorists (AATCC)
  - SGS
  - The Textile Research Institute (TRI)
  - The Atlas Material Testing Laboratory
  - The Hohenstein Institute
  - Centexbel
  - etc.
- Governmental research organizations and laboratories

Future trends:

- Innovative testing methods to assess product or process innovations
- Testing for sustainability assessment
- Artificial Intelligence (AI) tools
  - For quality assessment (computer vision for example defect detection)
  - Material profiles (models) for 3D simulations and visualisations



STANDARDIZATION OF TESTING

Test results should determine:

- The performance of a textile product during its life cycle;
- Conformity to the required specifications.

Core testing purpose: Repeatability and reproducibility (interlaboratory and/or between-operator)

Factors affecting the repeatability/reproducibility of test results:

- Variation in material – for example, a test sample is not representable or comparable, the material is uneven or damaged, the sample is biased;
- Variation in test procedure – for example, different testing conditions and/or equipment, the operator's professionalism and objectivity

Standards organizations:

- International standards (International Organization for Standardization (ISO))
- National standards (British Standards Institution (BSI), American Society for Testing and Materials (ASTM), Americal National Standards Institute (ANSI), American Association of Textile Chemists and Colorists (AATCC), German Institute for Standardization (DIN), Bureau of Indian Standards (BIS), Japanese Industrial Standards (JIS))
- Testing procedures developed within large organizations (International Wool Secretariat (IWS), Marks & Spencer)

REPEATABILITY/ REPRODUCIBILITY

QUALITATIVE

(Accuracy between results for the same material from identical methods in identical conditions)

QUANTITATIVE

(Test results fall within the accepted spread of values when analyzed applying appropriate statistical criteria)

NEED FOR STANDARDIZATION

STANDARDS FOR TESTS

- **TEST METHOD**
- **MINIMUM ACCEPTABLE LEVEL OF PERFORMANCE ON A PARTICULAR TEST**

QUALITY CONTROL

Quality management:

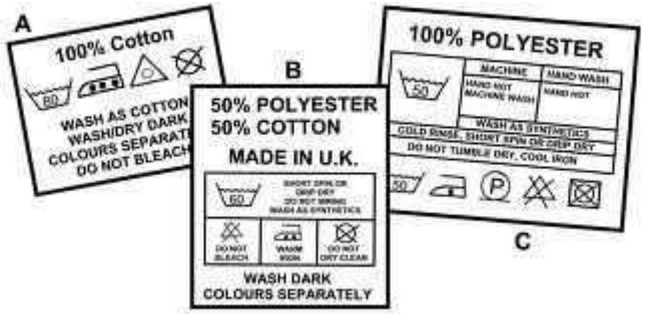
- IMPARTIALITY AND OBJECTIVITY;
- Each test method has a detailed procedure (in written form, most often a standard);
- Defined level of accuracy;
- Used equipment and its maintenance (calibration, performance monitoring, related documentation);
- Details of the required test environment (temperature, relative humidity);
- A sampling plan of test specimens;
- Trained personnel;
- Information included in test reports;
- Maintenance of baseline data and testing records, as well as tested specimens;
- Procedure for rejection of test material;
- Procedure for handling and disposal of hazardous samples;

Quality Standards:

- ISO 9000 family – Quality management
- ISO 45001: Occupational Health and Safety
- **ISO 17025: Testing and Calibration Laboratories**

TEXTILE PRODUCT LABELLING

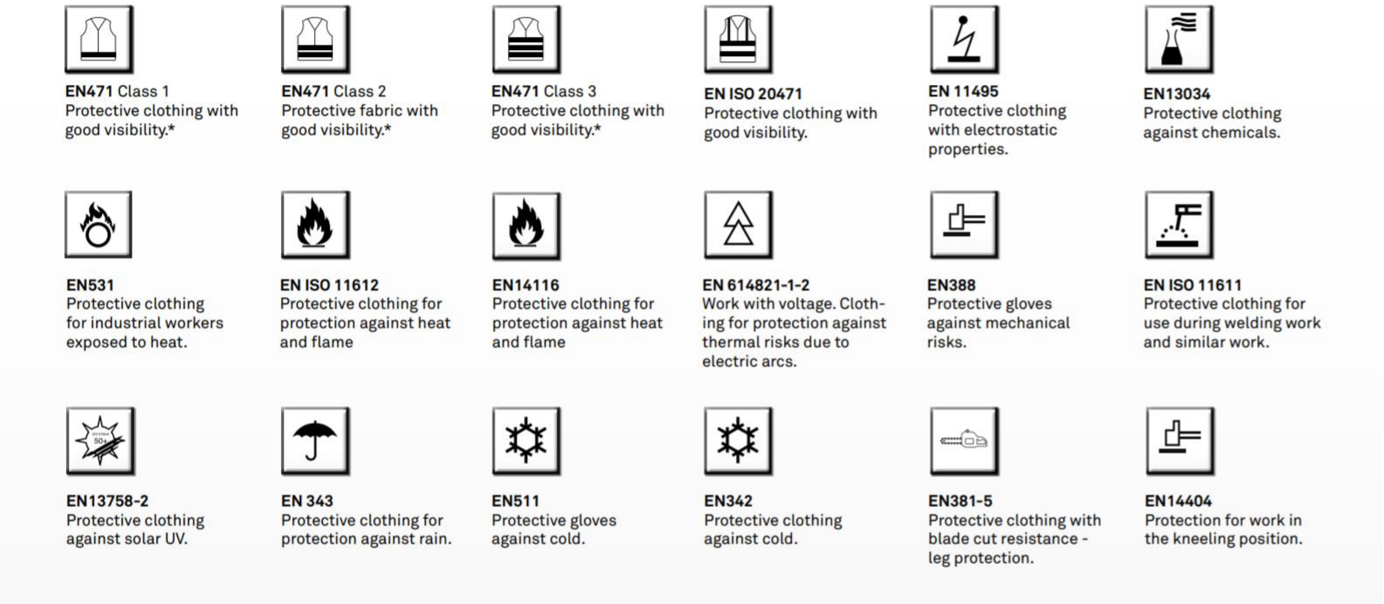
EU Regulation on textile labelling and fibre composition (currently under revision)



EU Ecolabel

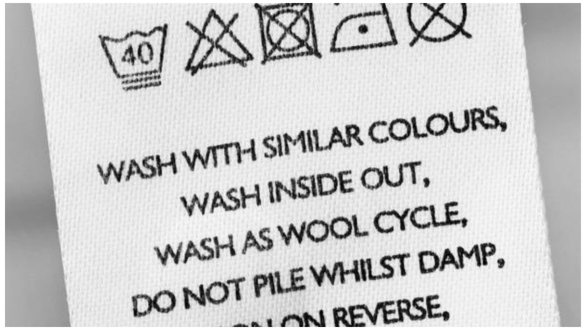
EU Ecolabel
www.ecolabel.eu

Protective clothing labels



Performance labels

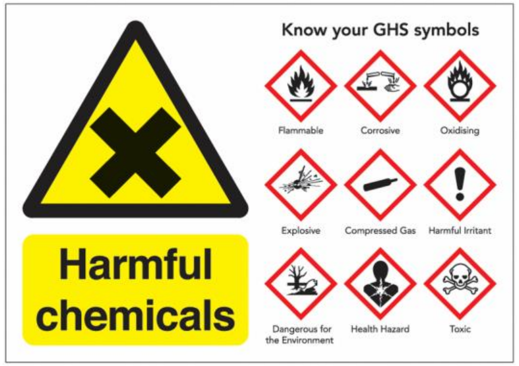
Care labels



OCCUPATIONAL SAFETY (1/2)

Potential risks while working in a textile testing laboratory:

- **Exposure to dust and other particles** → respiratory disorders
- **Exposure to hazardous chemicals** → respiratory disorders, chemical burns, allergic reactions, skin irritation
- **Exposure to harmful disease-causing agents** → possibility of infection
- **Exposure to heat, flames, and fumes** → burns of various degrees, respiratory disorders, smoke poisoning
- **Exposure to noise** → damages the eardrum, negative impact on mental health
- **Exposure to vibrations** → negative impact on mental health
- **Ergonomic issues** → musculoskeletal disorders
- **Mechanical hazards** → possible injuries working with high pressure, high temperature equipment, or equipment with moving parts
- **Electrical hazards** → possible accidents if if work safety regulations are not followed



OCCUPATIONAL HEALTH RISKS

- PHYSICAL HAZARDS
- CHEMICAL HAZARDS
- BIOLOGICAL HAZARDS
- MECHANICAL HAZARDS
- ERGONOMIC HAZARDS
- PSYCHOLOGICAL HAZARDS
- ELECTRICAL HAZARDS

OCCUPATIONAL SAFETY (2/2)

PERSONAL PROTECTIVE EQUIPMENT					
LAB COAT	CLOSED-TOE SHOES	SAFETY GOGGLES	SAFETY GLOVES	DUST MASK	EAR PROTECTION
					
To protect clothes and skin	To protect against injury	To protect from flying debris and chemicals	To protect from hazardous chemicals or heat and flames	To protect form particles and textile dust	To protect the auditory system from increased noise

Preventive measures to reduce risk in the workplace:

- Personal protective equipment
- Appropriate attire, ensuring clothing has no loose or protruding elements that could get caught in equipment
- Long hair should be securely tied back
- Training of employees in the safe use of equipment and execution of test methods
- Safety briefings, information on first aid and first aid kits, warning signs placed in the premises
- Equipment and infrastructure monitoring, maintenance
- Annual work safety briefings
- Mandatory health checks

ACCREDITATION OF TEXTILE TESTING LABORATORY – ISO/IEC 17025

ISO/IEC 17025 Testing and calibration laboratories:

- Sets requirements for the competence, impartiality, and consistent operation of laboratories;
- Ensures the accuracy and reliability of testing results – enhaced credibility;
- Globally recognized quality assurance;
- Facilitates cooperation;
- Enhances sustainability of testing by reducing the need for retesting

State agency
"Latvian National
Accreditation Bureau"

Signatory of the Multilateral Agreement of the European Cooperation for Accreditation (EA MLA) in the field of accreditation of testing and calibration laboratories, certification bodies for products, persons and management systems, inspection bodies, validation and verification bodies

ACCREDITATION CERTIFICATE

State agency Latvian National Accreditation Bureau approves that

Riga Technical University

Personal Protective Equipment Laboratory

Registration number 90000068977

Legal address Ķīpsalas Street 6A, Riga, LV-1048

conforms to the requirements of the standard LVS EN ISO/IEC 17025:2017 and is competent to perform testing

Accreditation period from 23rd of February 2024 to 22nd of February 2029

Date of the Accreditation Committee decision: 23rd of February 2024, Riga
Accreditation Certificate No LATAK-T-670-00-2024 on 7 pages

Information about the accreditation scope and status is available on web page www.latak.gov.lv (Accreditation registration No T-670)
State Agency "Latvian National Accreditation Bureau" Brīvības Street 55, Riga, LV-1010, Latvia
E-mail: pasts@latak.gov.lv; phone +371 67373051

PPC TESTING

General characteristics of materials

- Air permeability
- Breaking resistance, load, tensile strength
- Climate chambers
- Drying and heating chamber
- Forced air circulation furnace
- Professional washing machine and clothes dryer
- Color fastness when washing-drying
- Burst strength and elongation at break
- Abrasion resistance (with water supply)
- Color fastness to abrasion
- Color fastness to heating
- Qualitative and quantitative analysis of composition
- Analysis of surface morphology (microscopically)

EN 9237 Textiles –Determination of permeability of fabrics to air

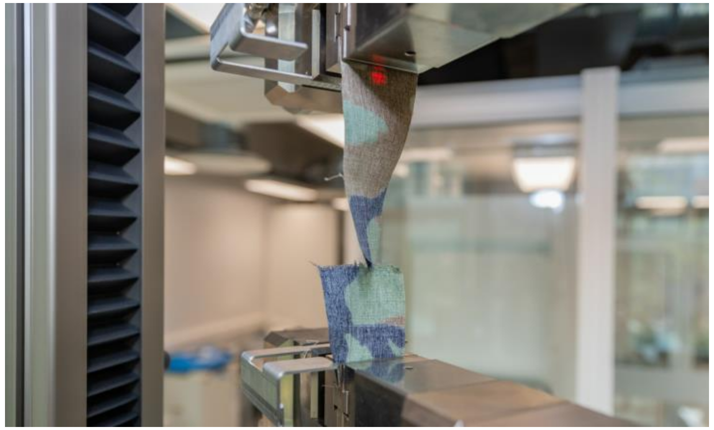
EN 4674-1 EN 9073-4

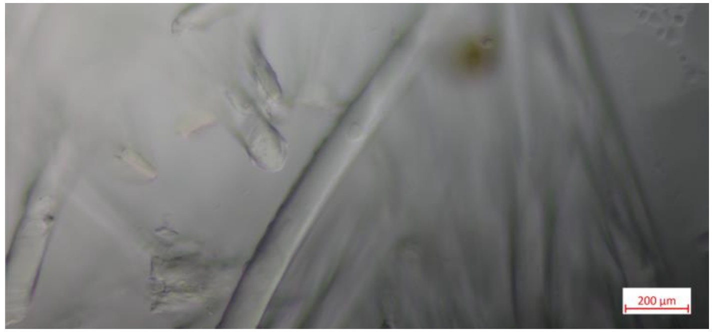
EN 9073-5 EN 9073-18

EN 13934 EN 13937

EN 20932 Determination of tear resistance (different circumstances)

ISO 5077 Determination of dimensional change in washing and drying





Respiratory Protective Devices

EN 143
EN 149 EN 405
EN 12941
EN 12942 EN 13274-3
EN 13274-6 EN 13274-8
EN 14593-1 EN 14593-2
EN 14594 EN 1827
EN 14683

- Parameters to be determined for respirators:
  - visual inspection;
  - material;
  - cleaning and disinfection;
  - practical performance;
  - total internal leakage;
  - permeability of the filter material;
  - skin compatibility;
  - flame resistance;
  - carbon dioxide content;
  - head mount;
  - field of vision;
  - the strength of the mounting of the exhalation valve body;
  - respiratory resistance (exhalation, inhalation);
  - clogging;
  - demountable parts.

- Medical face masks are divided into 3 types (I, II, IIR) according to the following set of indicators:
  - bacterial filtration efficiency (BFE,%);
  - differential pressure (Pa / cm2);
  - splash resistance (kPa);
  - bioburden (microbial cleanness) (cvv / g).

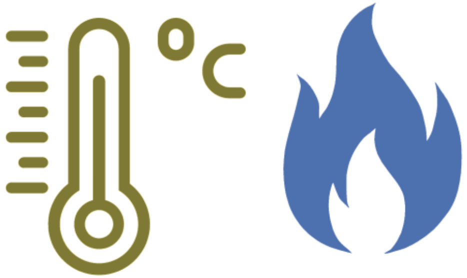
Biohazards (cleanness and protection)

BIOHAZARD

ISO 22612 ISO 22609
ISO 22611 Clothing for protection against infectious agents
EN 149 EN 143 EN 12941
Respiratory protective devices

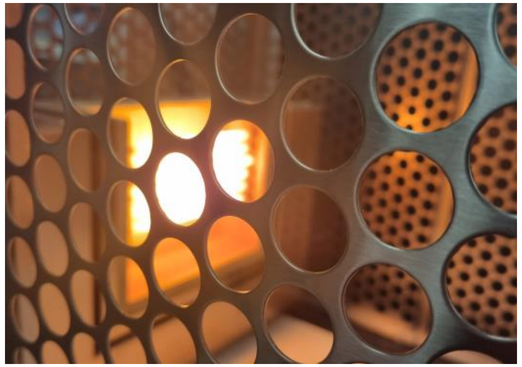
- Dry Microbial Penetration Resistance Tester
- Face Mask Blood Penetration Resistance Tester
- Biologically Contaminated Aerosols Penetration Tester
- Paraffin oil filter penetration test equipment
- Bacterial filtration efficiency test

Protection against heat and flame



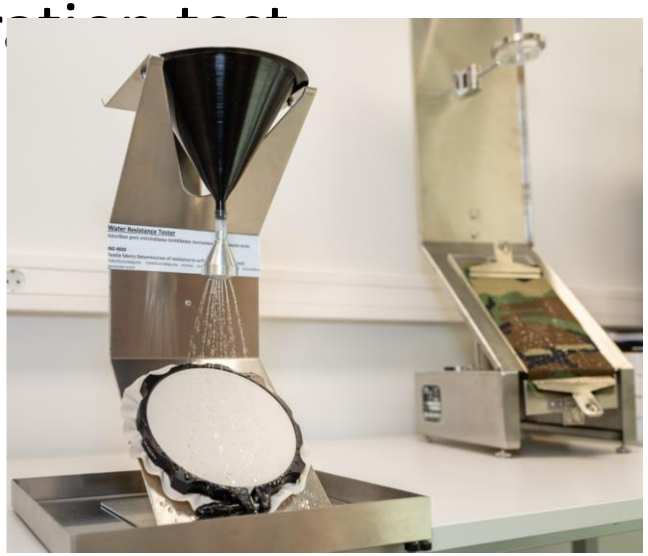
ISO 17492 ISO 9151
ISO 12127-1 Clothing for protection against heat and flame
ISO 6942 Protective clothing — Protection against heat and fire
EN 13772 Textiles and textile products. Burning behaviour.

- Multipurpose Flammability Tester
- Thermal Protective Performance (TPP) Test Device
- Radiant Heat Exposure Tester
- Thermal performance properties of material when exposed to a high heat source
- Contact Heat Resistance Tester (heating cilinder)

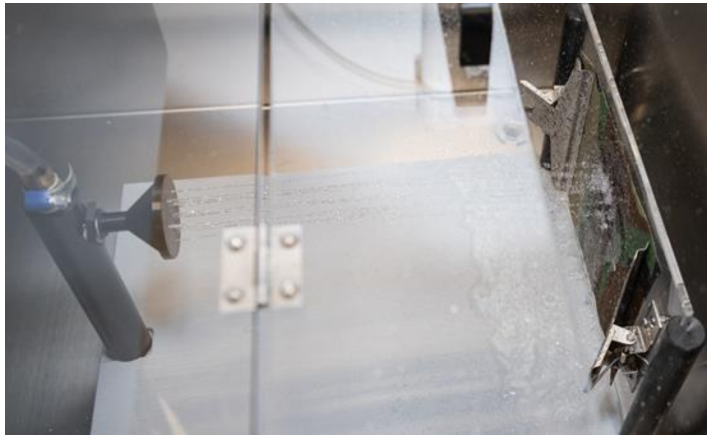


Water Resistance

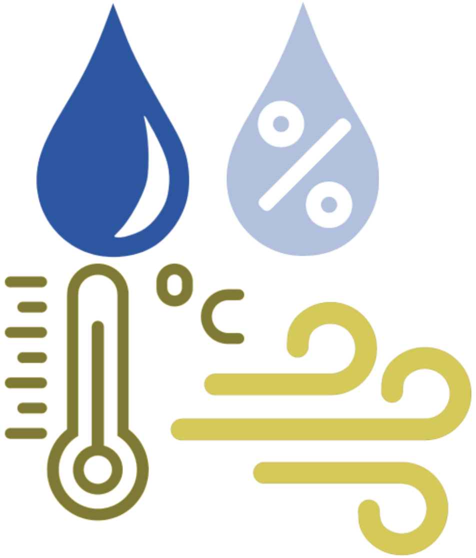
- Rain tests: exposure to a horizontal water spray
- Bundesmann rain-shower test
- Spray test
- Impact penetration test



ISO 22958 Textiles — Water resistance
ISO 9865 Textiles — Determination of water repellency of fabrics by the Bundesmann rain-shower test



Thermal and Water-vapour resistance

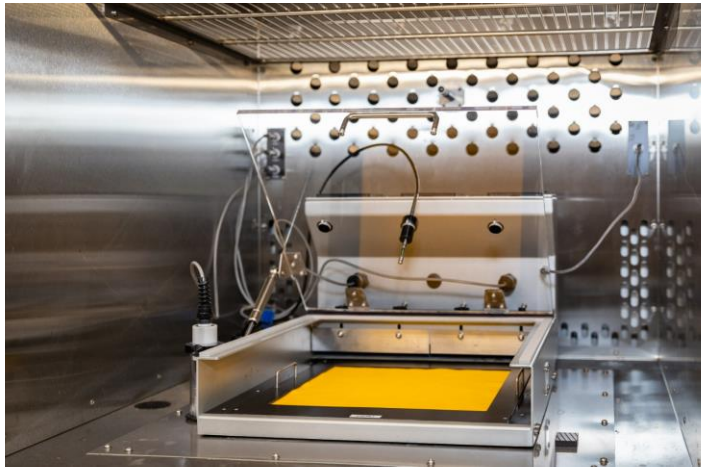


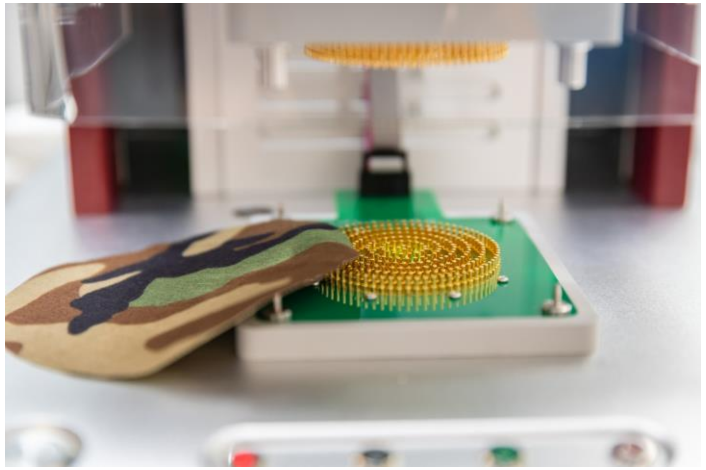
ISO 15496 Textiles — Measurement of water vapour permeability of textiles for the purpose of quality control

ISO 11092 Textiles — Physiological effects

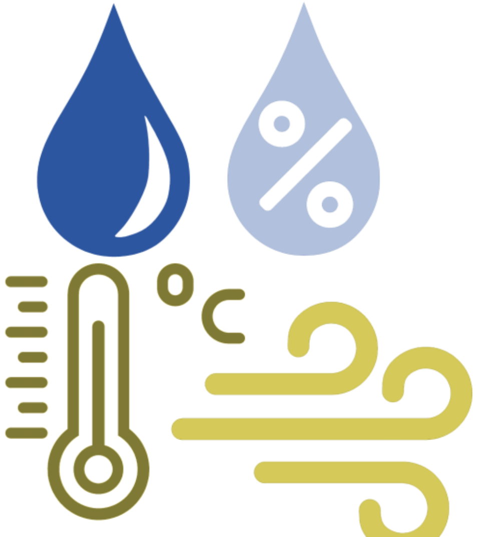
ISO 13029 Textiles — Determination of drying rate in dynamic state

- Water vapor permeability
- Moisture exchange testing equipment
- Heat resistance and water vapor permeability (protected hotplate)
- Moisture management test





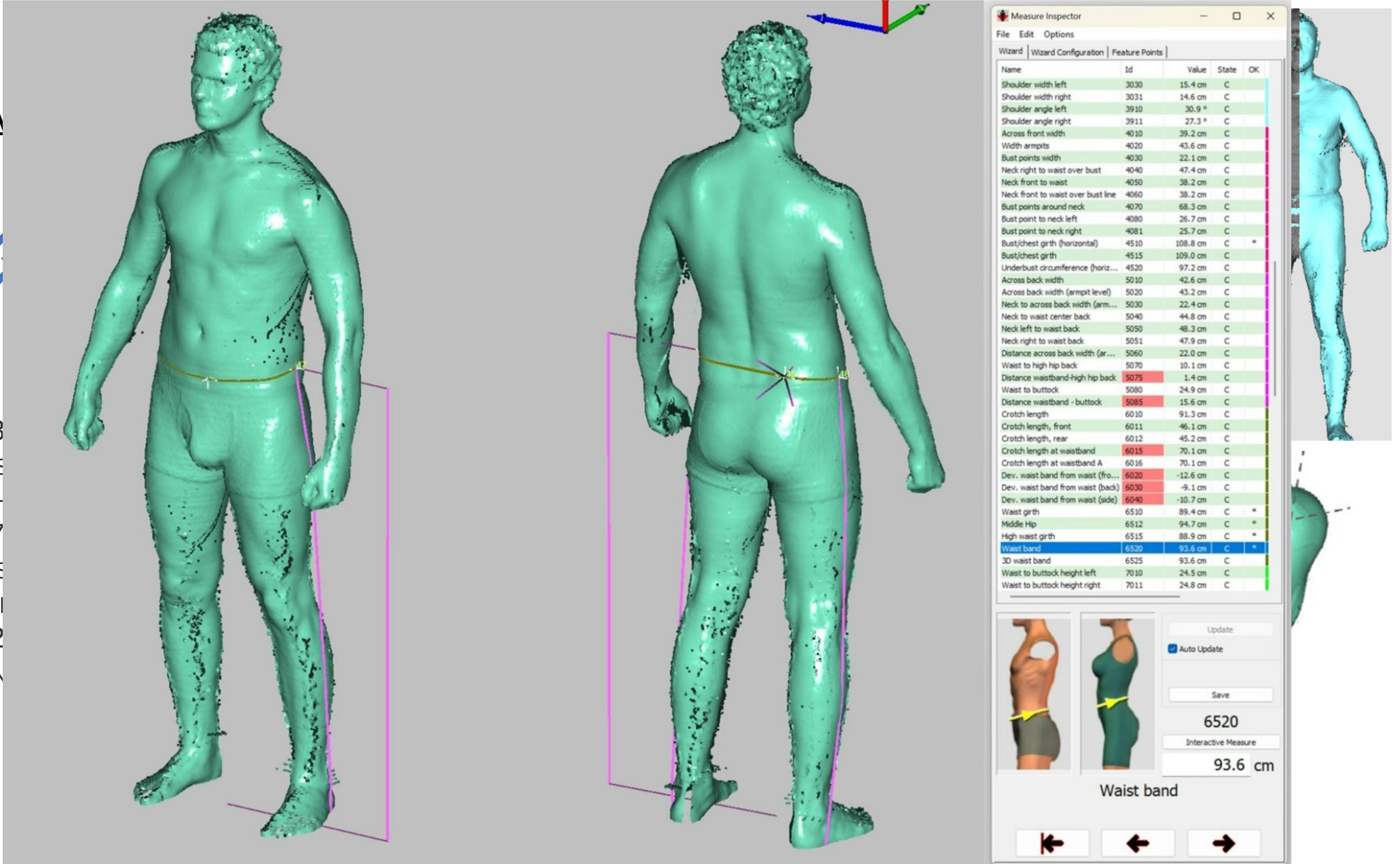
Microclimate - Thermal Manikin



ISO 15831 Clothing — Physiological effects — Measurement of thermal insulation by means of a thermal manikin
EN 342 Protective clothing
EN 23537-2 Requirements for sleeping bags ISO 7250 Basic human body measurements

- Simulate human physiology and test garments for heat loss and gain.
- Rapid Dynamic Heat Flux Sensing (35 zones)
- Active Cooling technology simulates the mass of a human; temperature range (-20˚C to +50˚C)
- ManikinPC (Manikin Physiology Control and Predictive Comfort) software simulates the human thermoregulatory system and provides metrics for thermal comfort and thermal sensation.
- Measures the complex thermal interactions between apparel and hot environments, yielding new insights for garment researchers.
- Precision sweat control and quick-change sweat pores that minimize maintenance time.

A



ISO 8

Meas

cloth

ISO 7

Meas

ergo

ISO 2

Scan

PROCEDURES FOR USE OF PPC, PROBLEMATIC

Challenges for the industry in supplying appropriate clothing to wearers of special-purpose clothing

- Data on anthropometric profiles
- Understanding of the structure of sizing systems
- Knowledge of the properties of textiles
- Design methods used
- Understanding of the specifics of clothing wearing conditions
- Access to wearers' assessment of the suitability of products (clothing)

Design of special-purpose clothing

- Protective clothing, work-wear, sports-wear and other special need clothing - unlike everyday fashion, design for specific wearer needs
- Compliance indicators - functional compliance, anthropometric fit and ergonomics, ensuring the ability of wearers to perform daily duties or other activities

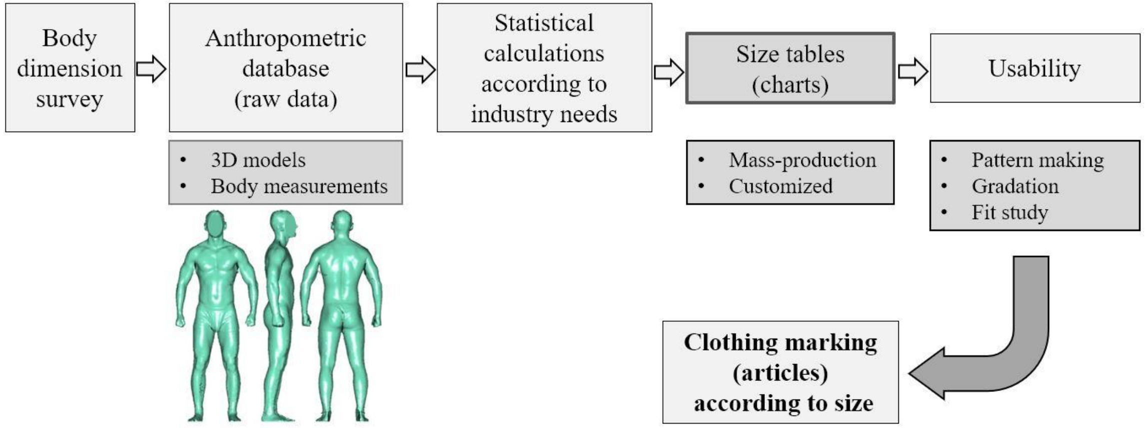
Supply of special-purpose clothing

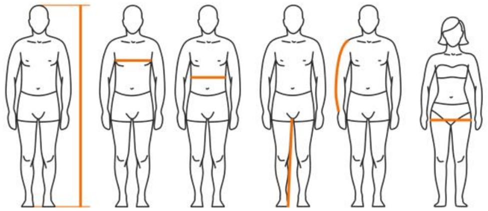
- State-level institutions whose responsible officials may not be sufficiently informed about the real needs and problems of wearers in the work environment in terms of clothing
- Procurement of inappropriate and/or unusable clothing can lead to economic losses at national level
- The creation of unusable and disposable products contributes to significant resource consumption and environmental damage

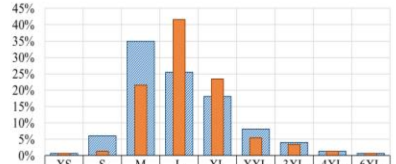
There is a need for a **set of practical principles** for assessing the anthropometric fit and ergonomics of clothing, facilitating both the parties' understanding of the parameters of appropriate clothing and their evaluation and decision-making process.

Standards for measuring the human body and developing clothing sizing systems

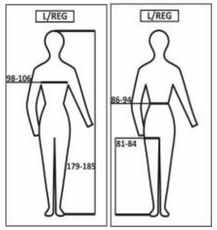
- EN 13402-1:2002 Size designation of clothes - Part 1: Terms, definitions and body measurement procedure
- EN 13402-2:2002 Size designation of clothes - Part 2: Primary and secondary dimensions
- EN 13402-3:2017 Size designation of clothes - Part 3: Size labelling based on body measurements and intervals
- ISO 5971:2017 Size designation of clothes -Tights
- ISO 8559-1:2017 Size designation of clothes - Part 1: Anthropometric definitions for body measurement
- ISO 8559-2:2017 Size designation of clothes - Part 2: Primary and secondary dimension indicators
- ISO 8559-3:2018 Size designation of clothes - Part 3: Methodology for the creation of body measurement tables and intervals

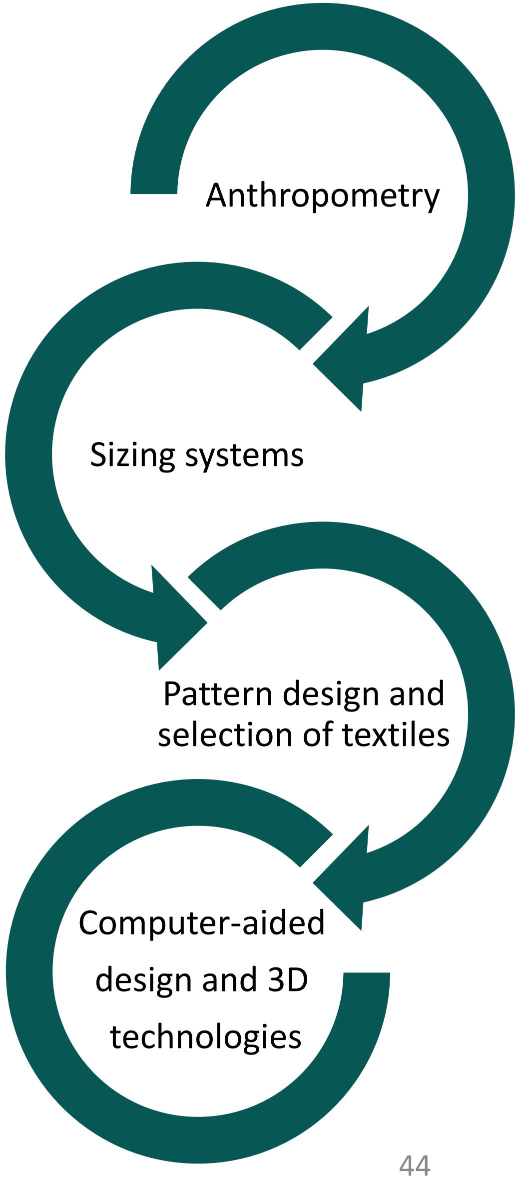






	XS	S	M	L	XL	XXL	3XL	4XL	6XL
SIZE by Waist	1%	6%	35%	26%	18%	8%	4%	1%	1%
SIZE by Waistband	1%	1%	21%	42%	23%	5%	3%	1%	1%

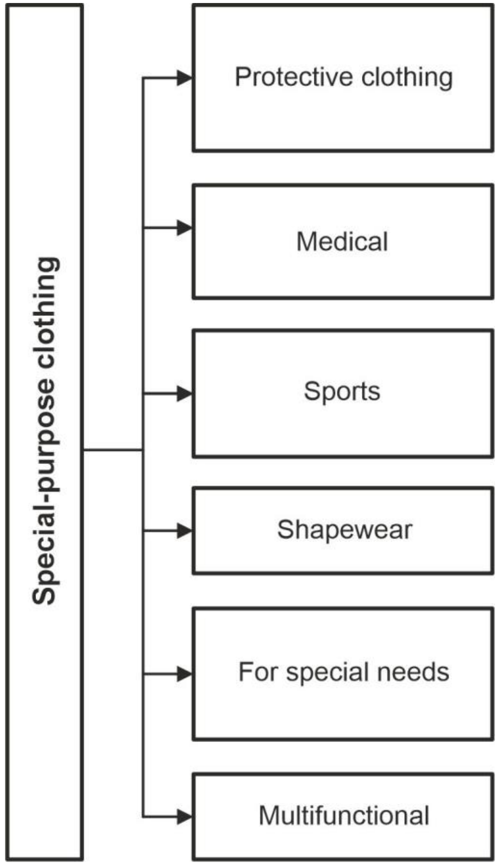




CONFORMITY ASPECTS OF CLOTHING

Anthropomteric fit - the conformity of the size and shape of the clothing to the size and shape of the human body

Ergonomics - product and process improvements/solutions for human use - the ability of wearers to perform daily duties or other activities



ILL-FIT AND

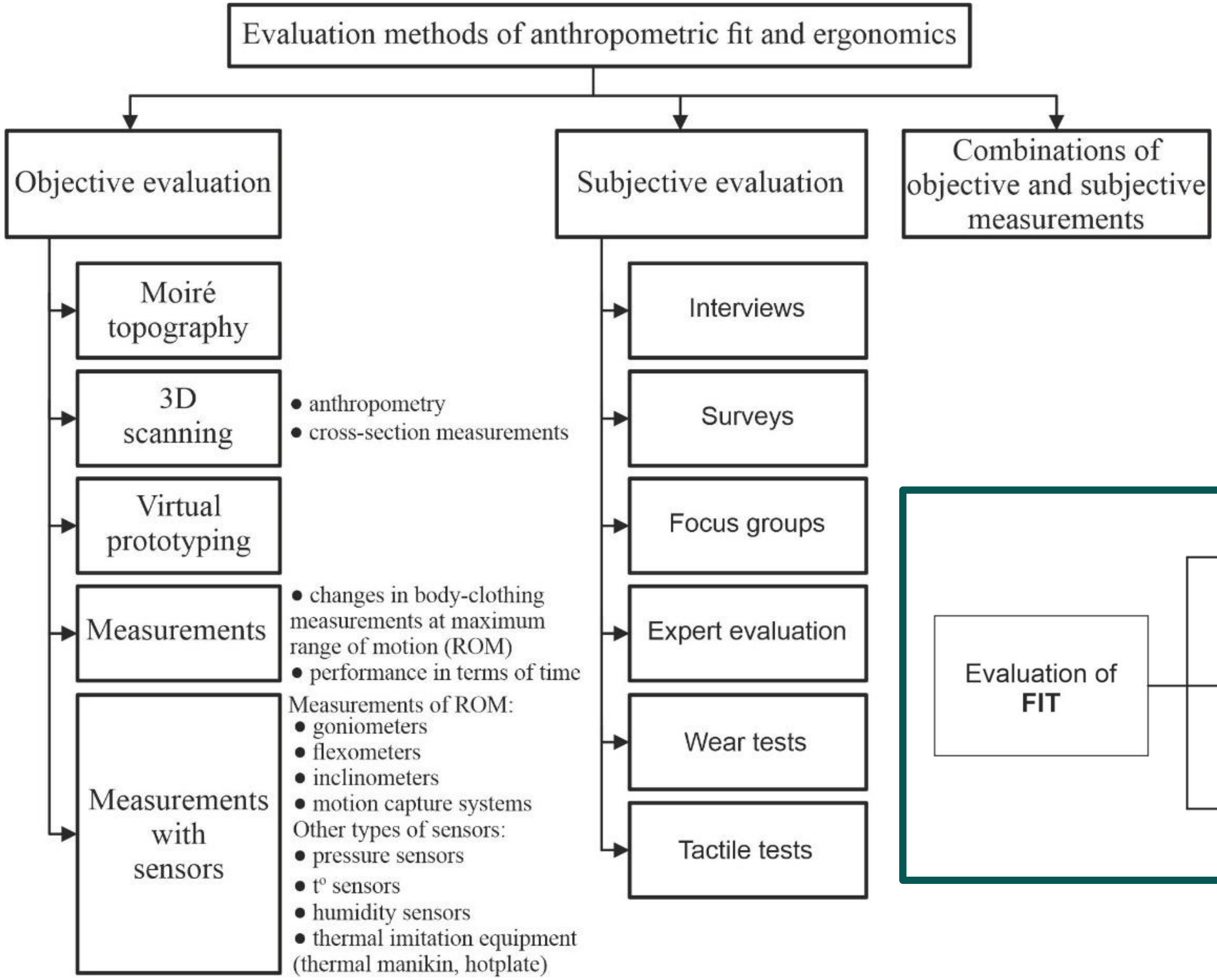
ERGONOMICALLY UNSUITABLE CLOTHING

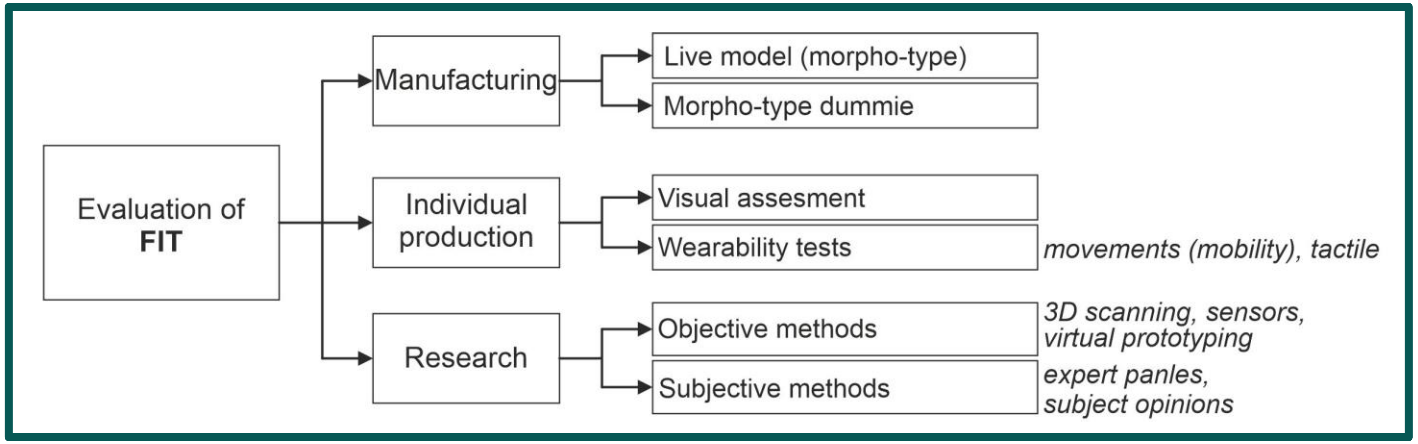
WITHOUT SECTOR-SPECIFIC CONFORMITY ASSESSMENT

PROCEDURES AND SYNERGIES BETWEEN WEARERS,

CUSTOMERS AND SUPPLIERS

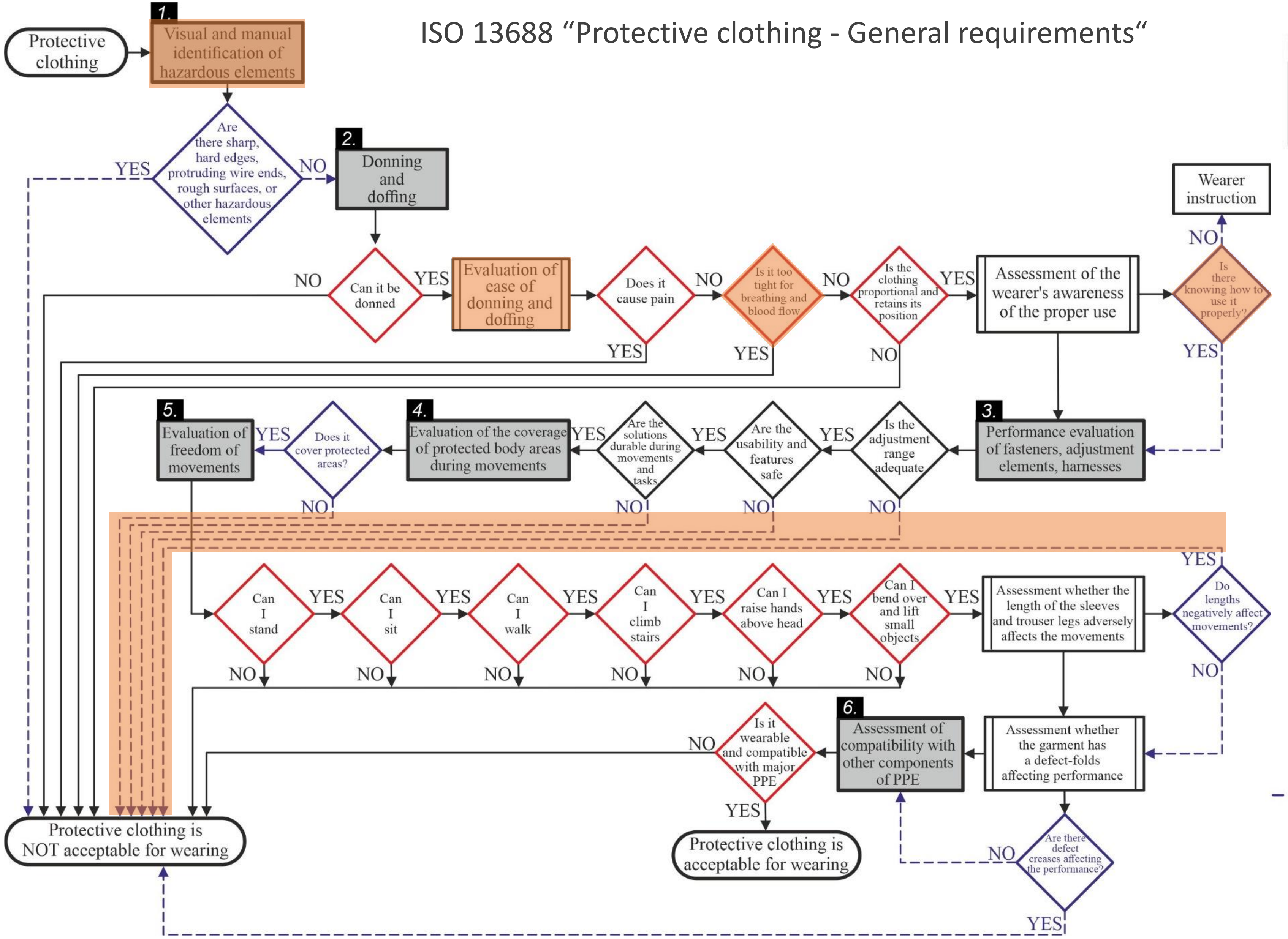
METHODS FOR ASSESSING ANTHROPOMETRIC FIT AND ERGONOMICS





ANTHROPOMETRIC FIT AND ERGONOMICS IN INDUSTRY STANDARDS

ISO 13688 “Protective clothing - General requirements“



Stages (components) of the evaluation process

Evaluations to be carried out

Defective values of protective clothing specified in the standard, which result in a decision on its non-compliance

The author's additional defective values of protective clothing, from which the decision on its non-compliance must be derived

Author's decision-making pathways

METHOD FOR EVALUATION OF ANTHROPOMETRIC FIT AND ERGONOMICS OF CLOTHING

- Special-purpose clothing *(research objects)*
- Material properties, tests
- Users/consumers *(subjects)*
- Competent contact-persons
- Experts/specialists
- Anthropometric research
- Interviews
- Surveys
- Tests of ergonomics

INPUT DATA

- About 3,000 firefighters in Latvia
- Every day during on-call wear a uniform - jacket and trousers
- The procurement of uniforms is centralized
- Procurement results and the use of uniforms show problems/shortcomings at all stages of supply, and there is a lack of knowledge and a systematic approach to their analysis and solution.

PROCESS COMPONENTS

Station-uniforms worn during daily work – jackets, trousers

Technical specification of station-uniforms

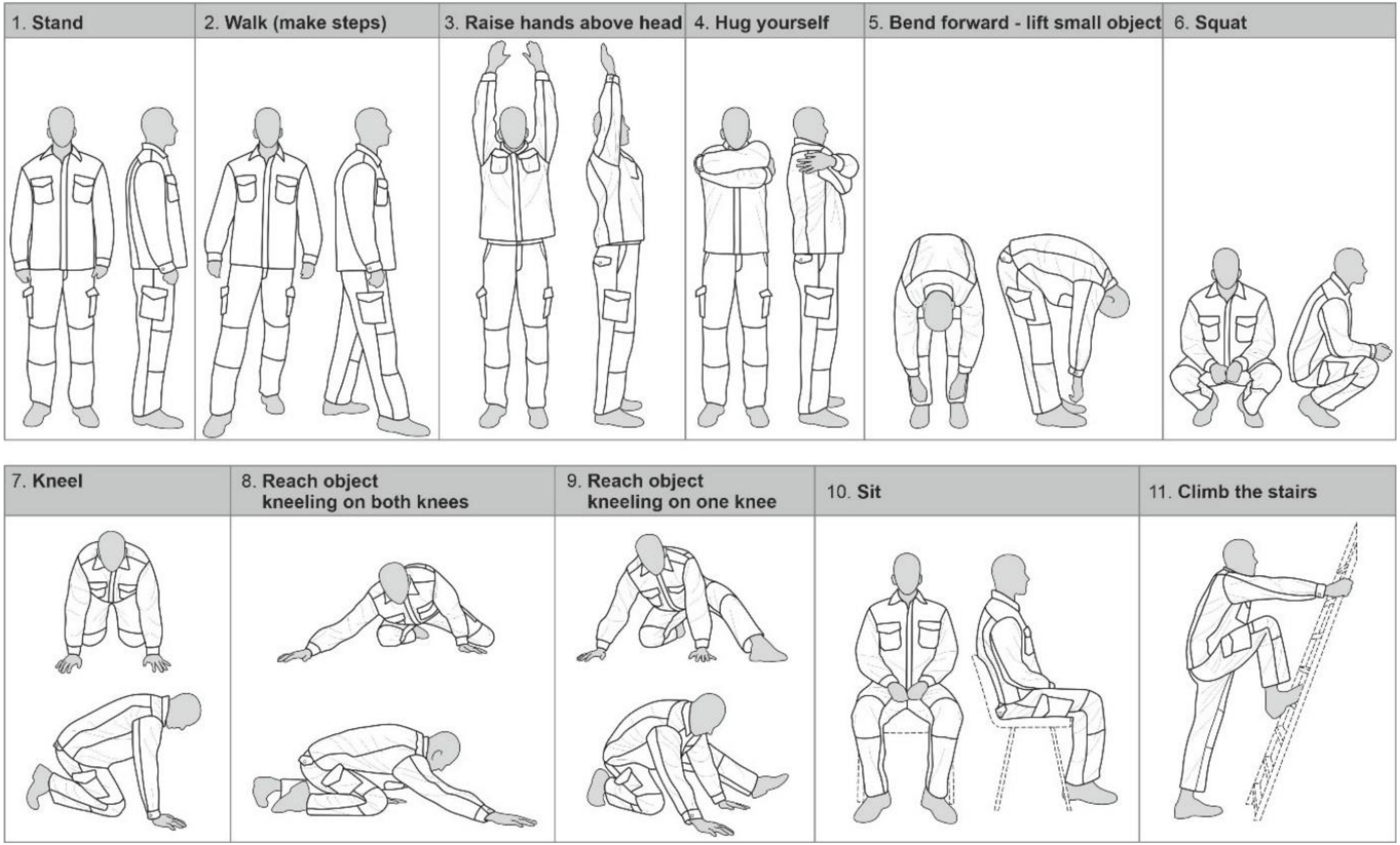
SFRS employees performing active work on a daily basis

Competent contact-persons to find out typical work movements and wearing habits

Industry specialists with knowledge and experience in the specifics of special-purpose clothing, anthropometry, and clothing pattern design

Anthropometric data obtained with 3D scanning device *VitusSmart XXL®* with data processing system *AnthroScan* and traditional anthropometric instruments - anthropometers, measuring tapes and calipometers

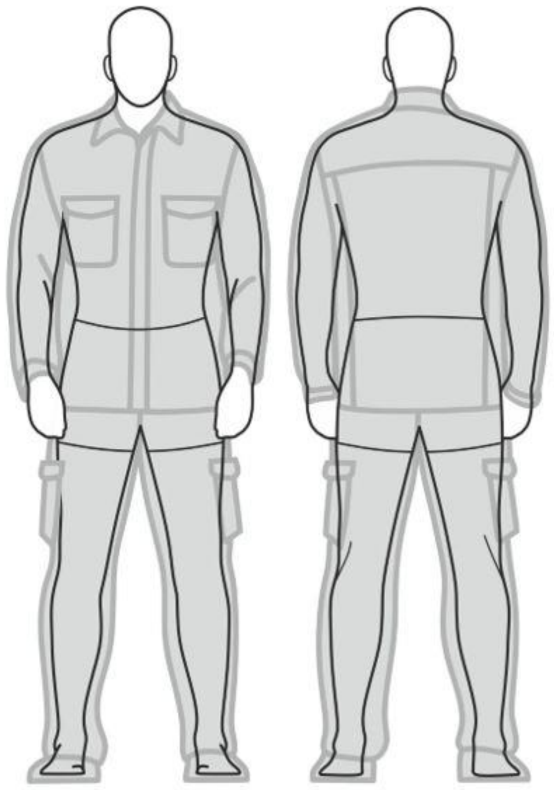
Body postures/movements for assessment of station-uniform ergonomics



Questionnaire for subjective evaluation of clothing fit and ergonomics

EVALUATION OF ANTHROPOMETRIC FIT AND ERGONOMICS

Date:		Participant CODE:		Clothing CODE:	



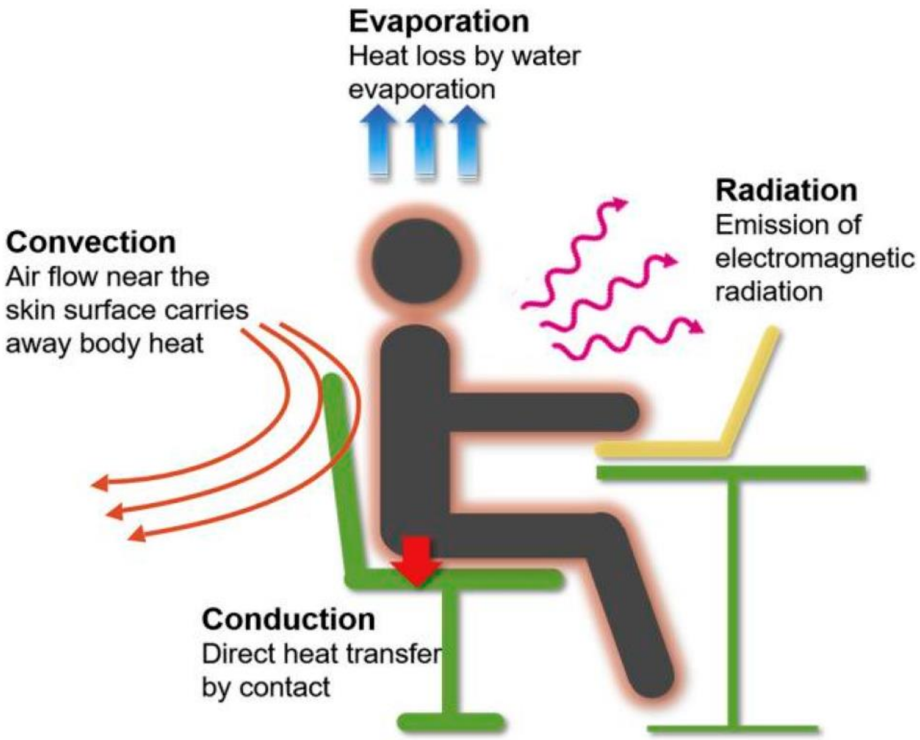
CLOTHING FIT:	Very easy	Easy	Moderate	Hard	Very hard
Donning and doffing	–2	–1	0	1	2
	Extremely small	Slightly small	Corresponding	Slightly big	Extremely big
Size conformity	–2	–1	0	1	2
	Very light	Light	Neutral	Heavy	Very heavy
Clothing weight	–2	–1	0	1	2
	Very comfortable	Comfortable	Moderate	Uncomfortable	Very uncomfortable
Fasteners and regulators	–2	–1	0	1	2
	Extremely tight	Too tight	Moderate	Too loose	Extremely loose
Looseness of clothing	–2	–1	0	1	2
	Extremely short	Too short	Moderate	Too long	Extremely long
Sleeve length	–2	–1	0	1	2
	Extremely short	Too short	Moderate	Too long	Extremely long
Trouser-leg length	–2	–1	0	1	2
	Totally not restricted	Not restricted	Neutral	Restricted	Extremely restricted
Joint restrictions	–2	–1	0	1	2

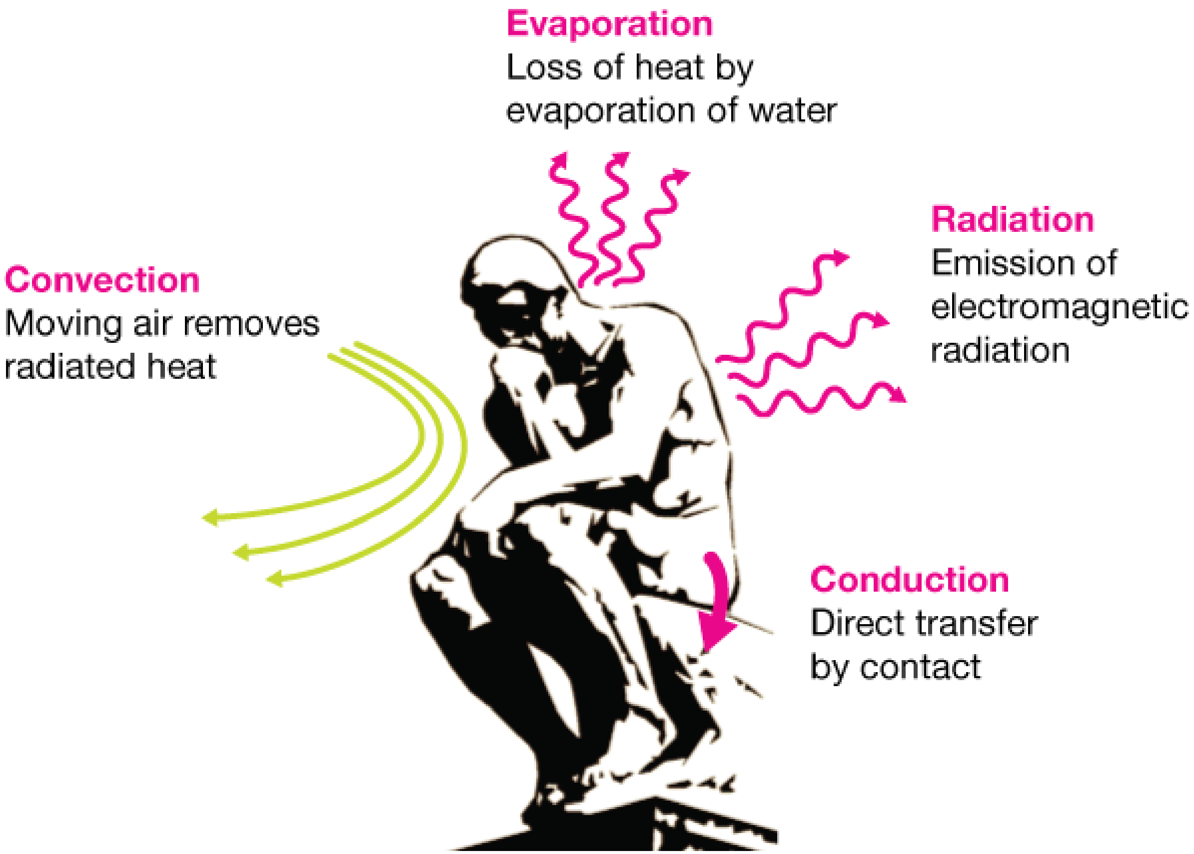
← *In the picture, additional problem areas should be indicated and commented on - restrictions on movement or other effects affecting the performance of work (areas can be outlined, coloured, or otherwise visually indicated and commented on in the text).*

	FREEDOM OF MOVEMENTS:	Very easy	Easy	Moderate	Hard	Very hard
1.	Stand	–2	–1	0	1	2
2.	Walk (make steps)	–2	–1	0	1	2
3.	Raise hands above head	–2	–1	0	1	2
4.	Hug yourself	–2	–1	0	1	2
5.	Bend forward - lift small object	–2	–1	0	1	2
6.	Squat	–2	–1	0	1	2
7.	Kneel	–2	–1	0	1	2
8.	Reach object kneeling on both knees	–2	–1	0	1	2
9.	Reach object kneeling on one knee	–2	–1	0	1	2
10.	Sit	–2	–1	0	1	2
11.	Climb the stairs	–2	–1	0	1	2

Place for other comments (optional):

Thermo-Physiological

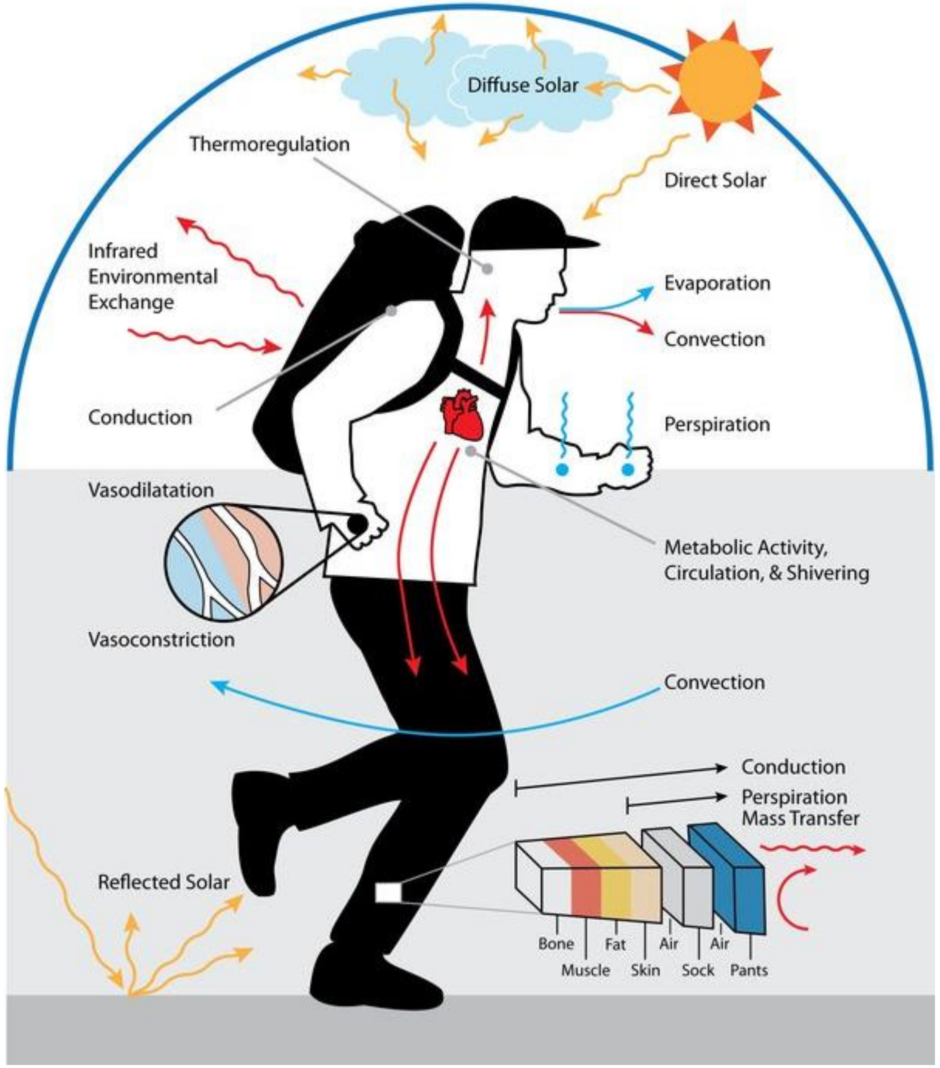


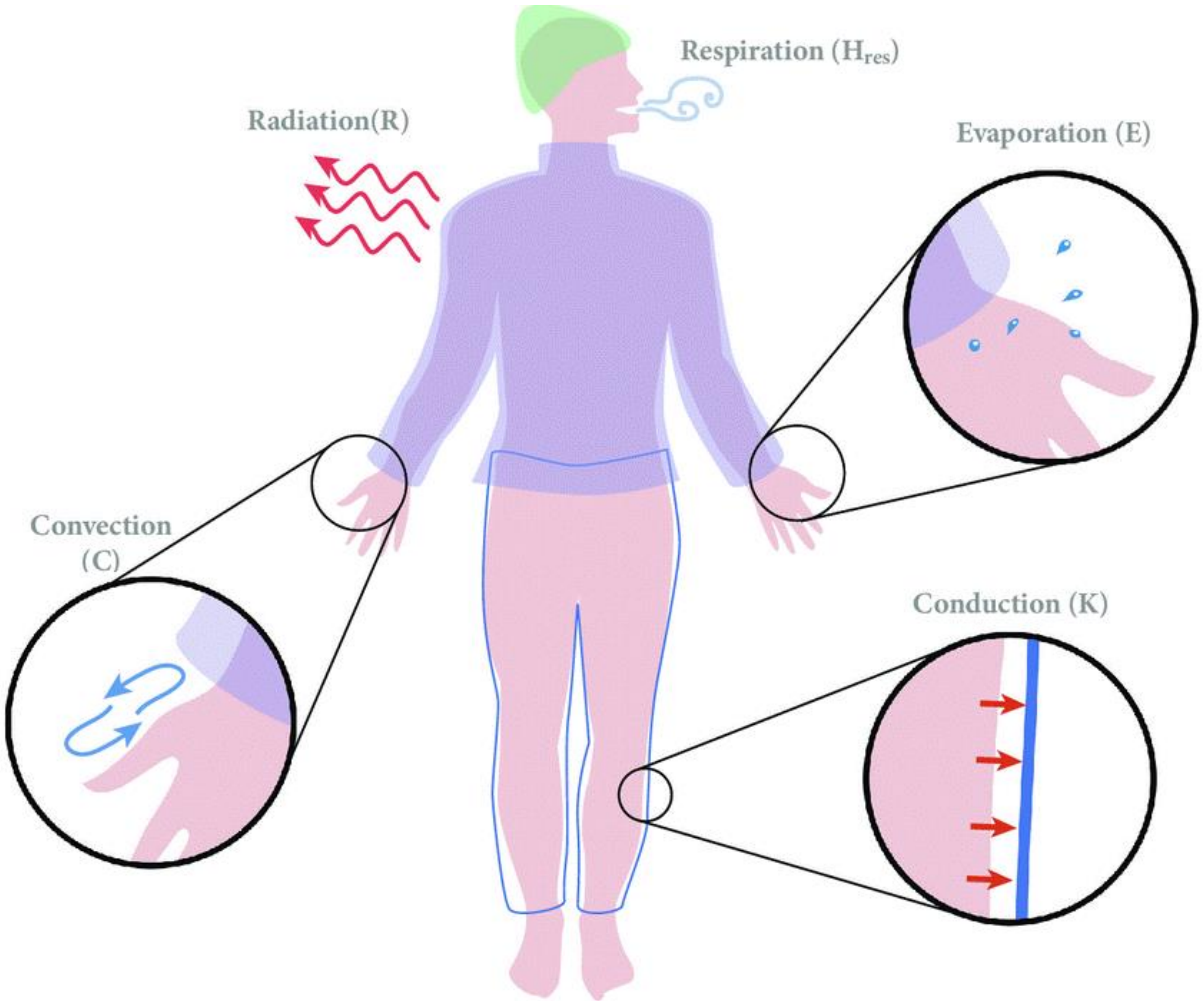


Personal thermal and moisture management [Peng, Y.; Cui, Y. Advanced Textiles for Personal Thermal Management and Energy. *Joule* **2020**, *4*, 724–742.]

1. https://xaktly.com/HeatTransfer.html

Thermo-Physiological





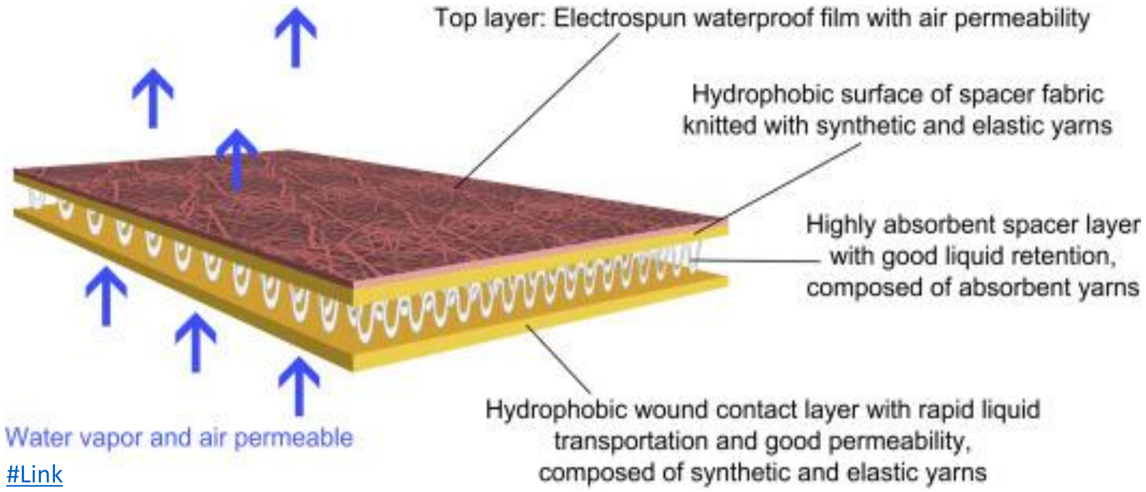
1. https://www.thermoanalytics.com/human-thermal-extension
2. https://autogarment.com/analysis-of-thermal-resistance-and-humidity-resistance-test/

Thermo-Physiological

Solutions for thermal comfort

Spacer mesh fabrics

#Link



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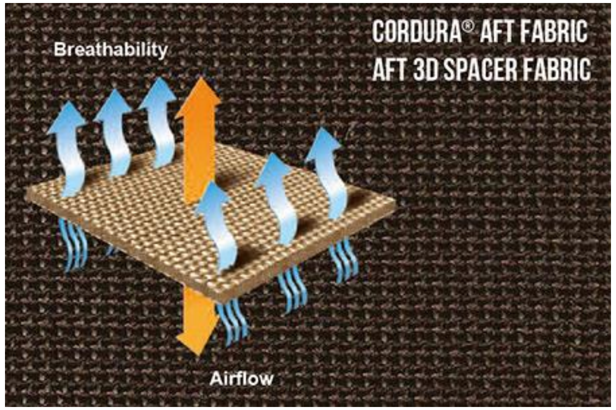
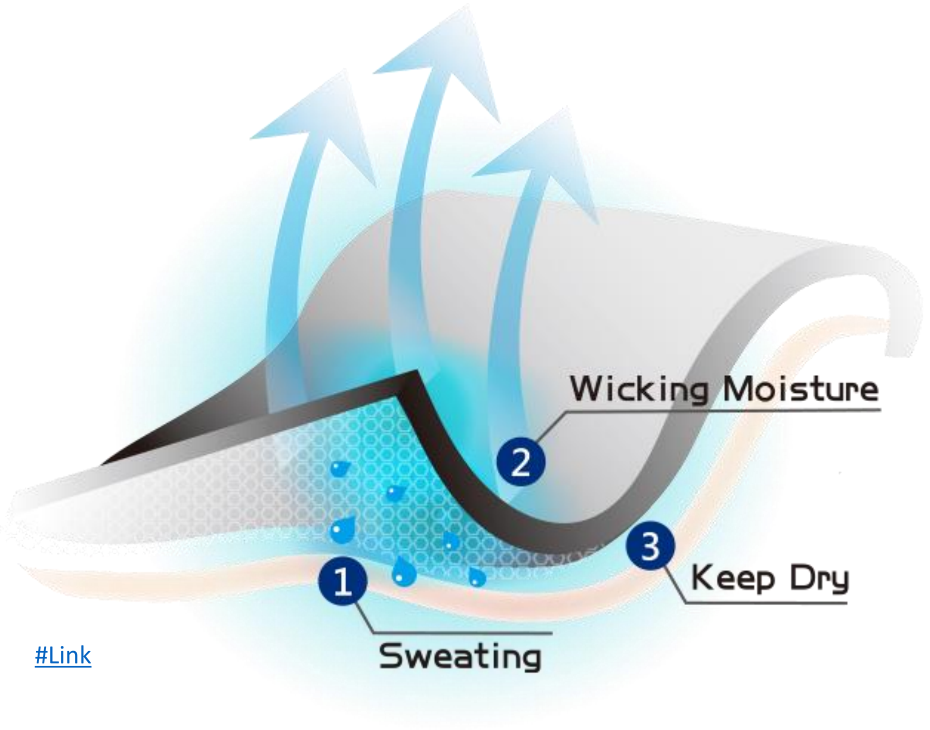


#Link

Waterproof 3D mesh vest

Solutions for thermal comfort

Moisture-wicking fabrics



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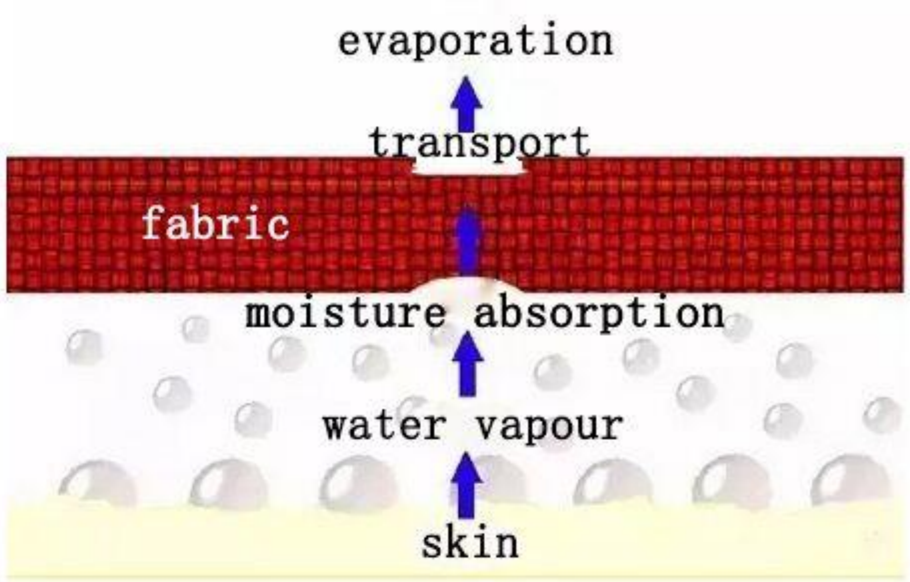
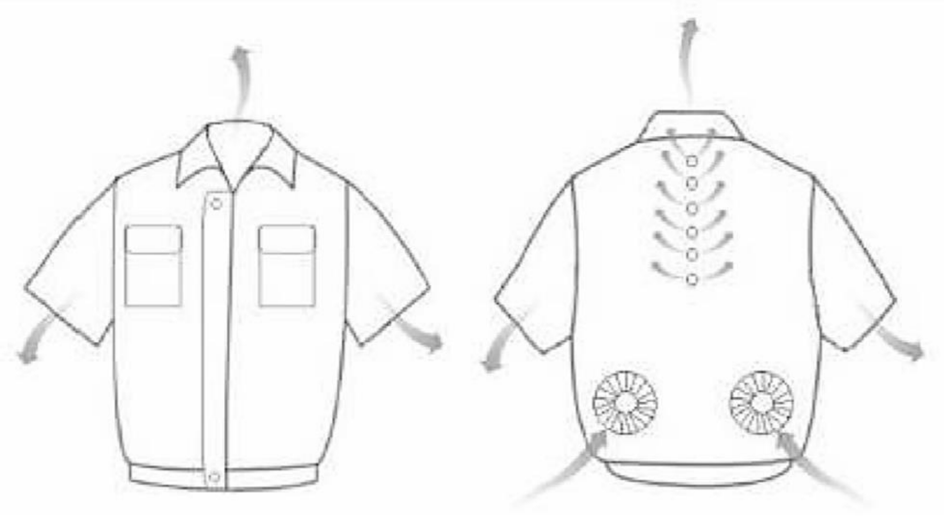


#Link

Solutions for thermal comfort

Active Cooling techniques

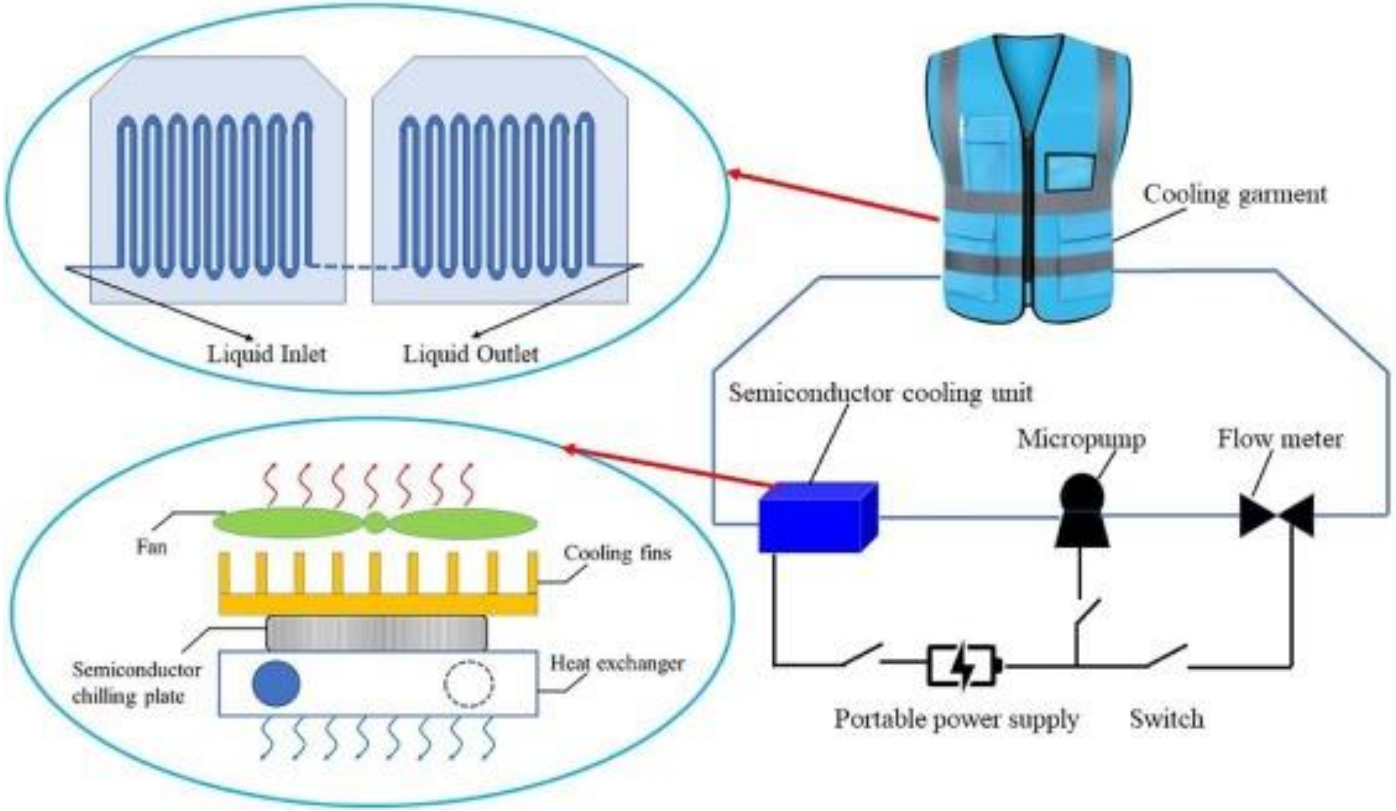
Cooling with fans #Link



Solutions for thermal comfort

Active Cooling techniques

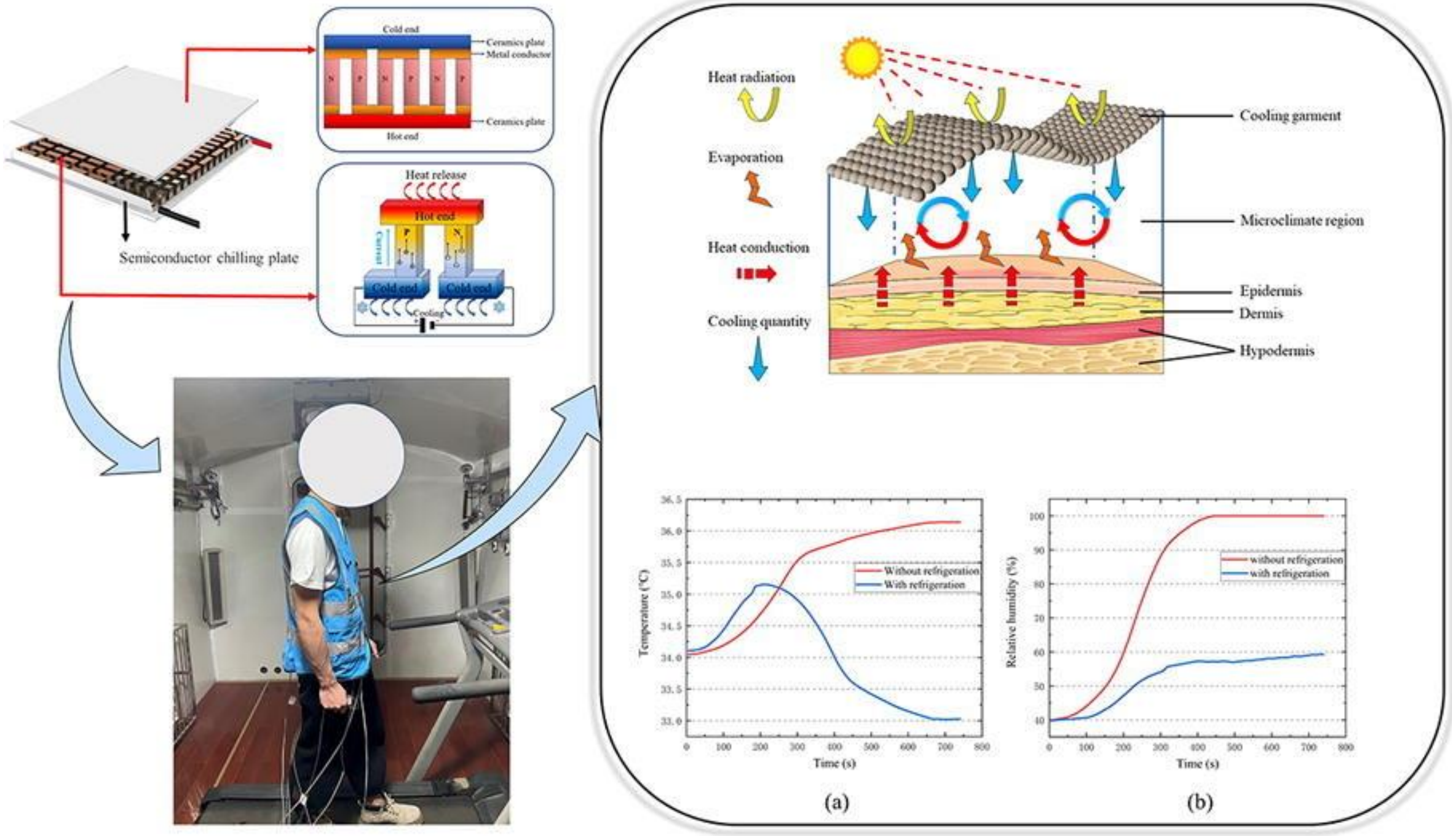
Cooling with liquid [#Link]



Solutions for thermal comfort

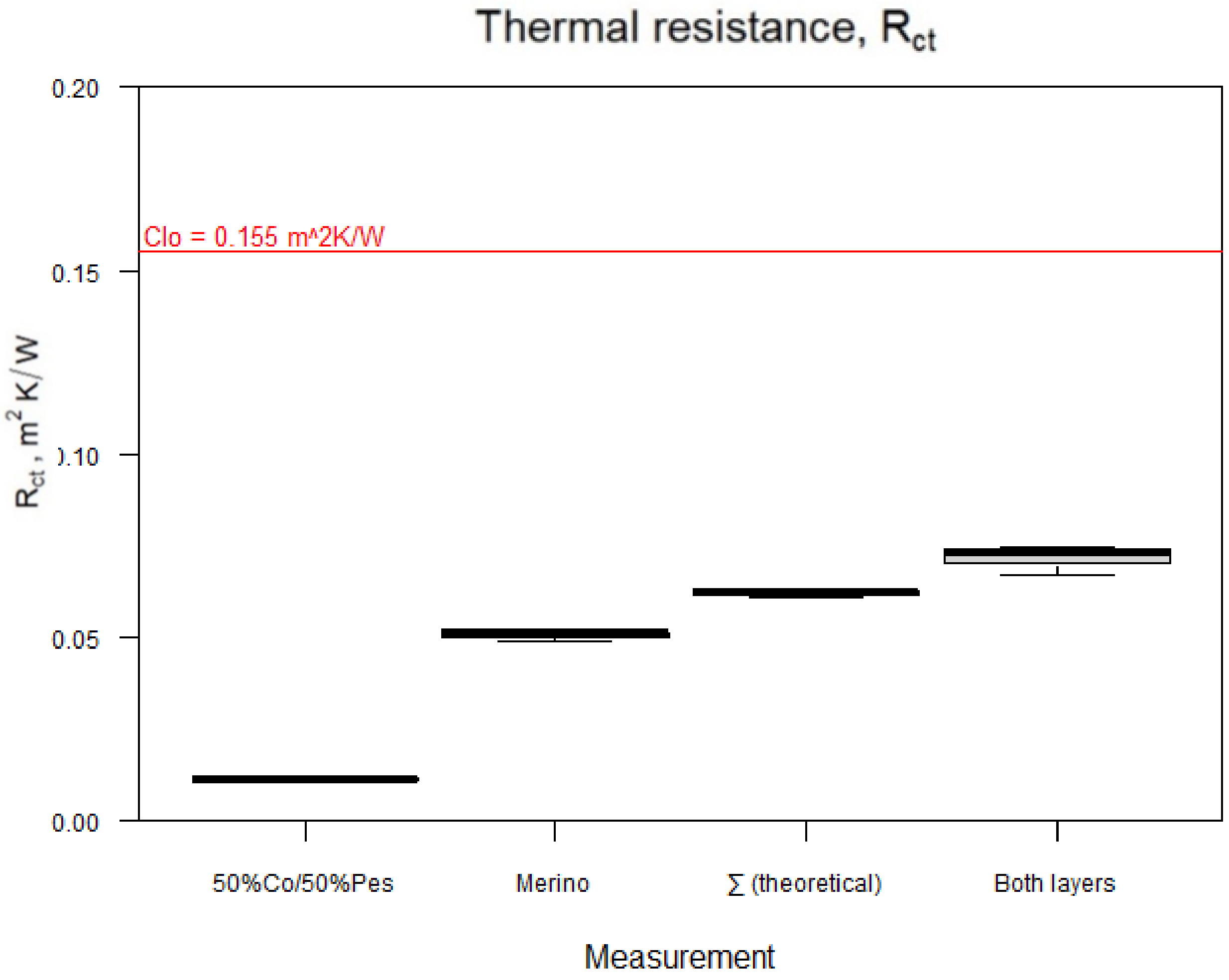
Active Cooling techniques

Thermoelectric cooling #Link



Thermal resistance, R_{ct}

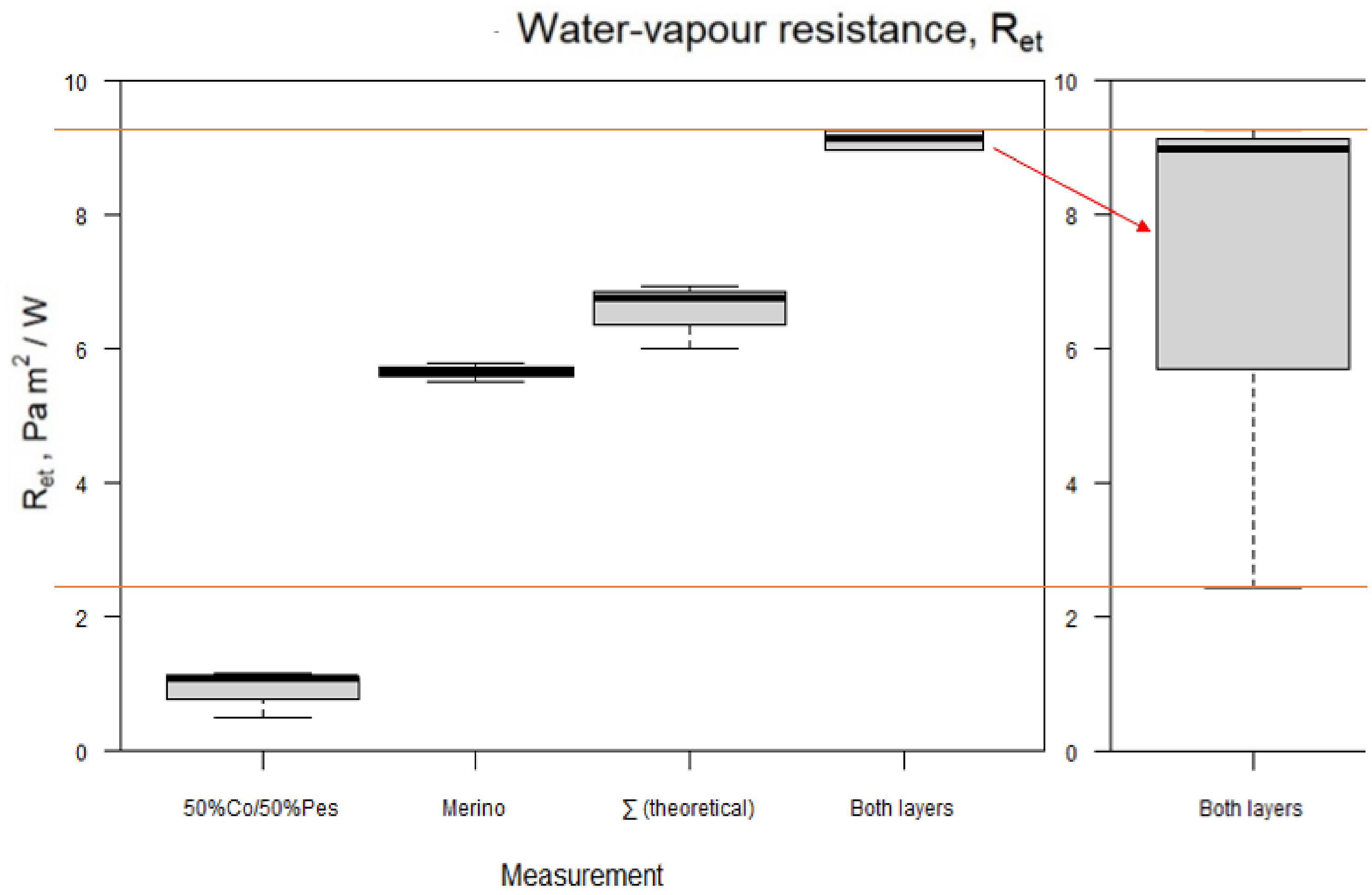
- The R_{ct} value determines the thermal resistance of the material. It is measured with a sweating guarded hotplate (SGHP).
- The higher the R_{ct} value, the better the insulation properties. For example, to maintain body temperature and prevent frostbite, materials with higher R_{ct} values are needed at ambient temperatures around 10°C than at 20°C.
- R_{ct} value can be converted to clo value: 1 clo = R_{ct}/0.155. The clo value determines the thermal performance of materials and/or clothing.
- The R_{et} measurements shown in Figure also allow to conclude that the sum of two materials is not a measurement of the layering of the two materials (in this study, material tests are described, the materials are tested overlying without an air gap, which occurs during the wearing of clothing, which allows the summation to be performed without taking into account a theoretical air gap



Water-vapour resistance, R_{et}

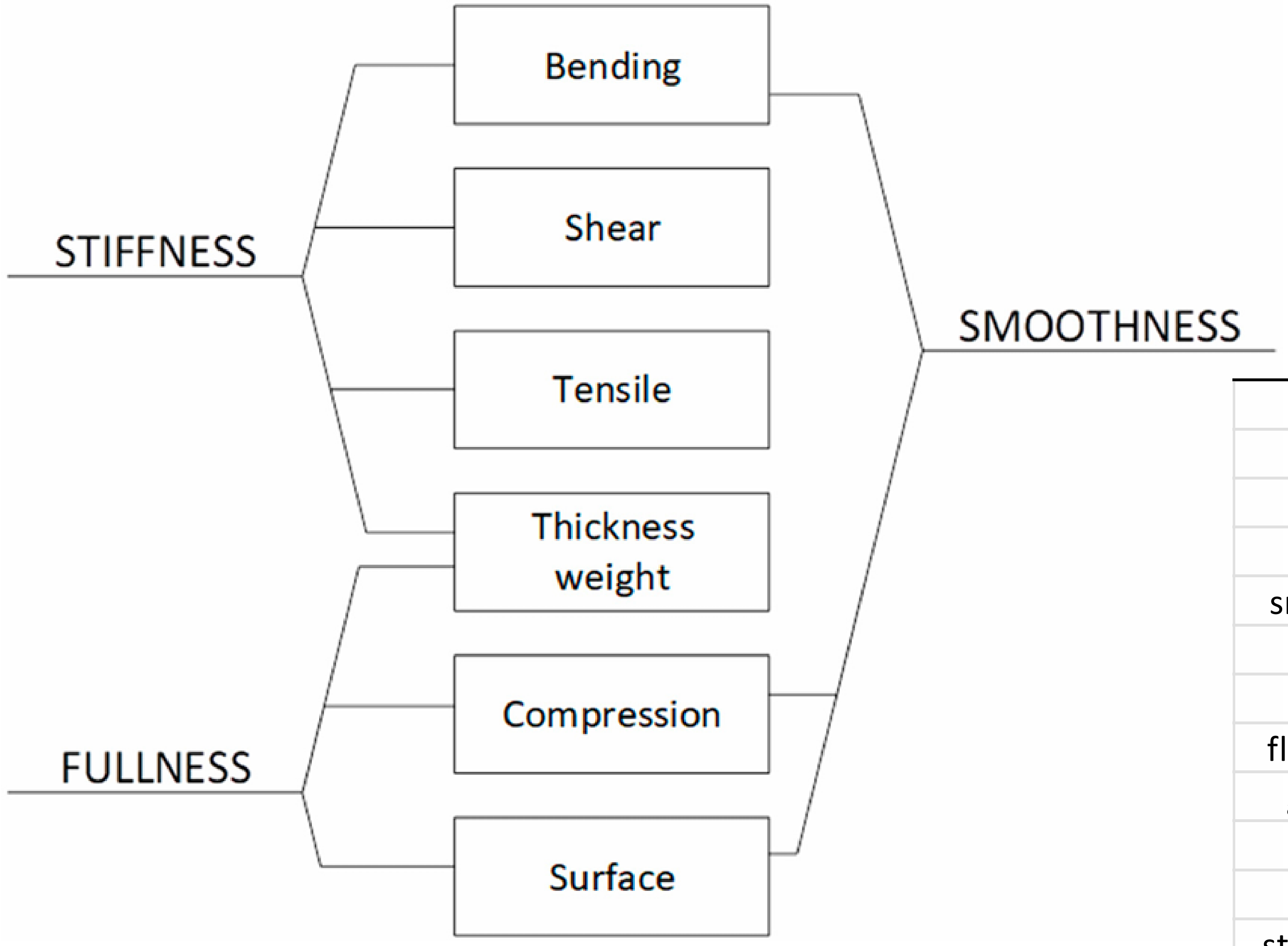
- Measurements of heat and water vapor resistance allow us to understand the ability of PPC layering to protect rescuers and ensure the ability to provide the necessary microclimate conditions.
- Although the existing methods allow for complex measurements, the standard's requirement to measure 3 samples may turn out to be too small, in addition, the SD value should also be indicated - to check the reliability of the data.
- More measurements are planned in the next stage of this study, including repeated testing and error analysis. Further studies also include measurements for ready-to-wear ensembles, according to ISO 9920

Layers	R_{et}, Pa m^2 W^{-1}		
	1st sample	2nd sample	3rd sample
Both (50%Co/50%Pes and 100% Merino) layers measured	2.440 ↓	8.969	9.269



EVALUATION OF FABRIC HAND

Fabric hand

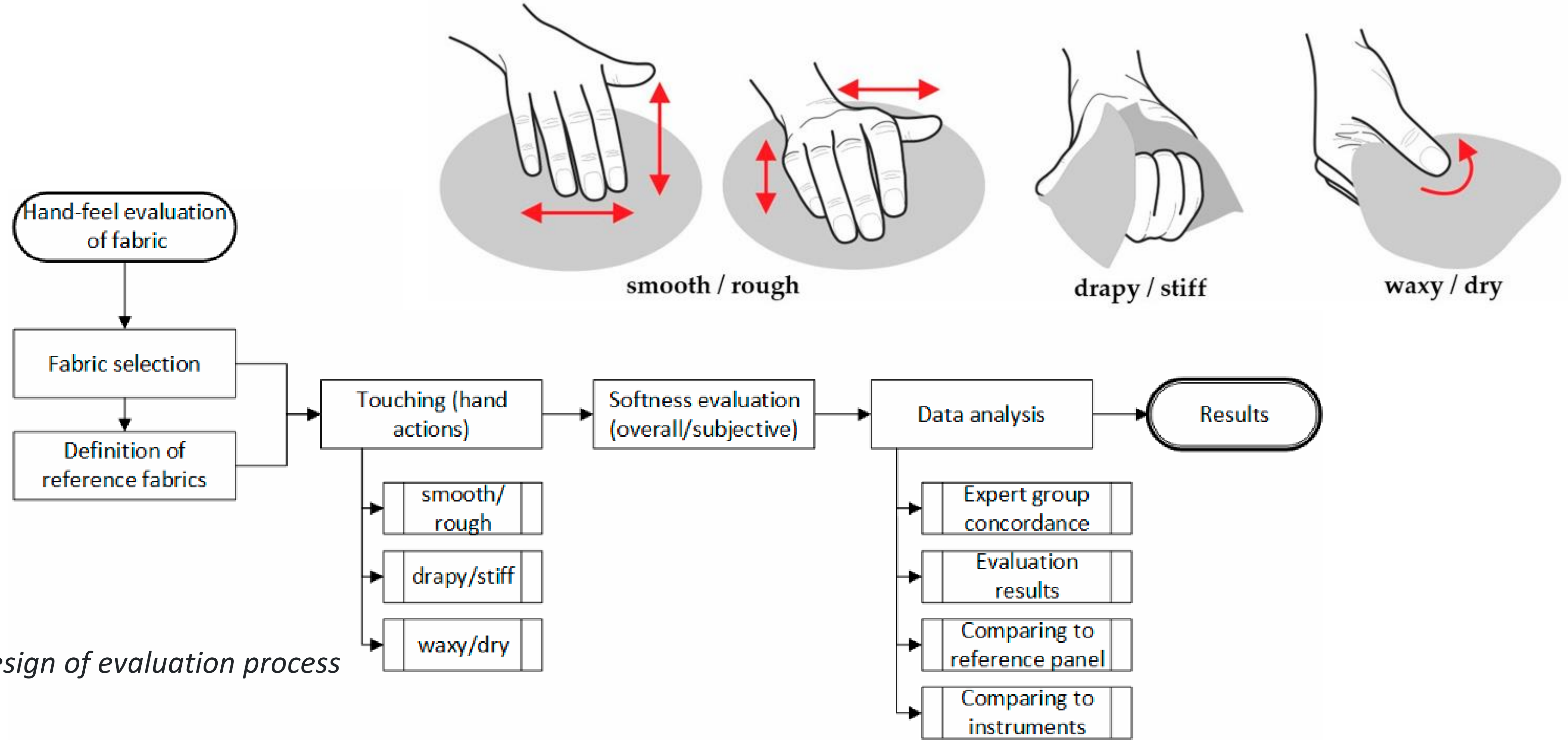


Linked fabric properties

	1	2	3	4	5	6	7	8	9	10	
cool	1	2	3	4	5	6	7	8	9	10	warm
light	1	2	3	4	5	6	7	8	9	10	heavy
thin	1	2	3	4	5	6	7	8	9	10	thick
smooth	1	2	3	4	5	6	7	8	9	10	rough
loose	1	2	3	4	5	6	7	8	9	10	compact
soft	1	2	3	4	5	6	7	8	9	10	hard
flexible	1	2	3	4	5	6	7	8	9	10	stiff
gentle	1	2	3	4	5	6	7	8	9	10	harsh
limp	1	2	3	4	5	6	7	8	9	10	crisp
sleazy	1	2	3	4	5	6	7	8	9	10	firm
stretchy	1	2	3	4	5	6	7	8	9	10	not stretchy

Example of evaluation table

Fabric hand

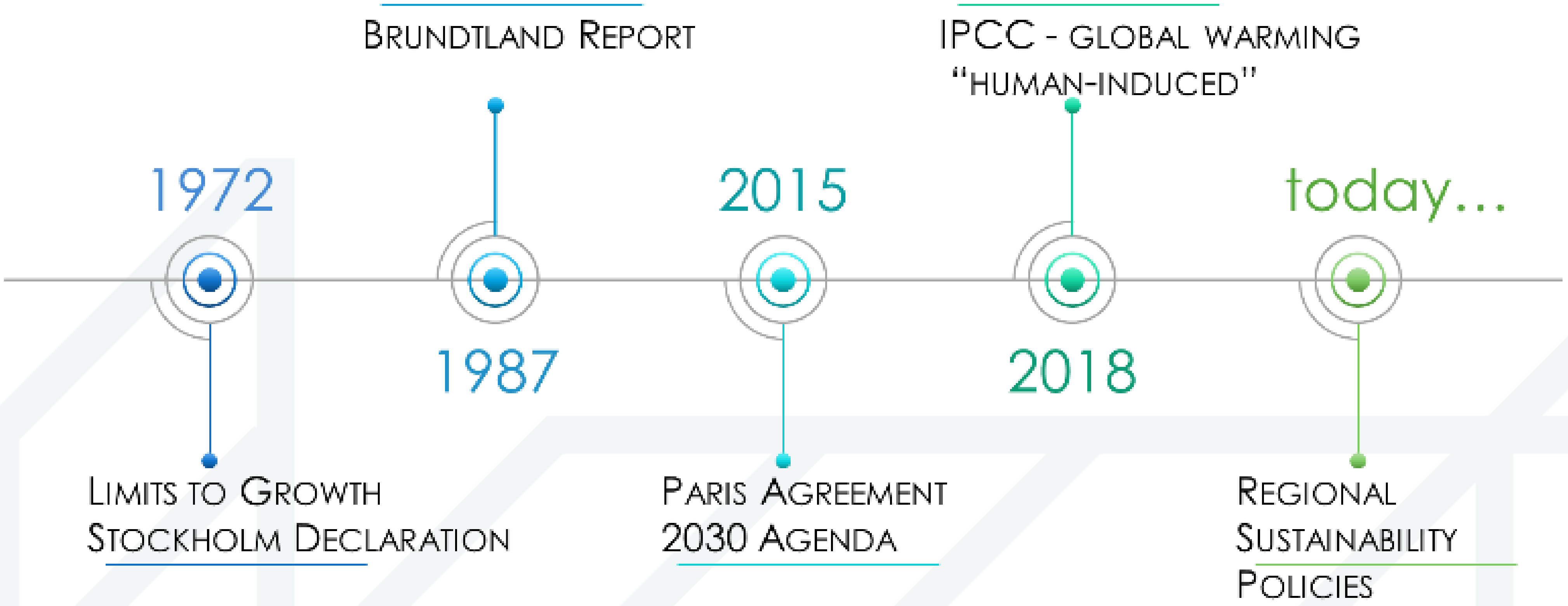


Design of evaluation process

TEXTILE WASTE MANAGEMENT, SUSTAINABILITY OF TEXTILE PRODUCTS

Development of the concept of sustainability

«Anyone who believes that exponential growth can go on forever in a finite world is either a madman or an economist» (Kenneth E. Boulding, 1973)



EU sustainability policy – textile industry

EU strategy for sustainable and circular textiles (2022)

By 2030 textile products placed on the EU market are long-lived and recyclable, to a great extent made of recycled fibres, free of hazardous substances and produced in respect of social rights and the environment. Consumers benefit longer from high quality affordable textiles, fast fashion is out of fashion, and economically profitable re-use and repair services are widely available. In a competitive, resilient and innovative textiles sector, producers take responsibility for their products along the value chain, including when they become waste. The circular textiles ecosystem is thriving, driven by sufficient capacities for innovative fibre-to-fibre recycling, while the incineration and landfilling of textiles is reduced to the minimum.

Main objectives:

- Transition to a circular economy model
- Mandatory Ecodesign requirements
- Zero pollution
- Stopping the destruction of unsold or returned textiles
- Tackling microplastics pollution
- Digital Product Passport
- Fibre-to-fibre recycling
- Green Claims
- Extended producer responsibility
- Reversing the overproduction and overconsumption
- Addressing the challenges from the export of textile waste
- Promote the environmental, social and economic sustainability of the textile industry in the EU and beyond

Related strategies and documentation:

- European Green Deal (2020)
- Circular economy action plan (2020)
- Industrial strategy (2021)
- EU Action Plan: 'Towards Zero Pollution for Air, Water and Soil' (2021)
- **Ecodesign for Sustainable Products Regulation (2022)**
- REACH Regulation (2007)
- Industrial Emissions Directive (revized 2023)
- Best Available Techniques (BAT) Reference Document for the Textile Industry (2022)
- Textile Labelling Regulation (2011)
- Directive on Green Claims (2023)
- Empowering Consumers in the Green Transition Directive (2022)
- **Waste Framework Directive (under revision 2023)**
- **Waste Shipment Regulation (2021)**
- Plastics strategy (2018)

https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52022DC0141

EU waste management policy

Waste Framework Directive (revision 2023)

Main objectives:

- Mandatory separate collection of textile waste from 2025
- Mandatory producer responsibility for the full cycle of textile products - ecomodulation (Extended producer responsibility schemes)
- Sustainable textile waste management according to the waste management hierarchy
- Promote the development of the separate collection, sorting, reuse, and recycling sector of textile products
- Reduce the negative impact of the textile industry on the environment
- Promote the development of innovations in fiber-to-fiber recycling
- Promote the creation of new jobs
- Revise the Regulation on shipments of waste, thus targeting the illegal export of textile waste

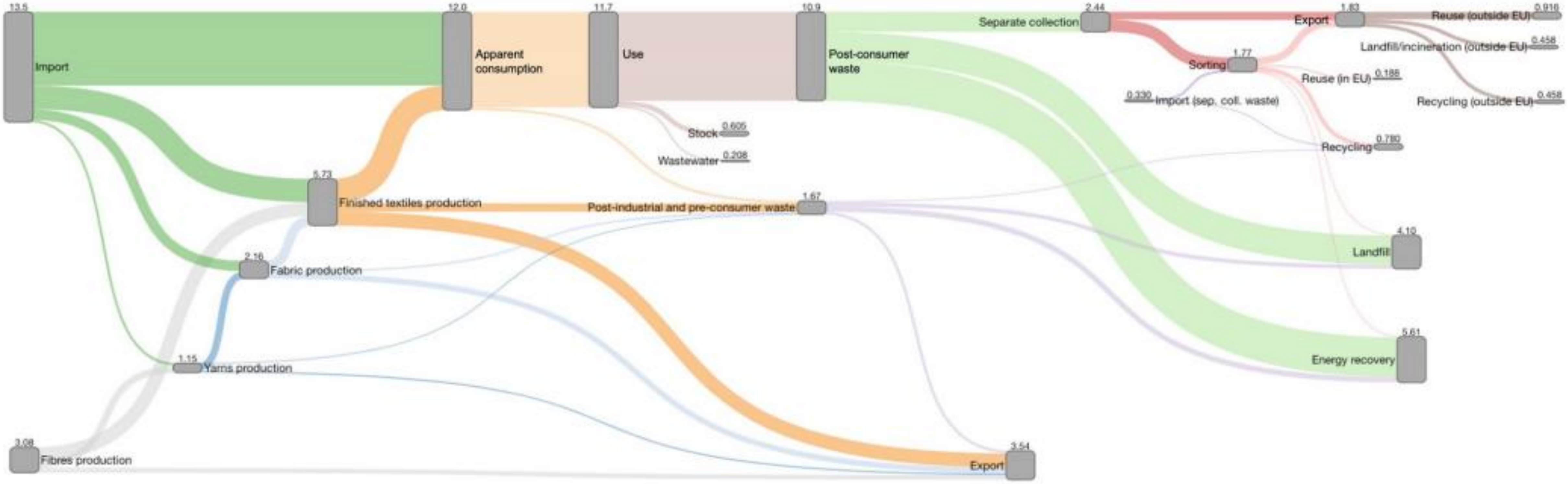
Primarily the longevity of textile products, recycling as the last step!

Reduce → Reuse → Recycle

https://environment.ec.europa.eu/publications/proposal-targeted-revision-waste-framework-directive_en

Textile waste - statistics (EU)

Textile production and waste management in the EU, 2019 (Mt/year)



Textile waste amount **12,6 Mt**

Landfilled or incinerated **78%**

Collected **22%**

Re-used **8%**

Exported **90%**

Per person 12 kg/year

https://environment.ec.europa.eu/system/files/2023-07/IMPACT%20ASSESSMENT%20REPORT_SWD_2023_421_part1_0.pdf

Textile waste streams

Types of textile waste

- **Pre-consumption**
  - **Industrial**
    - The composition of the fibers is known
    - A certain degree of purity
    - Good quality
    - Recyclable
- **Post-consumption**
  - **From organizations**
    - The composition of the fibers is known
    - A certain degree of purity
    - Reduced quality
    - Recyclable
  - **User**
    - Unknown fiber composition
    - Unknown degree of purity
    - Reduced quality
    - Recycling is possible but difficult

Potential textile waste management scenarios

- **Landfill**
- **Incineration**
- **Reuse/ recycle**

Preparation of textile waste for recycling

Textile waste

Pre-consumption (Production waste)	**Post-consumption** (Organizations, households)

↓

Collecting

↓

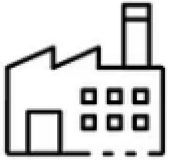
Sorting

Reusable	Recyclable	Non-recyclable

↓

Pre-processing (sort by fiber type, color, fabric type)

↓



Recycling

Mechanical	Thermal	Chemical

https://www.pilsetvide.lv/lv/jaunumi/uzsakam-daliti-vaktu-tekstila-atkritumu-pienemsanu-aluksne

Textile waste recycling

Recycling level

- **Fiber level**
- **Polymer level**
- **Monomer level**

Recycling methods

- **Mechanical**
- **Chemical (cellulose fibers)**
- **Thermo-mechanical (synthetic fibers)**
- **Chemical**
  Thermal
  (complex materials)

The deeper into the material structure, the longer the product production cycle, thus the greater impact of recycling on the environment and lower economic profitability!

Recycling - methods, their advantages and disadvantages (1/4)

Mechanical recycling

Textile waste is shredded to fiber level.

+

- A simple, mechanical process
- Economically profitable even in small volumes, requires relatively small investments
- Relatively developed infrastructure
- Used for processing various materials
- Do not use chemicals, water (except if pre-treatment is required)
- Low power consumption

−

- Fiber length decreases, physical-mechanical properties deteriorate
- The quality of the fibers decreases, and it is impossible to predict or change it in advance
- For post-consumer waste, possible hygiene problems, chemical contamination (non-compliance with the REACH regulation)
- Mass purity is important for quality
- The dyes remain in the final product
- Not suitable for coatings and laminates
- The quality of the final product varies from time to time (possible non-compliance with the Textile Labeling Regulation)

Textile waste → **Pre-treatment** → **Mechanical processing** → **Fibers** / **Filling material**

https://sourcingjournal.com/sustainability/sustainability-news/post-consumer-textile-recycling-gains-momentum-in-apparel-sector-69406/

https://www.jackjones.com/en-fi/content/abetter-world/recycling

https://www.ecologic.eu/sites/default/files/publication/2022/50030-study-textile-recycling-web.pdf

Recycling - methods, their advantages and disadvantages (2/4)

Thermo-mechanical recycling

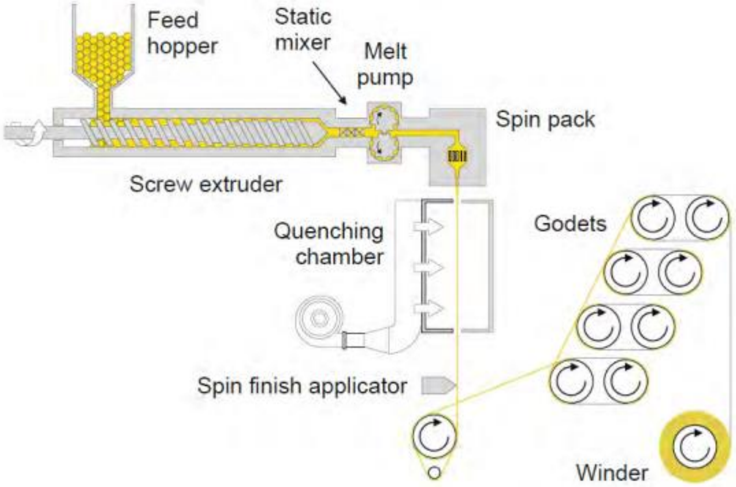
Thermoplastic synthetic fibers are melted down to obtain raw material for fiber spinning.

+

- A process similar to plastic recycling
- It is possible to process relatively small amounts while maintaining economic profitability
- Variable filament length

−

- As a result of repeated melting, the quality of the material decreases, physical-mechanical properties deteriorate
- Impurity/unevenness of the mass can affect the quality of the resulting material (thus post-consumer textile waste recycling is a challenge)
- Each type of synthetic fiber requires different temperature regimes and processes
- The dyes of the raw materials are preserved
- Chemical contamination may persist (REACH non-compliance)



Textile waste → **Pre-treatment** → **Melting** → **Fibers** / **Pellets**

https://www.ecologic.eu/sites/default/files/publication/2022/50030-study-textile-recycling-web.pdf

Recycling - methods, their advantages and disadvantages (3/4)

Chemical recycling (cellulose fibers)

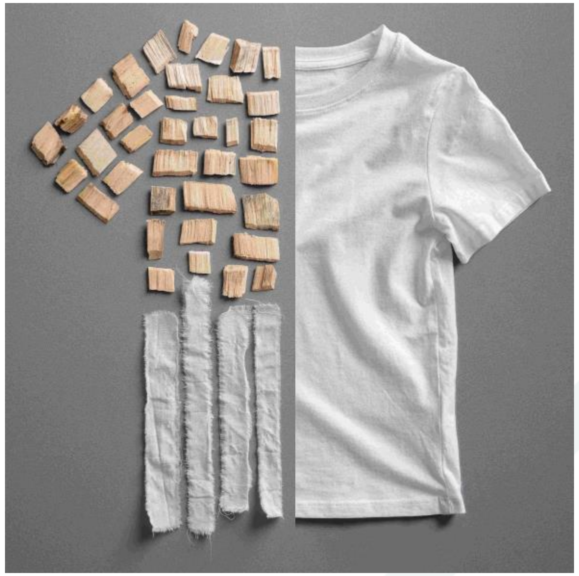
Cellulosic textile waste is dissolved and spun into new fibers.

+

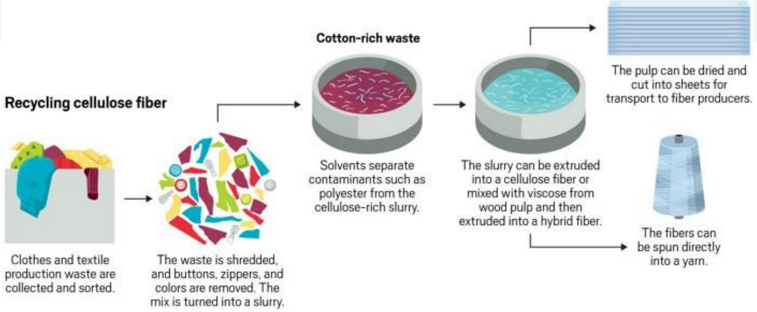
- It is possible to restore fiber quality
- Hygiene problems are solved with the help of chemicals
- A pure material without impurities and dyes can be obtained

−

- Resource-intensive process suitable for high volume (otherwise not economically viable)
- High consumption of water and energy, high consumption of chemicals, which can potentially have a negative impact on the environment
- The impurity of the pulp can affect the process and the result, pre-treatment increases the cost
- Large investments, highly qualified workforce are required



https://www.the-spin-off.com/news/stories/The-Materials-How-Lenzing-wants-to-accelerate-in-circularity--17218



https://cen.acs.org/environment/green-chemistry/Transforming-textiles/100/i11

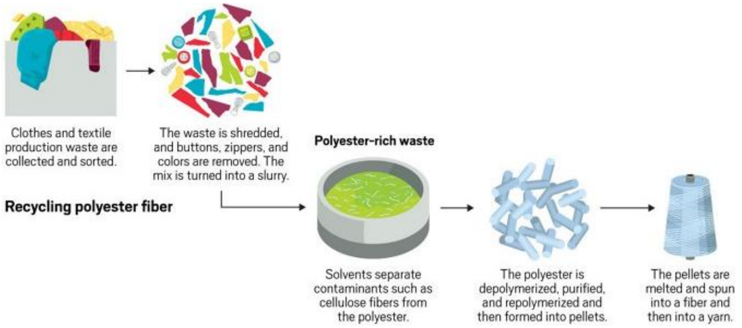
Textile waste → Pre-treatment → Pulping process (↓ Separation of contaminants) → Pulp / Dried pulp sheets → Man-made cellulose fiber

https://www.ecologic.eu/sites/default/files/publication/2022/50030-study-textile-recycling-web.pdf

Recycling - methods, their advantages and disadvantages (4/4)

Chemical recycling (synthetic fibers and fiber blends)

Synthetic polymers are broken down at the monomer level



https://cen.acs.org/environment/green-chemistry/Transforming-textiles/100/i11

+

- It is possible to restore fiber quality and purity
- Can be used for fiber blends as well as coated and laminated textiles
- Can be used even for worn and contaminated (e.g. work clothes) textile waste, as the polymer structure is restored

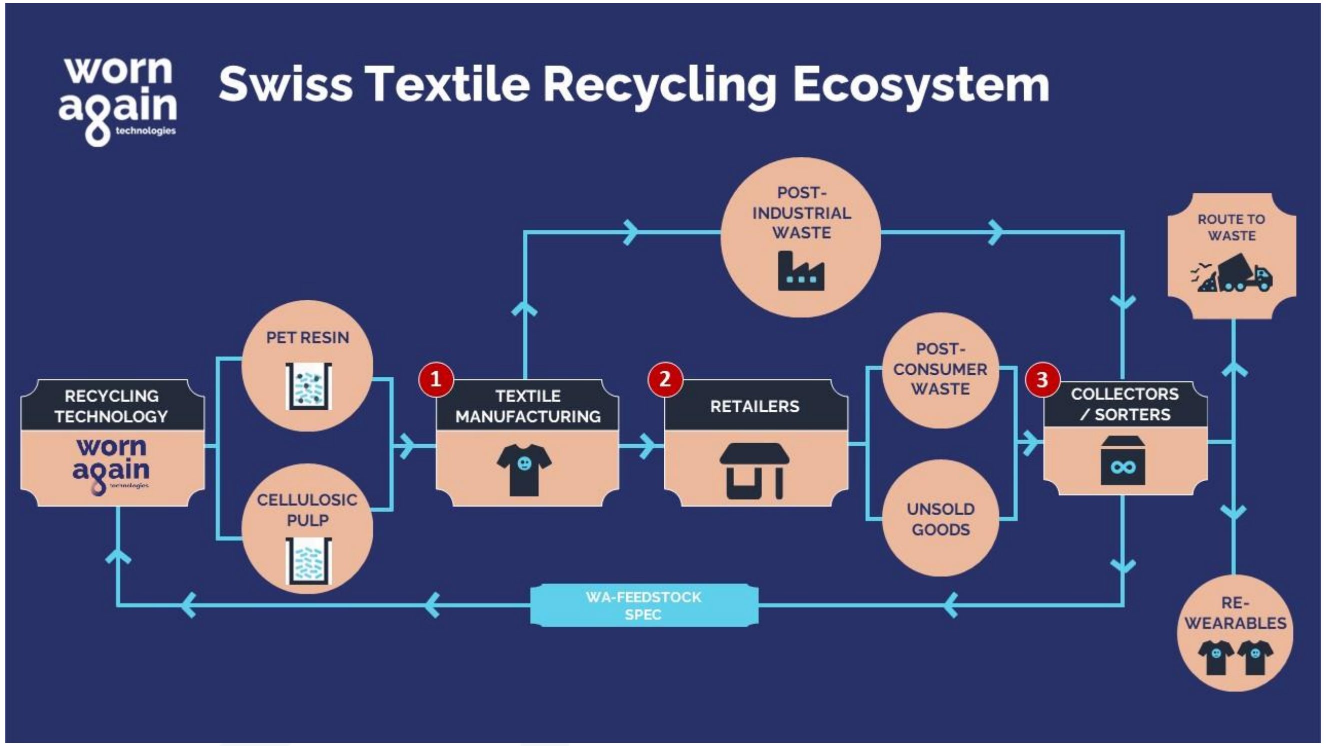
−

- Extends the production cycle of the product, thus increasing the environmental impact and reducing economic profitability
- Resource-intensive process suitable for high volume (otherwise not economically viable)
- Large investments, highly qualified workforce are required

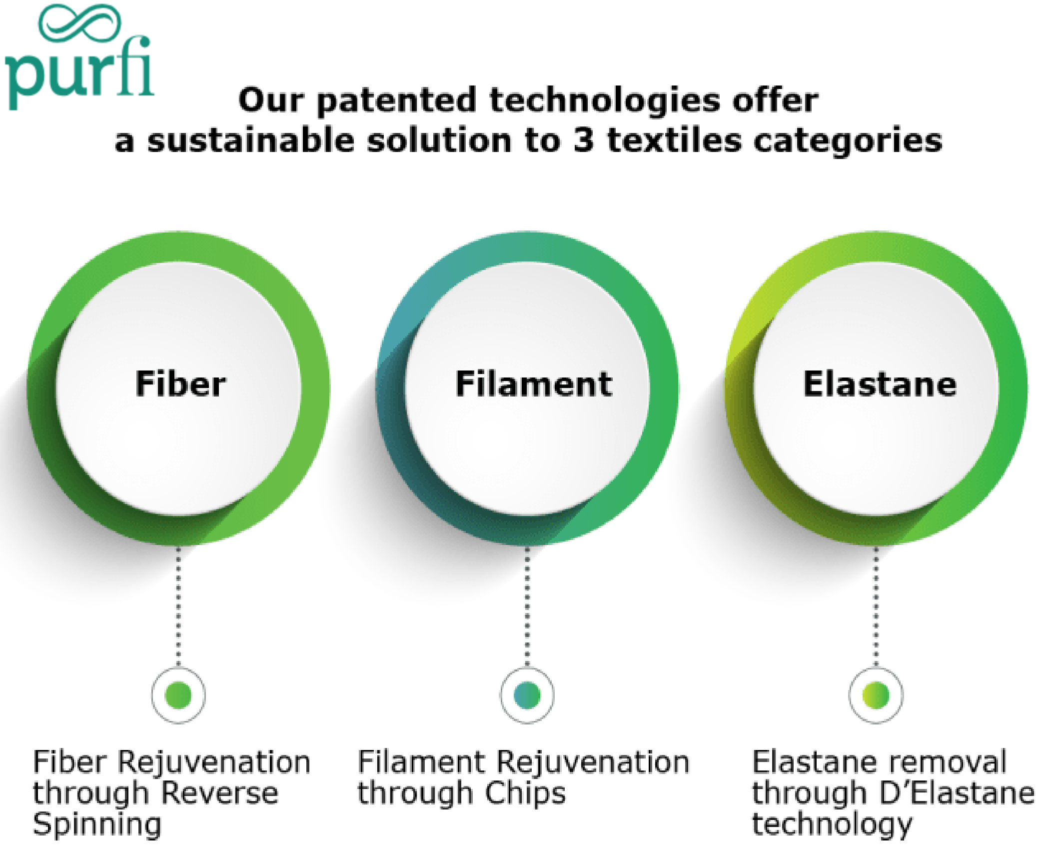
Textile waste → **Pre-treatment** → **Depolimerization** → **Post-treatment** → **Monomers** → **Repolimerization** → **Fibers**

https://echa.europa.eu/documents/10162/13632/polymers_lv.pdf/f727bbeb-7b06-4f81-b6f6-52aae085abd0
https://www.ecologic.eu/sites/default/files/publication/2022/50030-study-textile-recycling-web.pdf

Examples of technology holders (1/3)

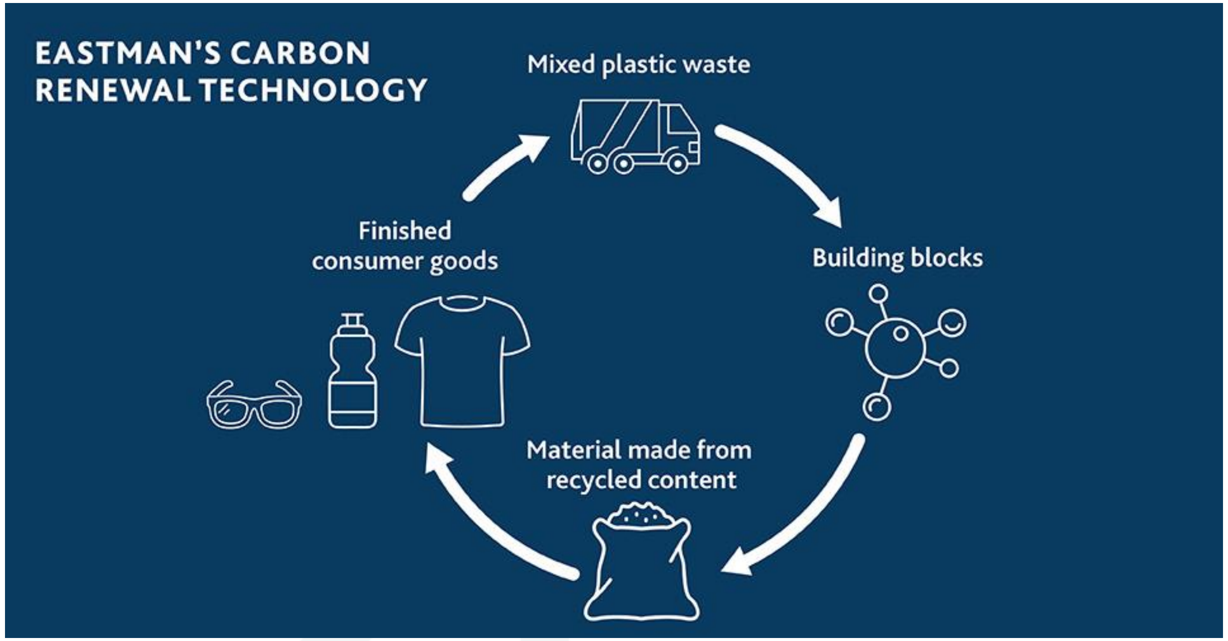


https://wornagain.co.uk/



https://purfi.com/

Examples of technology holders (2/3)

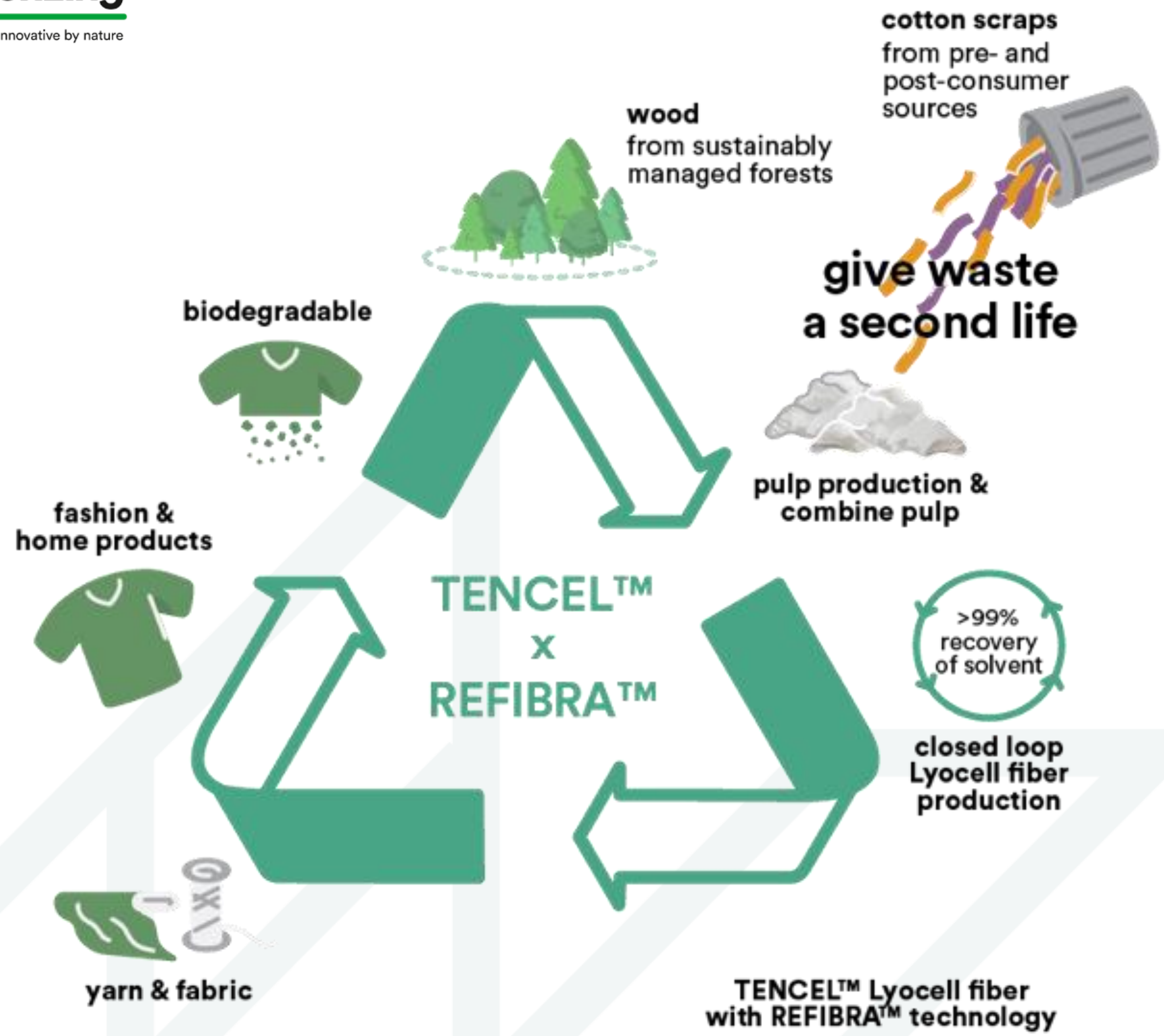


https://www.eastman.com/en

https://saxcell.com/

Examples of technology holders (3/3)

Lenzing
Innovative by nature



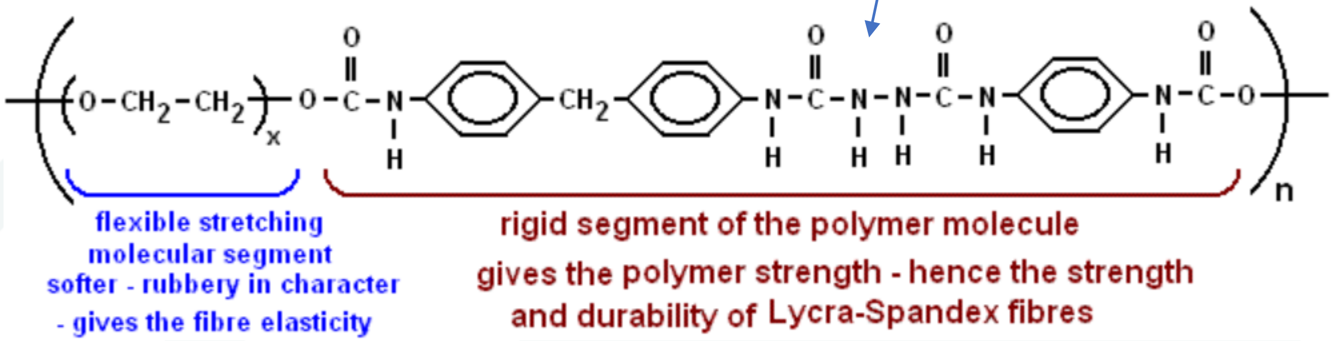
https://www.lenzing.com/

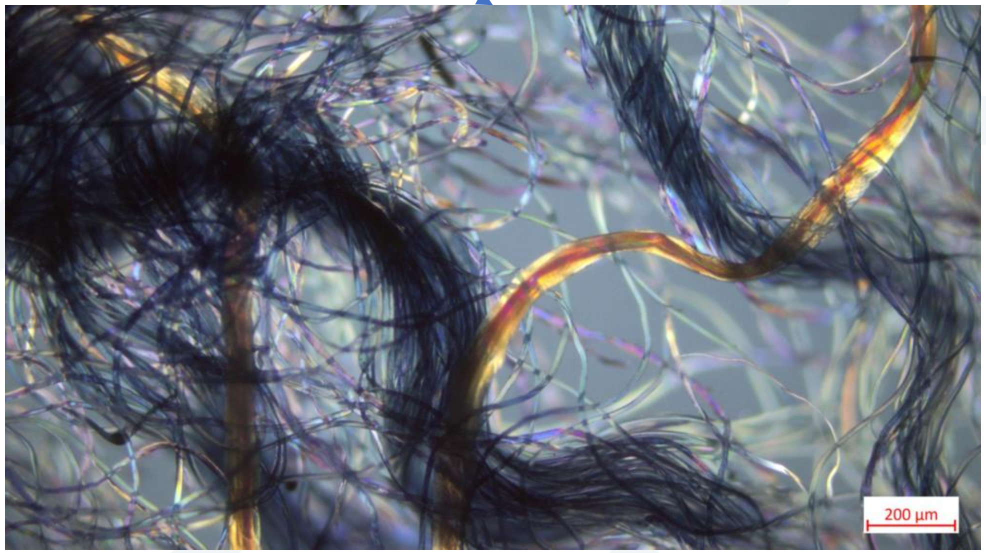
https://www.renewcell.com/en/

Textile waste recycling – challenges

- Purity of textile waste mass
- Lack of infrastructure
- The volume required for economic viability of the processes
- Especially for synthetic materials - new raw materials are cheaper
- Fiber-to-fiber recycling is still in the development/research stage, there are but a few solutions on an industrial scale
- Environmental impact of existing technologies
- Lack of quality data on the product

Elastane!





Inga.Dabolina@rtu.lv