This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No. 859957.

ENHAnCE

Featuring Engineering

POTENTIAL INPUTS FOR POLICY FEEDBACK

Project Acronym: ENHAnCE	
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Index

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1. Introduction

Enhance is a European training Network in intelligent prognostics and Health mAnagement in Composite structurEs, based on 9 partner beneficiaries involving universities, research organisations, government agencies and industries. This H2020 MSCA ITN project is focused on performing the most cutting-edge research and training in the field of intelligent prognostics of composite structures satisfying all Principles for Innovative Doctoral Training.

The direct industrial engagement through 4 industrial partners ensured a multidisciplinary and multisectoral training of 10 employed Early Stage Researchers (ESRs). Europe's human capital base in R&I was therefore strengthened with a new generation of more entrepreneurial and highly-skilled early career researchers.

All the beneficiaries involved in ENHAnCE have a recognized international reputation in composite technologies research, sensing technologies, AI, embedded systems, and structural modelling, and carry significant experience in European and national research and training projects in cooperation with major universities, research centres and other technological companies. ENHAnCE partners have been carefully chosen from Germany, Italy, Belgium, France, Netherlands, Great Britain and Spain and are among the most prominent investigators in their fields worldwide, thus complementing the research excellence of the network.

Table 1. Researchers, Supervisors and Beneficiaries of the project ENHAnCE

ESR		Supervisors	Beneficiaries	Dept./Division /Laboratory	Country
1	Shankar Galiana	Peter Wierach Daniel Schmidth	DLR, German Aerospace Center	Institute of Composite Structures and Adaptive Systems	Germany
2	Aravind Balaji	David Dumas Ingrid Lepot	CENAERO, Centre de Recherches en Aéronautique ASBL	Polymer Processes and Composites Lab.	Belgium
3	Amond Sarr Allouko	Alain Lhemery Vahan Baronian	CEA List, Laboratory for Integration of Systems and Technology	NDE Department	France
4	Tasdeeq Sofi	Maria Rodriguez Mª Isabel Martín	FIDAMC, Foundation for the research development and application of composite materials	R&D Section	Spain
5	Morteza Moradi	Dimitrios Zarouchas Rinze Benedictus	TU Delft, Delft University of Technology	Faculty of Aerospace Engineering/Department of Aerospace Structures and Materials	Netherlands

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ESR		Supervisors	Beneficiaries	Dept./Division /Laboratory	Country
6	Tianzhi Li	Francesco Cadini Claudio Sbarufatti	Politecnico di Milano	Dept. Mechanical Engineering	Italy
7	Javier Contreras	Athanasios Kolios Feargal Brennan	University of Strathclyde	Faculty of Engineering/Dept. Naval Architecture, Ocean and Marine Engineering	U.K.
8	Wen Wu	Rasa Remenyte-Prescott John Andrews	University of Nottingham	Faculty of Engineering / Composites Research Group	U.K.
9	Juan Fernández	Juan Chiachío Francisco Herrera	University of Granada	Dept. Structural Mechanics/Institute of Data Science and Computational Intelligence	Spain
10	Ali Saleh	Manuel Chiachío Juan Chiachío	University of Granada	Dept. Structural Mechanics/Institute of Data Science and Computational Intelligence	Spain

Table 2. Partner organisations of the project ENHAnCE

Name	Scientist-in-Charge	Dept./Division /Laboratory	Country
TUC, Clausthal University of Technology	Peter Wierach	Institute for Functional Materials and Functional Structures	Germany
KU Leuven, Katholieke Universiteit Leuven	Dimitrios Chronopoulos	Dept. Mechanical Engineering	Belgium
Société Nationale de Construction Aérospatiale SA (SONACA)	Nicolas Van de Hille	Research & Technology Department	Belgium
Ramboll	Ursula Smolka	Ramboll Wind (Asset Management Group)	Germany
Oritia& Boreas (S.L)	José María TerrésNicoli	Monitoring & Control Division	Spain
KBR	Matteo Corbetta	KBR LLC, NASA Ames Research Center	U.S.A.

2. Responsible research and innovation

Research and innovation processes do not occur in isolation but are deeply embedded within the broader context of societal values, political debates, and institutional frameworks. In the current context, the overarching political framework guiding these processes is provided by the United Nations' Sustainable Development Goals (SDGs) and targets from the EU Agenda 2030. This means that research and innovation efforts are increasingly oriented towards addressing the challenges outlined in the SDGs, aligning with the global agenda for sustainable development. As such, they are

expected to contribute to the achievement of the SDGs by generating knowledge, technologies, and solutions that promote sustainable development outcomes across various sectors and regions.

To begin, it is crucial to identify specific SDGs and targets from the EU Agenda 2030 that align with the policies under consideration. In the current context, this may include goals related to quality education (SDG 4), Industry, innovation and infrastructure (SDG 9), Sustainable cities and communities (SDG 11) and Climate Action (SDG 13).

Once recommendations and policies are drafted, it becomes necessary to assess the extent to which these policies contribute to or hinder the achievement of the selected SDGs and EU Agenda 2030 targets. This analysis should consider how these policies tackle the root causes and influencing factors that affect sustainable development.

The potential inputs for policy feedback should be explored, attending to the different contributions by:

- Evaluating the effectiveness of policies in engaging with diverse stakeholders, including civil society organizations, affected communities, businesses, and government agencies.

- Examining the availability and quality of data and indicators used to monitor progress towards SDGs and EU Agenda 2030 targets, and assess whether policies are supported by robust monitoring and evaluation mechanisms.

-Investigating the incorporation of participatory mechanisms such as public consultations, citizen assemblies, and participatory budgeting processes to enhance transparency, accountability, and democratic legitimacy.

-Assessing the use of impact assessments to evaluate the potential social, economic, and environmental impacts of policies, including distributional effects on vulnerable and marginalized groups.

- Analyzing how policymakers utilize feedback mechanisms to learn from past experiences, adapt policies in response to changing circumstances, and foster iterative policy design and implementation processes.

Based on the analysis performed, recommendations for enhancing the integration of potential inputs for policy feedback into the policymaking process appear in the following step.

Highlighting strategies for strengthening stakeholder engagement, improving data availability and quality, enhancing participatory mechanisms, conducting robust impact assessments, and fostering policy learning and adaptation are key to the success of this action.

The concluding phase involves elucidating how the implementation of these recommendations can propel advancements towards the designated SDGs and EU Agenda 2030 targets. It underscores the significance of aligning policies with the core tenets of sustainability, inclusivity, and resilience to foster transformative change on both national and global scales.

3. Inputs for the policy recommendations

Efforts have been made to gather potential inputs for the "Policy Feedback" by soliciting insights from researchers, participants and stakeholders to inform our policy feedback initiatives. In this deliverable, stakeholders' contributions are included, phrased as policy recommendations and provided evidence that underlines their importance.

2.1 Inputs from the Researchers' Questionnaire

This section compiles the findings and policy recommendations gathered from a questionnaire distributed among ENHANCE researchers. The aim was to assess the potential applicability of their theses to European policymaking, including the potential influence over the existing standards, and to identify specific areas of relevance within the EU's Horizon Europe framework.

The insights collected from researchers underscore the potential of academic research to inform and shape EU policymaking across various thematic areas. By leveraging innovative solutions proposed in research theses, the EU can advance its policy objectives, foster technological innovation, and address pressing societal challenges in line with the Horizon Europe framework. As can be observed in Figure 1, an overwhelming majority of researchers, representing 90% of respondents, indicated that their theses hold relevance for European policymakers.

In considering policy recommendations, it is also paramount to recognize the interface between proposed initiatives and existing standards. By ensuring coherence between them, policymakers can facilitate the integration of innovative technologies and practices while maintaining regulatory compliance and industry best practices. The researchers working with wind turbines indicated adherence to the standard IEC 61400 standards, whereas the remaining respondents stated

that their investigations did not specifically address any standards. Consequently, they expressed uncertainty regarding the potential impact of their thesis outputs on existing standards.

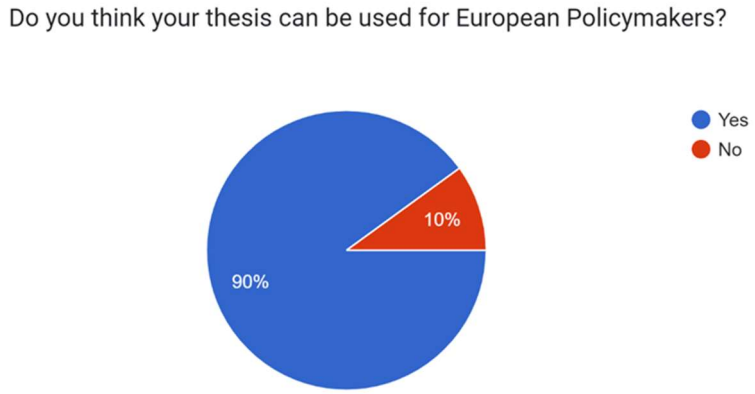

Figure 1. Results from the ESR questionnaire related to the thesis utility

The policy recommendations put forth in the researchers' questionnaire hold significant potential for synergizing with the thematic priorities and funding opportunities outlined in Horizon Europe calls. For instance, initiatives aimed at promoting research-industry collaboration and investing in digitalization and sustainable technologies resonate strongly with the objectives of several Horizon Europe clusters, including 'Digital, Industry, and Space' and 'Climate, Energy, and Mobility'.

2.1.1 Potential Horizon Europe Calls for Thesis Applications

- **Digital, Industry, and Space**

One respondent highlighted the potential alignment of his thesis with the 'Digital, Industry, and Space' call under Horizon Europe. It thesis proposes methods to construct a digital airplane model, facilitating online performance evaluation throughout the aircraft's service life. This innovative approach could significantly contribute to predictive maintenance, thereby reducing maintenance costs. This recommendation holds substantial promise for enhancing efficiency and sustainability within the aviation industry, aligning with the EU's objectives in the digital and industrial sectors.

- **Adapting to Climate Change Call**

Another respondent emphasized the relevance of their thesis output to the 'Adapting to Climate Change' call. Their thesis presents an autonomous decision-making system designed to streamline Operations and Maintenance (O&M) processes for wind turbines, particularly focusing on blade maintenance. By automating decision-making processes, this system has the potential to improve operational efficiency, prolong turbine lifespan, and reduce downtime, contributing directly to climate

change adaptation efforts. This recommendation aligns closely with the EU's goals of fostering renewable energy sources and promoting climate resilience.

2.1.2 Policy Recommendations

Based on the insights gathered from researchers, the following policy recommendations are proposed:

- **Promoting Research-Industry Collaboration**

Encourage collaboration between research institutions and industry stakeholders to facilitate the translation of innovative research findings into practical solutions. This collaboration can be incentivized through funding mechanisms and partnership initiatives.

- **Investing in Digitalization and Sustainable Technologies**

Allocate resources towards digitalization initiatives and the development of sustainable technologies, particularly in sectors such as aviation and renewable energy. This investment can drive technological innovation, enhance competitiveness, and support the EU's transition towards a greener economy.

- **Supporting Predictive Maintenance Initiatives**

Provide support for research and development initiatives focused on predictive maintenance solutions, particularly in critical sectors like aviation. By leveraging advanced technologies and data analytics, predictive maintenance can optimize asset management practices, improve operational efficiency, and reduce environmental impact.

- **Fostering Climate Resilience in Energy Infrastructure**

Prioritize investments in climate-resilient infrastructure and technologies, such as autonomous decision-making systems for wind turbine maintenance. By bolstering the resilience of energy infrastructure, the EU can enhance energy security, mitigate climate risks, and promote sustainable development.

In conclusion, the insights gathered from researchers underscore the potential of academic research to inform and shape EU policymaking across various thematic areas. By leveraging innovative solutions proposed in research theses, the EU can advance its policy objectives, foster technological innovation, and address pressing societal challenges in line with the Horizon Europe framework.

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2.2 Inputs from the Beneficiaries, Partners and Stakeholders

The perspectives and contributions provided by beneficiaries, partners, and stakeholders involved in the project ENHAnCE are gathered at this point. Their insights provide crucial guidance and shape the direction of the project's efforts in formulating a policy aligned with the aforementioned objectives.

2.2.1 EU to Develop technologies that help to achieve net-zero emissions target

To address the contemporary challenges of environmental degradation and energy scarcity, as well as to meet the net-zero emissions targets, there is a growing imperative for increased adoption of clean energy sources. Among these, wind power stands out as a promising avenue for generating sustainable energy. Against the backdrop of the rapid expansion of wind energy infrastructure, the development of robust condition monitoring techniques and asset management modelling tools emerges as a critical priority. These endeavours aim to mitigate operational and maintenance costs associated with wind turbines while ensuring their reliability and sustainability.

This project has developed a suite of innovative techniques and modelling tools to address these challenges. Firstly, a specialized physics-based Bayesian framework has been developed, tailored specifically for extracting damage characteristics from ultrasound measurements in plates and joints. This breakthrough significantly enhances the efficiency of structural health monitoring [1,2]. Secondly, a comprehensive methodology has been devised to evaluate the reliability of structural health monitoring systems throughout their operational lifespan [3]. Thirdly, a novel approach has been explored, integrating physics models with drone inspection data to forecast blade defect progression [4]. Lastly, an asset management Petri net model has been created and customized for wind turbine blades. This model seamlessly integrates the structural health monitoring process with reliability assessments, marking a significant advancement in wind turbine maintenance modelling [5].

Collectively, these innovative techniques have the potential to expedite the progress of wind energy deployment, thereby making substantial contributions to achieving net-zero emissions targets.

2.2.2 EU to Promoting the application of advanced technologies in industry

Transforming this "potential" into "reality" requires proactive efforts to encourage the application of our developed techniques within the industry. To facilitate this transition, it is crucial to foster greater collaboration between industry and academia. Promoting the implementation of more supportive policies that can bridge the gap between these two sectors becomes of paramount

importance. Such policies should aim to enhance partnerships, resource-sharing, and the practical application of academic research in industrial settings.

In addition, from a long-term development standpoint, it is essential to establish regulations that specifically promote the use of condition monitoring techniques in the wind energy sector. These regulations should standardize the application of advanced monitoring technologies. This will ensure consistent and effective monitoring across the industry, leading to more reliable and efficient wind energy production. The goal is to create a regulatory environment that not only supports but actively encourages the integration of cutting-edge research and technology into the everyday practices of the wind energy industry, thereby contributing substantially to the global pursuit of net-zero emissions.

2.2.3 EU to Rebuilding Collaboration between EU and UK

From September 7, 2023, UK researchers have been allowed to apply for grants and participate in projects under the Horizon programme [6]. This development is a source of great excitement and a positive step forward for researchers in both the UK and Europe. However, it's important to acknowledge the impact of the period during which the UK was excluded from the programme. The delays and resulting exclusion have inflicted considerable damage and fostered a sense of distrust within the scientific community [7].

To address these challenges, efforts are required to rebuild the cooperative relationships. It is not just about re-establishing connections; it is about fostering a renewed sense of trust and collaboration between UK and European researchers. Additionally, the implementation of corresponding policies is crucial to repair the caused damage. These policies should focus on promoting collaboration, facilitating ease of participation, and ensuring equitable access to resources and opportunities for researchers. By working together and implementing these measures, there is potential to realign and strengthen the partnership between the UK and Europe in scientific research and innovation, ultimately benefiting the broader scientific community and society.

2.2.4 EU to Provide access to a platform containing data from instrumented blades of wind turbines

To catalyze innovation and drive research initiatives within the renewable energy domain, a recommendation for the EU is to embark on a pioneering initiative. This entails establishing an open-access centralized platform dedicated to aggregating data sourced from instrumented blades of wind turbines. This platform would serve as a repository for valuable insights gleaned from real-time

monitoring and analysis of wind turbine performance, facilitating collaboration among researchers, industry stakeholders, and policymakers. By fostering transparency and knowledge-sharing, such a platform can accelerate advancements in wind energy technology, enhance operational efficiency, and contribute to the EU's broader objectives of transitioning towards sustainable energy systems.

It is necessary to address current research limitations, such as the absence of published data on instrumented wind turbine blades, which presents a significant hurdle for researchers beyond the industry. Establishing a comprehensive platform can bridge this information gap, granting broader access to critical data. This fosters collaborative research, facilitates knowledge exchange, and accelerates advancements in wind energy technology.

The incorporation of diverse sensor technologies into the platform can act as a technological demonstrator, showcasing cutting-edge instrumentation integration on wind turbine blades. This promotes innovative sensor technology development and lays the foundation for digital twin creation. Access to data from instrumented blades is invaluable for researchers and engineers advancing digital twin technologies, deepening understanding of blade behaviour and performance.

In addition, widening access to data from instrumented wind turbine blades significantly enhances prognostic algorithm development for composite structures. With abundant information, researchers and data scientists can refine algorithms predicting potential structural issues, enabling proactive maintenance and ensuring wind turbine longevity and reliability. This initiative aligns with the EU's sustainability commitment and optimizes renewable energy resource utilization.

In conclusion, advocating for open access to a platform containing data from instrumented wind turbine blades enables the EU to encourage collaboration, stimulate technological innovation, and propel research in renewable energy. This initiative not only addresses current data availability limitations but also propels the EU to the forefront of sustainable energy research, establishing the region as a leader in shaping the future of wind energy technology.

4. Dissemination of the policy recommendations

To ensure this work has a significant impact, all partners will extensively share it with key stakeholders involved in the policy and decision-making process, leveraging their existing networks and contacts. Similarly, at a European level, these recommendations will be forwarded to the European Commission and other relevant European networks.

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