COLLECTION CARE

Green Paper

On Multi-Material Preventive Conservation Guidelines

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the grant agreement No 814624

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Innovative and affordable service for the preventive conservation monitoring of individual cultural objects during display, storage, handling and transport

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Abbreviations & Acronyms

AES-CBC	Advanced Encryption Standard-Cipher Block Chaining
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BIM	Building Information Modelling
BMS	Building Management Systems
CBC	Conservazione Beni Culturali Società Cooperativa
CEN	European Committee for Standardisation
CH	Cultural Heritage
CIE	Commission Internationale de l'Éclairage
CR	Condition Report
DSS	Decision Support System
EN	European Norm
EU	European Union
ICOM-CC	International Council of Museum - Committee for Conservation
ICOMOS	International Council on Monuments and Sites
IPCC	International Panel on Climate Change
IT	Information Technologies
IoT	Internet of Things
JHI	Jerzy Haber Institute of Catalysis and Surface Chemistry
KADK	The Royal Danish Academy of Fine Arts
LSIWC	Latvian State Institute of Wood Chemistry
PAS	Publicly Available Specification
PC	Preventive Conservation
RH	Relative Humidity
T	Temperature
TC	Technical Committee
TR	Treatment Report
TS	Technical Specification
TU/e	Eindhoven University of Technology
UNESCO	United Nations Educational, Scientific and Cultural Organization
UPV	Polytechnic University of Valencia
URO1	Sapienza Università di Roma
UV	Ultraviolet radiation
UW	University of Warsaw
VIS	Visible radiation
WG	Working Group

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Foreword

The variety and richness of museum collections, including works of art in churches and historic residences, pose a challenge to those responsible for their preservation. Many countries are well aware of the importance of cultural heritage and invest in maintaining and making art collections safe and available. There is general agreement that the effective use of resources incorporates knowledge-based strategies, which consider the individual operational context of the collecting institutions (e.g., desire to increase collection access or object loans), their financial and organisational capabilities, and the sensitivity of collections to environmental conditions.

In practice, the development of effective preventive conservation strategies is an issue for both large well-financed institutions and, smaller local museums. Determining the appropriate indoor environments for a collection is complicated by incomplete knowledge of how the environment affects artefacts. Furthermore, factors such as the sophistication of air-conditioning systems, changing costs of energy, local climate and projected climate change and evolving access to collections complicate the assessment of risk and the decision-making process. Compounding the problem is the often-complicated nature of the decision-making process in museum institutions and the lack of shared responsibility among stakeholders, resulting in risk aversion and, consequently, minimal or no action.

The development of new or modified preventive conservation strategies for collections requires not only reliable scientific data on damage mechanisms, but also a practical assessment of the risks associated with the implementation or non-implementation of these strategies. To be effective, the decision-making process must be well-organised, and the roles and responsibilities of the participants must be clear. The stakeholders must understand and agree on the overarching goals of the institution and have access to knowledge, expertise and tools to assess the risks and benefits of individual decisions. There is also a need to facilitate effective communication between various professionals (conservators-restorers, registrars, engineers, scientists and others) with varying expertise on the topic of environmental management.

These issues were motivating factors for the EU-funded CollectionCare project, which aimed to develop a preventive conservation decision support system for cultural heritage institutions. While focusing primarily on the implementation of effective technological advancements, the project team also considered existing guidelines, models, and tools that reflect current EU policy trends in the practice of preventive conservation; these are critically reviewed in this Green Paper with a view to presenting current available sources and stimulate discussion. Additional topics addressed in this publication include risk assessment of climate-induced damage, inherent material degradation, the potential loss of value, and an evaluation of degradation models and the data collection methods used to inform these models. The latter is particularly useful for those reviewing data collection practices for the purpose of risk assessment. The presented Green Paper emphasises that understanding the rationale behind existing environmental guidance is a key step in appropriately evaluating collection risk, eventually resulting in shifting attitudes from risk aversion to risk management and more sustainable management of cultural heritage collections.

Dr. Michał Łukomski (Getty Conservation Institute) *
Dr. Marion F. Mecklenburg (Smithsonian Institution) *

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1. Introduction

Cultural Heritage (CH) assets - tangible, intangible and digital (ASHRAE, 2019) - represent fragile, non-renewable resources (Publications Office of the European Union, 2018), and any alteration of their integrity contributes to the loss of their inestimable value. In fact, CH is the legacy from our past, what we live with today and what we pass on to future generations (UNESCO, 2021). This richness is not just an asset that we have to preserve for its own sake, it also has the potential of creating added value for society in the form of economic growth, employment and social cohesion.

Nowadays, 350 UNESCO heritage sites (322 cultural, 23 natural, 5 mixed sites) inscribed in the UNESCO World Heritage list (UNESCO, 2021), are located within Europe. They correspond to 30% of all sites (1152), as shown in Figure 1. European cultural sites, distributed throughout the 27 EU member states (Figure 2), include museums, archives, libraries and galleries. They house a huge variety of cultural objects encompassing different types of material such as glass, metal, paper, stone, textile, or wood. This immeasurable cultural richness, in all its forms, makes Europe's cultural legacy unique worldwide.

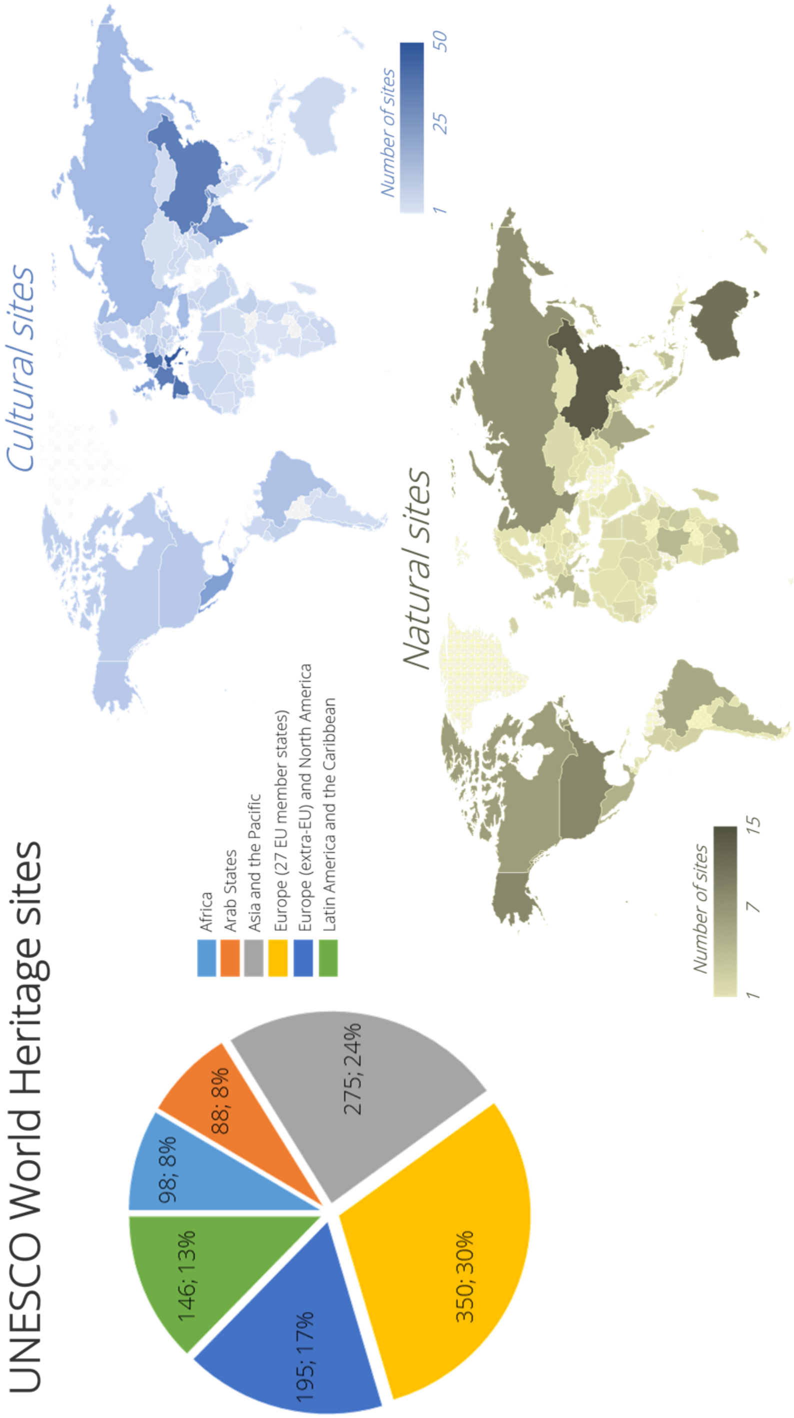

Figure 1. Geographical distribution of the UNESCO World Heritage sites (data extracted from UNESCO, 2021); map charts of cultural and natural sites (by Bing © DSAT for MSFT, GeoNames, Microsoft, Navteq, Thinkware Extract, Wikipedia)

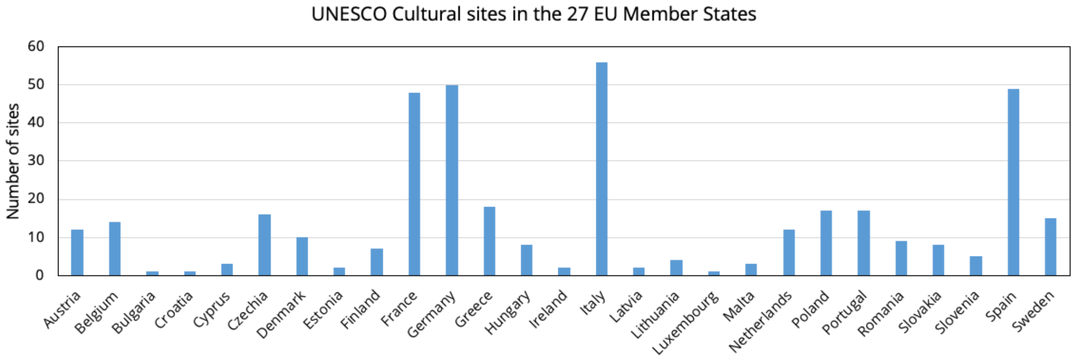

Figure 2. UNESCO cultural sites per each of the 27 EU Member States (data extracted from UNESCO, 2021). Sites belonging to more than one Member State are counted for each state

Cultural objects, studied as physical systems interacting with the environment, may undergo material responses (Figure 3). These ongoing interactions in addition to their natural ageing can be risky for the object itself, since they can lead to a progressive change in the rate of degradation or in the magnitude of risk damage.

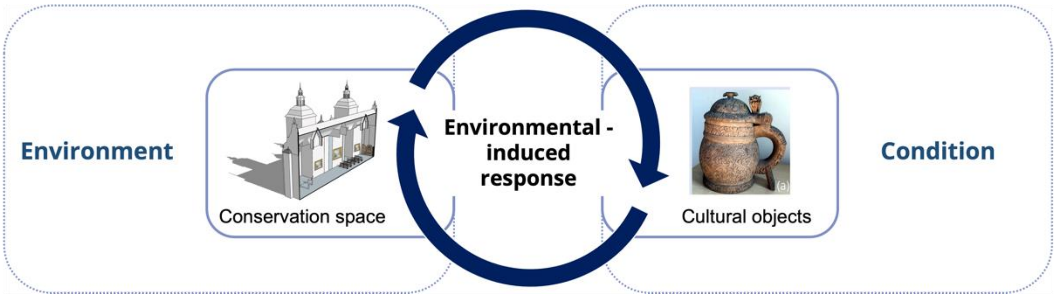

Figure 3. Interaction between the environment and cultural objects (condition stands for physical state of an object at a particular time). The detail in the Figure is one of the 40 objects selected in Rosenborg Castle (Copenhagen, Denmark), museum partner of the CollectionCare project.

The durability of cultural objects both exposed to the outdoor environment and housed in indoor spaces, depends on the vulnerability of the material type to specific stressors. These stressors act either independently or in synergy, leading to direct and indirect effects over a short and/or long-term time scale, and can trigger and/or accelerate the rate of material degradation.

The main risk agents are the environment, the expected climate change, the growing trend of cultural tourism, socio-economic pressures, inadequate conservation measures and management practices.

The **environment** (i.e., the ensemble of climatic conditions related to temperature, humidity and ventilation as well as light and pollution concentrations of surroundings of the object) is considered an agent of great importance for the CH preservation. The principal environment-induced risks affecting the durability of cultural objects include mechanical, chemical, biological deterioration and photodeterioration. Mechanical damage entails cracking material loss and permanent deformation, while the chemical damage includes hydrolysis, oxidation and corrosion; biological damage comprises insect infestation, mould germination, bacteria attack; the photodeterioration includes colour fading and discoloration.

Given the importance of the conservation and safeguarding of CH, since 1986 the European Commission has supported several projects both in the Framework Programmes (FPs) and H2020 Programme. They are devoted to the challenges posed by environmental and climate change impacts on CH and to increase their overall resilience (Chapius, 2009; Publications Office of the European Union, 2018).

"Climate Change" is expected to be responsible for the exacerbation of an unfavourable environment, which in turn could have an impact on CH conservation in the future. Indeed, climate projections provided by the Intergovernmental Panel on Climate Change (IPCC, 2021) encompass global warming with some regional differences. This represents a further potential threat as it could exacerbate the natural decay and/or contribute to the appearance of new deteriorations (Bertolin, 2019). The climate change impacts on cultural objects exposed to outdoor environment and in the interiors of buildings were tackled in the framework of dedicated European Union (EU) funded projects focused on evaluating risk scenarios in the near and far future over Europe and the Mediterranean basin: *Noah's Ark*[1] - *Global climate change impact on built heritage and cultural landscapes* (2004-2007); *Climate for Culture*[2] - *Damage risk assessment, economic impact and mitigation strategies for sustainable preservation of cultural heritage in times of Climate Change* (2009-2014);

[1] European Commission. CORDIS EU research result. *Global Climate Change Impact on Built Heritage and Cultural Landscapes*. Retrieved 17th June 2022. https://www.ucl.ac.uk/bartlett/heritage/research/projects/project-archive/noahs-ark-project

[2] European Commission. CORDIS EU research result. *Damage risk assessment, economic impact, and mitigation strategies for sustainable preservation of cultural heritage in the times of climate change*. Retrieved 17th June 2022. https://www.climateforculture.eu/

ProteCHt2save[3] - *Risk assessment and sustainable protection of cultural heritage in changing environment* (2020 - 2022). In recent years, a growing research interest has been devoted to the evaluation of climate change impacts on CH assets in order to identify mitigation and adaptation measures (Bertolin, 2019; Orr et al., 2021; Sesana et al., 2021). The results provided by experimental research, field practice, building, and climate simulation are pivotal to infer rational heritage management strategy and policies.

In 2021, *Europa Nostra* together with ICOMOS and Climate Heritage Network launched the European Cultural Heritage Green Paper. The document highlights the relevance of a sustainable management of CH for achieving the goals of the European Green Deal (Potts, 2021).

Preventive Conservation (PC) includes all measures and actions aimed at avoiding or minimising future damage, deterioration, loss and, consequently, any invasive intervention (EN 16893:2018). Nowadays, PC is considered as the most cost-effective approach for the preservation of indoor cultural objects (Michalski and Karsten, 2018).

Some changes in the material condition of an object (such as chemical degradation) are inherent and cannot be stopped, but they can be slowed down by careful consideration of the environmental conditions. Some changes like deformation can be reversible, and may be remedied by conservators-restorers, or they can be accepted as marks of time. Other irreversible changes such mechanical failure (cracks, tears, etc.) can be experienced if a moisture-sensitive object is exposed to, for example, a sudden drop in relative humidity in a short period of time. These changes are often possible to be avoided, but it requires knowledge about tolerance thresholds of an object, especially if the latter is made of heterogeneous materials. In order to manage risk and changes, it is necessary an ongoing debate among the experts about acceptable levels/types of damage and potential loss of value.

One of the main problems faced by the conservation community - conservation scientists, conservators-restorers, curators and other professionals involved in conservation activities – consists of identifying methods to assess the deterioration risk induced by environmental conditions and their variations on different materials of which cultural objects are composed. Part of this great challenge is that the conservation of each cultural object depends mainly on its material characteristics (including added conservation materials) and thus on its interaction and adaptation to the environmental conditions. Therefore, relying

[3] Interreg Central Europehttps. *Risk Mapping Tool for Cultural Heritage Protection*. Retrieved 17th June 2022. https://www.protecht2save-wgt.eu/

on general recommendations for the conservation of collections may not be the most applicable for their preservation. It is, however, possible to define timely and rational approaches for the mitigation of the deterioration risk based on knowledge of the deterioration mechanisms and the anticipation of their behaviour (Bertolin, 2019) and, in the case of different materials housed in the same exhibition space, to find balanced solutions to their conflicting conservation needs.
Several standards and guidelines for PC of the cultural objects provide environmental risk targets based on laboratory and field studies. Recent approaches consider the outputs from material degradation models to identify the range of indoor climate conditions that may be adequate for the object preservation. An overview of the current EU standards published by the European Committee for Standardisation (CEN) is described in Section 2.

A joint multidisciplinary effort, interconnecting expertise from material and environmental sciences and computer modelling, together with conservation condition reports, is pivotal to provide insights for an effective assessment of the environmental impact on cultural objects. This approach includes recording and analysing environmental data, the outputs from material degradation models, and the history of the conditions and of the past conservation treatments on the cultural objects. A wide-ranging understanding on the role of the environment in the deterioration risks supports the design of rational and sustainable mitigation strategies. In this context, the cooperation among different professionals and between professionals, stakeholders and the wider community, has a crucial role in managing all risks to CH collections and in properly choosing the conservative interventions.

CollectionCare[4] EU-funded project - *Innovative and affordable service for the Preventive Conservation monitoring of individual Cultural Artefacts during display, storage, handling and transport* – acknowledges the value and importance of the above topics through the development of an innovative PC decision support system targeting the needs of small to medium-sized museums and collections. The vibrant themes attracted the interest of an international audience of stakeholders (mainly conservation scientists, conservators-restorers, curators, museums, science and managers) at the final conference entitled *New Challenges in Preventive Conservation, Predictive Analysis and Environmental Monitoring* (December 1-3, 2021, Valencia, Spain).

[4] CollectionCare. *Innovative and affordable service for the Preventive Conservation monitoring of individual Cultural Artefacts during display, storage, handling and transport.* Retrieved 17th June 2022. www.collectioncare.eu

1.1 Purpose of the CollectionCare Green Paper

The purpose of this **Green Paper** is to encourage a **broad reflection on new approaches to Preventive Conservation (PC) of cultural objects** considering their materiality and condition and, to stimulate the discussion on environmental monitoring and conservation strategies at EU level.

With this perspective in mind, the CollectionCare project brings together the latest research outcomes and technological advances in monitoring systems, wireless communication, multi-material models and degradation knowledge, big data and cloud computing into a single system. This system is able to cover both the complexity of monitoring multiple climate parameters and degradation predictions to offer suitable recommendations for PC, all according to the specific needs of small to medium-sized museums and their collections.

The PC Decision Support System (PC-DSS) developed by the CollectionCare project targets the needs of small to medium-sized museums and collections (which represent approximately 40% of European museums). This PC-DSS, schematically shown in Figure 4, includes:

a) a single **IoT-based monitoring system** of the environment (temperature, relative humidity, light, vibration, air pollutants) surrounding each individual object at any place (either at exhibition, storage, handling or during transport, including emergency planning) comprising wireless communication, big data and cloud computing;
b) material and multi-material **degradation models** and degradation knowledge;
c) recommendations on environmental topics provided by the **EU norms** devoted to the conservation of CH.

This Green Paper does not aim to cover all the issues that may have an impact on PC approaches, but addresses some key thematic areas related to EU standards on environmental topics for the CH preservation, based on what was achieved in the CollectionCare project. The key issues proposed within the area of interest take advantage from useful insights provided by the tasks of the project and from the ongoing fruitful discussion among the partners involved with the aim of advocating a more harmonised approach to strengthen the way in which the shared European heritage is cared for.

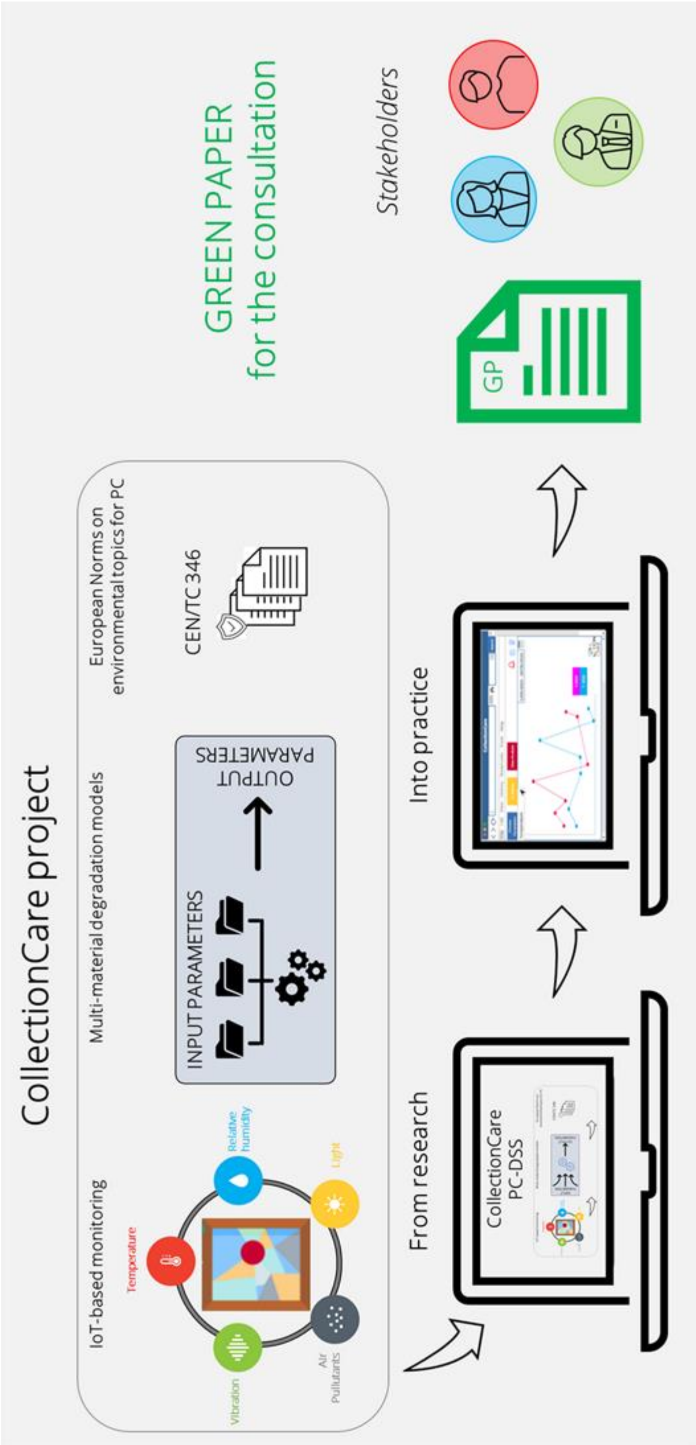

Figure 4. The CollectionCare project, from research into practice - the basis for the Green Paper

2. European Standards Concerning the Environmental Topics for Cultural Heritage

This section provides a synopsis on the current EU standards issued by the European Committee for Standardisation (CEN) in the field of Cultural Heritage related to the environment in line with the CollectionCare objectives.

The **Technical Committee CEN/TC 346**[5] established in 2002 is devoted to the conservation and restoration of CH with the aim of producing standards for professionals involved in this field. Specifically, the remit of the CEN/TC 346 is to establish standards for the characterization of materials, practice, methodologies and documentation of conservation of tangible CH to support its preservation, protection and maintenance and to enhance its significance (Fassina, 2015). This includes standardisation of the characterisation of deterioration processes and environmental conditions for CH and methods and technologies used for the planning and execution of conservation treatments. Figure 5 shows the timeline of the Working Groups (WGs) in producing the standards devoted to the environmental topics in the field of CH from 2002 to date. WG 4 issued three standards starting from 2010. Since that year, two additional WGs (WG 6 and WG7) have been involved in environmental topics and four standards and one technical specification were issued.

Table 1 shows the list of all the EU standards on the environmental topics issued by the CEN/TC 346. Although some EU standards are not strictly related to the key areas of the CollectionCare project, they are here reported for the sake of completeness. The norm EN 16095:2012 is included in this synopsis even if is not related to the environment, it is considered since one of the tasks of CollectionCare project is dedicated to the elaboration of condition reports on selected artworks housed in the partner museums.

The ten standards issued by CEN/346 have been divided into the three key areas of interest and, for each area, the key issues for public consultation are then proposed:

1. Methodologies, procedures, and instruments for accurate environmental measurements for cultural heritage;
2. Specifications to limit conditions that pose a risk to the environment-vulnerable materials of cultural objects;
3. Strategies for the management of spaces for preserving cultural objects.

[5] CEN. *CEN/TC 346 - Conservation of cultural property.* Retrieved 17th June 2022. https://standards.iteh.ai/catalog/tc/cen/782ad083-d5d4-4d4f-ac6d-36572d262c15/cen-tc-346

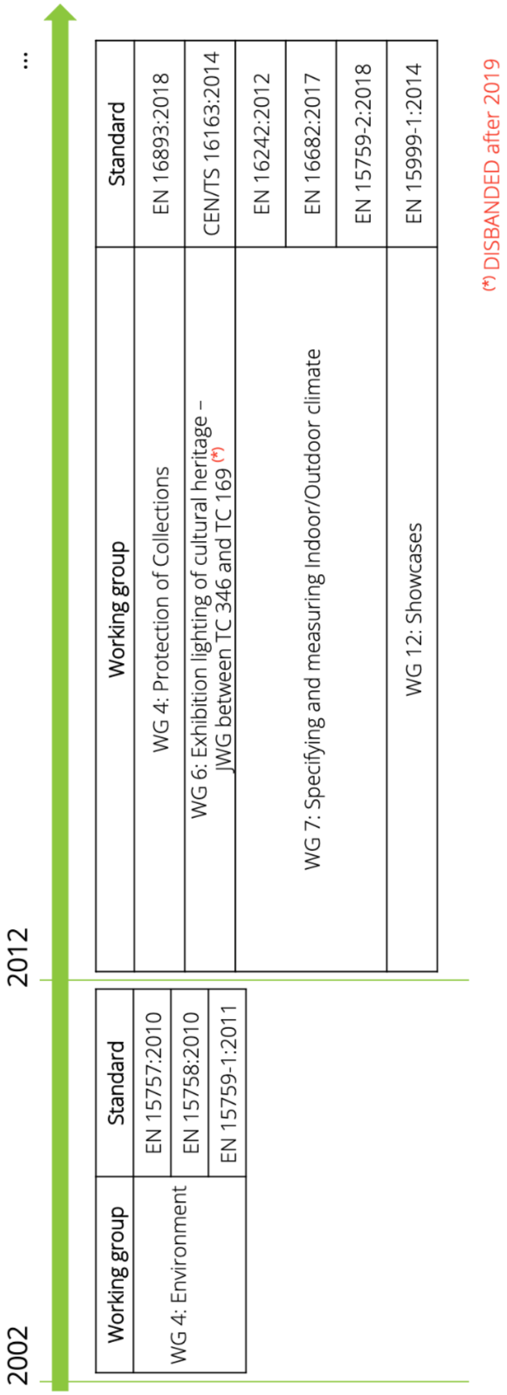

Figure 5 Timeline of the evolution of Working Groups (WGs) concerning the environmental topics for cultural heritage in the framework of the CEN/TC 346. The European standards are named as EN plus the identification number plus the year of issue. TS stands for Technical Specification

Based on the above classification the standards are briefly described in the following section.

Table 1 European standards on environmental topics for the conservation of cultural objects issued by the CEN/TC 346.

Standard	Title	Summary
EN 15757:2010	Conservation of Cultural Property - Specifications for temperature and relative humidity to limit climate-induced mechanical damage in organic hygroscopic materials	Recommended Historical climate (acclimatisation concept) – mechanical damage. Informative *Annex A*: Determination of the relative humidity (RH) targets.
EN 15758:2010	Conservation of Cultural Property - Procedures and instruments for measuring temperatures of the air and the surfaces of objects	Recommended Metrological specifications for temperature sensors and measuring methods.
EN 15759-1:2011	Conservation of cultural property - Indoor climate Part 1: Guidelines for heating churches, chapels and other places of worship	Guidelines on the specifications for the choice of heating strategies and systems.
EN 16242:2012	Conservation of cultural heritage - Procedures and instruments for measuring humidity in the air and moisture exchanges between air and cultural property	Recommended Metrological specifications for relative humidity sensors and measuring methods. Informative - Formulae for calculating humidity variables; - Examples for indoor climate measurements; - Instrumental errors.

Standard	Title	Summary
EN 16095:2012	Conservation of cultural property - Condition recording for movable cultural heritage.	Outlines the possible purposes of a Condition Report (CR). Makes recommendations on: - the categories of information to include in the CR; - required professional level of the compilers; - - best practices to obtain the data.
EN 15999-1:2014	Conservation of cultural heritage - Guidelines for design of showcases for exhibition and preservation of objects - Part 1: General requirements	Guidelines on the specifications of showcases for safe and secure display.
CEN/TS 16163:2014	Conservation of Cultural Heritage - Guidelines and procedures for choosing appropriate lighting for indoor exhibitions	Light sensitivity classification of materials and recommended limits. Informative *Annex A*: Characteristics of light sources; *Annex B*: Glasses and films characteristics related to light exposure; *Annex C*: Filters to modify spectral distribution of incident radiation; *Annex D*: Relative damage of specific light sources; *Annex E*: Lamps and lighting attachments.
EN 16682:2017	Conservation of cultural heritage - Methods of measurement of moisture content, or water content, in materials constituting immovable cultural heritage	Recommended *Appendix A*: Absolute methods; *Appendix B*: Relative methods. Informative *Appendix C*: Other methods; *Appendix D*: Other special methods.

Standard	Title	Summary
EN 16893:2018	Conservation of cultural heritage - Specifications for location, construction and modification of buildings or rooms intended for the storage or use of heritage collections	Informative *Annex A:* Automatic fire-fighting systems; *Annex B*: Relative risks of damage and deterioration due to temperature (*); *Annex C*: Relative risks of damage and deterioration due to relative humidity values (*); *Annex D*: Air pollution sources; *Annex E*: Light Sensitivity of coloured materials (**); *Annex F:* Recommended maximum loads for shelves.
EN 15759-2:2018	Conservation of cultural heritage - Indoor climate ventilation management for the protection of cultural heritage buildings and collections	Informative *Annex A*: Area of application of a condition report; *Annex B*: Example format for a condition report.

(*) based on PAS 198:2012; (**) based on Michalski (2010)

2.1 Methodologies, Procedures, and Instruments for Accurate Environmental Measurements for Cultural Heritage

This key area includes three standards: EN 15758:2010, EN 16242:2012 and EN 16682:2017. They provide the metrological specifications of sensors to be used and the recommendations related to measuring methods for indoor climate variables.

EN 15758:2010, *Conservation of Cultural Property - Indoor Climate - Procedures and instruments for measuring temperatures of the air and of the surfaces of objects*. The purpose of this standard is to provide a detailed list of the different types of sensors with the minimum requirements for correctly measuring air temperature and surface temperature in indoor and outdoor environments. The standard gives specifications for the calibration, instrument accuracy, resolution, and stability of instruments for such measurements. Recommendations on the use or not use of a given sensor depending on the vulnerability of the object as well as the recommended procedure to take accurate measurements of surface temperature without compromising the objects are also provided.

EN 16242:2012, *Conservation of cultural property — Procedures and instruments for measuring humidity in the air and moisture exchanges between air and cultural property*. The purpose of this standard is to provide a detailed list of the different types of sensors with the minimum requirements for measuring relative humidity in indoor and outdoor environments. The standard gives specifications for the calibration, instrument accuracy, resolution, stability, and periodic maintenance of the instruments. The recommended procedure for accurate measurements either in the laboratory or in the field is specified. Moreover, it includes three informative annexes regarding: A) formulae for calculating humidity variables from the output of different hygrometric sensors; B) how to recognise the penetration of external air across a room, or the occurrence of evaporation/condensation from walls based on the exchange in the mixing ratio between the wall and the surrounding air; C) instrumental errors due to particular environmental conditions that should be avoided.

EN 16682:2017, *Conservation of cultural heritage — Methods of measurement of moisture content, or water content, in materials constituting immovable cultural heritage*. This standard provides the most appropriate methods to obtain moisture content in wood and masonry of built cultural heritage. The standard describes absolute and relative methods, identifying their principal characteristics, and discussing their uncertainties and the pros and cons of each method when used in the cultural heritage field.

2.2 Specifications to Limit Conditions that Pose a Risk to the Environment-Vulnerable Materials of Cultural Objects

This key area includes two standards (EN 15757:2010, EN 16893:2018) and one technical specification (CEN/TS 16163:2014). They provide specifications for limiting conditions that pose a risk to the environment-vulnerable materials of cultural objects.

EN 15757:2010, *Conservation of cultural heritage - Specifications for temperature and relative humidity to limit climate-induced mechanical damage*. This norm establishes the priority of the historic climate of the object - the climate to which an object has become acclimatised - if this climate has proven to be beneficial for the conservation of the object. Consequently, no specific values of relative humidity (RH) intervals to limit climate-induced mechanical damages for vulnerable objects, such as organic, hygroscopic materials, are provided. An informative annex includes the procedure for determining RH targets starting from the collection of at least 12 months of hourly observations, as long as a conservator-restorer has verified that the state of conservation of the object is satisfactory. At that point, it is possible to determine the safe band of the RH variability. This means that fluctuations below/above the safe intervals are considered potentially risky.

CEN/TS 16163:2014, *Conservation of cultural heritage - Guidelines and procedures for choosing appropriate lighting for indoor exhibitions*. This technical specification establishes criteria for an adequate lighting of both public and private indoor exhibition spaces. It provides recommendations for measuring the illuminance and UV radiation, the values of limiting illuminance and annual luminous exposure for four categories of light-sensitive cultural objects (CIE 157:2004). Four informative annexes (A-C and E) describe light sources, filters, etc., whereas the informative Annex D shows an example of the typical relative damage potential for different light sources, useful to manage the lighting in exhibition spaces with higher awareness.

EN 16893:2018, *Conservation of cultural heritage - Specifications for location, construction and modification of buildings or rooms intended for the storage or use of heritage collections*. This standard deals with criteria necessary to identify adequate spaces for permanent exhibitions of collections. Except for Annexes A and F (Table 1), four informative annexes (B-E) are dedicated to the environmental variables responsible for objects degradation. Annexes B and C (based on the published British Standard PAS 198:2012) provide the relative risks of damage and deterioration due to temperature and relative humidity. The acceptable climate ranges are provided to prevent specific degradation mechanisms. Annex D gives some examples of risky gaseous pollutants and their sources. Finally, Annex E provides the light sensitivity of several coloured materials.

2.3 Strategies for the Management of Spaces to Preserve Cultural Objects

This key area includes three standards: EN 15759-1:2011, EN 15999-1:2014 and EN 15759-2:2018. They are related to the strategies for the management of spaces to preserve cultural objects. The standard EN 16095:2012 related to the compilation of condition reports is also included in this group.

EN 15759-1:2011, *Conservation of cultural property — Indoor climate - Part 1: Guidelines for heating churches, chapels, and other places of worship.* The purpose of this standard is to provide guidelines for the selection of heating strategies and systems in most places of worship to prevent damage to cultural property and allows for a sustainable use of these buildings.

EN 15999-1:2014, *Conservation of cultural heritage - Guidelines for design of showcases for exhibition and preservation of objects - Part 1: General requirements*. This standard provides the specifications of the showcase components for a safe and secure display of objects in order to reduce environmental interaction. Particular attention is advised when the environment inside the showcase is different from that in the conservation/storage space. In such a case, adequate measures should be adopted to limit gaseous pollutants and particulate matter accumulation as well as to keep temperature and relative humidity at given levels.

EN 15759-2:2018, *Conservation of cultural heritage. Indoor climate ventilation management for the protection of cultural heritage buildings and collections.* This standard aims to provide guidelines for indoor climate conditions, ventilation strategies and technical solutions to improve the preservation conditions of immovable heritage and collections. It should be used together with the first part EN 15759-1:2012 as a complement to existing general standards on ventilation that are focused on human comfort.

EN 16095:2012, *Conservation of cultural property - Condition recording for movable cultural heritage*. The purpose of this standard is to record in the condition report (CR) the condition of movable heritage following inspection and assessment. It has to be noted that condition reports can take different forms depending on purpose. It lays down the essential contents to be included in the CR, suggesting which information could be added and how to collect it. EN 16095:2012 only discusses the content of a report and not the format and layout (digital, paper, photography) used.

2.4 The Use of the EU Standards in the Literature

A literature survey of the studies that have considered the EU norms issued by the CEN/TC 346 concerning the environmental topics for cultural heritage, was carried out. The published papers were identified via the "Scopus" (Elsevier's abstract and citation database, The Netherlands) database. The query string included each of the EU standards reported in Table 1 together with the term "Cultural Heritage".

The search was limited to papers published over the 2010-2021 period, i.e. since the first norm issued by CEN/TC 346 was published in 2010. All the identified papers are written in English and the full text is available online. We find (Figure 6) that EN 15757:2010 shows the highest number of citations, followed by EN CEN/TS 16163:2014, whereas the less cited standards are EN 15759-2:2011 and EN 15999-1:2014.

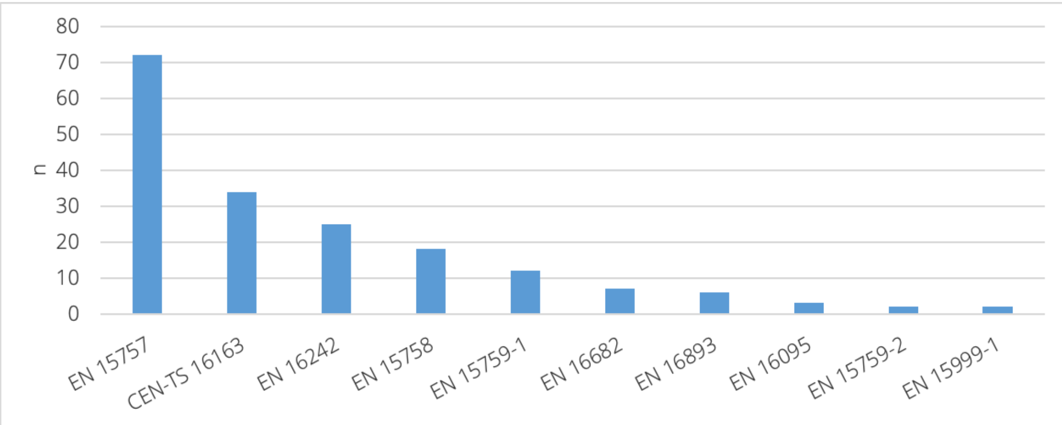

Figure 6 Number of citations of EU standards issued by CEN/TS 346 on environmental topics and of EN 16095:2012, by scientific publications (source: Scopus). It is worth noticing that the figure has an illustrative purpose (some papers may be missing as they could not be captured in the database)

Furthermore, the literature survey has revealed that the application of standards is carried out mainly by the authors of the publications and only rarely, by the staff of museums. This could be ascribed to the fact that, when a norm entails the application of a mathematical analysis, it is difficult for the staff of museums to put it into practice. Another important factor for application of the norms is related to the difficulty of purchasing both hardcopy and online documents not always accessible due to their high cost as well as that of making e a copy of the norms owing to their copyright restrictions.

There are also few citations for EN 16095:2012, *Conservation of cultural property - Condition recording for movable cultural heritage*. In part, this is likely because the personnel responsible for compiling CRs have much less contact with the European standards in their day-to-day work than other more technically oriented professions. But it is probably also because (as the standard implicitly acknowledges) CRs are produced for many specific purposes and their template and content vary enormously depending on the purpose. Furthermore, each institution tends to make its own template designs.

3. Key Issues for Public Consultation

The European Committee for Standardisation (CEN) has published nine standards through Technical Committee 346 (TC 346) concerning the environmental topics for cultural heritage. The CEN/TS 16163:2014 is currently under review.

This section illustrates the key issues of this Green Paper in relation to the current EU standards on environmental topics for the conservation of cultural heritage. They are raised from the outcomes obtained in the several tasks of the CollectionCare project.

Some of the issues may not be within the competence at EU level but could serve as a basis to identify where improvements can be made and to raise a debate on different points of view emerging from multidisciplinary skills involved in the project. In this respect, this Green Paper seeks to stimulate innovation for adopting new thematic strategies or reinforcing the existing procedures in the field of CH conservation.

The key issues of this Green Paper, where environmental and heritage conservation stakeholders' input is sought, are grouped in the following three areas of interest in relation to EU standards issued by CEN/TC 346 described in Section 2:

1. Methodologies, procedures, and instruments for accurate environmental measurements for cultural heritage;
2. Specifications to limit conditions that pose a risk to the environment-vulnerable materials of cultural objects;
3. Strategies for the management of spaces for preserving cultural objects.

3.1 Methodologies, Procedures, and Instruments for Accurate Environmental Eeasurements for Cultural Heritage

The environment surrounding an object (including climate conditions, pollution concentrations, VIS-UV radiation) influences the chemo-physical and structural properties of cultural objects. Thus, the monitoring of environmental conditions does not merely represent a collection of observations of a variable, but the observations keyed to a particular location in the exhibition space (Camuffo, 2019). Over the years, indoor environmental monitoring has become an increasingly common practice to analyse the effects caused by the agents responsible for the deterioration of cultural objects. When environmental monitoring is planned, whatever its objectives, the focus is on knowledge of the indoor environmental conditions to limit the climate-induced damage to objects.

This section presents three key issues related to environmental measurements for cultural heritage that should be dealt with and, where necessary, could be approached specifically by CEN/TC 346.

3.1.1 Guidance for the Deployment of Sensor Devices to Monitor Environment in Different Museum Scenarios

The current EU standards provide recommendations concerning the choice of the type of sensor devices to be used to measure temperature (EN 15758:2010) and relative humidity (EN 16242:2012), as well as their technical requirements and general information for the sensor locations, e.g., as close as possible to climate-sensitive objects and in free air. At present, there is no golden rule to address the issue of deploying sensors in indoor space (Frasca et al., 2022).

In fact, there are neither norms nor guidelines that define a specific methodology on the most adequate deployment of sensors in order to have a comprehensive picture of environment behaviour in the museums.

The pursuit of a proper deployment of sensors would guarantee:

- the representativeness in time and space of the whole environment surrounding individual artworks;
- the assessment of environment-induced risks;
- the reduction of a redundant number of sensors being strategic, in terms of maintenance and calibration costs, and sustainable for the museums.

Q1. Where needed, which measures should be taken to define some guidelines for the proper deployment of sensors to monitor the environmental variables?

Q2. Which actions could be implemented at the EU level (e.g., through the CEN/TC 346) to promote this process?

3.1.2 Recommendations on Instruments for the Measurements of Indoor Air Pollutants

The current EU standards specifying the procedures for measurements of air quality and concentrations of given air pollutants (EN ISO 14956:2002, EN 14211:2012, EN 14212:2012, EN 14625:2012, CEN/TS 16976:2016), were not issued by CEN/TC 346 and therefore they can be hardly applied in the PC field. Furthermore, the given ranges of the concentration levels are mostly related to outdoor concentrations rather than indoors. The theoretical and empirical relationships, developed to evaluate the potential damaging impacts on various types of materials can include both the key climate variables (temperature and humidity) and also other forcing agents as a function of pollution concentrations.

Air pollutants in conservation spaces are classified with reference to their sources: outdoor-generated (mainly inorganic gaseous pollutants); indoor-generated (mainly organic gaseous pollutants). In addition, they can also be brought in by visitors or museum staff (i.e., anthropogenic stressors). However, a relationship between anthropogenic stressors and environmental conditions has not been yet objectively defined to support management strategies. In this context, indoor pollutants could be included among the heritage environmental variables relevant for the protection of cultural objects indoors. The inclusion of key air pollutants in the environmental monitoring would allow a more precise and richer understanding of deterioration processes and hence better risk assessment and degradation mechanisms in any conservation space.

The current available sensors, designed for outdoor air quality monitoring, would in theory measure indoor air pollutants. However, the concentrations indoors are low and accurate measurements of the typical low concentrations in conservation spaces (Ryhl-Svendsen, 2006) could be difficult if performed by such instruments. Furthermore, an accurate choice of the location of sensors is of primary importance in order to obtain a complete chemo-physical characterisation of the environmental agents that can interact independently or synergically in the deterioration mechanisms.

Q3. Where needed, how to evaluate the impact of the indoor levels of air pollutants and of anthropogenic pressure on cultural objects? How to promote the integration of measuring indoor levels of air pollutants in safeguarding strategies for cultural objects?

Q4. What policy steps (e.g., through the CEN/TC 346) are necessary to specify the indoor levels of air pollutants that pose a risk to key materials of cultural objects?

Q5. How can existing technologies be implemented to measure air pollutants levels in conservation spaces? What can the role of the EU be in supporting such technological innovation?

3.1.3 Recommendations on Instruments for the Measurements of Visible and Ultraviolet Radiation

The current EU standards CEN/TS 16163:2014 and EN 16893:2018 specify recommendations related to luminous exposure with regard to conservation policies. EN 16893:2018 specifies characteristics to be considered for luminous exposure when designing and assessing new sites exhibiting cultural objects. The draft prEN 16163 focusing on appropriate lighting for indoor exhibitions is currently under discussion at CEN/TC 346 with the aim of revising and updating the recommendations already provided in CEN/TS 16163:2014.

However, most spaces housing collections do not carry out regular controls of the lighting systems (lamps, window filters, etc.) and may have inadequate levels of luminous exposure. Continuous monitoring of visible (VIS) and ultraviolet (UV) radiation allows detecting unexpected harmful situations (e.g., wear of UV filters) and simplifies the assessment of cumulative effects to evaluate whether a location is suitable for a given object. In real contexts, e.g. when solar radiation is not sufficiently filtered/sheltered, VIS-UV sensors designed for indoor monitoring might be deficient for measuring of luminous exposure levels exceeding the instrumental range (Verticchio et al., 2022). It follows that recommended and desirable specifications on instruments for lighting monitoring with regard to the conservation policies would be an important issue to be included in prEN 16163. It is worth highlighting that an accurate choice of the location of sensors is of primary importance in order to achieve a complete characterisation of the environmental agents triggering degradation mechanisms.

Q6. Which existing technologies can be exploited for a continuous monitoring of visible and ultraviolet radiation in indoor spaces with regard to conservation activities?

Q7. What can the potential role of the EU be in supporting a technological upgrade?

3.2 Specifications to Limit Conditions that Pose a Risk to the Environment-Vulnerable Materials of Cultural Objects

In this section, three key issues are proposed with reference to the EU standard on the environmental ranges to limit risk conditions for the environment-vulnerable materials of cultural objects. These key issues also consider both the effect of treatments on objects and the output from degradation models. Environment-induced deterioration can be better understood through the gathering of sufficient statistical environmental data combined with degradation models as well as exploiting the experience of scientists, conservators-restorers, and other experts in the field. Developing evidence-based environmental specifications is clearly a process of iterative decision-making that needs to consider and reconcile inevitable conflicts. For this reason, the topic of the proposed key issues has been addressed taking into consideration the perspective of conservation scientific domains (exploiting innovative environmental monitoring and degradation models) together with expertise on conservation treatments on cultural objects.

3.2.1 Specifications for Temperature and Relative Humidity to Limit Climate-Induced Damage of Humidity-Sensitive Materials

Climate-induced damage of humidity-sensitive materials (e.g., organic hygroscopic materials) is an important type of risk in most museum collections and historical interiors. When materials loss or gain moisture, the constraint from free movement induces stresses in the objects that cause deformation, cracking, and delamination. Heritage science and conservation practice have developed two approaches to climate specifications limiting damage: 1) analyses of the historical climates to which the objects have "acclimatised", and 2) analysis of the physical response of materials and objects to relative humidity and temperature fluctuations.

Awareness of object acclimatisation to a particular indoor environment has long been reflected in the requirement that climate conditions should be retained as fully as possible when vulnerable objects are moved from their usual location (e.g., in case of restoration or temporary exhibitions/loans). The acclimatisation concept has been convincingly confirmed by direct tracing of damage in objects using non-invasive methods (such as acoustic and optical techniques) as well as observations by experts reporting uniform damage patterns in large groups of similar objects (generally formed before the objects entered the museum collections, thus reflecting their early "acclimatisation" to their uncontrolled historical environments).

The acclimatisation concept was expressed in European standard EN 15757:2010. Though the standard is widely used and referred to by museums and research institutions as a reference for the climate specifications for collections, it cannot be applied in some common cases, as: 1) new damage continues to accumulate in an object; 2) an object has to be moved to climatic conditions different from the those to which it has acclimatised (e.g., object moved from historical location to a museum, or loaning object from one museum to another); or 3) conservation treatment may alter the safety of an object achieved by its acclimatisation to the past conditions. In these instances, the decision-making requires analysis of moisture and mechanical response of materials and their assemblies to address how much variation in the climate parameters is actually safe for a specific object. Furthermore, the standard does not allow for straightforward implementation in climate control systems and is therefore mainly used by scientists. According to the knowledge of the authors of this Green Paper, there are no examples of the practical use of EN 15757:2010 in Building Management Systems (BMS) to control the environment in conservation spaces housing valuable collections.

The IIC & ICOM–CC joint declaration of 2014 on environmental guidelines for museums stated that “the issue of collection and material environmental requirements is complex, and conservators-restorers/conservation scientists should actively seek to explain and unpack these complexities” (IIC & ICOM–CC, 2014), reflecting the general conviction that any environmental specifications must address specific risks to the collection, while considering the needs of staff and visitors and the capability of the building housing the collection, as well as costs and sustainability aspects. Developing evidence-based environmental specifications is clearly a process of iterative decision-making that needs to consider and reconcile inevitable conflicts.

WG 7 *Specifying and measuring indoor/outdoor climate* of the CEN/TC 346 could be approached by a group of interested experts willing to propose and draft a new work item covering the development of evidence-based environmental specifications. Necessary details should be provided, especially the scope and aim of the work, to facilitate the decision by the working group and, when the proposal is accepted, to inform the interested parties and involve further experts through the CEN call. Two key existing documents should be used to facilitate the process: the EN 15757:2010 standard and Chapter 24 *Climate Control in Museums, Galleries, Libraries and Archives* of a handbook published by the American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE). The latter document, published since 1999 and revised in 2019, has a global influence, setting standards of climate control in museums worldwide, especially through its climate control classes, ranging from precision to relaxed control, with risks for various categories of objects provided for each class. The elements of the ASHRAE chapter could possibly be quoted in annexes of the new European standard so that harmonisation in the area covered by the standard clearly relates to the existing work used by the conservation and museum community.

Q8. Which concrete steps can be taken to develop a better comprehensive European standard on the specifications for temperature and relative humidity to limit climate-induced damage of humidity-sensitive materials that goes beyond the approach of EN 15757:2010?

3.2.2 The Effect of Conservation Treatments on Artworks Resilience Towards Climate Conditions

A substantial number of objects in museums have previously been treated by conservators-restorers and this has in many cases changed their resilience towards climate conditions. For example: in some collections, up to 80-90% of paintings are impregnated with glue or wax. Although this is a significant change in material composition, this factor is not considered in degradation scenarios and, therefore, also not considered in PC management.

In the CollectionCare project, standards for preventive conservation are discussed and integrated into decision-making and management tools. In addition, recently developed degradation models are provided to promote decision making in museums, archives and historic buildings. Nevertheless, in the CollectionCare project, conservation treatments are not considered either.

Whenever an object is treated, the structure is inevitably changed even if the addition or removal of materials is limited. Surface cleaning of an object can remove particles or substances that support its structure. A surface coating can provide support but may also have unintended adverse effects if, for example a crack that was releasing the stress from contraction is filled up. Impregnation with a hygroscopic glue or wax is another example of a conservation treatment that can change the way a structure responds to the climate conditions. Such significant material changes should be considered in models and standards.

Many objects have been exposed to the same climate for centuries and are therefore accustomed to the historic fluctuations in temperature and relative humidity. This phenomenon was introduced by Michalski (Michalski, 1993) as proofed fluctuations. However, this concept had the clear exception of conservation treatment. Even if an object has been "proofed" in a specific climate before, it will be nullified with conservation treatment.

Whether a treatment makes objects resilient or vulnerable - and to what degree - will have to be investigated in each case and comprehensive modelling and testing is needed to obtain a full understanding of the effect of each treatment. Observing treated objects over a period of time can provide equally valuable information.

The discussion about adequate climate conditions for cultural heritage objects should be expanded to include the significant parameter of conservation (the conservation factor). More knowledge is needed about the effect of different conservation treatments and future research projects should thus include the effect of conservation.

Q9. How to include the conservation factor in the discussion on adequate climate for cultural heritage objects and to assess how many objects are affected by the conservation factor?

Q10. Which conservation treatments are promoting resilience and which ones are making objects more vulnerable?

Q11. How to revise the existing EU standards considering the effect of different conservation treatments of the object?

3.2.3 Degradation Models for Defining New Approaches to Identify Environmental Conditions to which Cultural Objects should be Exposed

As standards remain in use for decades, they play a key role in defining adequate conservation strategies and outlining adequate interventions to reduce vulnerabilities in cultural heritage. For this reason, it could be beneficial to integrate standards with the outcomes derived from consolidated degradation models.

Among standard procedures in this field, Chapter 24 of the ASHRAE Handbook (ASHRAE, 2019) is particularly relevant, as it provides guidance on air-conditioning systems for museums, libraries and archives. The chapter specifies climate quality criteria and explicitly provides which climate risks are avoided in varying levels of control, related to building type, climate zone and nature of objects. The chapter has been widely adopted for climate specifications in heritage institutions, including those in Europe.

One of the principal strong points of this guidance is the reference to methods to assess the deterioration risk induced by environmental conditions and their variations on different materials of which cultural objects are composed. In this way, the response of the materials can be studied in relation to their interaction and adaptation to the environmental conditions. This approach, based on knowledge of the deterioration mechanisms and the anticipation of their behaviour, can support the definition of timely and rational strategies for mitigation of the deterioration risk also in the case of different materials with conflicting needs.

Several degradation models for cultural heritage (e.g., mechanical, chemical and biological) have been developed for the environment-induced risk assessment of specific types of materials (e.g., canvas paintings, wood, paper and metal objects). These models include a detailed description of the underlying physical mechanisms controlling the degradation of different specific types of cultural heritage objects, and therefore provide additional insight on the most appropriate environmental specifications. In reference to the CollectionCare project, different degradation models have been developed that cover the degradation response of canvas paintings (Lee et al, 2022), wooden art objects (Kuka et al., 2021), metal objects (Trybula, 2021) and paper artefacts (Parsa Sadr et al., 2022). However, there is a challenge related to the potential lack of material parameters that serve as input for the degradation models.

The safe climate targets derived from degradation models might not fully overlap those suggested by the currently available conservation guidelines on environmental specifications. This consideration suggests further effort in the proposal of new standards and in discussing/updating of the existing ones. The advantage of considering the specific response of different materials to indoor climate variations can be helpful to reduce vulnerabilities in cultural heritage and to design more rational and energy-sustainable climate control strategies. Therefore, it is fundamental to integrate the needs of conservation with the new challenges imposed by climate changes and sustainability in the near future.

Q12. How to use the outputs from the degradation models to support the environmental management strategies in museums? Where needed, how to integrate the outputs in the existing EU standards?

Q13. How to make simple and understandable outputs of degradation models for the interpretation of environment-induced risk for museums in order to help them in designing environmental control strategies?

Q14. How can the outcomes derived from the degradation models be used to provide scenarios of material response in view of the climate change projections?

3.3 Strategies for the Management of Spaces for Preserving Cultural Objects

In this section, six key issues for the consultation are presented. Three key issues result from the need to facilitate a bridge between research/technology and practices of preventive conservation. Another issue concerns the evaluation of the condition of an object to assess its vulnerability or sensitivity to humidity variations. The next one highlights the lack of a European database on treatments and deterioration of cultural objects, while the last one looks into a possible system using the risk assessment and the risk management to integrate collection care and standards application in the wider framework of the museum management.

3.3.1 Transfer of Standards into Practice

The main roles of standardisation in the CH field, are: to give precise and appropriate indications on diagnostic studies to be performed; to reduce maintenance costs of conservation work, therefore reducing costs in the long-term because conservation treatments will be needed less frequently; to improve methodology, protocols and guidelines to allow implementations of better practices.

However, the application of standards is not a purely technical problem. It is intimately connected with expertise of human resources and managerial issues: what (if any) staff are available? Is funding available for acquisitions and long-term staffing expenses? How important is it compared to other tasks or projects requiring implementation? Indeed, the use of standards is not trivial for museums with limited funds due to their costs, possible copyright restriction and, even when standards are consulted and can be afforded, one of the main concerns in their application will be how to convert the procedures outlined from theory into practice. As an example, choosing appropriate instruments to be used in indoor climate monitoring or the application of some procedures (e.g., the historical climate for the preventive conservation of organic hygroscopic artworks) might need given expertise that is not available in the museums. The main consequence is that even if museum staff are aware of standards for the conservation of CH, they are not able to put them into practice, leading to a failure in the transfer of knowledge.

Another problem is that the use of standards is likely to be competing for limited resources with a large number of other issues involved in the running of the museum.

The decision to use these standards will involve agreeing with management and other staff on the relative priority of resource allocation compared to other activities of the museum. This is probably especially difficult if the issues of standards have never been discussed before.

Consequently, if management and staff do not see implementation of standards as high priority and/or they do not receive appropriate training and support, the standards will not be used successfully.

Q15. What policy action would be appropriate to support user-friendly access to the standards by museum staff and at which level (European, national)?

Q16. How to improve the promotion and support of the use of standards and their application in conservation?

3.3.2 Transfer of Degradation Models from Research into Practice

The mechanisms behind the ageing and degradation of cultural objects are known. Traditionally, in the recent decades, conservation literature has been mostly object-oriented. In this context, (experimental) tests are performed, providing which intervention should be done on the specific considered object. Though this is useful for conservation practice, it is difficult to harmonise all results in a comprehensive theoretical understanding of the response of the materials involved as a function of the environmental factors.

However, in recent years, the increasing importance of the benefits of numerical modelling and predictive analysis to the conservation of CH has been recognised. Degradation models enable us to describe the degradation processes, predict the extent of degradation as a function of degradation stressors, and support the definition of more effective conservation strategies. Output from numerical modelling simulations can possibly be exploited as tools to study the impact on cultural objects of different environmental management strategies adopted by museums.

The key challenge in relation to the use of degradation models is the difficulty of transferring the results of modelling to practical guidelines to be used by a wider community that operates in CH conservation. The promotion of further research on degradation models is recommended as well as the possible integration in decision-making strategies. It is advisable to foster the technical training of cultural heritage experts, such that they may be able to use modelling work as an additional tool when taking informed conservation decisions.

Q17. How to transfer degradation output from research models into practice in order to be effectively used by the conservation community for the development of decision-making strategies? What can be done so that this issue is tackled and by whom?

Q18. Where needed, what measures can be promoted to open up new job opportunities for emerging professionals capable of transferring degradation models from research into practice?

3.3.3 Identification of the most Vulnerable Objects in a Collection

When discussing standards for preventive conservation in comparison with the outputs from the degradation models, much emphasis is placed on how some classes of objects are more or less sensitive to changes in environmental conditions than others. In the literature, these classifications generally limit themselves to the material composition of the objects: as an example, a paper object is rated as more sensitive or more vulnerable than a wooden artefact.

However, we often have objects in collections that are badly degraded, and which may be even more sensitive to environmental conditions than other objects composed of the same materials. They can even be significantly more vulnerable to changes in humidity than objects made of ostensibly more sensitive materials that are, however, in good condition. The identification of such extra-sensitive objects to climate conditions is a frequent experience in museums and conservation practices, being a key activity of good management. In many cases such objects may be subject to more regular checks, or special display conditions or even withdrawn from display and/or specially stored.

Standards and degradation models do not usually take such anomalous but common cases into consideration. An exception is the standard EN15757:2010 which specifies that "the proposed methodology is based on [...] a condition survey of the most vulnerable or valuable objects [in a collection]", suggesting how to determine the safe intervals of relative humidity after an expert has evaluated the state of conservation of the hygroscopic and organic objects. However, the standard does not cite a reference standard on how to identify the most vulnerable objects. Neither does the standard EN 16095:2012, which perhaps should provide a guide.

Identifying the most vulnerable objects in a collection can be a complex issue and should involve a comprehensive risk assessment of the entire collection as well as assessment of the risks faced by the individual objects (Michalski, 2016; Pedersoli, 2016). Furthermore, there should also be included a holistic assessment of how to balance the need to care for the (even few) most vulnerable objects in the collection with the available resources (in terms of human, economic, and infrastructure). In this way it may be possible to find methods of protection that can solve specific local problems rather than just depending on energy-demanding (sometimes inappropriate) climate control systems with far more expensive costs for the museum.

Q19. Where appropriate, which targeted procedures should be outlined to identify the most vulnerable objects in a collection?

Q20. Specifically, what policy steps are necessary to implement EN 16095:2012 with a specific procedure and to acknowledge it in EN 15757:2010**?**

3.3.4 The Use of Risk Assessment and Risk Management Strategies to Establish Priorities and Resources Regarding the Implementation of European Standards in Cultural Heritage

Even small and medium museums and collections are complex structures with many interrelated activities. They often have tight budgets, limited facilities and usually limited human resources.

Collection protection is one the main museum activities to reduce the risks faced by objects. Taking care of the collections involves many tasks —monitoring, maintenance, treatments, documentation etc. — which also compete for resources. At the same time, attention must be paid to various other factors (perhaps less obvious) that could put the collection at risk: the museum spaces, the visitors, the infrastructure, and the building management itself. In this context, it can be difficult to evaluate which activities should have the highest priorities.

Originating with the work of Stefan Michalski, several practical and methodological procedures have been developed to quantitatively assess the priorities among the different real-world risks to the collections (Michalski, 2016; Michalski and Pedersoli, 2016; Brokerhof, 2016; ASHRAE, 2019). This approach is particularly useful for identifying location-specific and object-specific problems. In some cases, an appropriate standard or guideline for most countries may not be adequate in a particular geographic location (ASHRAE, 2019). Risk assessment can also show that some objects can be much more vulnerable compared to other very similar objects depending on the conditions to which they are exposed (Michalski, 2007).

Risk assessment provides useful information on the utility and sustainability of changes to conservation policy and procedures, particularly in small museums where the application of guidelines usually relies on limited numbers of specialised staff having several other competing duties. Risk assessment together with risk management can provide useful insights into cost-benefit analyses of policies and activities. Moreover, it can stimulate strategic discussion with managers and other stakeholders on the feasibility and/or desirability of museum policies and guidelines, potentially affecting the management of visitor numbers, exhibition spaces and opening hours.

Q21. Which concrete steps can be taken to identify the most effective approach to risk assessment for collections? How to promote the implementation of risk assessment procedures in museums?

Q22. Which expertise should be involved in the risk assessment process?

3.3.5 Tools for the Analysis of Environmental Data for Easy Understanding by Curators and other Museum Staff

The continuous monitoring of environmental variables in spaces housing collections is essential to evaluate the potential impact on the material integrity of the objects. Technological solutions for the monitoring and subsequent analysis of environmental conditions have evolved over the years also in preventive conservation practices.

Nowadays, tools are manufactured with multiple sensors to monitor different environmental variables such as temperature, relative humidity, and light. These devices have attracted great interest in the recent decades, as their implementation —coupled with advances in information technology (IT) and digital tools — has offered new opportunities to develop innovative systems for monitoring and managing environmental data (Hassani, 2015). Innovative solutions and tools have been also developed in the field of preventive conservation: the eClimateNotebook® which manages and analyses environmental data (eClimateNotebook, 2021), OCEAN oriented to data collection for museum plans (Hancock, 2004), Eltek Darca Heritage a specific choice of devices (Eltek, 2022) and HERIe a solution oriented to degradation models (HERIe, 2020), are some of these analysis and monitoring tools to name but a few. However, none of them is a complete and integrated IT tool for preventive conservation in museums that automates the analysis of environmental data to facilitate the routine work of conservators-restorers and museum staff.

Within the CollectionCare project, a more comprehensive solution, a PC system, has been devised to enable conservators-restorers and museum staff to apply advanced PC strategies individually to each cultural object with limited knowledge of degradation models, statistical techniques or preventive conservation regulations and standards.

Q23. What features should an environmental data analysis tool have in order to assess the impact of environmental conditions on the material integrity of cultural property?

Q24. To what extent is a data analysis tool sufficient to assess the risk posed by environmental conditions to cultural property?

3.3.6 Use of Conservation Condition and Treatment Reports to Create a European Database for Collections and Artworks

While the technical conservation literature contains many publications about the use of materials on laboratory samples, and degradation is frequently studied through mathematical models, there is — relatively speaking — much less technical publishing on treatments and deterioration concerning real life objects in real world situations.

Undoubtedly, in real contexts, testing, for example, must be limited. However, this may mean that real-world treatments are far less reported as they do not satisfy the rigorous standards required by scientific publications (repeated trials, controls, destructive testing, etc.).

However, unpublished Conservation Reports (CR) and Treatment Reports (TR) clearly contain a lot of important and potentially useful — even if partial — information on degradation, treatment methods and materials, original techniques and diagnostics, etc.

Combining CRs and TRs from multiple sources into one searchable database, especially if it were European-wide, could be of enormous benefit: it would enable comparison, exchange of information, and the acquisition of practical, real-world knowledge bases that are currently out of the reach of small or medium-sized institutions in particular.

Such a project would also clearly require substantial resources — human, technical, financial —if it were to be at all sustainable in the long term.

There are several collaborative/combined data bases that can serve as an indicative model, for example those available through the RKD (Rijksbureau voor Kunsthistorische Documentatie - Netherlands Institute for Art History) portal.

Q25. Where needed, how to create a reliable database of Conservation Reports and Treatment Reports of European collections? How could the data and metadata be managed and presented?

Q26. Which steps could be taken to create a reliable database of Conservation Reports and Treatment Reports of European collections? What support can the EU give?

4. Conclusions and next steps

The current EU standards issued by CEN/TC 346 include specifications on the instruments for measuring indoor climate variables, to limit climate-induced damage of humidity-sensitive materials, and to give precise and appropriate indications on diagnostic studies to be performed. At the same time, there are other relevant issues (conservation management strategy, conservation treatment, risk assessment) that deserve attention and should be considered for adequate and affordable care of cultural objects.

As discussed in this Green Paper, there are several issues related to the conservation of cultural heritage that can be dealt with in the short and long term, and which might improve the decision-making process in any conservation context. This Green Paper addresses 12 key issues related to the preventive conservation of cultural heritage with specific regard to EU standards on environmental topics. The key issues that have been put on the table with the related 26 questions are inspired by the outcomes of the CollectionCare project and the expertise of the various partners involved.

We hope that this Green Paper becomes a vector to stimulate further debate among environmental and heritage conservation stakeholders.

This Green Paper launches a [12]-week public consultation. All interested parties are invited to submit their views in response to the questions in this Green Paper. The consultation will follow the normal rules of the European Commission for public consultations. The Commission will take all contributions into consideration in its future work and provide feedback on the results.

Glossary

Alteration	Change in condition, beneficial or not, intentional or not (EN 15898:2011).
Collection	Group of objects having shared or combined significance (EN 15898:2011).
Condition	Physical state of an object at a particular time (EN 15898:2011).
Condition report	Record of condition for a specific purpose, dated and authored (EN 15898:2011).
Conservation	All of the processes of looking after a heritage place so as to retain its cultural or natural heritage significance. In some English-speaking countries, the term preservation is used as an alternative to conservation for this general activity (Labadi, 2021). All actions designed to understand a heritage property or element, know, reflect upon and communicate its history and meaning, facilitate its safeguarding, and manage change in ways that will best sustain its heritage values for present and future generations (NARA + 20, 2015).
Cultural heritage	Objects, collections, specimens, structures, or sites that have artistic, historic, scientific, religious, or social significance (ASHRAE, 2019; EN 15898:2011).
Damage	Alteration that reduces significance or stability (EN 15898:2011).
Deterioration	Gradual change in condition that reduces significance or stability (EN 15898:2011).
Environment	Surroundings of an object, some aspects of which may affect its condition (EN 15898:2011).
Immovable heritage	Built cultural heritage, historical ensemble, historic site, conservation area, historic garden (EN 15898:2011).
Informative procedures	Useful procedures to be followed, but not compulsory.
Intangible heritage	According to the United Nations Educational, Scientific and Cultural Organisation (UNESCO), includes traditions or living expressions inherited and passed on within a culture, such as oral traditions, performing arts, social practices, rituals, festive events, knowledge, and practices concerning nature and the universe or the knowledge and skills to produce traditional crafts (UNESCO, 2021).

Microclimate	The whole environment that needs to be studied in order to determine the factors which have a direct influence on the physical state of the monument and the interactions with the air and the surrounding objects (Camuffo, 2019).
Monitoring	Process of measuring, surveying and assessing the material properties of objects and/or factors of the environment over time (EN 15898:2011).
Movable heritage	See "collection".
Object	Single manifestation of tangible cultural heritage (EN 15898:2011).
Preservation	See "conservation".
Preventive conservation (also called preventive care)	Mitigation of deterioration and damage to cultural property through the formulation and implementation of policies and procedures for the following: appropriate environmental conditions; handling and maintenance procedures for storage, exhibition, packing, transport, and use; integrated pest management; emergency preparedness and response; and reformatting/duplication (ASHRAE, 2019).
Protection	The adoption of measures aimed at the preservation, safeguarding and enhancement of the diversity of all forms of cultural expressions (UNESCO, 2021).
Recommended procedures	Procedures that should be followed.
Stakeholder	A person, group, or organisation with a particular interest in heritage based on special associations, meanings, and/or legal and economic interests, and which can affect, or be affected, by decisions regarding heritage (NARA + 20, 2015).
Standard (also called as norm)	Technical document designed to be used as a rule, guideline or definition. It is a consensus-built, repeatable way of doing something. Standards are created by bringing together all interested parties such as manufacturers, consumers and regulators of a particular material, product, process, or service. All parties benefit from standardisation through increased product safety and quality as well as lower transaction costs and prices (CEN, 2022).
Tangible heritage	Buildings, historic places, and monuments, as well as objects and collections significant to the archaeology, architecture, science, or technology of a specific culture (ASHRAE, 2019).

Technical Specification	Normative document in areas where the actual state of the art is not yet sufficiently stable for a European Standard (CEN, 2022).
Value	The positive characteristics attributed to heritage places and objects by legislation, governing authorities, and/or other stakeholders. These characteristics are what make a site significant, and they are often the reason why society and authorities are interested in a specific cultural site or object. In general, groups within society expect benefits from the value they attribute to the resource (Labadi, 2021).

Annex

Background information on environment and cultural heritage

1 Legislative documents

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EN 15758 (2010). Conservation of cultural property. Procedures and instruments for measuring temperatures of the air and the surfaces of objects.

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EN 16893 (2018). Conservation of Cultural Heritage - Specifications for location, construction and modification of buildings or rooms intended for the storage or use of heritage collections

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