COMP-ECO

PROJECT DELIVERABLE

D5.3 – Roadmap for industrial implementation of Multifunctional Composites and Smart Structures

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DOCUMENT HISTORY

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1.0 – 01/12/2025	First version, developed by Michal Towpik (TPF), shared with all partners
1.1 – 05/12/2025	All partners shared inputs.
1.2 – 15/12/2025	Inputs consolidated by Michal Towpik and Rafal Kpzera (TPF). Shared to all partners
1.3 – 16/12/2025	Additional inputs provided by Otto Bergsma (Delft)
1.4 - 18/12/2025	Additional inputs provided by Albert Langkamp (Dresden)
2.0 – 22/12/2025	Second version, inputs consolidated by Michal Towpik and Anna Zmiievska (TPF)

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CONTENTS

1. INTRODUCTION

1.1. ABOUT THE COMP-ECO PROJECT

The COMP-ECO project was aiming at improving the research excellence of the Polish Mazovia region-based ecosystem in the field of Fibre-Reinforced Polymer (FRP) multifunctional composites and smart structures. The ecosystem is formed by 3 organizations: Technology Partners Foundation (TPF), Air Force Institute of Technology (AFIT) and Warsaw University of Technology (WUT). These 3 Polish partners have been supported by two leading EU universities: Delft University of Technology from the Netherlands and Technische Universität Dresden from Germany.

For 3 years the COMP-ECO partners jointly implemented exploratory research work to develop a technology for a permanent on-line non-destructive quality assessment of composite structures. For this purpose, 2 possible innovative sensing capabilities were developed: (1) self-diagnostics capabilities through the introduction of electroconductive carbon nano tubes in the composite's matrix during the manufacturing process and (2) self-sensing capability through embedding PZT sensors, encapsulated in a thermoplastic fibrous material (veils), in the composite structure.

In addition to the research work, the project organized technical workshops aimed on raising the research profile of Mazovian composite community, and management and administrative training workshops to strengthen research management capacities and administrative skills of the Polish partners' administrative staff.

The COMP-ECO activities established and strengthened a regional competence hub formed by TPF, AFIT and WUT, whose increased science and innovation capacities will lead to more ambitious collaboration with top EU research organisations and industry, higher participation in Horizon Europe, and a more attractive educational offer for students and young researchers.

1.2. SCOPE OF THIS DELIVERABLE

This deliverable presents the Roadmap for Industrial Implementation of Multifunctional Composites and Smart Structures, developed under Task 5.3 of the COMP-ECO project. Its purpose is to provide strategic guidance for translating COMP-ECO research results into industrially relevant applications and to support the preparation of future joint Research and Innovation Actions (RIA) by consortium members under Horizon Europe and other relevant funding frameworks.

The roadmap builds upon the technical outcomes achieved within COMP-ECO — particularly the development of multifunctional composite demonstrators and advanced sensing and heating solutions — and outlines concrete directions for engaging industrial stakeholders across key sectors such as aerospace, advanced manufacturing, energy, and dual-use applications. It identifies relevant industrial actors, cooperation mechanisms, and funding pathways that can support the further maturation, validation, and exploitation of COMP-ECO technologies.

A key foundation of this deliverable is the **structured consultation with the Scientific and Industrial Advisory Board (SIAB)** composed by:

- Prof. Vassilis Kostopoulos, Director of the Applied Mechanics and Vibrations Laboratory, University of Patras (Greece)
- Prof. Ferrie W.J. van Hattum, Lector for Lightweight Construction and Professor in Lightweight Structures, ThermoPlastic Composites Application Centre (TPAC) (Netherlands)
- Dr. Tomasz Gałaczyński, Lockheed Martin Fellow and Development Projects Office Manager, Polskie Zakłady Lotnicze Sp. z o.o. (Poland)
- Dr. Andrzej Czulak, Leader of the Polish Cluster of Composite Technologies (Poland)
- Ji-Young Hwang, Korea Carbon Industry Promotion Agency (KCARBON)

Several consultations were organized with the SIAB during the project, including three full consultative meetings:

- 11 March 2024: meeting focused on the presentation of early research results from WP1. SIAB members assessed the scientific quality and industrial relevance of the work and provided initial recommendations to steer further research development.
- 1 April 2025: SIAB reviewed updated research results and discussed how earlier recommendations had been addressed. The discussion concentrated on sensor development, repeatability, modelling support for multimodal data interpretation, and pathways towards more robust and scalable solutions.
- 8 December 2025: the final meeting was dedicated to the presentation of final demonstrator results and their potential industrial applicability.

Across these consultations, SIAB members provided targeted recommendations that directly informed this roadmap. These included guidance on improving sensor integration and durability, the use of modelling and AI-supported data interpretation, consideration of alternative manufacturing routes (such as additive manufacturing), assessment of thermal fatigue effects, and optimisation of system design parameters to improve energy efficiency and industrial robustness.

As such, this deliverable reflects not only the strategic ambitions of the COMP-ECO consortium, but also external validation and guidance from leading academic and industrial experts, ensuring that the proposed roadmap is realistic, forward-looking, and aligned with industrial needs and European innovation priorities.

2. EXPLOITABLE RESULTS OF THE JOINT PREPARATORY RESEARCH

Project developments showed that the embedded sensors remained functional during various mechanical tests and impact events, enabling direct monitoring of structural components via heating and current conduction. These findings represent a significant early step toward digital, self-monitoring composite structures and open possibilities for predictive maintenance, structural-health monitoring, and lightweight system optimisation. Although the results are currently at a low TRL, they provide clear evidence of feasibility and define the technical direction for further development. Importantly, the individual exploitable results i.e. sensors developments and integration, laminate-level functionality, and reliable strain data acquisition are highly complementary. Together, they establish a coherent technology chain in which materials, embedded sensing, and data interpretation are mutually reinforcing rather than standalone outcomes. This interdependency forms a robust basis for future joint activities, including upscaling to component-level demonstrations, integration with digital twins, and the development of shared exploitation pathways toward industrial validation. Advancing these combined results to higher TRLs will therefore benefit from coordinated follow-up projects and cross-partner collaboration, enabling a more efficient transition from proof of concept to application-ready solutions. Below is a summary of exploitable results from the joint preparatory research, showing the contributions of all partners.

2.1 TPF

The preparatory research carried out within COMP-ECO has enabled TPF to deliver several exploitable technological results aligned with the project’s two core sensing capabilities. TPF contributed both to the development of conductive nanocomposite intermediates — strips, filaments, and veils — and to the methodology for their integration into composite structures in prepreg/autoclave manufacturing environments. The achieved results demonstrate potential for industrial exploitation in structural health monitoring (SHM), non-destructive testing (NDT), and multifunctional composite structures.

- TPF fabricated melt-blown CNT-doped veils, which were subsequently metallized to enhance electrical conductivity for delamination sensing. The research confirmed that electroless Ni–P deposition can be successfully applied to PPS-based veils containing CNTs, producing continuous metallic coatings on fibers and enabling their future use as interlaminar sensing layers for damage detection in composites.
- Another exploitable outcome is TPF's development of neat thermoplastic veils for insulation of integrated sensors. These veils were used as dielectric barriers for PZT sensors and conductive pathways embedded inside CFRP and GFRP laminates, helping address electrical contact issues in carbon-fiber composites where isolation is required .
- TPF also demonstrated capabilities in fabrication of conductive 3D-printed grids as next-generation internal heaters for active thermography, supporting the transition from CNT-strips to fully patterned functional networks inside laminates (Figure 1). TPF's involvement in manufacturing composite laminates at TU Dresden provided practical validation of the integration processes, including autoclave layup, sensor placement, and post-manufacturing NDT inspection. These preparatory research results form a complete technological chain—from material development to component-level validation in icing wind tunnel (Figure 2)—which can be exploited across aerospace, automotive and renewable energy sectors.

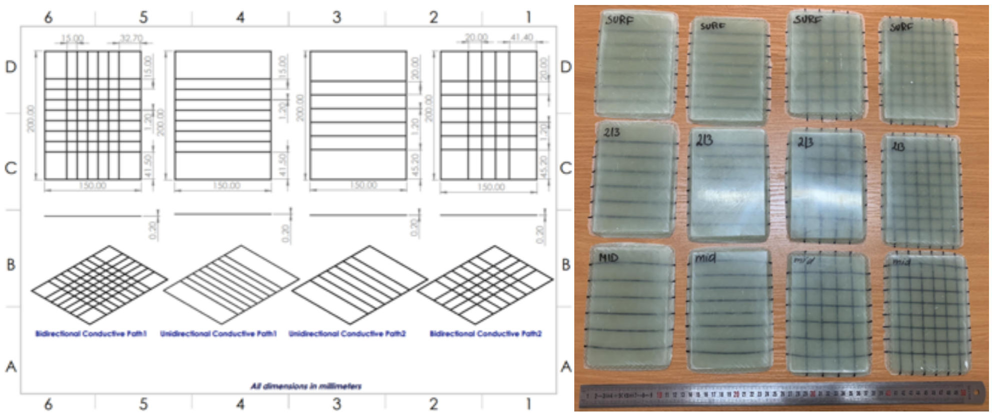

Figure 1. Conductive path printing geometry (left), fabricated laminates with embedded conductive paths (right)

Figure 2. Tests of NACA0012 profile demonstrator with embedded heaters in TPF's icing wind tunnel

2.2 WUT

As part of the COMP-ECO project, WUT presented a set of results with high exploitation potential, focusing on the development and optimization of strips (Figure 3) and nonwovens (Figure 4) made of polyphenylene sulfide (PPS) doped with carbon nanotubes (CNT), intended for use as lightweight internal heaters in composite structures. These elements can serve as internal heat sources in commonly used NDT methods, such as active thermography or shearography, eliminating the need for an external heat source. Their heating function can also be used to prevent or remove ice accumulation on composite structures, e.g., the leading edges of wind turbine blades. Additionally, they can be used as resistance-change sensors in SHM. Research has led to the development of PPS-CNT composites with controlled electrical resistivity and stable Joule heating properties. The work also focused on adapting the developed heaters to commonly used methods of composite polymer manufacturing techniques, i.e., autoclave technology, vacuum bag and infusion method. In addition, the effectiveness of the heaters on curved surfaces was verified - demonstrators (NACA0012 profiles) were produced for this purpose, and the durability of the implemented sensors was tested in accelerated hydrothermal aging. Testing protocols were also developed for newly designed internal heaters/resistivity sensors, and their impact resistance was verified.

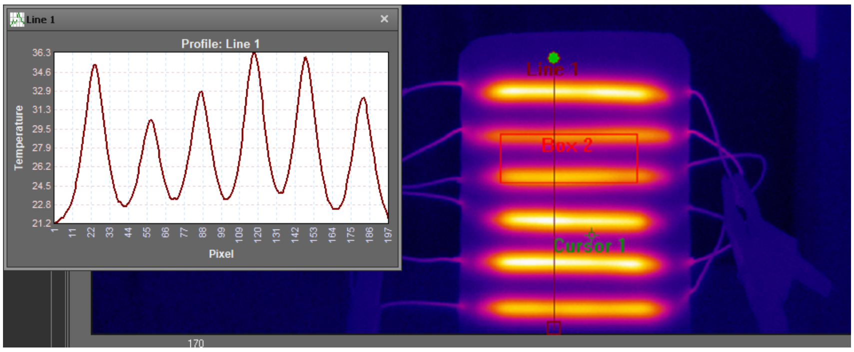

Figure 3. CNT-doped strips as an internal heater

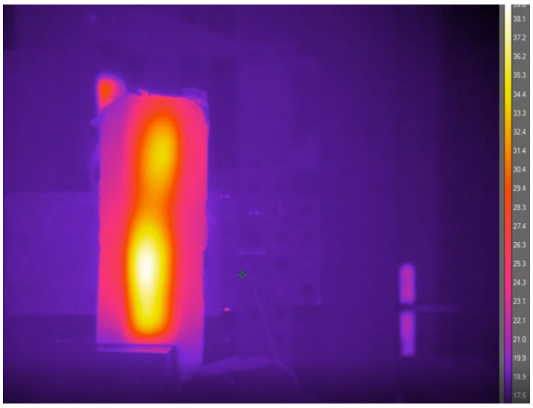

Figure 4. CNT-doped nonwoven as an internal heater

2.3 AFIT

During the Comp-Eco project, consortium discussions and guidance from the SIAB defined research goals to enhance the project's exploitation potential.

Safety methods for structural components

The project prioritized developing new methods to maintain the safety of structures, for example hydrogen tanks. This requires technologies capable of detecting and monitoring damage at very early stages, including sub-millimetre defects. Conventional linear PZT sensor methods are effective at identifying macroscopic damage such as large delamination, but early-stage degradation—micro-cracks or "kissing bonds" where surfaces touch without bonding—often produces little linear wave scattering. COMP-ECO research shows that analysing non-linear effects is essential to detect intra- and interlaminar micro-cracks and the initial delamination stages. This capability is particularly important for designing functional materials for hydrogen storage.

Sensor integration strategies

The performance of smart structures depends critically on how sensors are integrated into the composite. COMP-ECO tested three PZT implementation strategies:

- **Surface attachment (Figure 5)**
  - **Pros:** Lowest cost; no impact on manufacturing; replaceable.
  - **Cons:** Susceptible to environmental damage; potentially lower acoustic coupling stability.
- **Embedding in an additional layer (Figure 6)**
  - **Pros:** Minimal effect on host-structure mechanics; improved protection; good repeatability.
  - **Cons:** Slightly increased manufacturing complexity.
- **Internal embedding inside the composite (Figures 7–8)**

- **Pros:** Best acoustic coupling; maximum sensor protection; highest sensitivity to deep structural damage.
- **Cons:** Greatest complexity; risk of sensor damage during curing; potential effects on material strength.

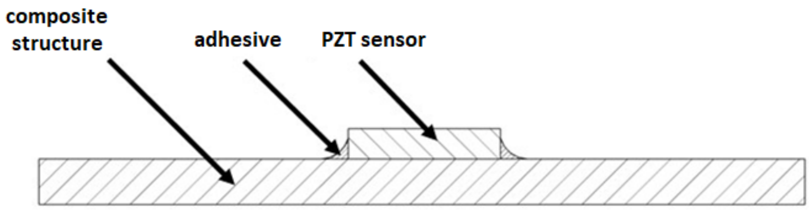

Figure 5: Cross section visualization of structure with surface attached PZT sensor

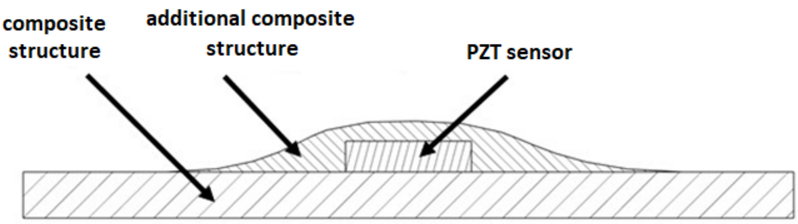

Figure 6: Cross section visualization of structure with PZT sensor embedded in additional layer of composite structure

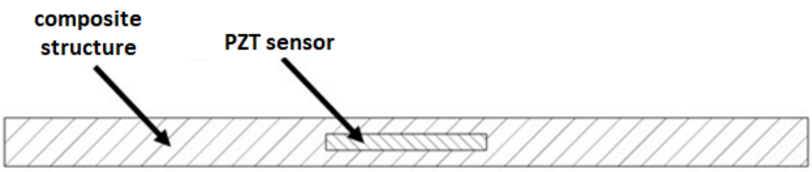

Figure 7: Cross section visualization of structure with PZT sensor embedded internally into composite structure

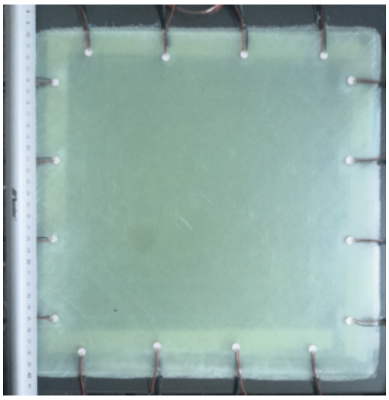

Figure 8: Scheme of a GFRP specimen with embedded embedded PZT sensors and view of specimen after curing

An essential step toward industrial deployment of multifunctional composites with embedded PZT sensors is assessing sensor performance and vulnerability under operational conditions. Following SIAB guidance, the project evaluated two environmental effects:

- **Cyclic loading**: Embedded sensors remained functional after 100,000 load cycles simulating landing-gear stresses.
- **Environmental exposure**: Sensors survived prolonged exposure to high humidity (80%) at elevated temperature (70 °C) and to freezing conditions (−70 °C) for six weeks.

2.4 TU DELFT

TU Delft carried out joint exploratory research on nondestructive testing (NDT) and structural health monitoring (SHM) for multifunctional composites and smart structures, working closely with visiting researchers from WUT, AFIT, and TP and supporting multiple tasks within the COMPECO project.

A shearography pair method was developed for reliable NDT of fiber-reinforced composites; this technique enables detection of sub-millimetre defects down to approximately 0.6–0.8 mm in diameter and has been applied to inspect smart structures containing CNT-doped sensors in the form of strips and veils, contributing directly to Task 2 (conductive CNT-doped strips as heaters for thermography) and Task 3 (conductive CNT-doped veils as delamination sensors).

In parallel, a numerical study investigated the nonlinear response of guided waves interacting with damage: a 2 mm thick unidirectional GFRP laminate with a single transverse matrix crack was modelled in ABAQUS and the propagation of the fundamental symmetric (S0) mode was analysed for various crack lengths and depths. The simulations show that nonlinear wave responses arise in the presence of cracks and that the nonlinear signatures differ between half-thickness and through-thickness cracks, indicating the potential to use nonlinear guided waves to distinguish through-thickness damage from other crack scenarios; these findings are relevant for NDT/SHM of composite hydrogen tanks and feed into Task 4 (integration of PZT sensors).

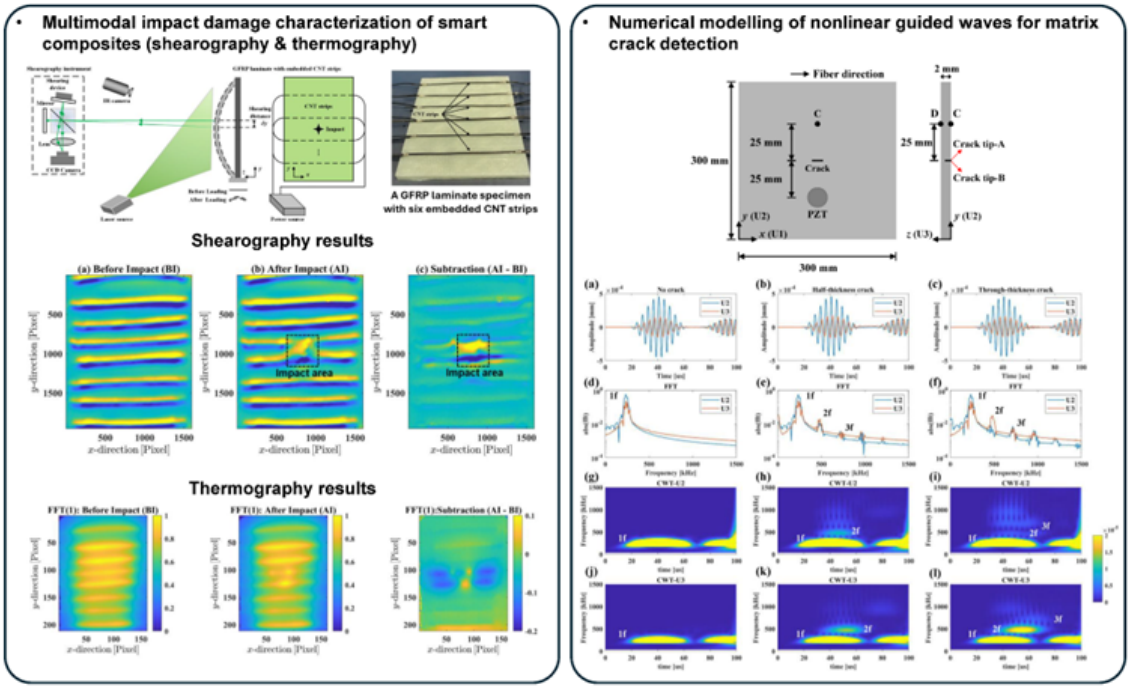

Figure 9. Overview of research results on NDT/SHM of multifunctional composites and smart structures (TU Delft).

All activities were carried out in close coordination with partner teams during their visits to TU Delft, providing hands-on support for experiments, modelling, and validation across the COMPECO work packages.

2.5 TU DRESDEN

TU Dresden focused its joint preparatory research on the feasibility of carbon-nanotube-doped (CNT-doped) thermoplastic filaments as embedded strain-sensing elements for composite structures. The work demonstrated that CNT-doped PPS filaments provide a stable, repeatable piezoresistive response while remaining compatible with standard composite manufacturing processes. Comprehensive mechanical and electromechanical testing confirmed that integrating these filaments does not degrade laminate performance, indicating strong potential for their use as minimally intrusive in-situ sensors. A baseline configuration—4 wt% CNT content with a 200 mm free length—was established, producing predictable sensing behaviour with filament-level gauge factors of approximately k\approx 2.

Laminate-level experiments further showed that the embedded sensors remain functional under bending, enabling direct strain monitoring within structural components. These results represent an important early step toward digital, self-monitoring composite structures and open opportunities for predictive maintenance, structural-health monitoring, and lightweight system optimisation.

Although the findings are currently at a low TRL, they provide clear evidence of feasibility and define a technical direction for further development; advancing exploitation will require scale-up, long-term durability testing, and integration with data-acquisition and processing systems.

3. PROJECT PARTNERS' RELEVANT CAPABILITIES

The partner consortium brings together highly complementary capabilities that collectively cover the full value chain needed to advance COMP-ECO results toward higher TRLs. Partners contribute deep, synergistic expertise in polymer processing and CNT-based functional materials, spanning nanocomposite formulation, extrusion, melt-blown veils, and the integration of conductive layers and heaters into composite structures. This combination enables scalable manufacturing and tailored embedding of sensing and heating elements across different composite systems, and is complemented by mature know-how in active sensing with PZT transducers for elastic-wave and electromechanical-impedance methods. Together, these strengths support robust damage detection and self-sensing functionality that augments CNT-based strain and heating concepts, forming a coherent foundation for coordinated development, integration, and validation of smart, self-monitoring composite structures. Beyond technical capabilities, partners have built strong experience in EU project coordination, industrial networking, dissemination, and exploitation planning through joint workshops and collaborative work.

3.1 TPF

TPF contributes a unique mix of materials engineering, polymer processing, and composite integration skills that directly support exploitation of COMP-ECO outcomes. TPF operates twin-screw extrusion facilities for thermoplastic nanocomposites, including CNT-filled masterbatches and functionalized filaments, strips, and fibres, and runs a melt-blown nonwoven pilot line for producing CNT-doped veils with controllable GSM ranges for tailored interlaminar sensing layers and dielectric insulation. TPF's hands-on experience in prepreg/autoclave manufacturing—gained through joint laminate fabrication with TU Dresden—includes embedding CNT strips, printed conductive grids, and PZT sensors, together with electrical interfacing using conductive adhesives, copper electrodes, and sensor packaging. Demonstrators have been validated in TPF's icing wind tunnel, which supports testing down to −20 °C and wind speeds up to 60 m/s in a 20 × 20 cm cross-section chamber with 50 cm length.

3.2 WUT

WUT develops and manufactures internal heaters and resistivity sensors adapted to specific composite manufacturing technologies and end-user materials. WUT has advanced capabilities in polymer processing, nanocomposite formulation, and functional materials engineering, with specialised infrastructure for compounding polymer matrices with conductive nanofillers to achieve uniform dispersion and repeatable electrical performance. WUT's expertise covers compounding thermoplastics with CNTs and graphene oxide to produce materials tailored for electrical and thermal applications, and its facilities include extrusion lines, thermoforming and lamination equipment, and testing rigs for electrical conductivity, resistive heating, and microstructure evaluation. WUT also focuses on integrating functional layers into composite structures to assess the behaviour of CNT-doped heaters and resistive sensors when embedded or surface-bonded.

3.3 AFIT

AFIT brings extensive experience in applying PZT transducers as both actuators and sensors for elastic waves, making them well suited for self-sensing structures. AFIT has deployed PZT-based methods such as guided/Lamb-wave inspection for impact damage, cracks, and delamination detection, and electromechanical-impedance (EMI) techniques to identify local deterioration including bolt loosening, adhesive degradation, and small cracks. AFIT's practical experience includes sensor installations on aircraft, helicopters, gas pipelines, and chemical storage tanks; the COMP-ECO work complements this background and will help accelerate broader applications.

3.4 TU DELFT

The Aerospace NDT (ANDT) Laboratory contains a well-equipped fibre optic sensors laboratory, with the capability to design, manufacture and test optical fibre sensors and sensor systems. The Delft Aerospace Structures and Materials Laboratory (DASML), collocated with the ANDT Laboratory has extensive facilities for the manufacturing and testing of aerospace materials, composites. The manufacturing facilities consist of numerically controlled milling and moulds for the fabrication of thermoplastic or thermosetting composite components. Composite parts can be formed by: diaphragm forming, deep drawing, vacuum assisted resin transfer moulding, filament winding, rubber press techniques and high temperature techniques. The laboratory has experience with a wide range of bonding and welding techniques, as well as riveting and other mechanical joining techniques. The testing facilities consist of a wide range on fatigue equipment, tensile test, compression test, 3-point bending, 4-point bending, impact tests, stiffness measurement, strain measurement, dynamic characterization of fibre-reinforced composites, thermal cycling simulation and material ageing.

3.5 TU DRESDEN

TU Dresden provides comprehensive technical capabilities to validate and mature the project's sensing concepts. The Institute of Lightweight Engineering and Polymer Technology (ILK) operates advanced laboratories for material, component, and system-level testing, enabling end-to-end validation under realistic mechanical and environmental conditions—from specimen preparation to system integration. TU Dresden's strong industrial interfaces, notably the Rolls-Royce University Technology Centre, offer direct channels for industrial feedback and alignment with aerospace and propulsion application needs, facilitating early assessment of exploitation potential, technology maturation pathways, and compatibility with industrial certification processes.

4. IDENTIFIED INDUSTRIAL NEEDS / INTEREST IN RELATION TO THE PERFORMED RESEARCH WORK (THROUGH SIAB CONSULTATIONS AND PARALLEL ACTIVITIES)

The project outcomes align closely with industry demand for smart, lightweight, and energy-efficient heating and sensing solutions. Feedback from SIAB consultations and parallel activities identifies clear priorities that, if pursued, could accelerate technology adoption and open new markets for high-performance composites. Four industry interest areas are summarised below.

4.1 EMBEDDED SENSING SOLUTIONS

SIAB consultations confirmed strong industrial interest in embedded sensing for in-service inspection and life-cycle monitoring of composite structures. Sectors under pressure to reduce maintenance costs and improve reliability—particularly aerospace, defence, energy, and automotive—seek lightweight, low-intrusiveness systems such as CNT-doped thermography strips, conductive veils for delamination detection, and PZT-based SHM networks embedded in laminates.

Manufacturers emphasised the need for scalable, production-ready solutions compatible with autoclave and infusion processes and able to withstand operational loads, temperature cycles, and impact. The COMP-ECO technologies were recognised as addressing key needs: low-power internal heat sources for NDT, integrated strain and delamination sensing, and multifunctional composite architectures that preserve mechanical performance. SIAB members recommended progressing toward demonstrators and TRL-focused follow-up projects.

4.2 HEATER STRIPS

Industrial stakeholders expressed substantial interest in the CNT-doped PPS heater strips and associated sensors, noting their potential to improve composite curing, repair, structural monitoring, and functional integration. To increase cross-sector applicability, industry highlighted several practical requirements:

- Conformability: Heater strips and sensors must be flexible and resistant to brittleness—especially after thermo-pressing—to fit curved geometries without failure.
- Manufacturing scalability: Move beyond flat samples to continuous processes that enable integration into large or complex structures.
- Cost transparency: Provide clear cost-per-metre estimates for CNT-doped heaters to support adoption in high-volume sectors.
- Digitalisation and additive manufacturing: Explore FDM 3D printing for functional sensors to enable rapid prototyping, custom geometries, and on-demand production near assembly lines.
- Thermoplastic compatibility: Assess performance with thermoplastic matrices to leverage welding, recycling, and automated processing advantages.
- Robotic integration: Evaluate integration with robotic routes such as Automated Tape Placement for in-situ temperature control and monitoring.
- Long-term validation: Demonstrate fatigue resistance, thermal cycling stability, and degradation mechanisms; use computer modelling to predict durability and optimise sensor geometry and placement for certification.

4.3 SMART STRUCTURES

Demand for smart, multifunctional composites is growing across aerospace, power generation, oil and gas, and chemical processing, where failures carry high economic, human, and environmental costs. The convergence of materials science with Industry 4.0—AI and Digital Twin technologies—creates a data gap: digital models require real-time sensor data to predict reliability accurately.

Adding an embedded sensing layer delivers two primary benefits:

- Maintenance optimization: Enables predictive maintenance to reduce unplanned downtime and extend asset life, supporting circular-economy goals.

- Design optimization: Replaces conservative safety factors with data-driven design, enabling lighter, more efficient, and safer structures.

4.4 DURABILITY AND MAINTAINABILITY

SIAB feedback emphasised real-world implementation considerations. Industry recommended studying weathering and environmental effects on the piezoresistive performance of CNT-doped filaments, since long-term stability is critical for SHM applications. They also suggested locating sensing elements in outer laminate layers to support recyclability and allow component-level replacement after damage.

Both durability and maintainability considerations were incorporated into the research programme, reinforcing alignment with industrial expectations and practical deployment requirements. Addressing these factors early increases the relevance and readiness of the results for future applications.

4.4 CONCLUSION

The project's technologies meet clear industrial needs and have strong commercial potential. Priorities for next steps include advancing demonstrators, validating long-term performance, refining cost models, and demonstrating compatibility with industrial manufacturing routes and thermoplastic matrices. Pursuing these actions will accelerate adoption and unlock new applications across high-performance composite markets.

5. INDUSTRIAL ACTORS TO BE CONSIDERED IN FUTURE RIA ACTIVITIES

Below are presented companies to be considered in further TRL-raising activities.

NDT and SHM technology providers

- CTS / Noliac — piezoelectric components and SHM integrators: noliac.com / ctscorp.com.
- PI Ceramic — manufacturer of piezoceramic components and actuators: piceramic.com.
  These suppliers are natural partners for validating embedded excitation sources and piezo-based sensor networks.
- Optics11 – develops fiber optic sensing systems for harsh environments, https://optics11.com/
- Photon First – focuses on photonics-based sensing solutions for structural health monitoring, https://www.photonfirst.com/

- Tarucca – applies AI and optical sensing for renewable energy asset monitoring, https://www.tarucca.com/
- Dehn – specializes in lightning and surge protection solutions: https://www.dehn-international.com/en
- Mistras Group – provides asset protection and non-destructive testing services worldwide, https://www.mistrasgroup.com/

These companies are potential partners for commercialising sensing applications.

Aerospace sector and OEMs

- Saab — aerospace systems with SHM interests: saab.com.
- Airbus — prime for composite wing and fuselage supplier networks: airbus.com.
- Leonardo — integrated aerospace systems and composite applications: leonardo.com.
- Embraer – commercial airframes with composite programmes: embraer.com.
- Fokker services – customized aerospace solutions for operators, MRO's, manufacturers, lessors or governments: https://fokkerservicesgroup.com/
- LM Wind Power (relevant for aero-derived blade technologies and composites): lmwindpower.com.

These OEMs and prime contractors are priority targets for embedded sensing in shells, control surfaces and nacelles and for TRL-raising demonstrators.

Regulatory and standards stakeholders

- EASA — European aviation regulator; essential for SHM-based certification pathways: easa.europa.eu.
- ESA — space agency stakeholder for high-reliability composite systems in space applications: esa.int.
Engaging these bodies early helps ensure data requirements and validation protocols meet certification needs.

Composite manufacturers, moulders and material suppliers

- Compositec — advanced composite manufacturer and systems supplier: compositec.eu.
- MOULD Krzysztof Bodyński — composite tooling and form producer (CNT-doped veil heating concepts): mould.pl.
- Lockheed Martin / PZL Mielec — industrial aerospace manufacturing and systems integration (Polish facility): pzlmielec.pl; lockheedmartin.com.

These actors can integrate CNT strips, conductive veils and heating elements into production lines and tooling.

Automotive, mobility and industrial composites

- STS-Group — composite parts and systems supplier for transport: sts.group.
- KATCON — thermal, exhaust and composite solutions for mobility: katcon.com.
  These companies are well placed to trial lightweight structural modules, EV enclosures and sensorised hydrogen-tank composites.

Renewable energy (wind) manufacturers

- Siemens Gamesa — wind-turbine systems and blade technologies: siemensgamesa.com.
- Vestas — global wind-turbine OEM: vestas.com.
- LM Wind Power — rotor blade supplier (also relevant to on-blade SHM and de-icing): lmwindpower.com.
  These partners are key for delamination sensing, on-blade diagnostics and integrated de-icing/self-heating demonstrations.

6. FURTHER RIA ACTIVITIES WITHIN HORIZON EUROPE OR OTHER FUNDING FRAMEWORKS

Based on the developments achieved during realization of the project, consortium identified following possible frameworks for further collaboration and exploitation of investigation results and their demonstrators:

ON-GOING projects

- HORIZON-MSCA-2023-DN-01-01. MSCA-DN – ASSESS Automated online monitoring of smart composite structures. Awarded 2024. This project continues the collaboration between the COMP-ECO partners in the area of structural health monitoring during the period 2024-2028. TU Delft PhD candidates funded by the ASSESS project will perform secondments at Warsaw University of Technology and the Air Force Institute of Technology, Poland as part of the ASSESS research project.
- TU Delft collaborates with consortium partners in COST Action HISTRATE - Advanced Composites under HIgh STRAin raTEs loading: a route to certification-by-analysis. This network is exploring future collaboration opportunities in MSCA-DN calls and in European projects.

SUBMITTED proposals

- HORIZON-WIDERA-2025-01-ACCESS-01. In November 2025 WUT, TPF and DRESDEN submitted the ASCEND proposal – Advancing sustainable composites and excellence through networks for digital and green industrial transformation. ASCEND contains a research component that will extend COMP-ECO results by addressing such issues as digital twins for composite integrity and bio-based and circular multifunctional composites.

UPCOMING CALLS for projects

Work program Cluster 4 – Digital, Industry & Space (Advanced Materials & Smart Structures):

- HORIZON-CL4-2026-01-MATERIALS-PRODUCTION-23: Accelerating the discovery and development of chemicals and innovative advanced materials through digitalisation and artificial intelligence (IA) (Innovative Advanced Materials for the EU partnership)
- HORIZON-CL4-2026-01-MATERIALS-PRODUCTION-01: Advanced manufacturing for key products (IA) (Made in Europe partnership)
- HORIZON-CL4-2026-01-MATERIALS-PRODUCTION-05: Circular innovative advanced materials: facilitating the transition from design to markets (RIA) (Innovative Advanced Materials for the EU and Made in Europe partnerships)

Work program Cluster 5 – Climate, Energy & Mobility (Smart Multifunctional Composites, Aviation, Infrastructure Monitoring):

- HORIZON-CL5-2026-01-D6-07 — Innovative construction and maintenance using new materials and techniques (RIA)
- HORIZON-CL5-2026-02-D4-03 — Innovative pathways for low-carbon and climate-resilient building stock (Built4People Partnership)
- HORIZON-CL5-2026-02-D3-07 — Improved reliability and optimised O&M for wind energy systems (RIA)

EIC Transition: Single applicants (SMEs, spin-offs, start-ups, research organisations, universities) or small consortia (minimum 2, maximum 5 eligible entities) - Grants of up to EUR 2.5 million to validate and demonstrate technology in application-relevant environment (starting at TRL 3 achieved or 4 aiming at achieving TRL 5 or 6) and to develop business and market readiness.

M-ERA.NET CALL 2026: aims at funding ambitious transnational RTD projects addressing materials research and innovation supporting the European Green Deal and the United Nations's Sustainable Development Goals (SDG). The Call 2026 includes the following thematic areas: a) Sustainable materials for energy applications; b) Innovative surfaces, coatings and interfaces; c) Advanced composites and lightweight materials; d) Functional materials; e) Materials addressing environmental challenges; f) Next generation materials for electronics.

INNOGLOBO is a national programme that enables Polish organisations to form research and development partnerships with foreign entities in countries that maintain diplomatic relations with Poland. The competition funds international R&D

projects of varying sizes and topics, including highly specialised or niche areas. Key eligibility requirements are: at least one foreign partner must be involved, and the project's thematic scope must appear on the current List of National Smart Specializations.

JoinED-Call. The objective of the call is to fund transnational research focussing on a wide range of topics related to aeronautics, in particular but not exclusively: (i) Alternative, climate-neutral propulsion technologies (open to all energy sources), (ii) Reducing energy demand and increasing the competitiveness, performance and operational efficiency of air transport, (iii) Improving safety, resource efficiency and reducing the ecological footprint. 7 funding organisations from 5 countries, Austria, Germany, the Netherlands, Romania and the United Kingdom, are participating in this cooperation of national funding programmes. Partners have already discussed possible topics for a join application and will monitor the possible accession of Poland to this call.

SUMMARY

This deliverable outlines a structured roadmap for the industrial implementation of multifunctional composites and smart structures developed within the COMP-ECO project. Building on the collaborative research efforts under WP1 and strategic inputs from project partners, it identifies key steps, stakeholders, and mechanisms to transition COMP-ECO innovations into industrial applications.

The roadmap is grounded in insights gathered through three structured consultations with the Scientific and Industrial Advisory Board (SIAB), composed of leading experts from academia and industry. These consultations played a central role in validating research directions, highlighting industrial challenges and needs, and identifying potential use cases, strategic partners, and application pathways. Specific recommendations focused on modelling, manufacturing processes, sensor integration, and industrial validation.

The deliverable proposes concrete actions to increase industrial engagement, including demonstrator-based pilots, targeted dissemination, participation in trade fairs and innovation clusters, and joint preparation of Research and Innovation Action (RIA) proposals. It aligns with key European policy frameworks such as Horizon Europe, the European Defence Fund, and M-ERA.NET, while leveraging national ecosystems in Poland, Germany, and the Netherlands. It also identifies synergies with industry networks such as SAMPE, the Polish Cluster of Composite Technologies, and international platforms including Korea Carbon.

The roadmap will support the COMP-ECO consortium in achieving long-term impact through industrial valorisation. It ensures that multifunctional composite technologies developed within the project are positioned for practical implementation, scalability, and uptake across relevant markets, contributing to European strategic priorities and industrial competitiveness in the field of advanced materials.