PENGUIN

Bioinspired and advanced fibres and materials for sustainable outdoor textiles with biomimetic functionalities

4th NEWSLETTER
June 2026

Our coordinator *speaks*

After two years of work, PENGUIN is entering an important new phase: moving key developments from lab scale research into pilot scale validation. The project has already made strong progress in developing cellulose-based fibres with polyester-like properties, cellulose-based lightweight insulation materials, water repellent cellulosic fabrics with biomimetic functionalities, and integrated heating functionalities for next generation sustainable textile and insulation applications.

In recent months, partners have focused on scaling up manufacturing routes such as foam forming and air-laid processing, while also fine tuning fibre processing, blending, finishing, and overall production stability for real industrial conditions. Pilot activities are now getting underway across several developments, bringing the consortium closer to one of the key goals of the project: two outdoor jacket prototypes by the end of the project. As this phase ramps up, tight collaboration across all work packages is essential to keep everything aligned and on schedule.
Sustainability continues to guide the work. PENGUIN is advancing Safe and Sustainable by Design (SSbD) approaches, Life Cycle Assessment (LCA), circularity principles, and the use of renewable raw materials to reduce reliance on conventional synthetic materials. Early results are encouraging, showing clear potential environmental benefits compared to traditional fibre based solutions.

Alongside technical progress, the project is also shifting towards market readiness through demonstrations, cost analysis, and ongoing dialogue with industrial stakeholders. The communication and dissemination activities are shifting from awareness raising to results oriented.

In the coming months, the focus will be on selecting the most suitable materials for the prototypes and scaling up their production, while continuing performance assessments and circularity work. At the same time, stakeholder engagement will remain an important part of the process, all of which will steadily move the project towards its goals.

Insulation *material*

Redefining insulation with bio-based fibres

One of the most exciting developments within PENGUIN is the progress achieved in next generation insulation materials designed to replace conventional polyester-based fillings with more sustainable cellulose-based alternatives.

This work, mainly driven by Molina and VTT in collaboration with CITEVE, OrganoClick and Spinnova combines biomimetic design principles, advanced fibre engineering, and scalable textile manufacturing approaches to create lightweight insulation systems capable of promising thermal comfort performance, softness, and durability for outdoor applications.

The ambition is clear: to develop bio-based insulation materials that can compete with traditional synthetic fillers while significantly improving sustainability and circularity.

To achieve this, the consortium has explored multiple complementary insulation approaches, each targeting different structural and functional properties. VTT is developing continuous insulation paddings and MOLINA loose-fill fibre balls.

Highly porous structures through foam forming and air-laid technologies

To achieve high performance bio-based insulation systems, VTT explored two complementary web-forming technologies: foam forming and air-laid processing.

VTT focused on the development of lightweight and highly porous insulation structures capable of combining thermal resistance, breathability, and compression recovery. Through foam forming technology, the project generated interconnected pore architectures specifically designed to trap air efficiently while maintaining flexibility and low density.

Insulation *material*

Several foam-formed structures achieved thermal insulation values comparable to or even higher than polyester based references, while also showing promising compression recovery and bulk behaviour for garment insulation applications.

In parallel, air-laid technology enabled the production of compact webs with improved handling and processability shape retention and handling properties. The work included optimisation of fibre length, fibre opening process, moisture conditioning, feeding strategies, and different bonding approaches to improve web uniformity and process stability

Insulation *material*

Rather than simply replacing polyester fibres with cellulose-based alternatives, the project highlighted the need to redesign how insulation materials are structured and functionalized. For example, fibre chemistry, wetting behaviour, pore architecture, and internal bonding all proved critical for achieving competitive insulation performance.

CITEVE further supported the optimisation and validation of these materials through needle punching, binder application, thermal conductivity analysis, and integration into garment-like sandwich structures representative of final applications.

These activities provided valuable insights into how the developed insulation systems behave under realistic textile conditions, particularly regarding structural integrity, thermal behaviour, and durability after repeated laundering cycles.

Loose-fill fibreballs inspired by conventional down systems

Alongside structured nonwovens, Molina has focused on loose fill insulation concepts through the development of fibreballs intended for puffer jackets, sleeping bags, and other textile applications.

Insulation *material*

The objective is to replicate the loft, softness, and compressibility of conventional down or polyester fillings while relying on more sustainable fibre systems.

Several material combinations have been evaluated, including blends of SPINNOVA® fibres with recycled polyester (RPET) and PLA. Among the most promising results, the combination of 50% SPINNOVA® and 50% RPET achieved loft and compression/recovery performances very close to commercial polyester fibreballs currently available on the market

Encouraging progress has also been achieved with fully bio-based SPINNOVA®/PLA blends, bringing the consortium closer to fully biodegradable insulation solutions. As **Andrea Molina** explains:

> *"Initial results show promising progress towards using **fully biodegradable and bio-based materials** with a similar performance as polyester fibreballs. This represents a breakthrough target in terms of sustainability and innovation."*

Insulation *material*

Current challenges

One of the major technical challenges for cellulose-based insulation materials remains moisture absorption. Cellulosic fibres naturally absorb large amounts of water, which can negatively affect washing stability and promote clumping during laundering.

To address this issue, **OrganoClick** developed dedicated water-repellent treatments adapted to the insulation systems. The impact has been significant: water absorption values were reduced from over 1500% to below 100%, substantially improving moisture resistance and reducing clumping after repeated washing cycles, with **CITEVE** further supporting the evaluation of wash durability and thermal behaviour through laundering campaigns. **OrganoClick** also contributed bio-based additive and hydrophobization strategies to reduce moisture uptake

These developments demonstrate how combining fibre engineering with surface chemistry can dramatically improve the behaviour of biobased insulation systems and move them closer to industrial applicability. While repeated laundering still presents challenges related to bulk retention, fibre migration, and structural stability, the latest results already show a clear improvement in material robustness and provide a strong foundation for the next optimisation phase. Altogether, these advances reinforce the potential of PENGUIN to deliver durable, high-performance, and truly circular bio-based insulation solutions for future textile applications.

Insulation *material*

Moving from laboratory concepts towards industrial production

The transition from laboratory scale concepts towards industrial manufacturing is also a critical step to ensure the transferability, scalability, and real industrial applicability of the developed solutions. By scaling up high performance, sustainable textiles inspired by nature (biomimicry), the PENGUIN project aims to successfully replace synthetic materials with advanced bio-based alternatives.

According to **Molina**, adapting high-speed industrial equipment to advanced, lightweight cellulose fibres, such as SPINNOVA® and Biocelsol, requires substantial optimisation of fibre opening, mixing accuracy, and process stability. Several pilot scale processing steps, including mixing, fine opening, carding, and fibreball formation, have already been successfully validated, marking an important step towards future industrial deployment.

VTT validates pilot-scale production routes for both foam-formed and air-laid insulation materials, enabling the consortium to benchmark web uniformity, bulk preservation, thermal behaviour, and process reproducibility under representative manufacturing conditions. These pilot activities are providing highly valuable insights for process optimisation while confirming the scalability potential of the developed concepts.

In parallel, **OrganoClick** also developed bio-based additive and hydrophobization strategies to reduce moisture uptake; meanwhile **CITEVE** has contributed to the integration and evaluation of the developed insulation systems within textile structures representative of final applications. Activities such as needle punching and multilayer assembly have enabled the consortium to assess how the developed materials behave once incorporated into realistic textile configurations, supporting the development of more functional, durable, and application-oriented solutions.

Together, these advances demonstrate the strong progress achieved in bridging laboratory developments with industrial manufacturing realities. The combination of pilot-scale validation, textile integration, and process optimisation is progressively paving the way towards scalable, high performance, and industrially relevant bio-based insulation systems. In parallel, circularity strategies focusing on reuse, repair, component recovery and recycling pathways are being developed to support the future sustainability of outdoor textile products

The next phase of the project will focus on further scaling production activities, validating integrated textile structures, and benchmarking thermal and comfort properties under representative outdoor use conditions.

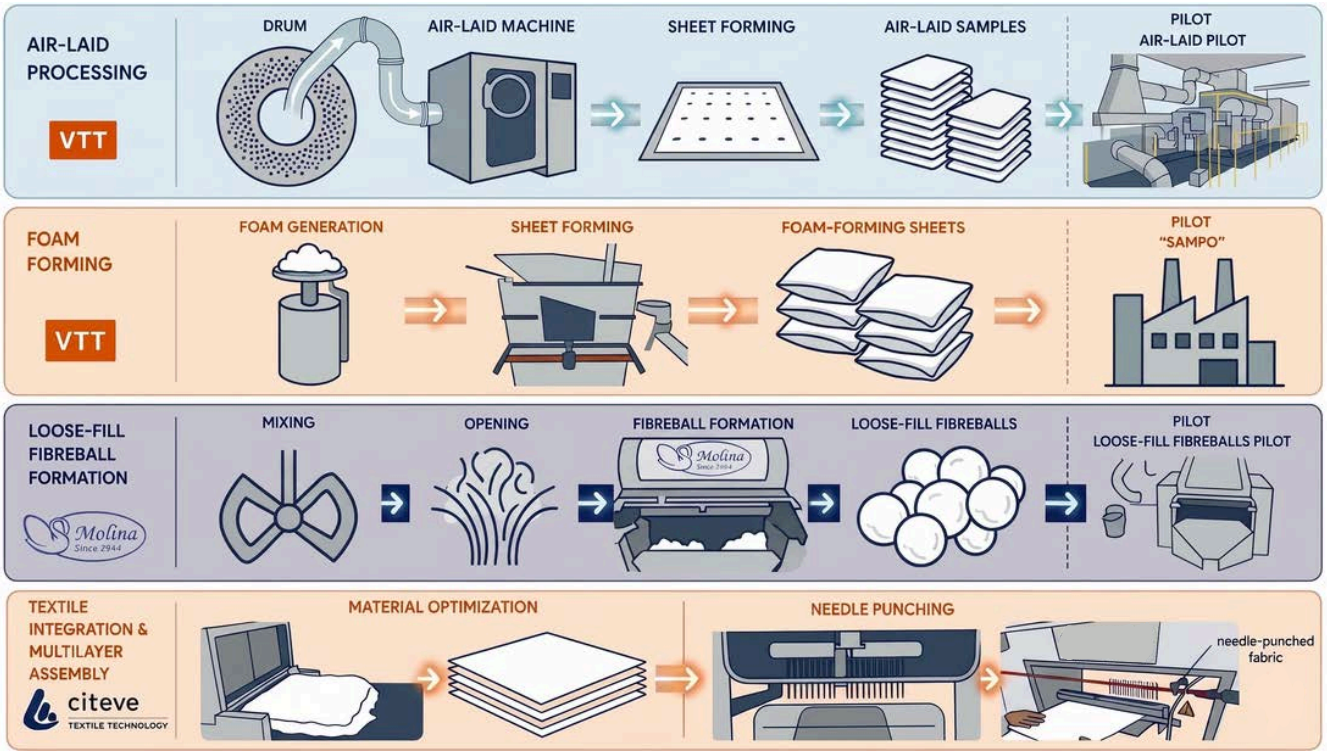
Insulation *material*

Towards the next generation of sustainable insulation

Beyond outdoor apparel, the insulation systems developed within PENGUIN demonstrate how bio-based fibres are progressively evolving from niche alternatives into realistic high-performance solutions for the textile sector.

From sleeping bags and bedding to lightweight technical applications, these developments highlight the strong potential of cellulose based insulation systems to combine comfort, functionality, durability, and sustainability within scalable industrial solutions.

Supported by continuous advances in material optimisation, pilot scale manufacturing, and textile integration together with circular design approaches aimed at facilitating future reuse, repair and recycling strategies. The project is steadily moving closer to real application environments and industrial implementation. As PENGUIN progresses towards pilot and industrial validation, the consortium continues laying the groundwork for a new generation of insulation materials designed to reduce dependence on fossil-based resources while supporting more circular and sustainable textile value chains.



From Progress to *production*

Functional cellulosic fibres

VTT OrganoClick® citeve SPINNOVA®

One of the most important transitions taking place within PENGUIN is the move from small scale fibre optimisation towards processing routes compatible with industrial textile manufacturing.

Spinnova has continued scaling up insulation fibre production by further developing fibre handling, finishing, wet opening, and drying processes. Recent activities have also included the assembly and testing of pilot-scale processing equipment, as well as preparing larger fibre batches for downstream evaluation.

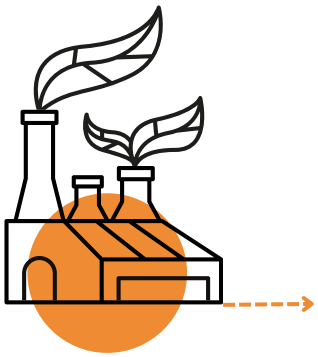
From Progress to *production*

Advanced fabrics

As material maturity increased, the project focused heavily on pilot scale processing and fibre handling optimisation to smoothly integrate bio-based materials into textile structures representative of real garment configurations. Driven by advancements in upscaling, specifically through the fine-tuning of wet opening and drying parameters, the lightweight fibres were optimally prepared for downstream validation. CITEVE contributed significantly to the development and evaluation of these components within multilayer textile assemblies, sandwich structures, and needle-punched architectures, combining the optimized insulation systems with functional fabrics. Parallel testing campaigns assessed tensile behaviour, wash stability, thermal response, and structural integrity after repeated laundering cycles.

At the same time, new ripstop constructions integrating the optimized SPINNOVA® fibres demonstrated encouraging high abrasion resistance, mechanical stability, and hydrophobic behaviour after repeated washing, reinforcing the potential of cellulose-based fabrics for technical outdoor textile applications. Together, these rigorous improvements in fibre processing and textile configuration are helping bridge the gap between material development and realistic textile implementation.

From Progress to *production*



Biomimetic chemistries & material functionality

OrganoClick®

idener.ai RINA

Another important focus of the project has been developing bioinspired chemistries to improve textile performance while meeting sustainability and circularity objectives. OrganoClick continued optimising biobased binders and functional finishing chemistries to improve the wet strength, hydrophobicity, processability, flexibility, and structural cohesion of cellulose-based systems. Recent campaigns demonstrated how tuning binder formulations significantly improves the integrity of lightweight textile structures under realistic processing and washing conditions, enabling biobased textiles to align with technical requirements. Integrating eco design and circularity-by-design principles into these material layers also establishes the traceability required for future Digital Product Passports.

Building on this sustainable foundation, PENGUIN is advancing textile integrated heating systems, detachable functional elements, sensor integration strategies, and wearable validation approaches. Recent developments demonstrated reusable heating elements compatible with disassembly and circular design, while ongoing activities are progressively aligning garment-level testing with comfort, thermal behaviour, and performance benchmarking under representative outdoor conditions.

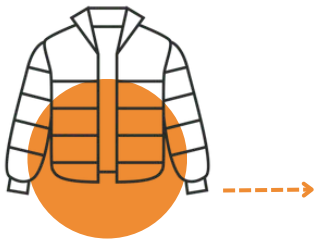
PENGUIN is also beginning to integrate smart functionalities into next-generation outdoor textile concepts.

Smart functionalities & wearable integration

VTT

Grado Zero and VTT continued advancing smart functionalities, garment-level integration activities, circular design approaches and wearable validation linked to future outdoor garment applications. Recent developments explored smart functionalities compatible with circular design approaches and future textile applications, including considerations related to disassembly, repairability and future material recovery.

From Progress to *production*



Towards next-generation outdoor demonstrators

One of the clearest signs of the project's growing maturity is the transition from isolated material developments towards integrated, modular wearable demonstrators. Prototype activities involving Colmar, Grado Zero, CITEVE, Spinnova, and other partners are progressively converging towards complete circular demonstrators including insulated jackets, multilayer outdoor garments, and sensor enabled textile systems designed for thermal comfort and performance validation.

Circularity considerations are also being incorporated into demonstrator design, supporting future reuse, repair and recycling pathways.

News

F2F meeting in Genoa

The The PENGUIN project consortium recently met for its third face-to-face meeting, hosted by RINA at their facilities in Genoa. Marking the project's 24 month milestone, the two day hybrid event enabled European partners to review overall progress, align on project management, and welcome new work package leaders from VTT, RINA, Spinnova, and IDENER.

Project Coordinator Emmi Nuutinen confirmed that work packages are moving forward on schedule. Additionally, the team established alignment strategies for LCA (Life Cycle Assessment), LCC (Life Cycle Costing), and stakeholder engagement for the upcoming project phases.

A key part of the gathering was a hands on workshop dedicated to finalizing product specifications for the project's garment demonstrations. Partners from Colmar, Grado Zero, and VTT evaluated physical material samples to establish design pathways for prototypes, including sustainable ski jackets and vests featuring integrated sensor technologies.

The meeting concluded with a collaborative roadmap for upcoming fabric production and insulation testing.

News

PENGUIN partners visited CITEVE facilities

Representatives from Spinnova and VTT recently visited CITEVE's facilities for a technical exchange focused on sustainable textile production. The visit centered on exploring CITEVE's air-laid process, a technology being used to transition circular materials from laboratory research to prototyping.

During the visit, the partners conducted pilot airlay trials utilizing SPINNOVA®'s bio-based fibers. The joint effort aimed to develop cellulose-based paddings designed for outdoor jackets. This collaboration allowed the teams to combine fiber properties, processing methods, and research insights to establish a foundation for the upcoming phase of garment manufacturing.

Moving forward, the results from these trials will be used to optimize the thermal and structural properties of the paddings before integrating them into final product designs. By combining SPINNOVA®'s fiber technology with CITEVE's manufacturing capabilities and VTT's research expertise, the partnership aims to evaluate the viability of circular materials for the outdoor apparel market.

News

PENGUIN Champions Textile Circularity at International 'PLASTICE in Action' Event

PLACE: Izmir, Turkey

DATE: November 14th

PARTNER: RINA

PENGUIN actively contributed to the international hybrid workshop "**PLASTICE in Action: Overcoming Recycling Barriers and Enabling Circular Solutions**," held on-site in İzmir, Türkiye, and online. Hosted by the European PLASTICE Consortium, the event brought together key stakeholders to tackle systemic bottlenecks in the plastic and textile sectors. During the dedicated "Textile Recycling Horizons" sessions, PENGUIN lent its expertise to critical discussions surrounding the technical challenges of textile recycling, actionable circular economy strategies, and the regulatory and infrastructural enabling conditions required to scale future circular value chains across Europe.

PENGUIN at HaDEA Showcase Event 2026

PLACE: Brussels, Belgium

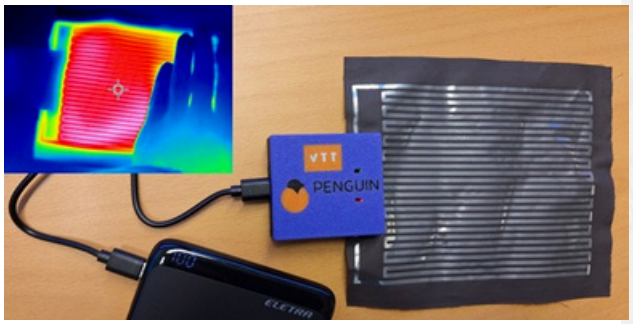
DATE: January 19th

PARTNER: VTT

Emmi Nuutinen (**VTT**), Project Coordinator for the PENGUIN project, attended the **HaDEA Showcase Event 2026** as an observer to learn how EU-funded initiatives support European competitiveness and innovation across digital technology, industry, space, and health. The event served as a platform to build cross-project synergies, enabling Nuutinen to network with European Commission officials, sister project coordinators, and other EU representatives. These discussions focused on identifying potential partnerships, sharing best practices, and aligning efforts to support circular economy and textile research across the continent.

News

VTT Showcases Advanced Heater Demonstrator at PRINSE'26 Seminar



VTT

PLACE: Oulu, Finland

DATE: January 28

PARTNER: VTT

Sirpa Nordman, representing **VTT**, participated in the **PrintoCent Industry Seminar (PRINSE'26)**, an international event focused on how printed intelligence is utilized across industrial value chains. As part of the technical dissemination, Nordman presented a flexible heater demonstrator at the VTT booth. The prototype showed how printed heating elements can be integrated into surfaces and smart textile applications, illustrating the viability of low-energy printed electronics to industry stakeholders.

Advanced Cellulose Insulation Showcased at New Wood Exhibition in London

VTT

PLACE: London, UK

DATE: March 9-27th

PARTNER: VTT

VTT delivered samples of a cellulose-based insulation material for outdoor garments to the **New Wood: Building a Bio-Based Future exhibition**, held at The Garrison Chapel in Chelsea from March 9 to 27, 2026. The event highlighted forest bioeconomy innovations and drew industry attention. By displaying this wood-derived padding material to decision-makers and visitors, VTT demonstrated the viability, scalability, and role of bio-based alternatives in replacing fossil-derived components within the textile and apparel sector. The successful event attracted widespread industry attention and featured distinguished guests, including Finnish President Alexander Stubb and King Charles III.

News

Advanced Cellulose Insulation Featured at Pulp & Beyond Fair in Helsinki

PLACE: Helsinki, Finland

DATE:April 15-16th

PARTNER: VTT

VTT dispatched samples of its cellulose-based insulation material for outdoor garments to the **New Wood exhibition**, showcased during the Pulp & Beyond 2026 fair at the Helsinki Expo and Convention Centre. Held from April 15 to 16, 2026, the event served as an international hub for the forest and pulp industries, drawing stakeholders, researchers, and industry leaders. By presenting this wood-derived padding alternative, the consortium demonstrated to the sector how forest bioeconomy innovations can replace fossil-based materials in textile and apparel applications.

PENGUIN Project Showcases Smart Fashion Breakthroughs at SAMAB International Congress

PLACE: Milan, Italy

DATE: May 28th

PARTNER: Confindustria Moda

Confindustria Moda, representing the PENGUIN project consortium, participated in the **SAMAB International Congress** at the Palazzo Giureconsulti in Milan, an event exploring digital transformation and technology integration within the fashion production chain. CM delivered a presentation highlighting the project's engineering developments, focusing on the design pathways and integration of advanced bio-based materials and smart functionalities into outer garment prototypes. By sharing these textile developments with an audience of fashion supply chain leaders, technology developers, and industry experts, the project contributed to the dialogue surrounding the sustainable and digital transition within the apparel industry.

News

UPCOMING *events*

PARTNER	EVENT	YEAR	DATE	LOCATION
Confindustria Moda	Pitti Uomo	2026	June 16-19th	**Florence,** Italy
Confindustria Moda	Milano Unica	2026	July 7-9th	**Milan,** Italy

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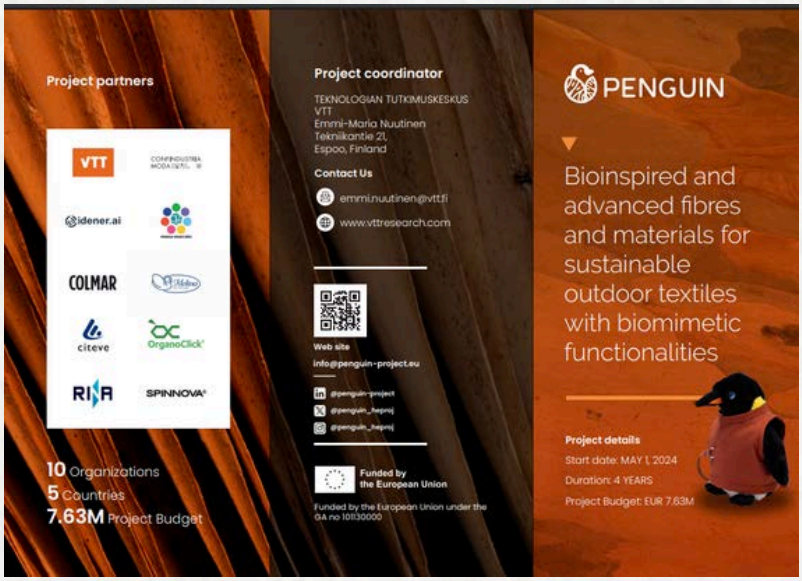
Communication and *dissemination*

New leaflet: meet PENGUIN fibres



The PENGUIN project has officially released its latest informational leaflet, highlighting its biomimicry-inspired mission to replace fossil-based synthetic textiles with high-performance, wood-derived cellulose alternatives. The publication details the project's strategic dual-technology approach, contrasting the unique mechanics of SPINNOVA® fibers, produced without harmful chemicals, with the advanced technical modifications of Biocelsol fibers. While SPINNOVA® pioneers a clean, mechanical spinning process from microfibrillated cellulose to drastically reduce carbon and water footprints. Biocelsol stands out as a modified man-made cellulosic fiber (MMCF) engineered specifically for high-demand insulation applications.

The leaflet highlights PENGUIN's recent technical milestones in modifying Biocelsol fibers to directly challenge synthetic market dominators like polyester and nylon. By altering the cross-sectional geometry of the fibers and applying novel biobased finishing chemistries, researchers have successfully enhanced fiber hydrophobicity (water repellency) and structural integrity after laundering, all without compromising tenacity or its signature soft handfeel. These breakthroughs bring the consortium a significant step closer to deploying functional, biodegradable, and highly insulated garment prototypes engineered to replicate nature's efficiency.

Click here to take a look!

Communication and *dissemination*

New poster: meet PENGUIN fibres

The PENGUIN project has officially unveiled its new core dissemination poster, detailing the initiative's bio-inspired approach to developing sustainable outdoor apparel. Funded by the European Union, the visual asset outlines four primary innovation areas guiding the research: Advanced Fibres, Insulation Materials, Functional Textile Architectures, and Smart Functionalities & Wearable Integration. By focusing on tailoring advanced cellulose fibers like **SPINNOVA**® and **Biocelsol**, the project showcases highly promising milestones, such as achieving high water-repellency contact angles, impressive thermal insulation values, and integrated heating elements directly within textile structures.

Beyond the technical pillars, the publication emphasizes the foundational principles steering the project toward real-world market readiness. Through the implementation of bio-inspired chemistries, rigorous circularity by design practices, reuse and repair strategies, and intensive field-testing under realistic outdoor conditions, and intensive field-testing under realistic outdoor conditions, the PENGUIN consortium aims to entirely bridge the gap between laboratory development and scalable textile manufacturing. The newly released asset serves as a vital tool for stakeholder engagement, illustrating a clear, sustainable roadmap toward high-performance, fossil-free apparel alternatives.

Click here to take a look!

PENGUIN

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