White Paper for

Safeguarding Cultural Heritage in a Changing Climate: A perspective from the Green Cluster on Cultural Heritage

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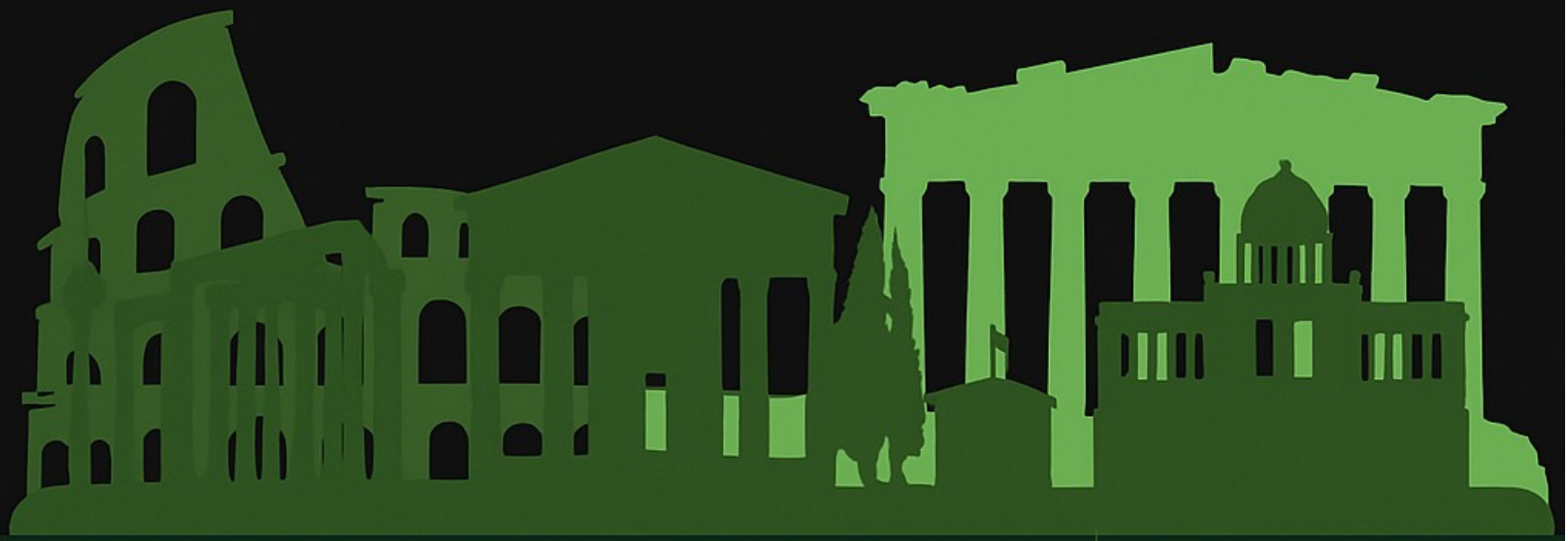
Coordinated by TRIQUETRA project on behalf of the Green CH Cluster



TRIQUETRA THETIDA RESCUE ME RESILIENT CULTURAL LANDSCAPES STECCI

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Executive Summary

Cultural Heritage (CH) across Europe is increasingly at risk due to the multifaceted impacts of Climate Change (CC), including sea level rise, flooding, extreme temperatures, and growing pressures from tourism. These challenges threaten not only cultural and natural landscapes but also the communities connected to them. To safeguard our heritage for future generations, it is vital that protection and management measures are recognised within various funding streams and supported by the development and implementation of advanced, adapted technologies. Furthermore, societal engagement is crucial to ensure that local needs are addressed alongside expert perspectives. Achieving more sustainable and transferable outcomes requires continuity beyond the typical lifespan of EU-funded projects. Investing in cultural heritage not only preserves identity and supports local economies but also strengthens climate change adaptation, disaster risk reduction, and even security and defence by ensuring that heritage sites, essential societal assets, remain resilient and continue to play a pivotal role in community cohesion and regional stability.

The **Green Cluster on Cultural Heritage** -a collaborative initiative linking EU-funded projects under the topic "*Effects of climate change and natural hazards on cultural heritage and remediation*" such as **TRIQUETRA**, **THETIDA**, **RescueME**, and **STECCI** -was established in early 2023 as a means to address these issues.

The leadership of the Green CH Cluster was initiated by EC during 2023 with the ''Climate Effects'' Team, composed of four EU projects (THETIDA, RescueME, TRIQUERTA, STECCI), which has an overarching aim to address the urgent need to protect monuments, historic buildings, and sites from the diverse impacts of climatic risks, natural and anthropogenic hazards[1]. THETIDA project initially led the cluster for the period of September 2023 to September 2024 which involved a dedicated session and Green CH Cluster meeting on CH at the European Geosciences Union General Assembly 2024. TRIQUETRA consortium took over the lead for 2024–2025, continuing the EGU session and organising the authoring of the White Paper to shape the strategic direction of the Green Cluster on Cultural Heritage. For 2025–2026, the leadership is transitioning to RescueME project with the continuation of the EGU session and a Green CH Cluster meeting in May 2026 to share final outcomes of projects.

Through this White Paper, the **Green CH Cluster** aims to establish cultural heritage as a central component of climate resilience strategies in Europe, by providing

insights for technology integration, novel methodologies, and policy recommendations.

Core Insights

- **Technology Integration:** Multi-scale modelling, novel sensing approaches (Light Detection And Ranging (LiDAR), hyperspectral), AI-driven analysis, and citizen-based monitoring are transforming risk identification, quantification, and mitigation. Yet, access to high-performance computing, and digitalisation of heritage assets remains a barrier. For heritage practitioners, however, another obstacle is also understanding how to apply these technologies.
- **Societal Engagement:** Initiatives such as Living Labs, workshops, citizen science activities, and collaborative partnerships with local communities, including civil society representatives, local businesses, as well as special expert groups like fishermen or divers, demonstrate the vital importance of inclusive involvement in cultural heritage protection. By embracing co-creation among community members, experts, researchers, and policymakers, solutions can be jointly designed to reflect a true understanding of both public and expert perspectives. This collaborative approach not only fosters greater acceptability and uptake of proposed measures, but also enables effective transfer of knowledge, ensures that solutions address real-world needs and challenges, and cultivates a shared sense of ownership. Moreover, co-creation bridges information gaps, empowering local communities with up-to-date insights about their regions' current and future risks, while allowing expert assumptions to be tested and refined through lived experience. Achieving a genuine balance between all stakeholders enhances the relevance, resilience, and sustainability of cultural heritage interventions.
- **Sustainability of Outcomes:** There is a pressing need for specifically targeted funding streams to ensure the long-term sustainability of project outcomes, such as through the adoption of blended funding approaches. Additionally, greater emphasis should be placed on advancing standardisation efforts and establishing more effective mechanisms to facilitate policy integration.
- **Policy Positioning:** Cultural heritage should be regarded as an integral pillar of Europe's resilience agenda, standing on equal footing with climate

adaptation, disaster risk management, sustainable development, digital transformation, and social innovation. Its distinctive societal, cultural, and resilience value generates cascading benefits for identity, economy, and community well-being.

Overview of Recommendations

1. Cultural heritage management should be embedded into European Union (EU) and national climate adaptation and disaster risk management frameworks.
2. Technology transfer from defence, aerospace, and medical sectors into cultural heritage management has to be supported and promoted.
3. Sustainable funding models combining EU, national, and organisational contributions should be created.
4. Citizen engagement through Living Labs and co-creation practices has to be a central pillar when developing methods, tools, and strategies for heritage management.
5. All interested parties should advocate for the recognition of cultural heritage as a vital component of Europe's resilience agenda.
6. Capacity building and training in digital technologies, climate risk assessment and resilience planning should be prioritised for heritage professionals.
7. Advocacy, visibility and strategic communication should be strengthened to position cultural heritage as a vital component of Europe's resilience and innovation agenda.
8. Policy guidance and tools should be developed to support integration of heritage considerations into sectoral regulations.

1. Introduction

Cultural Heritage (CH) plays a fundamental role in shaping European identity, supporting economic development, and enhancing societal well-being. Heritage assets, ranging from notable landmarks and lesser-known archaeological sites to large cultural landscapes, represent collective history and contribute significantly to the preservation and distribution of local traditions. In today's rapidly evolving technological landscape, however, they face unprecedented risks from climate change and related societal pressures, turning their protection and management into an increasingly complex challenge.

The **Green Cluster** on Cultural Heritage was created with the aim to bring together projects working at the intersection of **cultural heritage and climate resilience**[1]. Resilience here is referring to the capacity of Cultural Heritage systems, including sites, communities and governance structures, to anticipate, withstand, adapt to and recover from slow-onset stresses and sudden onset threats, while preserving their cultural significance[2]. The cluster fosters exchanges among participating projects, recognising that solutions require both technological innovation and societal engagement.

Following regular exchanges in multiple formats, ranging from the in situ **Green CH Cluster kick-off meeting in Athens (December 2023)**, through **dedicated meetings at the European Geosciences Union General Assembly 2024 and 2025 (EGU24, EGU25)**, to **regular online discussions**, representatives of TRIQUETRA, THETIDA, STECCI, and RescueME have identified common challenges and opportunities. Discussions focused on three interlinked topics:

- **Technology:** Emerging and disruptive tools, integration across scales, and barriers to adoption.
- **Society:** Citizen science, living labs, and the co-production of knowledge.

[1] Gerakis, A., Hemmelskamp, J., Kowalczyk-Kedziora, I., and Vyzika, M.: The Green Cluster of Cultural Heritage: Climate Effects Team EU funded projects , EGU General Assembly 2024, Vienna, Austria, 14–19 Apr 2024, EGU24-17228, https://doi.org/10.5194/egusphere-egu24-17228, 2024.

[2] *EUR-LEX - 52021DC0082 - EN - EUR-LEX*. (2021). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:52021DC0082

- **Policy:** The positioning of cultural heritage in EU, national and regional frameworks and the debate on its recognition as critical infrastructure.

This White Paper consolidates those insights into a coherent narrative, aiming to **inform policymakers, guide practitioners, and inspire further collaboration**, ensuring that cultural heritage management is prioritised within the broader European Green Deal as well as climate adaptation and disaster risk management agendas.

2. Cultural Heritage & Climate Change – The Urgency

Across Europe, CH assets are increasingly exposed to the combined pressures of **climate change, environmental degradation,** and **human activity**. Climate change is not a distant scenario -in fact, it is already altering the conditions under which heritage sites exist. As per UNESCO[3], 60% of World Heritage properties in the Mediterranean region have already reported risks such as coastal flooding and erosion, resulting from sea-level rise, while 70% are located in urban areas, rendering them vulnerable to the unrelenting pressures of urbanisation and climate change. At the same time, 60% of World Heritage forests and marine sites are threatened by human pressures and climate-related hazards like wildfires, floods and cyclones. These observations are also supported by recent studies showing that 73% of World Heritage Sites are highly exposed to water-related hazards, and that significant proportions of cultural heritage in Europe are already being damaged by wildfires and other climate-driven hazards[4].

It is important to stress that these **hazards are not abstract**: they are already impacting monuments, archaeological sites, and landscapes, placing CH in the most fragile position yet. The cumulative effect is the **continuous endangerment or even loss of tangible and intangible heritage**, with cascading impacts on identity, economy, and resilience. In fact, 1/6 of cultural heritage properties are under threat from climate change externalities, while 1/3 of the World Heritage

[3,4] UNESCO World Heritage Centre. *Climate Change and World Heritage.* https://whc.unesco.org/en/climatechange/

cities are located in coastal areas, which makes them increasingly at risk from coastal hazards due to sea-level rise[5].

Despite the necessity of robust investment in security and defence, evidenced by the allocation of approximately €343 billion by EU Member States in 2024 (about 1.9% of EU GDP)[6], there remains a **pressing need to ensure that cultural heritage receives adequate funding and policy attention.** General government spending on all forms of culture and media, including cultural heritage, amounted to around €81.1 billion in 2023, just 1% of all government expenditure[7]. At the same time, Horizon Europe and related programmes, EU funding and policy frameworks continue to emphasise competitiveness[8]. While these figures highlight the strategic priorities of the EU, they also underline the relative scarcity of resources dedicated to safeguarding cultural heritage, which continues to face mounting threats from climate change, environmental degradation, and human activity. This is particularly concerning, as cultural heritage is not only a cornerstone of tourism - employing over 11.2 million people in 2021 and contributing nearly 4.5% of EU gross value added (~€572 billion)[9,10] - but also plays a vital role in fostering societal resilience. In times when communities and societies are increasingly under pressure from various threats, the protection and sustainable management of cultural heritage assets strengthen social cohesion, identity, and the capacity to recover from crises. Therefore, increased support for cultural heritage is an investment in Europe's long-term resilience and well-being. The CH sector also fosters innovation, taking into account that many new technologies in imaging

[5] UNESCO World Heritage Centre. *Nearly Three-Quarters of World Heritage Sites Are at High Risk from Water-Related Hazards*. https://whc.unesco.org/en/news/2788.
[6] European Council, EU defence in numbers. https://www.consilium.europa.eu/en/policies/defence-numbers/
[7] Eurostat (2025), Government expenditure on cultural, broadcasting and publishing services. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Government_expenditure_on_cultural,_broadcasting_and_publishing_services
[8] European Commission: Directorate-General for Research and Innovation, Horizon Europe strategic plan 2025-2027 analysis, Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2777/637816
[9] Eurostat (2024). Tourism industries – employment. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Tourism_industries_-_employment
[10] Eurostat (2025). Tourism statistics. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Tourism_statistics

and remote sensing are first pioneered in CH contexts[11], yet heritage management.

Evidence from the Green CH Cluster projects demonstrates the urgency:

- Today, European **coastal cultural landscapes** are most threatened by river floods, landslides, and wildfires; by 2071–2100, coastal floods and heatwaves emerge as the most urgent, pan-European risks, driven by exposure/sensitivity (coasts) and vulnerability/exposure (heat), requiring fast-tracked measures in land-use planning, protection standards, early warning/health protection, and governance capacity.[12]
- **Urban monuments** are deteriorating faster due to air pollution and over-tourism.
- **Underwater sites** remain largely invisible and difficult to monitor, which makes them even more susceptible to both natural and anthropogenic stressors.

If Europe does not respond swiftly, the resulting **losses will be permanent**. Once cultural heritage is gone, it cannot truly be restored; while copies may be created, the unique authenticity and historical significance of the original are lost forever. Safeguarding cultural heritage is not a luxury, it's a vital investment in Europe's sustainability, social cohesion, and collective future. Therefore, the Green CH Cluster calls for cultural heritage to be recognised as a strategic, standalone priority for resilience.

3. Policy Context

Cultural heritage lies at the crossroads of several EU strategies and policy frameworks.

[11] Cigna, F., Balz, T., Tapete, D., Caspari, G., Fu, B., Abballe, M., & Jiang, H. (2023). Exploiting satellite SAR for archaeological prospection and heritage site protection. Geo-Spatial Information Science, 27(3), 526–551. https://doi.org/10.1080/10095020.2023.2223603

[12] Klose, A., Abajo, B., Salpina, D., Durrant, L. (2024). RescueME D1.3 Policy Report on Climate Change Impacts on European Coastal Landes. HE RescueME, GA no. 101094978. https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e509c6cd9e&appId=PPGMS

At the highest level, the **European Green Deal**[13], approved in 2020, is a set of policy initiatives by the European Commission with the overarching aim of making the EU climate neutral by 2050. While heritage is not always explicitly referenced, its protection is embedded in the Green Deal's objectives of sustainable growth, environment stewardship, and cultural sustainability. Simultaneously, the **EU Adaptation Strategy**[14], adopted in 2021, is about helping the EU to become climate resilient. It clearly calls for safeguarding CH against climate hazards as a component of building resilience across societies.

The New European Bauhaus (NEB) [15] is a policy and funding initiative designed to make the green transition in built environments, and beyond, not only accessible, but also appealing and practical for everyone. Within the NEB framework, cultural heritage is repositioned as a central and proactive force in both the green and digital transitions. The initiative explicitly connects cultural heritage with sustainable design principles, social inclusion, and the advancement of digital technologies, highlighting its vital role in shaping a more sustainable and equitable future.

In addition, the **EU Intergenerational Fairness Strategy**[16] recognises cultural heritage as a fundamental asset to be passed on to future generations, viewing it not merely as cultural capital, but also as an essential facet of social equity, shared prosperity, and justice. This perspective aligns closely with the aims of the New European Bauhaus. Together, these strategies underscore the importance of safeguarding heritage as a matter of both environmental responsibility and intergenerational justice.

In contrast to the strategic emphasis outlined in the previous three paragraphs, where cultural heritage is increasingly recognised as central to Europe's resilience and sustainability, other sectoral policies, such as the **Energy Performance of Buildings Directive (EPBD)**[17], directly affect the historic housing stock through

[13] The European Green Deal. (2020). European Commission. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en
[14] EU Adaptation Strategy. (2021). Climate Action. https://climate.ec.europa.eu/eu-action/adaptation-and-resilience-climate-change/eu-adaptation-strategy_en
[15] *New European Bauhaus: beautiful, sustainable, together.* (2020). New European Bauhaus. https://new-european-bauhaus.europa.eu/index_en
[16] *Intergenerational fairness*. (n.d.). Citizens' Engagement Platform. https://citizens.ec.europa.eu/intergenerational-fairness_en
[17] *Energy Performance of Buildings Directive*. (2023). Energy. https://energy.ec.europa.eu/topics/energy-efficiency/energy-performance-buildings/energy-performance-buildings-directive_en

ambitious renovation targets. While these policies sometimes generate tensions, they also open up significant opportunities. The EPBD, for instance, encourages adaptive re-use and greater multi-functionality of heritage buildings, assets already renowned for their enduring construction and inherent resilience. When managed sensitively, such initiatives can foster sustainable conservation practices and demonstrate how heritage spaces can continue to serve evolving community needs. However, the pressure to meet modern energy standards can occasionally result in interventions that threaten the authenticity and integrity of these sites, potentially compromising unique features and traditional craftsmanship that define their cultural value and sense of place.

Similarly, the **Affordable Housing Initiative**[18], with its aim to at least double renovation rates across the EU by 2030, brings both promise and risk. By focusing on removing barriers to energy- and resource-efficient refurbishment and promoting reuse and recycling, these priorities can enhance the resilience and longevity of historic housing, supporting broader goals of urban sustainability and social cohesion. Nevertheless, the drive for rapid, widespread renovation, especially in densely built-up urban contexts, may inadvertently endanger the very heritage that underpins local identity and historical continuity. Insensitive interventions or wholesale replacement of historic fabric could undermine the cultural and historical significance of these buildings and neighbourhoods. A balanced approach, therefore, is essential: one that recognises the resilience and adaptive potential inherent in heritage, while ensuring that modernisation efforts do not erode the unique character and living legacy that cultural heritage offers to Europe's sustainable future.

On the research and innovation front, the **ARCHE (Alliance for Research on Cultural Heritage in Europe) Strategic Research and Innovation Agenda (SRIA)**[19] serves not only as a guiding framework but as a rallying point for embedding the resilience and adaptive capacity intrinsic to cultural heritage at the heart of European policy. The SRIA translates ARCHE's long-term vision into actionable roadmaps with measurable objectives, underscoring the necessity of stronger alignment between heritage research and EU missions to fully harness heritage's

[18] Affordable housing initiative. (2020). Internal Market, Industry, Entrepreneurship and SMEs. https://single-market-economy.ec.europa.eu/sectors/proximity-and-social-economy/social-economy-eu/affordable-housing-initiative_en

[19] Heritage Research Hub. (2025, September 8). Strategic Research and Innovation Agenda | Heritage Research Hub. https://www.heritageresearch-hub.eu/arche-home/sria/

potential for climate resilience. The **OMC Expert Group on Cultural Heritage**[20] , active between 2021 and 2022, echoed this imperative, stressing the need for the integration of heritage into disaster resilience, sustainable development, and digital strategies. However, realising this vision demands better data, as well as **integrated, trans-disciplinary, and inclusive** approaches ensuring that insights and solutions are drawn from across sectors and communities. The **European Collaborative Cloud for Cultural Heritage (ECCCH)**[21] stands out as a forward-looking initiative, offering the digital infrastructure needed to connect cultural heritage institutions and professionals across the EU. By addressing fragmentation in data infrastructures, the ECCCH paves the way for a future in which heritage's resilience and adaptability are supported by robust, accessible, and interoperable resources, enabling a truly joined-up and inclusive response to Europe's evolving challenges.

These policy frameworks combined demonstrate that CH is not a standalone sector but cross-sectoral asset in direct dialogue with climate, energy, housing, research, technology and intergenerational equity.

4.Technological Challenges & Opportunities

Technological innovation offers a plethora of opportunities for safeguarding cultural heritage. The Green Cultural Heritage Cluster brings together diverse tools and methods, ranging from high-resolution satellite imaging and hyperspectral sensors to IoT devices, novel coatings, and participatory digital platforms, decisively contributing to the way risks are identified, quantified, and mitigated. Nevertheless, these opportunities come with significant challenges involving scaling, accessibility, interoperability, and sustainability.

Multi-scale modelling remains a demanding task: local measurements at the millimetre or centimetre level, which provide detailed data regarding the structure, need to be combined with broad climate projections. Likewise,

[20] Strengthening cultural heritage resilience for climate change – Where the European Green Deal meets cultural heritage, Publications Office of the European Union, 2022, https://data.europa.eu/doi/10.2766/44688

[21] *The cultural Heritage cloud*. (2023). Research and Innovation. https://research-and-innovation.ec.europa.eu/research-area/social-sciences-and-humanities/cultural-heritage-and-cultural-and-creative-industries-ccis/cultural-heritage-cloud_en

balancing **short-term forecasting** with **long-term climate projections** is vital for both immediate and strategic responses.

Another challenge lies in addressing **multi-hazard scenarios**. CH sites are rarely threatened by a single hazard, therefore developing models that capture these compound risks is increasingly necessary, however technically demanding it may be.

Emerging and disruptive technologies present both challenges and opportunities for cultural heritage. Innovations adapted from other sectors, such as hyperspectral sensors, flash imaging LiDAR, sonar originally designed for fisheries, and mobile 3D scanning, demonstrate the **benefits of interdisciplinary collaboration**. For example, sonar technology from the fishing industry can be repurposed to monitor seabed stability at underwater heritage sites, while medical-grade underwater flashlights enable monitoring in low-visibility environments. However, the high cost of these advanced tools remains a significant barrier, particularly for heritage institutions operating under tight budgets, further widening inequalities across the sector.

Artificial intelligence (AI) and high-performance computing (HPC) are essential for handling complex datasets, yet access to HPC is often prioritised for other sectors such as aerospace or medicine, while CH is not explicitly listed among primary sectors[22]. Streamlining access to this type of resources is crucial to scale up risk assessment and predictive modelling, e.g. through the detection of patterns of deterioration or the automation of classification of risk indicators. The **ECCCH** recognises this need by aiming to provide heritage stakeholders with access to advanced computing resources and interoperable digital infrastructures.

Despite technological potential, large parts of Europe's CH remain **undigitised**, limiting opportunities for the transmission of heritage, as well as monitoring and conservation. Adding to the problem, in many cases, municipalities and managing authorities often lack the expertise, resources or staff to undertake documentation and digitisation campaigns, while funded projects usually produce isolated datasets that are not easily shared or reused outside of the project cycle. To overcome this, the Green CH Cluster highlights the importance

[22] *High performance computing*. (2021). Shaping Europe's Digital Future. https://digital-strategy.ec.europa.eu/en/policies/high-performance-computing

of **standardised repositories** and data-sharing frameworks to close these gaps, making datasets easily accessible across projects, countries and relevant authorities. This aligns with the broader **European Open Science Cloud (EOSC)** and **ECCCH** vision for FAIR (Findable, Accessible, Interoperable, Reusable) data.

5. Societal Challenges & Community Engagement

Co-creation stands at the heart of safeguarding cultural heritage, ensuring that interventions are not only technically sound but also deeply rooted in the communities they aim to benefit. **Living Lab approaches** exemplify this principle by fostering collaborative spaces where citizens, heritage professionals, and policymakers work side by side. These environments encourage the **co-design of solutions**, blending expert insight with local priorities and lived experience. Approaches such as co-creation **impact chains** empower participants to jointly trace the links from hazard to risk, clarifying how environmental or societal pressures translate into tangible challenges for heritage. Likewise, the use of **serious tabletop gaming** provides an engaging, hands-on format for communities and stakeholders to collaboratively design strategies, test responses, and build shared understanding of both risks and opportunities.

Inclusive engagement is essential for cultural heritage management. It is crucial to ensure that women, marginalised groups, and representatives from all generations have a voice, fostering a diversity of perspectives and fostering intergenerational dialogue. **Training and education across all ages and backgrounds** are vital to build capacity and cultivate a sense of stewardship. Initiatives should be accessible, using clear language and participatory formats, from school outreach programmes to community fairs and professional development workshops. Digital tools such as **chatbots and crowdsourcing** platforms can further broaden participation, making it easier for individuals to contribute with local knowledge, report risks, and engage in ongoing dialogue regardless of their experience or professional status.

Societal challenges, such as over-tourism, the loss of traditional knowledge, the commodification of culture, and the difficult choices around which heritage to prioritise, require thoughtful, community-driven responses. Over-tourism, in particular, is increasingly recognised by local communities, local authorities and

heritage professionals alike as a pressing issue. Participatory approaches **empower those most affected** to advocate for sustainable visitor management and to balance economic realities with the need to protect fragile sites. Equally important is **recognising the value of intangible heritage** and the voices of those who sustain it day to day.

Ultimately, empowering communities to define, use, and transmit their heritage on their own terms is fundamental to long-term resilience. By embedding co-creation, inclusive engagement, and innovative tools at every stage, we not only enhance the effectiveness of technological and policy interventions but also honour the collective responsibility of safeguarding cultural heritage for present and future generations.

6.Sustainability & Future of Outcomes

One of the main challenges for CH monitoring, protection and innovation is the short duration of most EU-funded projects (typically three years), especially compared to the **long-term nature of heritage risks**. This mismatch creates a major pitfall that valuable results will remain isolated or unexploited once funding ends, undermining their long-term impact.

A blended funding model is already emerging, in which sustainability is supported jointly by multiple sources: EU, national, regional and private contributions. This distribution reflects a shared responsibility, ensuring that CH protection is not dependent on a single funding source. However, this model, and many other emerging financing and business approaches used for cultural heritage and landscape financing (e.g., impact funding, social entrepreneurship), demands greater commitment from governments, both national and at the EU level, which unfortunately, currently is not the case[23]. In fact, most EU Member States lack dedicated strategies for addressing climate risks to CH and existing interventions remain fragmented[24,25]. Governments need to recognise CH as a strategic priority

[23] Salpina, D., Casartelli, V., Marengo, A., Mysiak, J. (2025). Financing strategies for the resilience of cultural landscapes. Lessons learned from a systematic literature and practice review. Cities, 162(105922). https://doi.org/10.1016/j.cities.2025.105922

[24] Cultural heritage is threatened by climate change but has sustainable solutions to fight it. (2023, May 3). Culture and Creativity. https://culture.ec.europa.eu/news/cultural-heritage-is-threatened-by-climate-change-but-has-sustainable-solutions-to-fight-it

[25] The impact of climate change on cultural heritage | Think Tank | European Parliament. (2024). https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2024)762282

for climate resilience and consider the many ways in which CH is interconnected with the advancement of numerous sectors.

Sustainability also depends on the ability to transfer and reuse results beyond individual projects. **Standardisation, data protocols,** and **knowledge transfer** among projects, but also among authorities are essential. For this reason, tools must be interoperable, thoroughly documented, and adaptable across regions. Standardisation is a long-term challenge. One possible solution is for the European Commission to require transfer of research outputs into central services if they are not exploited within a set timeframe, ensuring that valuable results remain accessible and usable beyond project lifespans.

The Green CH Cluster initiative itself shows the value of continuity and ongoing dialogue. For example, the EU R&I Task Force on Climate-neutral and Resilient Historic Urban Districts was established by ARCH, SHELTER, and HYPERION, the predecessor projects of the current Green CH Cluster, and now numerous partners involved in this initiative are part of TRIQUETRA, THETIDA, and RescueME[26,27].

Surely, long-term sustainability depends on both institutional and community level continuity. Embedding project outcomes in EU, national, regional and even local policy frameworks ensures that they become part of official strategies. Concurrently, maintaining collaborative initiatives such as the Green CH Cluster provides a platform for meaningful exchange, building a cumulative ecosystem of experts. Thus, the Green CH Cluster recommends that the **Research Executive Agency (REA)** provides mechanisms ensuring continuity, if not among project consortia, then along clusters and/or task forces.

[26] Lückerath, D., et al. : EU R&I Task Force for Climate Neutral and Resilient Historic Urban Districts Paving the Way for Climate Neutral and Resilient Historic Districts. https://savingculturalheritage.eu/fileadmin/user_upload/Publications/JointPaper_EUTASKFORCE_revSept.pdf

[27] Peinhardt, K., Garzillo, C., Lückerath, D., Egusquiza, A., Michalis, P., and Istrati, D.: The EU R&I Task Force for Climate Neutral and Resilient Historic Areas, EGU General Assembly 2024, Vienna, Austria, 14–19 Apr 2024, EGU24-20296, https://doi.org/10.5194/egusphere-egu24-20296, 2024.

7. Rethinking the Framing of Cultural Heritage in Resilience Policies

In the current climate of uncertainty and conflict across the globe, it is vital to reconsider the status and value of cultural heritage (CH) within our societies. While CH in Europe is often appreciated as a touristic asset or a marker of civilisation, its importance extends far beyond these roles. The loss of CH carries consequences that are not merely symbolic; as discussed earlier in this White Paper, CH underpins local and national economies, sustains social cohesion, and provides communities with a sense of continuity and identity.

Cultural heritage should be recognised for its distinct societal relevance as a cornerstone of resilience, identity and cohesion. Its role extends across multiple domains (including climate adaptation, disaster risk management, sustainable development, digital transformation, and social innovation) positioning it as a key enabler within the EU's broader resilience and transformation agendas. This framing acknowledges that CH, from iconic landmarks to local traditions and practices, contributes to economic vitality, community well-being, and the long-term sustainability of Europe's cultural and natural landscapes.

Cultural heritage serves as a central pillar within the social-ecological systems that define communities, cities, landscapes, and regions. Its presence supports employment, sustains livelihoods, and strengthens the resilience of societies in the face of change. Everyday heritage, cherished and maintained by local communities, is just as essential as world-famous sites in anchoring identity, promoting well-being, and fostering stewardship across generations.

Recognising the significance of CH would facilitate access to funding streams, enable the integration of robust risk assessment frameworks, and normalise cross-sectoral cooperation among cultural, environmental, security, and civil protection authorities. Such an approach acknowledges the interconnectedness of cultural heritage with the broader social, economic, and ecological systems, ensuring that both globally recognised landmarks and local heritage assets receive the protection and investment they deserve.

8. The Way Forward for Cultural Heritage: Roadmap & Policy Recommendations

Safeguarding cultural heritage in the face of accelerating climate change requires a strategic, multi-dimensional approach, one that unites technological innovation, societal engagement, sustainable funding, and robust policy frameworks. The Green CH Cluster proposes a comprehensive roadmap to ensure that cultural heritage not only survives but thrives as a central pillar of Europe's climate resilience and sustainable development.

Accelerating Technology Access and Capacity Building

The integration of advanced technologies, such as multi-scale modelling, AI-driven analysis, and novel sensing approaches, has the potential to transform risk identification and mitigation for cultural heritage. However, barriers persist, particularly for heritage practitioners who often lack access to these tools and the expertise to apply them effectively. To address this, we recommend the **establishment of a European Technology Access Programme**, dedicated to providing training, practical toolkits, and ongoing support for heritage managers. **Technology transfer** from sectors such as defence, aerospace, and medicine should be actively promoted, with **targeted funding** for pilot projects and demonstration sites. Practitioner-friendly guidance and case studies must be developed to facilitate the adoption and understanding of new technologies in everyday heritage management.

Advancing Data Standardisation and Interoperability

The long-term impact of heritage research and innovation depends on the ability to share, reuse, and build upon project results. We call for the **mandatory adoption of common data standards and protocols** across all EU-funded heritage projects, ensuring that outputs are FAIR (Findable, Accessible, Interoperable, and Reusable). A **centralised repository**, linked to initiatives such as the European Collaborative Cloud for Cultural Heritage (ECCCH), the European Open Science Cloud (EOSC), and the Destination Earth (DestinE) programme, should be established to host heritage data and tools. Mechanisms must be put in place to **transfer unexploited research outputs** to Commission-managed platforms after project completion, guaranteeing that valuable results remain accessible and usable beyond individual project lifespans.

Institutionalising Societal Engagement and Co-Creation

Inclusive engagement and co-creation are essential for effective and sustainable cultural heritage management. **Living Labs and co-creation practices** should be scaled up and embedded in EU and national funding calls, with clear requirements for broad stakeholder participation. **Frameworks for risk-based prioritisation** must be developed, enabling communities to make informed decisions about which heritage assets to protect and how to communicate difficult choices. **Representation of marginalised groups, women, and all generations** should be ensured in decision-making processes, supported by **targeted outreach and education programmes** that foster stewardship and intergenerational dialogue.

Ensuring Long-Term Sustainability and Continuity

The mismatch between short project cycles and the enduring nature of heritage risks undermines the sustainability of outcomes. We advocate for **blended funding models** that combine EU, national, private, and philanthropic contributions, with incentives for **innovative financing** such as public–private partnerships and impact funding. Recent policy analysis (RescueME Policy Brief, 2025)[28] underscores the importance of robust institutional and regulatory support to unlock such opportunities, strengthen stakeholder capacities, and ensure strategic planning for sectoral policy alignment and transparent mapping of allocated and potential funds. **Strategic planning for sustainability** should be a requirement in all heritage projects, including provisions for post-project maintenance, knowledge transfer, and policy integration. The Research Executive Agency (REA) should establish **mechanisms to support the continuity of successful initiatives**, clusters, and task forces beyond the lifespan of individual projects, ensuring that expertise and momentum are not lost.

Embedding Cultural Heritage in Sectoral Policies

Cultural heritage must be explicitly recognised and integrated into climate adaptation, disaster risk management, energy, housing, and research policies at all levels of governance. Policy briefs and guidance should be developed to facilitate the inclusion of heritage considerations in sectoral regulations, such as

[28] Salpina, D., Casartelli, V. M., Marengo, A., & Mysiak, J. (2025). Innovative ways to finance the resilience of the cultural landscape. Zenodo. https://doi.org/10.5281/zenodo.14899416

the Energy Performance of Buildings Directive and the Affordable Housing Initiative, balancing the need for conservation with the imperatives of modernisation and sustainability.

Strengthening Policy Advocacy, Visibility, and Branding

Effective protection of cultural heritage requires strong advocacy and enhanced visibility. **Joint campaigns** coordinated through Communities of Practice and networks such as the Heritage Research Hub[29] can amplify the voice of cultural heritage in European policy debates, facilitate knowledge exchange, and foster cross-sectoral collaboration. **The role of heritage in resilience** should be highlighted through strategic branding, communication, and public engagement, leveraging project achievements and success stories.

Recent research, such as Nicu et al. (2025)[30], underscores the importance of **risk-based prioritisation, long-term monitoring, integrated data systems, adaptive legislation, and strengthened institutional capacity.** Their recommendations, developed for Arctic cultural heritage but broadly applicable, provide a transferable framework for policy and governance reforms that can guide resilience planning well beyond the Arctic context. Risk-based prioritisation and adaptive legislation, informed by such frameworks, should guide resilience planning and governance reforms across Europe.

Investing in Education, Training, and Capacity Building

Finally, the long-term resilience of cultural heritage depends on the capacity of professionals, policymakers, and communities to respond to evolving challenges. **Targeted education and outreach programmes** should be launched, focusing on climate risks, technology adoption, and stewardship. Professional development opportunities, including workshops, online courses, and peer learning, must be supported to ensure that all stakeholders are equipped with the knowledge and skills needed for effective heritage management.

Conclusion

[29] Heritage Research Hub. (2025a, August 5). Heritage Research Hub - Join the researcher community. https://www.heritageresearch-hub.eu/

[30] Nicu, I. C., Guzman, P., & Stoleriu, C. C. (2025). Unfreezing the past: near Pan-Svalbard assessment of cryospheric hazards to Arctic cultural heritage. *The Science of the Total Environment*, *1000*, 180424. https://doi.org/10.1016/j.scitotenv.2025.180424

By pursuing these interconnected priorities, Europe can ensure that cultural heritage is not left behind in the transition towards climate resilience. Instead, heritage will lead the way serving as a source of identity, cohesion, and innovation for a sustainable and inclusive future.

9. Achievements and Impact of Green CH Cluster Projects

Conclusively, it is worth briefly mentioning some of the innovations and tangible impacts of the Green CH Cluster.

TRIQUETRA, through its three-pillar approach of risk identification, quantification and mitigation, has deployed **novel tools**, such as a flash LiDAR sensor enabling 3D mapping in low visibility conditions for underwater sites and an in-situ water-quality analyser for continuous, real-time monitoring at underwater sites. Moreover, innovative protective coatings designed to enhance durability of materials against environmental stressors have been developed and tested. All the above are combined with thorough **risk assessment** studies for multiple categories of hazards, such as climate-related hazards, extreme water, snow and ice hazards, geological and geophysical hazards, as well as chemical and biological hazards. The studies carried out within the project are supported by a bibliographic repository, a WebGIS platform, and a **Decision Support System**, hosting a risk assessment module and a mitigation measure proposal module. What is also worth mentioning is that active citizen engagement has been achieved through the launch of the TRIQUETRA **AR Application**, which is based on crowdsourcing activities, as well as through the organising of workshops with local communities[31].

THETIDA protects Europe's coastal and underwater cultural heritage through a cutting-edge, multi-hazard risk management approach[32]. By integrating satellite, aerial, ground and innovative underwater monitoring technologies[33] — including smart buoys, Autonomous Underwater Vehicles (AUVs), side-scan sonar, subsea

[31] Ioannidis, C., Verykokou, S., Soile, S., Istrati, D., Spyrakos, C., Sarris, A., Akritidis, D., Feidas, H., Georgoulias, A. K., Tringa, E., Zanis, P., Georgiadis, C., Martino, S., Feliziani, F., Marmoni, G. M., Cerra, D., Ottinger, M., Bachofer, F., Anastasiou, A., ... Anyfantis, G. C. (2024). Safeguarding Our Heritage - The TRIQUETRA Project Approach. Heritage, 7(2), 758-793. https://doi.org/10.3390/heritage7020037

[32] P. Michalis *et al.*, "THETIDA: Enhanced Resilience and Sustainable Preservation of Underwater and Coastal Cultural Heritage," *IGARSS 2024 - 2024 IEEE International Geoscience and Remote Sensing Symposium*, Athens, Greece, 2024, pp. 2208-2211, doi: 10.1109/IGARSS53475.2024.10642229.

[33] L. Pavlopoulos, P. Michalis, M. Vlachos, A. Georgakopoulos, C. Tsiakos and A. Amditis, "Integrated Sensing Solutions for Monitoring Heritage Risks," *IGARSS 2024 - 2024 IEEE International Geoscience and Remote Sensing Symposium*, Athens, Greece, 2024, pp. 3352-3355, doi: 10.1109/IGARSS53475.2024.10641101.

LiDAR, and multispectral/hyperspectral imaging — with citizen science and participatory Living Labs, THETIDA delivers high-resolution environmental data and predictive modelling for underwater and coastal heritage sites. The decision support system (DSS) synthesizes these datasets to simulate damage scenarios, assess vulnerability, and guide proactive conservation strategies. Beyond technology, THETIDA actively engages communities through co-creation processes[34], AR/VR applications and mobile applications, ensuring that local knowledge plays a key role risk assessment and mitigation efforts. Across seven pilot sites, the project demonstrates the effectiveness of combining innovation with societal participation to enhance resilience, safeguard heritage assets, and inform long-term policy and planning for climate adaptation and sustainable coastal development.

RescueME strengthens the resilience of European coastal and rural cultural landscapes through a participatory, data-driven approach that places co-creation at its core. Across **five Resilient Landscapes Laboratories**, local communities, experts, and decision-makers collaboratively develop actionable strategies for climate adaptation and disaster risk management. The project's innovative **serious game** serves as both a tool for strategy development and a platform for raising awareness, engaging stakeholders in scenario planning and the identification of effective resilience measures tailored to local needs. RescueME's suite of tools—including the **RescueME Atlas** for vulnerability mapping, **impact chains** for risk assessment, an **incremental spatial decision support system**, and a **meta-repository of solutions**—ensures that adaptation strategies are accessible, evidence-based, and informed by community input. Digital engagement is further enhanced through a **chatbot for crowdsourcing** local knowledge, while pioneering **financing methods** support the implementation of resilience solutions. By integrating advanced technologies such as **AR and AI** with inclusive workshops and knowledge co-production, RescueME empowers stakeholders to safeguard both tangible and intangible heritage for future generations.

[34] Ikiz, D., Guzman Molina, P. C., Katika, T., Veiga-Pires, C., Oliveira, S., Nicu, I. C., & Michalis, P. (2024). THETIDA – Living Labs for inclusive and innovative climate risk monitoring of cultural heritage. In *Proceedings of the OpenLivingLab Days Conference 2024: "Living Labs Frontiers" Driving systemic change through Soci(et)al Engagement, for real impact* (pp. 164-167). ENoLL - European Network of Living Labs. https://doi.org/10.5281/zenodo.14039412

STECCI advances climate-resilient conservation through the study of medieval limestone tombstones (*stećci*) and similar stone and dolomite monuments across Europe. By combining climate modelling under IPCC scenarios (SSP2-4.5 and SSP5-8.5) with material science, conservation, and socio-economic analysis, the project pioneers the first **Preservation Guidelines** for limestone heritage under future climate conditions. STECCI introduces a **low-cost 3D digitisation methodology** aligned with EU policy on endangered heritage, and integrates **economic instruments** to support decision-making in conservation planning. Through citizen science, creative placemaking, storytelling and other educational initiatives, it enhances public engagement, scientific literacy and awareness and fosters shared cultural values among communities in post-conflict regions. The project serves as an example of successful professional and personal cooperation between formerly war-torn nations, with a focus on local communities, and promotes shared cultural values as a means of reducing and preventing social and political radicalism.

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