PENGUIN

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



5th NEWSLETTER
October 2026

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Our coordinator *speaks*

We are pleased to introduce Dr. Elina Ilen, Principal Scientist and Research Project Leader at **VTT**, as the new Coordinator of the PENGUIN project. With her extensive experience in the research, development, teaching and commercialisation of functional and smart textiles and circular-economy solutions. Her expertise also covers digitalisation-enabled technologies for textile research, production and logistics, with a focus on delivering environmental, economic and societal value across the textile value chain. She additionally coordinates the **VTT**-led European project TexMat.



Dr. Elina Ilen,
PENGUIN project coordinator

Her appointment comes at an important stage for PENGUIN, as the project transitions from developing individual materials towards integrating them into functional outdoor clothing. Over recent months, the consortium has advanced cellulose-based fibres, lightweight insulation materials and advanced fabrics, alongside heating and sensing concepts. These developments are progressively converging into integrated material systems intended for two outdoor-jacket demonstrators.

Following the laboratory development phase, partners are now preparing pilot-scale manufacturing and the evaluation of multilayer fabric–insulation sandwich structures. Progress has been particularly encouraging in the optimisation of foam-formed and air-laid insulation concepts, while fibre development, finishing treatments and scalable processing routes continue to advance. Material selection will consider not only thermal performance but also comfort, durability, processability and the behaviour of complete assemblies, ensuring that the selected solutions meet the requirements of the final demonstrators. During the remaining project period, efforts will focus on completing pilot-scale production, selecting the most promising material combinations and validating their performance through thermal and comfort testing under representative use scenarios. In parallel, the consortium will continue integrating temperature and humidity sensors, assessing lifecycle impacts and costs, testing recyclability and biodegradability, and developing exploitation plans. Close coordination across technical work packages will be essential to align these activities and support the successful delivery of the two outdoor-jacket prototypes.

Under Elina's coordination, PENGUIN will continue building on the progress achieved, bringing its technological developments together and moving closer to demonstrating innovative, sustainable and functional solutions for outdoor clothing.

e-Textiles & Smart Functionalities

Smart heating meets sustainable insulation: bringing new functionalities to outdoor textiles.

The integration of electronic functionalities into textiles is opening new opportunities for outdoor clothing, enabling garments to complement passive thermal protection with active responses to changing environmental conditions. Within **PENGUIN**, this approach is being explored through the combination of flexible heating elements and cellulose-based insulation, with particular attention to moisture management, textile performance and garment integration.

Developed by **VTT**, the heating technology is designed to work alongside **PENGUIN**'s bio-based materials rather than as a standalone electronic component. Initial laboratory investigations have demonstrated its potential to accelerate moisture removal from cellulose insulation, providing a promising basis for further development.

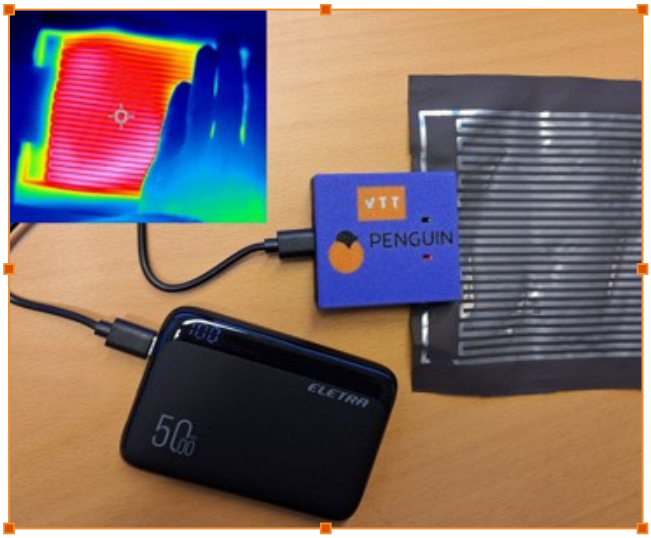
Beyond heating performance, the work also addresses manufacturing scalability, compatibility with textile structures and the possibility of separating electronic components to support more circular product lifecycles.

Printed e-Textiles and Smart Functionalities

PENGUIN's e-Textile technology is based on a flexible heating layer produced by integrating patterned metallic conductors onto a textile substrate. Developed by **VTT**, the system uses thin aluminium foil patterned through laser processing and laminated onto fabric using a thermoplastic adhesive. This approach enables the creation of lightweight, flexible heating elements while offering compatibility with roll-to-roll manufacturing processes.

An important consideration is preserving the characteristics that make textiles suitable for clothing. The conductive pattern is designed to leave approximately half of the fabric surface uncovered, helping maintain breathability and flexibility while incorporating the heating functionality.

e-Textiles & Smart Functionalities



A central aspect of the development is the interaction between active heating and **PENGUIN**'s cellulose-based insulation materials. While these materials offer a renewable alternative to conventional insulation, their moisture absorption and drying behaviour are important factors in maintaining thermal performance.

To investigate this interaction, **VTT** evaluated the heating elements in combination with air-laid and foam-formed cellulose insulation. Laboratory experiments assessed whether applying moderate electrical heating could accelerate drying after moisture exposure.

Laboratory results: active drying of cellulose insulation

~5 W
Applied heating power

~10 min
Foam-formed insulation drying

~40 min
Fully moisture-loaded air-laid insulation drying

**Results obtained under specific laboratory conditions. Differences in sample structure and moisture loading mean these values should not be interpreted as a direct comparison between insulation technologies.*

The experiments demonstrated that active heating can significantly accelerate moisture removal under the investigated conditions. The different drying responses also highlight the influence of insulation structure and moisture retention on the behaviour of the combined system.

e-Textiles & Smart Functionalities

These findings extend the potential role of textile heating beyond supplementary warmth. By supporting faster drying, active heating could help restore the thermal functionality of cellulose-based insulation following moisture exposure, an important consideration for outdoor applications.

Further development will focus on optimising the integration of heating elements into multilayer textile structures, including electrical connections, durability and compatibility with garment manufacturing.

Circular e-Textiles

Considering repairability, component separation and material recovery from the design stage

Combination of conductive materials, adhesives, textile substrates and electronic components can complicate maintenance, disassembly and end-of-life processing, particularly when different materials are permanently bonded. **PENGUIN** is therefore considering circular design principles alongside the technical development of its heating system. One of the approaches under investigation is the separation or detachment of heating elements from the surrounding textile structure, potentially allowing functional components to be replaced, recovered or reused independently of the garment.

This concept could offer advantages for product maintenance and repair, while also facilitating the separation of metallic components from textile fractions at end of life. It may also create opportunities for reusing heating modules where their technical condition and functionality permit.

These possibilities remain dependent on the final integration architecture and require further assessment. In particular, the balance between mechanical reliability during use and ease of disassembly will be an important design consideration. The eTextile development is connected to **PENGUIN**'s wider work on Life Cycle Assessment (LCA), Safe and Sustainable by Design (SSbD) and circularity, which will help assess the implications of material selection, manufacturing, energy consumption during operation and end-of-life management.

By addressing these aspects during technology development, the project aims to ensure that additional garment functionalities are considered within the broader sustainability objectives of its bio-based textile system.

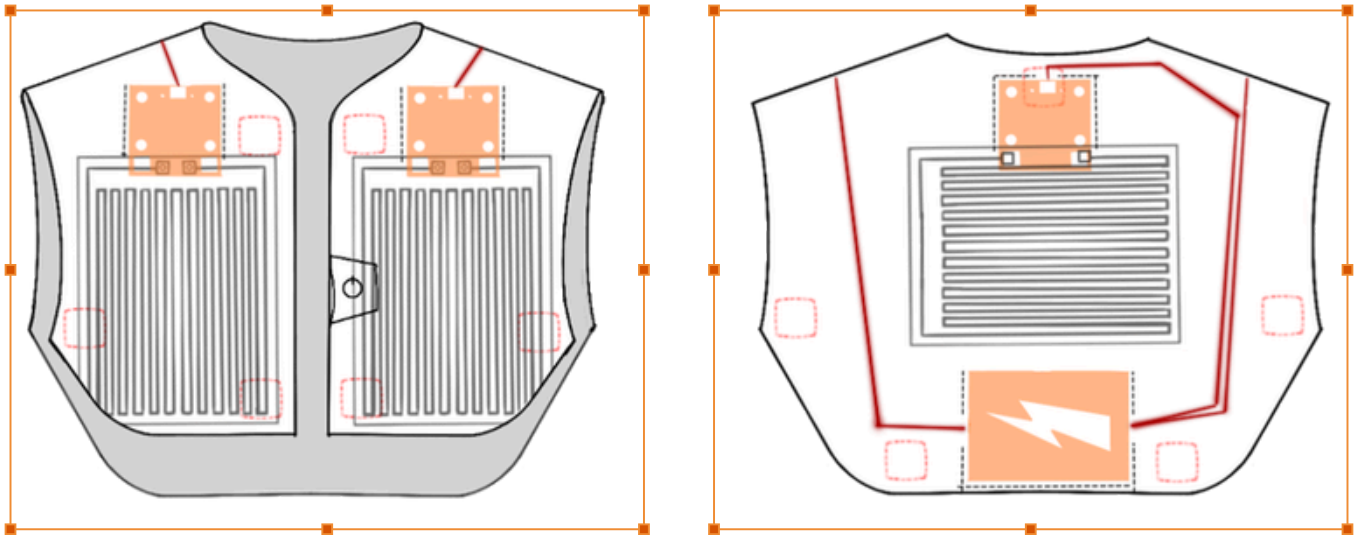
e-Textiles & Smart Functionalities

From Technology to the Wearer

Translating material-level developments into integrated outdoor clothing

The transition from a functional heating element to a wearable garment requires coordinated development across the different textile layers and components. Heating performance must be balanced with insulation efficiency, flexibility, breathability, mechanical durability and user comfort.

PENGUIN's proposed garment architecture integrates the heating elements beneath the cellulose-based insulation layer, combining passive thermal protection with active heating that may support moisture removal when required. The concept includes heating areas distributed across the front and back of the upper body, together with the associated electrical components.



This integration is particularly relevant as **PENGUIN** progresses from individual material developments towards complete multilayer assemblies and outdoor jacket demonstrators. The performance of the final system will depend not only on the properties of each component, but also on how the insulation, heating elements and surrounding fabrics interact.

e-Textiles & Smart Functionalities

The next development stages will address heating distribution, electrical connectivity, flexibility during movement and the durability of the integrated structure. Moisture transport and thermal comfort will also be important aspects of subsequent garment-level evaluation.

While the laboratory results provide evidence of the feasibility of combining active heating with cellulose-based insulation, wearer comfort, long-term durability and performance under representative outdoor conditions have not yet been established.

Through this work, **PENGUIN** is advancing an integrated approach to outdoor textiles in which bio-based insulation, smart functionalities and circular design are developed as complementary elements of the same garment system.

Last advances towards ***innovation***

Over the past months, **PENGUIN** has continued moving from the development and optimisation of individual materials towards their integration into functional textile systems. Across the consortium, efforts are increasingly focused on scaling up production, improving material performance and durability, and preparing the most promising solutions for integration into outdoor clothing.

These advances bring together the different stages of the textile value chain, from cellulose-based fibres and insulation to technical fabrics, functional finishing, sustainability assessment and garment development.



Scaling up renewable fibres for insulation applications

VTT OrganoClick® citeve SPINNOVA®

SPINNOVA has continued advancing the scale-up of its cellulose-based fibres, with particular attention to fibre handling, wet opening, finishing and drying processes. Recent activities have included the assembly and testing of pilot-scale processing equipment, including wet-opening with recently purchased device, alongside the optimisation of processing parameters and preparation of larger fibre batches for downstream evaluation.

Progress in hydrophobic fibre finishing and process control is also supporting the development of insulation fibres with improved handling and functional properties. These activities represent an important step towards establishing reliable manufacturing routes for bio-based fibres and facilitating their integration into downstream textile applications.



Last advances towards ***innovation***



Insulation material

VTT has continued optimising two cellulose-based insulation technologies: foam-formed and air-laid materials. Several developed structures achieved or exceeded the project's thermal insulation target of CLO ≥ 2.5, with some outperforming selected commercial references. Improvements in fibre selection, bonding and processing have also strengthened wash durability, allowing the developed structures to remain intact after laundering.

Complementing these developments, **MOLINA** has demonstrated promising wash resistance in loose-fill fibreballs composed of 50% SPINNOVA fibres and 50% PLA, achieving a thermal insulation performance of 3.06 CLO, slightly exceeding that of the 100% polyester fibreball reference (2.97 CLO). Through optimisation of water-repellent surface treatments, the team addressed the challenge of maintaining loft and structural integrity during washing. The resulting fully bio-based blend represents a promising alternative to conventional polyester loose-fill insulation, with potential applications beyond jackets, including sleeping bags and bedding.

The next stage will focus on pilot-scale production and further validation of selected insulation concepts in representative textile assemblies.

Last advances towards ***innovation***

Advanced fabrics

Developing durable cellulose-based fabrics for outdoor applications

CITEVE, **Grado Zero** and **SPINNOVA** have continued progressing from cellulose-based fibres and yarns towards woven textile structures suitable for technical outdoor clothing. Their work has focused particularly on optimising ripstop fabric constructions, improving processing compatibility and refining the surface and functional properties of the resulting materials.

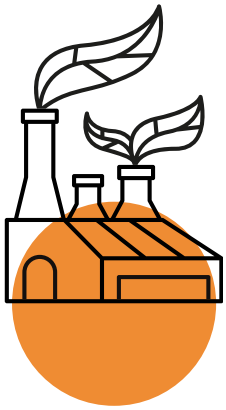
Recent developments include adjustments to the ripstop structure, with the grid spacing reduced from 10 mm to 5 mm, alongside enzymatic treatment and calendaring to improve fabric smoothness and appearance. Additional samples have been prepared for dyeing and subsequent functional finishing.

Material evaluation is addressing the mechanical stability, abrasion resistance, washing behaviour and water-repellent properties required for outdoor applications. These activities are helping identify suitable fabric configurations for integration with **PENGUIN**'s insulation systems and the final jacket demonstrators.



PENGUIN

Last advances towards ***innovation***



Biomimetic chemistries & material functionality

OrganoClick® SPINNOVA®

Improving textile performance through bio-based functional treatments

OrganoClick has continued optimising bio-based binders and functional finishing chemistries to improve the performance of cellulose-based textile materials. The work addresses key requirements such as hydrophobicity, wet strength, flexibility, processability and structural cohesion, while supporting the project's wider sustainability objectives. Recent developments have included industrial trials of water-repellent finishing on **SPINNOVA**-based fabrics, representing an important step towards applying functional treatments under manufacturing-relevant conditions. Further optimisation of binder formulations is also supporting the stability of lightweight insulation structures during processing and washing.

The next activities will focus on evaluating the compatibility of finishing treatments with selected textile constructions, including dyed fabrics, and assessing their performance within representative material assemblies.



Towards next-generation outdoor demonstrators

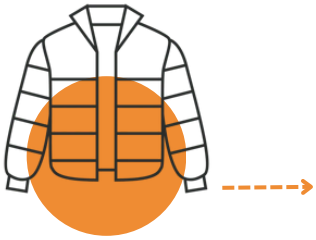
COLMAR

SPINNOVA® citeve

Bringing individual developments together into complete garment systems

As the individual material technologies mature, **PENGUIN** is increasingly focusing on their integration into representative textile assemblies and outdoor garment configurations. **Grado Zero**, **Colmar**, **CITEVE**, **VTT** and other partners are contributing to the selection and combination of insulation materials, functional fabrics and additional textile components for the project's two jacket demonstrators..

Last advances towards ***innovation***



Towards next-generation outdoor demonstrators

Current activities include the development and evaluation of multilayer sandwich structures, refinement of garment construction concepts and preparation for subsequent thermal, mechanical and comfort testing. Circularity considerations are also being incorporated into material selection and demonstrator design, with attention to future repairability, component separation and recycling pathways. These efforts represent the next stage of **PENGUIN**'s development: translating advances achieved across the consortium into integrated textile systems whose performance can be evaluated under representative conditions.

Last advances towards ***innovation***

PENGUIN



Modelling, sustainability and material validation

Connecting material performance with computational modelling, sustainability and circular design

idener.ai RINA

citeve

IDENER.AI has continued advancing the multiscale computational modelling of PENGUIN's cellulose-based materials, investigating molecular interactions, cellulose functionalisation and their influence on water interactions and material properties. These activities are complemented by modelling of fibrous insulation structures to better understand their thermal behaviour and support material optimisation. Recent developments were also presented at ESPA 2026, highlighting the contribution of computational approaches to sustainable textile innovation.

RINA has progressed the environmental and economic assessment of **PENGUIN**'s fibre production routes, completing the modelling of conventional viscose as a benchmark for Biocelsol and updating **SPINNOVA** fibre models using the latest available inventory data. Operating expenditure models are also being finalised to support economic feasibility assessments. In parallel, **RINA** has advanced the evaluation of circularity strategies for outdoor garments, addressing durability, reuse, recyclability and end-of-life management, alongside market and exploitation analyses.

CITEVE complements these activities through experimental validation and circularity assessment of the developed textile materials. Its work includes investigating chemical and enzymatic recycling routes for cellulose-based fibre blends and evaluating textile biodegradability. Recent tests on woven fabric containing 70% cotton and 30% SPINNOVA fibres showed 84% degradation after 35 days and over 90% after 50 days under the tested conditions, providing encouraging results for further assessment of end-of-life options.

Together, these activities connect computational modelling, environmental and economic assessment, and experimental validation to support the selection and development of more sustainable textile solutions as **PENGUIN** progresses towards its final outdoor garment demonstrators.

PENGUIN & its *sisters projects*

Connecting European research to advance sustainable and functional textiles

PENGUIN is strengthening collaboration with its Horizon Europe sister projects — **UPWEARS**, **SUBBIMATT** and **BioFibreLoop** — to exchange knowledge, explore complementary technologies and address common challenges in the transition towards more sustainable textile materials and products.

These projects bring together different approaches to textile innovation, from smart functionalities and bio-based materials to advanced surface treatments and circular design.

UPWEARS — **Next-generation multifunctional e-Textiles**
UPWEARS is developing a new generation of bio-based and hybrid fabrics integrating advanced functionalities, including functionalised fibres and yarns, biomimetic textile structures, embedded electronics and energy sensors. The project aims to combine high-performance e-Textiles with resource-efficient manufacturing, demonstrating its innovations through a recyclable cycling suit.

Website

PENGUIN and its *sisters projects*

Connecting European research to advance sustainable and functional textiles

SUBBIMATT — Bio-based smart materials for adaptive applications

SUBBIMATT focuses on sustainable, bio-based and bio-inspired smart textile materials capable of responding to changing conditions. Its innovations include debondable adhesives, bio-based polyurethanes and temperature-responsive materials, targeting applications ranging from adaptive garments to automotive interiors and shape-changing building envelopes.

SUBBIMATT

Website

BioFibreLoop — Bio-inspired textile functionalisation

BioFibreLoop is exploring innovative approaches to textile functionalisation inspired by natural surface structures. Using laser-based technologies, the project aims to create textile surfaces with properties such as water and oil repellency, self-cleaning and antibacterial activity, while significantly reducing the use of hazardous chemicals.

biofibreloop

Website

PENGUIN and its *sisters projects*

Connecting European research to advance sustainable and functional textiles

These collaborations help connect expertise across European research initiatives and strengthen the collective contribution towards more functional, circular and sustainable textiles.

Strengthening Collaboration for a Safer and More Sustainable Textile Industry

Collaboration across European research and innovation projects plays an important role in advancing safer, more sustainable and circular textile solutions. With this shared objective, on 13 October 2026, the PENGUIN project participated in an online meeting with its sister projects BioFibreLoop, SUBBIMATT and UPWEARS. The meeting provided an opportunity to exchange experiences, share ongoing developments and discuss how Safe and Sustainable by Design (SSbD) principles and circularity are being integrated into the innovative materials, technologies and solutions developed by each project. Beyond identifying common challenges and complementary approaches, the discussions helped strengthen connections between the four initiatives and explore opportunities for further collaboration and knowledge exchange.

By bringing together different perspectives and expertise, PENGUIN and its sister projects aim to contribute to the transition towards a safer, more sustainable, circular and innovative European textile industry. The collaboration will continue through future exchanges and joint activities, building on the synergies identified during the meeting.



News

PENGUIN Connects with the Fashion Industry at Pitti Uomo



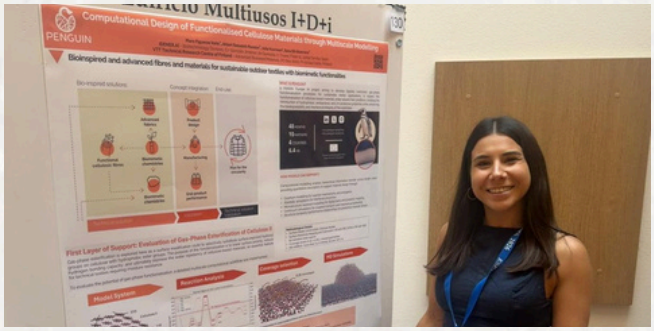
PLACE: Florence, Italy

DATE: June 16-19

PARTNER: Confindustria Moda

Pitti Uomo 2026 brought together international fashion brands, manufacturers and industry professionals to explore emerging trends and innovations in the fashion sector. As part of its industry engagement activities, **Confindustria Moda** identified the event as an opportunity to strengthen connections between **PENGUIN**'s research and the European fashion value chain, highlighting the growing relevance of sustainable materials, circular design and advanced textile functionalities.

PENGUIN Presents Multiscale Modelling Advances at ESPA 2026



PLACE: Salamanca, Spain

DATE: June 30 – July 3, 2026

PARTNER: IDENER.AI

IDENER.AI represented **PENGUIN** at the **Electronic Structure Principles and Applications (ESPA 2026)** conference, presenting a scientific poster on the project's multiscale computational modelling activities. The contribution highlighted how computational approaches can support the design and optimisation of functionalised cellulose-based materials, connecting molecular-level interactions with material properties. The conference provided an opportunity to exchange knowledge with the computational chemistry community and demonstrate the contribution of digital tools to sustainable textile innovation.

News

PENGUIN Explores Textile Innovation at Milano Unica



PLACE: Milan, Italy

DATE: July 7-9th

PARTNER: Confindustria Moda

Milano Unica 2026 gathered textile manufacturers, designers and fashion industry representatives to explore developments in materials, manufacturing and sustainability. Through its industry engagement activities, **Confindustria Moda** supported connections between the textile value chain and European research initiatives such as **PENGUIN**, whose work on bio-based fibres, functional fabrics and circular textile solutions responds to the growing demand for more sustainable materials in fashion and outdoor clothing.

PENGUIN Showcases Bio-Inspired Textile Innovation at ECOSYSTEX 2026



PLACE: Antwerp, Belgium

DATE: : September 22–24

PARTNER: Confindustria Moda & RINA

PENGUIN participated in the **ECOSYSTEX Conference 2026**, joining the European textile research and innovation community to exchange perspectives on circularity, sustainability and the future of textile manufacturing. At its dedicated display, the project showcased its bio-inspired approach to developing high-performance materials for more sustainable outdoor clothing. The event provided opportunities to strengthen connections with other European initiatives, exchange knowledge and explore collaborative approaches to advancing circular textiles beyond conventional recycling.

News

PENGUIN Connects with the Functional Textile Sector at Performance Days



PLACE: Munich, Germany

DATE: October 13–14

PARTNER: MOLINA

Performance Days Munich brought together leading stakeholders from the functional textile and sportswear industries to explore developments in performance materials, sustainable fibres and innovative textile technologies. The event provided a relevant industry context for **MOLINA**'s work within **PENGUIN**, particularly the development of cellulose-based insulation materials designed to combine thermal performance, durability and improved sustainability for outdoor applications.

UPCOMING *events*

PENGUIN Joins the ECOSYSTEX InSite Series to Discuss Sustainable Textile Innovation



PLACE: Online

DATE: November 13

PARTNER: VTT - Elina Ilén

PENGUIN's Project Coordinator, Elina Ilén (**VTT**), will participate as a speaker in the upcoming **ECOSYSTEX InSite Series**, delivering an extended presentation on the project's research and innovation activities. The webinar will provide an opportunity to share **PENGUIN**'s progress in developing bio-based insulation materials, advanced textile functionalities and circular solutions for outdoor clothing, while engaging with the wider European textile research community.

E-TEXTILES 2026: Exploring the Future of Electronic Textiles



PLACE: Plzeň (Pilsen), Czech Republic

DATE: November 24-25

PARTNER: VTT & Confindustria Moda

The upcoming **E-TEXTILES 2026 conference** will bring together researchers, technology developers and industry representatives to discuss advances in electronic textiles, including smart functionalities, wearable technologies and textile-integrated electronics. The event is particularly relevant to **PENGUIN**'s development of flexible heating systems and their integration into sustainable outdoor garments, offering opportunities to exchange knowledge on emerging technologies and future applications.

UPCOMING *events*

PENGUIN Looks Ahead to Heimtextil 2027



PLACE: Frankfurt, Germany

DATE: : January 12–15, 2027

PARTNER: MOLINA

Heimtextil 2027 will bring together international textile manufacturers, suppliers and industry professionals to explore developments in materials, technologies and market applications. The event offers **MOLINA** an opportunity to connect **PENGUIN**'s cellulose-based insulation developments with potential applications across the textile sector, including home textiles, bedding and other products requiring lightweight and sustainable thermal filling materials.

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