

### **INSTRUCTIONAL INFORMATION**

The following module template has been developed as part of Work Package 7 of the EU-funded GoGreen project. The module is designed in a skeletal format to allow for broad adaptation to a wide range of existing curricula and professional development schemes. To enhance flexibility, the module is divided into theme blocks with suggested content, assessments, and activities. The template has been constructed to serve as foundational material for curriculum development or course integration.

### **INTENDED AUDIENCE**

This module may be adapted for the instruction of conservation, conservation science, and the broader cultural heritage sector at the undergraduate, postgraduate, and professional level. The activities and assessments of this module have been developed for both group and individual audiences.

### **MODULE DELIVERY**

Content in this module supports in-person, hybrid, or virtual learning. The following online resources may be used for hybrid or virtual module instruction.

1. <https://padlet.com/>
2. <https://whiteboard.microsoft.com>
3. <https://www.mural.co/>

For optimal instructional delivery, this module benefits from access to case studies either from the suggested literature or from personal/local contexts.

### **PRE-REQUISITE KNOWLEDGE**

Prior to undertaking the module, module-takers should be familiar with the following topics which may be gained from previous coursework or complementary GoGreen modules:

1. Knowledge of the GoGreen definition for green conservation and green parameters, and the Green Decision-Making Model (DMM). Supported by the module ***Leadership in Green Conservation***
2. Familiarity of the 10 Agents of Deterioration for Cultural Heritage supported by the suggested pre-reading

Additionally, pre-requisite knowledge is supported by the recommended pre-readings detailed below.

### **RECOMMENDED PRE-READINGS**

**Canadian Conservation Institute** (2025) Agents of Deterioration. Government of Canada.

Available at: <https://www.canada.ca/en/conservation-institute/services/agents-deterioration.html>

### **MISSION STATEMENT**

To promote informed and adaptive decision-making for cultural heritage through knowledge of green preventive conservation strategies, tools, and material sensitivities.

## DESCRIPTION

*Determining Material Sensitivities and Green Decision-Making* introduces tools for identifying and evaluating material sensitivity and stability to support greener approaches in preventive conservation. Proposed topics encourage the development of interdisciplinary skills in material science and cultural heritage conservation.

Learners are introduced to tools including damage functions and the HERle a digital decision-support platform to assess environmental impacts and risks for cultural heritage. Using these tools, they develop sustainable, context-specific preventive conservation strategies that take into account climate, resources, human health and well-being, and cultural heritage.

At the end of the module, learners will have the opportunity to put their new knowledge and skills into practice by developing a preventive conservation approach for their personal or local context and advocating for its implementation, developing practical leadership skills in green conservation.

## LEARNING GOALS AND OUTCOMES

*Main Goal* Support learners to make green(er) decisions for preventive conservation using knowledge of material science of cultural heritage and tools for green decision-making

### *Subsidiary Goals*

- Develop awareness of how the environment influences the physical and chemical stability of materials in cultural heritage objects
- Build competence in using diagnostic tools and analytical techniques to identify and interpret environmental risks to cultural heritage
- Foster interdisciplinary understanding by linking material science, conservation, and sustainability to inform the decision-making process
- Reflect on preventive conservation approaches and decisions, and identify how they support long-term preservation while aligning with the green parameters

### **By the end of this module,**

#### Learning Outcomes

1. **(Evaluation)** Evaluate the sustainability impact of preventive conservation practices, in relation to waste management, energy consumption, environmental pollution, human health, and inclusion.
2. **(Analysis)** Analyse the extent to which one's preventive conservation actions conform to green conservation criteria and identify opportunities for improvement.
3. **(Application)** Apply diagnostic tools (e.g., HERle and damage functions) to evaluate how environmental parameters such as relative humidity, temperature, and light affect the stability, reactivity, and vulnerability of organic and inorganic cultural heritage, thereby supporting context-specific, risk-based greener preventive conservation strategies.
4. **(Communication)** Negotiate and advocate for greener preventive conservation strategies through assessing risks using diagnostic tools, such as HERle and damage functions

**RECOMMENDED READINGS**

Visit the GoGreen Zenodo for the full module bibliography

**Bickersteth, J.** (2016). IIC and ICOM-CC 2014 Declaration on Environmental Guidelines. *Studies in Conservation*, 61(sup1), 12–17. <https://doi.org/10.1080/00393630.2016.1166018>

**Bujok, S., Bridarolli, A., Łukomski, M., & Bratasz, Ł.** (2024). Reconsidering Museums' Climate and Seasonal Adjustment for Vulnerable Artifacts. *Studies in Conservation*, 69(sup1), 18–24. <https://doi.org/10.1080/00393630.2024.2375162>

**CIMAM.** (n.d.). *The BIZOT Green Protocol*. CIMAM. Retrieved 22 July 2025, from <https://www.cimam.org/sustainability-and-ecology-museum-practice/bizot-green-protocol/>

**Cosaert, A., & Beltran, V. L. (Eds).** (2022). *Tools for the analysis of collection environments: Lessons learned and future development; research report* (Download, Kopie). Getty Conservation Institute.

**Dalla Mora, T., De Vivo, M. A., Scarpa, M., & Peron, F.** (2025). Critical Review of the Application of the Principal International Standards and Guidelines on Indoor Microclimates for the Preventive Conservation of Cultural Heritage. *Sustainability*, 17(3), 1189. <https://doi.org/10.3390/su17031189>

**Kramer, R. P., Schellen, H. L., & Van Schijndel, A. W. M.** (2016). Impact of ASHRAE's museum climate classes on energy consumption and indoor climate fluctuations: Full-scale measurements in museum Hermitage Amsterdam. *Energy and Buildings*, 130, 286–294. <https://doi.org/10.1016/j.enbuild.2016.08.016>

**Kupczak, A., Jędrychowski, M., Strojecki, M., Krzemień, L., Bratasz, Ł., Łukomski, M., & Kozłowski, R.** (2018). HERle: A Web-Based Decision-Supporting Tool for Assessing Risk of Physical Damage Using Various Failure Criteria. *Studies in Conservation*, 63(sup1), 151–155. <https://doi.org/10.1080/00393630.2018.1504447>

**Quabeck, N.** (2023). Reviewing processes, relaxing parameters: On-collection climate research at the Kunstsammlung Nordrhein-Westfalen. *ICOM-CC Valencia*. <https://www.icom-cc-publications-online.org/5596/Reviewing-processes-relaxing-parameters--On-collection-climate-research-at-the-Kunstsammlung-Nordrhein-Westfalen>

**Saunders, D.** (2022). A Methodology for Modelling Preservation, Access and Sustainability. *Studies in Conservation*, 67, 245–252. <https://doi.org/10.1080/00393630.2022.2055933>

**Strlič, M., Thickett, D., Taylor, J., & Cassar, M.** (2013). Damage functions in heritage science. *Studies in Conservation*, 58(2), 80–87. <https://doi.org/10.1179/2047058412Y.0000000073>

**Thickett, D.** (2018). Frontiers of Preventive Conservation. *Studies in Conservation*, 63(sup1), 262–267. <https://doi.org/10.1080/00393630.2018.1504455>

**Thickett, D.** (2023). Practical Use of Damage Functions for Environmental Preventive Conservation and Sustainability—Examples from Naturally Ventilated Buildings. *Heritage*, 6(3), 2633–2649. <https://doi.org/10.3390/heritage6030139>

**Thickett, D., Emmerson, N., Larsen, R., Odlyha, M., & Watkinson, D.** (2022). Analysing Objects to Tailor Environmental Preventive Conservation. *Heritage*, 6(1), 212–235. <https://doi.org/10.3390/heritage6010011>

**Thickett, D., Mélinis, A., & Shah, B.** (2024). Measurement of Sorption Isotherms to Guide Mixed Display of Archaeological Iron, Bone, and Glass. *Materials*, 17(23), 5934. <https://doi.org/10.3390/ma17235934>

**European Commission. Joint Research Centre.** (2024). Safe and sustainable by design chemicals and materials: Methodological guidance. Publications Office. <https://data.europa.eu/doi/10.2760/28450>

**European Commission. Joint Research Centre.** (2024). Safe and sustainable by design chemicals and materials: Methodological guidance. Publications Office. <https://data.europa.eu/doi/10.2760/28450>

## SUPPLEMENTARY READINGS

**Camuffo, D.** (2023), Microclimate for Cultural Heritage: Conservation and Restoration of Indoor and Outdoor Monuments: Conservation, Restoration, and Maintenance of Indoor and Outdoor Monuments, Elsevier

**Grau-Bové, J., & Strlič, M. (2013).** Fine particulate matter in indoor cultural heritage: a literature review. *Heritage Science*, 1(1), 8. <https://doi.org/10.1186/2050-7445-1-8>

**Saunders, D.** (2025). Sustainability in Museum Lighting. In Á. F. Perles-Ivars, L. Fuster-López, & E. Bosco (Eds), *Collection Care* (pp. 71–87). Springer Nature Switzerland. [https://doi.org/10.1007/978-3-031-85655-6\\_7](https://doi.org/10.1007/978-3-031-85655-6_7)

**Taylor, J., & Beltran, V. L. (Eds.).** (2023). *Technical Note 10: Considerations for the process of managing collection environments*. In Getty Conservation Institute.

**Thickett, D.** (2018). Frontiers of Preventive Conservation. *Studies in Conservation*, 63(sup1), 262–267. <https://doi.org/10.1080/00393630.2018.1504455>

DETERMINING MATERIAL SENSITIVITIES AND GREEN DECISION-MAKING

THEME	TOPICS	DESCRIPTION	LEARNING OUTCOMES	ACTIVITIES + ASSESSMENTS
<b>Preventive Conservation and Sustainable Development</b>	<i>Impact of Preventive Conservation on Sustainability</i>	Explores the impact of preventive conservation on the four impact areas highlighted in the definition of green conservation and parameters.	Evaluate the sustainability impact of preventive conservation practices, in relation to waste management, energy consumption, environmental pollution, human health, and inclusion.	<b>Assessment:</b> Choose a case study of a preventive conservation strategy or approach to apply the green conservation definition and parameters and discuss how it affects the four impact areas (i.e., climate, use of resources, human health and well-being, and cultural heritage). Reflect on the challenges of this approach in relation to sustainable development, and suggest how it could be improved or adapted for future practice.
<b>Green Decision-Making Tools &amp; Frameworks</b>	<i>Tools, Frameworks, and Guidelines for Green Decision-Making</i>	Introduces tools and frameworks available for green decision-making in preventive conservation. Topic provides an overview for the following tools from the GoGreen project: HERle, Damage Functions, DSA App.	Analyse the extent to which one's preventive conservation actions conform to green conservation criteria and identify opportunities for improvement.	<b>Activity:</b> Deep dive into a tool or framework and in a presentation provide a summary of its applications and emphasize how insights from the tool or framework contribute to evolving traditional strategies toward more sustainable, green(er) practices. <b>Activity:</b> Identify and describe personal preventive conservation practices, then research one traditional method and one greener alternative related to the same area. If in pairs, share findings and collaboratively compare the two in terms of techniques, environmental/resource impact, effectiveness, and practical challenges. Evaluate how personal measures align with green conservation principles and parameters and identify ways they could be improved to be greener. Reflect on the potential benefits and feasibility of adopting greener strategies in your own context.
	<i>Comparing Measurements to Models</i>	Through case studies, reviews how the green decision-making tools and frameworks predict object behaviour and how it compares to reality. Topic considers limitations for application in preventive conservation decision-making.		
<b>Analysing Objects: Composition, Rate of Deterioration, and Preservation</b>	<i>Inorganic Objects: Metals</i>	The following topics explore how assessing an object's material composition, deterioration rate, and preservation state supports preventive conservation planning. Each topic focuses on a specific material group and demonstrates how green tools and frameworks can be applied to evaluate object stability and risks for decision-making in preventive conservation. Learners apply these tools to case examples to develop sustainable preventive strategies.	Apply diagnostic tools (e.g., HERle and damage functions) to evaluate how environmental parameters such as relative humidity, temperature, and light affect the stability, reactivity, and vulnerability of organic and inorganic cultural heritage, thereby supporting context-specific, risk-based greener preventive conservation strategies.	<b>Assessment:</b> Utilize a green decision-making assessment tool on a case study and present your findings. Discuss how material composition, deterioration rates, and preservation state influences preventive conservation strategies and analyse its impact on the following four areas: climate, resource use, human health and well-being, and cultural heritage.
	<i>Inorganic Objects: Ceramic, Stone, and Glass</i>			
	<i>Organic Objects: Paper, Wood, and Canvas</i>			
	<i>Complex Cases, Adaptation and Limitations of measurements and tools</i>	Introduces adaptations and limitations of measurements, tools and frameworks for complex cases and personal contexts. Considering how object individuality may impact preventive strategies.		
<b>Green(er) Preventive Strategies</b>	<i>Green(er) Approaches for Preventive Conservation</i>	Explores green(er) approaches for preventive conservation through the review and analysis of case studies	Negotiate and advocate for greener preventive conservation strategies through assessing risks using diagnostic tools, such as HERle and damage functions	<b>Assessment:</b> Building on previous work, explore green(er) approaches to preventive conservation and design and present a preventive conservation strategy. Compare previous preventive approaches with proposed new strategy in terms of the green conservation definition and parameters. Consider various forms of communication strategies to create a proposal for implementing strategy.
	<i>Practical Application</i>	Provides learners with the opportunity to apply green conservation principles to their personal and local contexts to develop and present their strategy in an accessible format, advocating for sustainable practices within their sphere of influence.		

## **DISCLAIMER**

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or Horizon Europe. Neither the European Union nor the granting authority can be held responsible for them.

## **AUTHORS AND CONTRIBUTORS**

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Additionally, we would like to thank the broader conservation community for collaborating in the development of the module templates through inputs and feedback via workshops, surveys, and focus groups. For more details on the list of contributors see the project deliverable 7.1 report.

## 1: Impact of Preventive Conservation on Sustainability

Lead author: Sky-Lyn Munoz

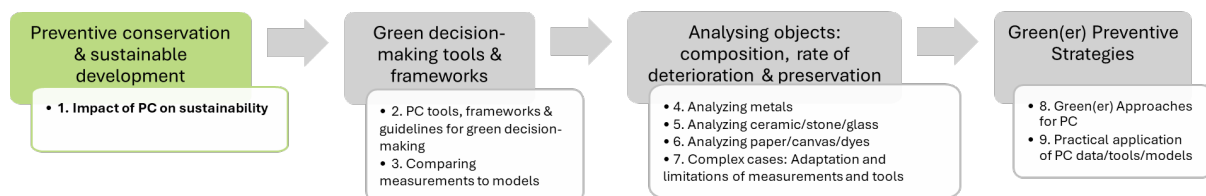
This session introduces green preventive conservation by applying the GoGreen definition and parameters to preventive strategies. It examines how preventive conservation strategies influence sustainability across the four impact areas highlighted in the green conservation definition: climate, resources, human health and well-being, and cultural heritage. Through integrated discussion and in-lecture case study analysis, learners will apply the green conservation framework to evaluate trade-offs, challenges, and opportunities for more sustainable preventive practices.

Key Concept 1      **Greener Preventive Conservation**  
 Key Concept 2      **14 Green Parameters**

### OBJECTIVES

- Objective 1      Familiarity with the definition of green conservation, 14 green parameters and their application to preventive conservation.
- Objective 2      Use the green conservation parameters to support preventive conservation decision-making.
- Objective 3      Evaluate impacts of preventive conservation strategies on: climate, human health and well-being, resources, and cultural heritage.
- Objective 4      Identify compromises and challenges to support green preventive conservation practice.

### Module placement in Determining Material Sensitivities learning trajectory



## PREPARATORY MATERIALS

Fife, G., Wagner, J., & Keune, K. (2025). GoGreen deliverable D8.3: Definition of green standards and parameters. Zenodo. <https://doi.org/10.5281/zenodo.16981204>

Fife, G. R., Turrina, A., Wagner, J., Del Curto, D., Southwick, C., & Keune, K. (2025). *Defining Green in the Conservation of Cultural Heritage*. Manuscript accepted for publication in *Studies in Conservation*, <https://doi.org/10.1080/00393630.2026.2653274>

Saunders, D. (2022). A Methodology for Modelling Preservation, Access and Sustainability. *Studies in Conservation*, 67(sup1), 245–252. <https://doi.org/10.1080/00393630.2022.2055933>

Practitioner-tested Decision Model, Taylor, J. (available on [GoGreen Zenodo](#))

Thickett, D. (2018). Frontiers of Preventive Conservation. *Studies in Conservation*, 63(sup1), 262–267. <https://doi.org/10.1080/00393630.2018.1504455>

R.P. Kramer, H.L. Schellen, A.W.M. van Schijndel (2016). Impact of ASHRAE’s museum climate classes on energy consumption and indoor climate fluctuations: Full-scale measurements in museum Hermitage Amsterdam, *Energy and Buildings*, Volume 130, Pages 286-294, <https://doi.org/10.1016/j.enbuild.2016.08.016>.

Bickersteth, J. (2016). IIC and ICOM-CC 2014 Declaration on Environmental Guidelines. *Studies in Conservation*, 61(sup1), 12–17. <https://doi.org/10.1080/00393630.2016.1166018>

### *Frameworks & guidelines:*

1) Globally Harmonized System (GHS): United Nations. (2023). Globally Harmonized System of Classification and Labelling of Chemicals (10th ed.). <https://unece.org/transport/dangerous-goods/ghs-rev10-2023>

2) Life-Cycle Assessments (LCA): [Life Cycle Assessment Explained - STiCH](#)

3) Safe and Sustainable by Design principles: European Commission. Joint Research Centre. (2024). Safe and sustainable by design chemicals materials: Methodological <https://data.europa.eu/doi/10.2760/28450>

4) The Bizot Green Protocol: CIMAM. (n.d.). The BIZOT Green Protocol. CIMAM. Retrieved 22 July 2025, from <https://www.cimam.org/sustainability-and-ecology-museum-practice/bizot-green-protocol/>

**SESSION OUTLINE** (total 2 hours)**Introduction** (5 minutes)

- Introduce preventive conservation as a decision-making process
- Poll: Which preventive strategies do you think are most energy/resource intensive?

**GoGreen definition and parameters** (15 minutes)

- Present the GoGreen definition of green conservation and the 14 green parameters
- Explain how the parameters apply to preventive conservation
- Introduce the four impact areas:
  - Climate
  - Resources
  - Human health and well-being
  - Cultural heritage
- Activity: Individually or in pairs, identify one preventive action and map it to one impact area

**Traditional environmental guidelines in context** (30 minutes)

- Overview and development of commonly accepted environmental parameters for relative humidity, temperature, light as outlined in the following guidelines and frameworks:
  - The Museum Environment by Gary Thomson
  - ASHRAE guidelines
  - Bizot Green Deal
- Discussion:
  - How do these guidelines and frameworks influence the four impact areas?
- Examine sustainability implications for each impact area:
  - Climate: energy for HVAC, heating/cooling systems, lighting
  - Resources: materials for equipment, consumables, replacement cycles
  - Human health and well-being: indoor air quality, lighting comfort, staff exposure
  - Cultural heritage: preservation benefits vs. over-control, visitor access
  - Mini exercise scenario: museum implements tight RH and temperature control. Learners identify positive and negative impacts on the 4 areas of green conservation.

**Beyond environmental control: other preventive strategies** (20 minutes)

- Overview of key preventive strategies:
  - Storage and enclosures
    - Passive vs active control
    - Material use and longevity
  - Monitoring and maintenance
    - Sensors, inspections, routine interventions
    - Resource use and staff workload
  - Access and handling
    - Balancing protection and public access

**Guided in-lecture case study and discussion session** (45 minutes)

- Choose a case study of a preventive conservation strategy or approach to apply the green conservation definition and parameters and discuss how it affects the four impact areas (i.e., climate, use of resources, human health and well-being, and cultural heritage).
- Reflect on the challenges of this approach in relation to sustainable development and suggest how it could be improved or adapted for future practice (*full guidance provided below*).

**Conclusion** (5 minutes)

- Represent the definition for green conservation and highlight that it is contextual and adaptive

**METHODOLOGY**

**Delivery Format**      Blended approach of lecture and group discussion

**Activities**              Activity from **Guided in-lecture case study** (total 45 minutes)

**Analyse a case study** (25 minutes)

- Introduce a single preventive conservation case study (real or hypothetical)
- Walk through the impacts the case study has on the four areas
- Note conflicts between preventive goals and sustainability goals
- Discuss trade-offs/ compromises that can be made to promote green conservation

**Reflection, challenges and adaptation** (20 minutes)

- Reflect on:
  - Where preventive conservation creates sustainability tensions
  - Institutional, financial, ethical, and professional constraints

- Discuss adaptation strategies:
  - Risk-based control
  - Prioritisation
  - Passive and low-energy approaches
  - Flexible standards

**Facilitator notes**

- Encourage comparison between frameworks and guidelines

## 2. Tools, Frameworks and Guidelines for Green Decision-Making

Lead author: Sky-Lyn Munoz

Building on an understanding of how preventive conservation can support greener conservation, this session introduces tools, frameworks, and guidelines that support green decision-making in practice. Learners explore analytical, risk-based, and decision-support approaches from the GoGreen project and broader conservation sector focusing on how their outputs can inform decisions that reduce impact to climate, human health and well-being, resources, and cultural heritage. Learners will learn key collections demography terms, understand the basics of quantitative risk assessment, and use open-access tools in practice.

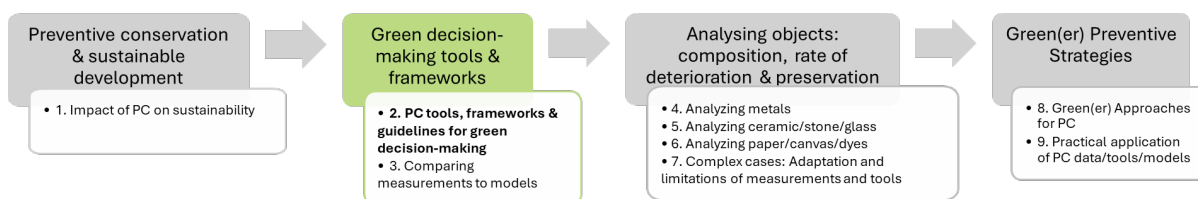
Key Concept 1  
Key Concept 2

**Tools for Preventive Conservation**  
**Sustainable Decision-Making**

### OBJECTIVES

- Objective 1 Familiarity with the definition of green conservation, the 14 green parameters, and the decision-making model developed in GoGreen.
- Objective 2 Awareness of the supporting frameworks and tools for the implementation of green conservation (according to the definition, parameters, and decision-making model).
- Objective 3 To apply green conservation frameworks to an example of decision-making in an assessment for a preventive conservation strategy.
- Objective 4 To interpret outputs from conservation tools and use them to support recommendations for greener preventive conservation strategies.

### Module placement in Determining Material Sensitivities learning trajectory



## PREPARATORY MATERIALS

Practitioner-tested Decision Model, Taylor, J. (available on [GoGreen Zenodo](#))

Thickett, D., Emmerson, N., Larsen, R., Odlyha, M., & Watkinson, D. (2022). Analysing Objects to Environmental Preventive Conservation. *Heritage*, 6(1), 212–235.

<https://doi.org/10.3390/heritage6010011>

Thickett, D. (2023). Practical Use of Damage Functions for Environmental Preventive Conservation and Sustainability—Examples from Naturally Ventilated Buildings.

*Heritage*, 6(3), 2633–2649. <https://doi.org/10.3390/heritage6030139>

Strlič, M., Thickett, D., Taylor, J., & Cassar, M. (2013). Damage functions in heritage science. *Studies in Conservation*, 58(2), 80–87.

<https://doi.org/10.1179/2047058412Y.0000000073>

Kupczak, A., Jędrychowski, M., Strojecki, M., Krzemień, L., Bratasz, Ł., Łukomski, M., & Kozłowski, R. (2018). HERle: A Web-Based Decision-Supporting Tool for Assessing Risk of Physical Damage Using Various Failure Criteria. *Studies in Conservation*,

63(sup1), 151–155. <https://doi.org/10.1080/00393630.2018.1504447>

Starters Manual (see parallel session in *Paintings* module on how to apply parameters and use the DSA app)

Annelies Cosaert, Vincent Laudato Beltran, Geert Bauwens, Melissa King, Rebecca Napolitano, Bhavesh Shah, and Joelle Wickens, 2022, Tools for the Analysis of Collection Environments: Lessons Learned and Future Development, [Tools for the Analysis of Collection Environments](#)

*Tools:*

1) GoGreen DSA (available on [GoGreen Zenodo](#))

2)STiCH: Carbon Calculator -[Carbon Calculator - STiCH](#)

3)HERiE - [HERle.pl – Risk Assessment and Cultural Heritage Conservation](#)

4) Paper degradation app: [hsl.shinyapps.io/COL\\_DEM\\_3/](https://hsl.shinyapps.io/COL_DEM_3/)

4) Gallery Climate Coalition Carbon Calculator: [GCC Carbon Calculator](#)

5) Our Collections Matter: [Our Collections Matter | ICCROM](#)

## SESSION OUTLINE (total 2 hours)

### Overview of conservation tools and frameworks (10 minutes)

- Conservation tools and the information they provide

<i>Tool/ framework</i>	<i>Use</i>	<i>Information provided</i>
STiCH	Impact assessment	Life-cycle impact
GoGreen DSA App	Decision Support	Conservation scenario comparisons
HERle	Decision Support	Damage predictions
Damage Functions	Predictive modelling	Deterioration rates

### Life cycle thinking and STiCH (30 minutes)

- Introduction to LCA and how it is applied in the conservation of cultural heritage
- Showcase how LCA tools can be used to assess environmental impact
- Discuss how STiCH outputs can inform decisions about energy and resources
- Strengths and limitations of LCA for preventive conservation decisions
- Discussion: How might LCA data challenge current preventive approaches? Which preventive strategies are most likely to appear unsustainable when viewed through LCA?

### Predictive and decision-support tools: HERle, damage functions and the GoGreen DSA App (30 minutes)

- Overview of three GoGreen related tools which utilize data to make risk-based decisions for environmental control
- Damage functions predict material response under combined environmental conditions
- HERle utilizes environmental data to predict damage
- GoGreen DSA App: Provides a structured way to compare conservation scenarios using the green conservation parameters

### Interpreting tools outputs for Greener decisions (45 minutes)

- Activity options detailed in section **below**

### Discussion wrap-up (5 minutes)

- Reflect on applying the green conservation frameworks and tools in practice on the preventive conservation case study. What outputs from the conservation tools aided in supporting recommendations for greener preventive conservation strategies?

## METHODOLOGY

**Delivery Format** Blended approach. The session will comprise an initial lecture with PowerPoint presentation, then group activity, followed by discussions.

**Activities** Activity from **Interpreting tools outputs for Greener decisions** (total 45 minutes)

### **Interpreting tools outputs for Greener decisions** (25 minutes)

Directions: Divide learners into groups and assign each one a tool discussed in the lecture

Groups identify:

- What the tool measures or predicts
- What is required to use the tool (ex. yearly vs. monthly vs. daily data for environmental conditions)
- What assumptions does the tool make
- What conservation question it answers
- How its outputs could support a greener preventive decision
- Where uncertainty remains

### **Rethinking a preventive strategy** (20 minutes)

Format: Individually or in pairs

Tasks:

- Select a preventive conservation strategy
- Identify which tools could inform a greener alternative or compromise
- Evaluate both approaches using the green conservation definition and parameters

### **Facilitator Notes**

Materials:

- Each learner equipped with computer for interactive with the tools OR session deliverer projects tools
  - For HERie and STiTCH utilise case studies and open-access data sets provided by the tool
- Reference data (e.g. RH/T data sets, light data, material composition)
- Case study scenarios
  - Prepare different environmental/collection/space scenarios to enable learners to understand where the tools are most applicable. For example, case studies from historic churches vs. Purpose built museum/storage buildings
- Video projector

**ADDITIONAL RESOURCES**

Webinar links from GoGreen: <https://www.youtube.com/@GoGreenConservation> (WP2)

HERle Courtauld Lecture: <https://youtu.be/ru83-0ig7vQ?si=O93pc33kNOKBilsk>

HERle Youtube: <https://youtu.be/nFhZczTPnqY?si=1gqI73KJOJ29tfd>

### 3. Comparing Measurements to Model: Interpreting Predictions in Preventive Conservation

Lead author: David Thickett

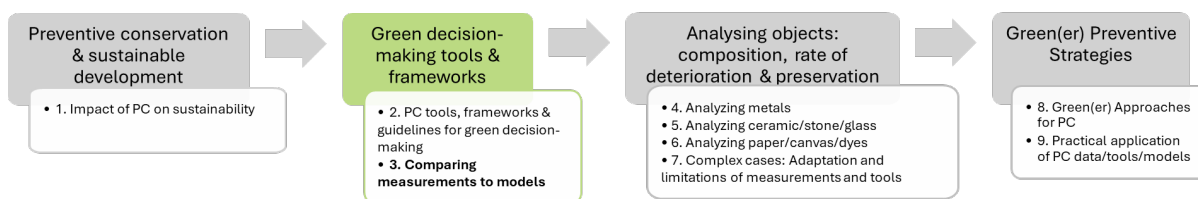
This session examines the utility, assumptions, and limitations of predictive models used in preventive conservation. It enables learners to develop skills in interpreting model predictions in relation to observed, or perceived change, and at a finer scale, measured change.

- Key Concept 1    **Measurements can be more sensitive/reliable than observations**  
 Key Concept 2    **All models have assumptions/limitations**  
 Key Concept 3    **Some give very good correlation with precise measurements**

#### OBJECTIVES

- Objective 1    Identify key assumptions embedded in models  
 Objective 2    Explain limitations of predictive tools  
 Objective 3    Interpret model predictions in relation to measurements  
 Objective 4    Understand limitations of observations

#### Module placement in Determining Material Sensitivities learning trajectory



#### PREPARATORY MATERIALS

Thickett, D. (2023). Practical Use of Damage Functions for Environmental Preventive Conservation and Sustainability—Examples from Naturally Ventilated Buildings. *Heritage*, 6(3), 2633–2649. <https://doi.org/10.3390/heritage6030139>

**SESSION OUTLINE** (total 2 hours)

**Introduction:** What models do that other approaches can't, what are assumptions and why it matters (45 minutes)

- Explain limitations of range approach (setting ranges of RH such as ASHRAE), synergistic effects, both T and RH essential to accurately predict mould risk. Movement of water into wood, affects response.
- Activity 1: use ASHRAE and HERle restrained wood module to assess impact of demo environment on wooden furniture.
- Identify assumptions underlying a relevant model may have such as:
  - Materials are treated as uniform (not true HERle, Climate for culture)
  - Environmental conditions are averaged or stable (not true HERle, Climate for culture, strong evidence monthly averaging still provides good prediction for metals)
  - Past damage is often excluded (not for HERle painted wood).
  - Interactions between factors are simplified or unknown
- Activity 2: In groups or individually, assign a model and identify two assumptions and one limitation of the model. Where and when would you use the model for preventive conservation practice?

**Limits and sources of uncertainty** (20 minutes)

- Explain common sources of uncertainty
  - Incomplete or unknown material data (not only an issue for models)
  - Short monitoring periods
  - Lack of data for environment, showcases,
  - Lack of data on previous environment, past conservation treatment, etc

**Interpreting model outputs** (20 minutes)

- Introduce how to interpret model outputs:
  - Predictions indicate relative risk not certainty
  - Useful for comparison between scenarios
  - Can make much more realistic targets

**Comparing predictions to measurements** (25 minutes)

- Highlight observations in practice and their limitations:
  - Condition reports
  - Environmental records
- Utilise a case study to compare model outcomes to recorded measurements and discuss:
  - Do the prediction and observation broadly align?
  - What might explain the differences?
  - How might the differences impact conservation decision-making?

**Implications for preventive conservation decision-making** (10 minutes)

- Highlight risks of over-control with uncertainty
- Reflecting on how models and measurements can be used to evolve traditional strategies toward more sustainable, green(er) practices

**Key takeaways**

- Predictive models can be useful for preventive conservation
- Models should be corroborated against measurements

**METHODOLOGY**

**Delivery Format**      Blended approach

**Activities**            **Activity 1:** Comparing HERIe prediction to acoustic emission measurements for furniture, from forthcoming paper and HERIe datasets

**Activity 2:** Compare the measured value of copper corrosion to damage functions?

Time: 10 minutes each

These activities will support the information presented in the **Introduction** of this module. They will provide students with practical examples of models.

**By the end of the activity, learners will:**

- Be able to use several different models and apply them
- Accurately interpret and explain results
- Be able to identify the limitations and assumptions of each model

**Materials:**

- HERIe website, datasets to be added to HERIe, AE data for single object
- Sample pollution, T/RH datasets, from fig 10 heritage DF paper

**Tasks:**

- Run HERIe restrained wood module with RH data, compare to AE events
- Run the copper DF calculations with year 1 (used for prediction) and year 2 (actual) data, compare to measured copper corrosion rate.

**Facilitator Notes**

- Highlight that each available model has inbuilt assumptions and limitations
- Models should be checked against real-life measurements
- Models are valuable tools for the prediction and communication of preventive conservation practice

## 4. Analysing Metal Objects: Composition, Rate of Deterioration, and Preservation

Authors: David Thickett and Cathryn Harvey

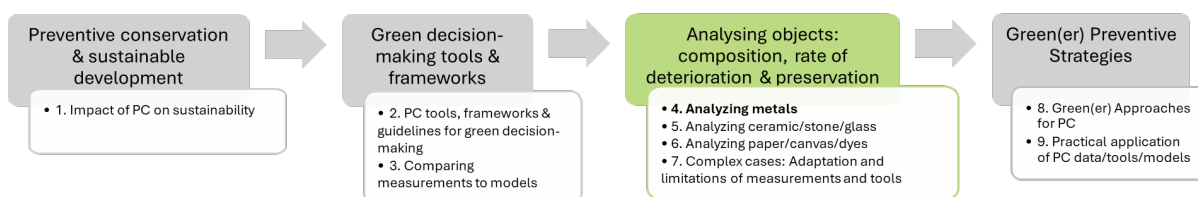
This session explores the material sensitivity of metals such as silver, iron, copper, lead and their alloys. It introduces damage functions as tools to predict corrosion rates and guide targeted, sustainable environmental management. Participants will examine how corrosion depends on multiple factors, including pollutants, relative humidity, temperature, and object-specific properties. Using damage functions enables green, risk-based preventive strategies that balance preservation, resource use, and long-term sustainability.

Key Concept 1	<b>Damage functions</b>
Key Concept 2	<b>Corrosion mechanisms</b>

### OBJECTIVES

Objective 1	Describe how material composition influences sensitivity to environmental conditions.
Objective 2	Explain how corrosion results from combined effects of pollutants, relative humidity, and temperature
Objective 3	Use damage functions to predict corrosion rates for metal objects and discuss how rate influences preventive conservation strategies
Objective 4	Evaluate the broader impacts of environmental control decisions on climate, resource-use, human health and well-being, and cultural heritage.

### Module placement in Determining Material Sensitivities learning trajectory



## PREPARATORY MATERIALS

Thickett, D., Emmerson, N., Larsen, R.; Odlyha, M., & Watkinson, D. (2022) Analysing Objects to Tailor Environmental Preventive Conservation, *Heritage* (6), 212-235.

Available at: <https://doi.org/10.3390/heritage6010011>

Thickett, D., Melinis, A., Cheung, C. S., & Lang, H. (2023) Analysing objects to produce more sustainable conservation environments, *e-Journal of Non-destructive Testing*.

Available at: <https://www.ndt.net/search/docs.php3?id=28945>

Thickett, D., Odlyha, M., & Lankester, P. (2023) Assessing and predicting sustainability for maintaining silver collections, ICOM-CC 20th Triennial Conference Preprints, Valencia. Available at: <https://www.icom-cc-publications-online.org/5638/Assessing-and-predicting-sustainability-for-maintaining-silver-collections->

Thickett, D., and Harvey, C. (2025) Assessing the Performance and Lifetime of Cellulose Nitrate Lacquer on Silver, *Materials* 4155. Available at:

<https://doi.org/10.3390/ma18174155>

## SESSION OUTLINE (total 2 hours)

### Introduction (10 minutes)

This session concerns risk-based, object-specific environmental management rather than generalized universal standards which enables preventive conservation to shift from maximum control to appropriate control promoting greener conservation practice.

- Overview of common metals found within cultural heritage (silver, iron, copper, lead and their alloys)
- Why metals present particular environmental challenges?
  - Metals are strongly affected by environmental conditions, particularly pollution, relative humidity, and some by temperature
  - Brief discussion question: What environmental factor(s) worries you most for metal objects?
- Emphasise that predicting corrosion rate supports targeted, appropriate parameters rather than universal minimums
- Highlight that striving for the lowest possible environmental values is often resource-intensive and unnecessary.
- Position session around risk-based decision making

### Material sensitivity of metals (25 minutes)

Provides foundational understanding of how different metals respond to environmental conditions based on composition, manufacture, and prior history.

- Silver
  - Tarnishing mechanisms
  - Highlight sensitivity to reduced sulfur gases
- Iron
  - Active vs. stable corrosion
  - Role of Chlorides and moisture (RH) in corrosion
- Copper and copper alloys
  - Patination, bronze disease
  - Sensitivity to acids and chlorides
- Discuss influence of alloying, surface finishes, and manufacturing methods on corrosion rate
- Emphasis on different corrosion mechanisms between metals and implications for environmental control

### **Corrosion as a multi-factor process (20 minutes)**

- Combined effects of:
  - Gaseous pollutants
  - Particulates
  - Relative Humidity
  - Temperature
- Why pollutant concentration alone is misleading in determining corrosion rate
- Synergistic effects of variables
- Limitations of single-parameter environmental targets
- Understanding interactions supports more efficient, lower-impact greener preventive conservation control strategies

### **Damage functions and corrosion prediction (30 minutes)**

- Definition and purpose of damage functions
- Overview damage calculators
- Structure of calculators:
  - Required inputs for calculations and how to acquire the values needed:
    - Pollutants, RH, Temperature
  - Outputs
    - Predicted corrosion rates
  - Assumptions built into calculators/models
  - Sources of uncertainty and variability
- Emphasis of separate calculators for different metals which must be reviewed individually depending on object in question

### **Applied learning activity: damage function case study (30 minutes)**

- Learners will work individually or in small groups to review and utilise one of the damage function calculators on a provided case study (full activity detailed **below**)

**Case study**

Copper Alloy Sculpture of Queen Victoria loaned to Apsley House. Damage function used to select display room. Details: Heritage 2023, 6(3), 2633-2649; <https://doi.org/10.3390/heritage6030139>

**Key takeaways** (5 minutes)

- Metal corrosion is driven by interacting environmental factors
- Damage functions enable targeted, object-specific preventive conservation by predicting deterioration rates under defined conditions
- Object-specific assessment is essential for informed environmental management

**METHODOLOGY**

**Delivery format**      Blend of lecture and practical exercise

**Activity**                **Damage Function Case Study** (30 minutes)

Learners will work individually or in small groups to review and utilise on the damage function calculators on a provided case study and recommend preventive conservation strategies. The activity integrates material sensitivity, environmental variables, and sustainability considerations.

**By the end of the activity, learners will:**

1. Predict corrosion rates for a specific metal under given environmental conditions
2. Identify the environmental factors affecting corrosion risk
3. Recommend environmental guidelines or preventive strategies tailored to the object
4. Evaluate trade-offs between preservation, sustainability, and resource-use
5. Reflect on the broader impacts of their recommendations on the green parameters (climate, resources, human health and well-being, and cultural heritage)

**Materials:**

- Damage function calculators for copper, steel, and silver
- Case study datasets which include (RH, temperature, pollutant levels) and object specific details (composition, surface area, finish, preservation state)

**Tasks:**

- Review the relevant calculator for the metal type
- Input environmental and object data from case study
- Record predicted corrosion rates, risk levels, and critical contribution factors
- Compare predicted corrosion rates to object's current state
- Identify which environmental factors contribute most to risk
- Propose environmental guidelines and preventive strategies using predicted and observed damage?

**Questions:**

- What environmental change would have the biggest impact and at what cost?
- Where might resource constraints force compromises?
- How does the preventive strategy support both preservation and sustainability?

**Discussion and analysis:**

- As a group discuss findings and how material composition, deterioration rate, and preservation state influence preventive conservation strategies, analysing impacts across four areas:
  - Climate:
    - Energy demand of environmental control
    - Carbon implications of stricter vs targeted parameters
  - Resource Use
    - Costs of air filtration and environmental management
    - Long-term sustainability of proposed strategies
  - Human Health and Well-Being
    - Indoor air quality
    - Staff and visitor comfort and exposure
  - Cultural Heritage
    - Risk tolerance and significance
    - Preventing loss of material and cultural value
- Compare outcomes across different metals and calculators
- Reflect on how damage functions influence environmental decision-making
- Discuss trade-offs between preservation, sustainability, and operational constraints
- Identify acceptable compromises in preventive conservation practice

**Facilitator notes**

- Keep returning to the idea of “appropriate” rather than “ideal” environment
- Highlight the damage function calculators as tools rather than absolute predictors which quantify risk not eliminate it
- Emphasis that each calculator has its own model and assumptions
- Encourage learners to articulate why they would accept certain risks

- Key prompt: What do we gain and what do we lose by trying to control everything?

#### ADDITIONAL RESOURCES

- Time-lapse video of deterioration: Two Iron Keys, Incorrect Relative Humidity and Pollutants [Time-lapse Video of Deterioration: Two Iron Keys, Incorrect Relative Humidity & Pollutants - Canada.ca](#)

## 5. Analysing Ceramic, Stone, Glass: Composition, Rate of Deterioration, and Preservation

Authors: David Thickett and Cathryn Harvey

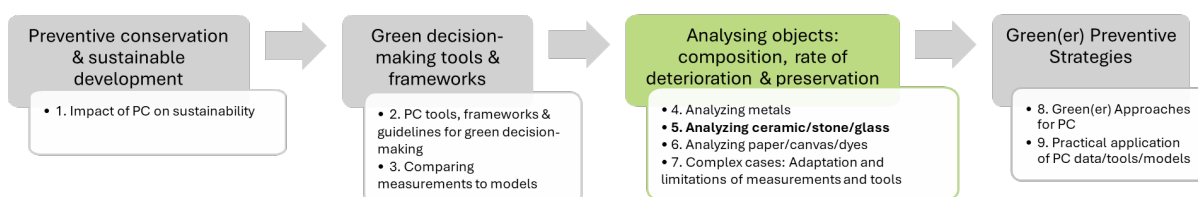
This session explores the material sensitivity of ceramic, stone, and glass cultural heritage. It introduces assessment methods and damage functions as tools to determine material sensitivity and guide targeted, sustainable environmental management. Participants will examine how decay depends on multiple factors, including pollutants, relative humidity, temperature, and object-specific properties. Determining material sensitivity enables green, risk-based preventive strategies that balance preservation, resource use, and long-term sustainability.

- Key Concept 1    **Decay mechanisms in stone and ceramics**  
 Key Concept 2    **Decay mechanisms in glass**  
 Key Concept 3    **Assessment methods for stone and ceramics, and damage functions for glass**

### OBJECTIVES

- Objective 1    Describe how material composition influences sensitivity to environmental conditions.
- Objective 2    Explain how rate of deterioration results from combined effects of pollutants, relative humidity, and temperature
- Objective 3    Use assessment methods to predict risks for ceramic and stone, and damage functions for glass, and discuss how this influences preventive conservation strategies
- Objective 4    Evaluate the broader impacts of environmental control decisions on climate, resource-use, human health and well-being, and cultural heritage.

### Module placement in Determining Material Sensitivities learning trajectory



## PREPARATORY MATERIALS

Thickett, D., & Melinis, A. (2025). Sustainability of Maintaining Glass Collections. *Heritage*, 8(7), 251. <https://doi.org/10.3390/heritage8070251>

Thickett, D. (2023). Analysis of Salts and Clays for Conservation of Porous Cultural Heritage. *Applied Sciences*, 13(22), 12434. <https://doi.org/10.3390/app132212434>

## SESSION OUTLINE (total 2 hours)

### Introduction (10 minutes)

This session concerns risk-based, object-specific environmental management, which enables preventive conservation to shift from maximum control to appropriate control, promoting greener conservation practice.

- Introduce types of ceramic, stone, glass in cultural heritage
- Highlight their differing sensitivities and the impact of environmental conditions
- Emphasise that identifying vulnerable objects deterioration rate supports targeted, appropriate parameters rather than universal minimums
- Assessment methods are tools for decision-making rather than definitive judgement

### Material sensitivity overview (30 minutes)

Provides foundational understanding of the material sensitivities of ceramic, stone, and glass to the environment based on the influence of their composition, surface finish, prior treatment, and age.

- Ceramics and stone:
  - Material composition impacts sensitivity:
    - Ceramics: clay type/content, firing temperature, glaze type/thickness, porosity
    - Stone: porosity, mineral composition, clay content
  - Environmental sensitivities:
    - Soluble salts – crystallisation/hydration cycles under RH/temperature fluctuations
    - Expanding clays – structural damage under RH changes
    - Pollutants -gaseous or particulate pollutants can accelerate deterioration in porous materials

- Sensitivity and damage type is dependent on salt type and concentration, porosity, clay content, and exposure to pollutants, both historic and current
- Glass
  - Stability determined by material composition, which affects chemical stability, and prior corrosion.
  - Environmental sensitivities:
    - Hydration from fluctuating RH and temperature
    - Pollutants contribute to leaching, crizzling, and surface corrosion
- Discussion question: What are the different tolerance windows for each the materials?

### **Environmental factors and multi-factor deterioration (20 minutes)**

- Combined effects of:
  - Relative humidity
  - Temperature
  - Pollutants
  - Particulate matter
  - Light
- Synergistic degradation mechanisms
  - For example: expanding clays causing swelling
- Limitations of single-parameters environmental targets
- Understanding interactions supports more efficient, lower-impact greener preventive conservation control strategies
- Discussion Questions: How do porosity, material composition, and pollutants interact to influence material sensitivity in ceramics and stone? How does chemical stability and prior corrosion influence glass sensitivity?

### **Risk assessment tool (20 minutes)**

Demo one process for learners

- Definition and purpose of assessment method
- Overview of required tools
- Structure of software:
  - Required inputs for calculations and how to acquire the values needed:
    - Ceramics and Stone Specific: salt and clay content
    - Glass Specific: surface-ion concentration
    - Pollutants, RH, Temperature
  - Outputs
    - Predicted decay rates for ceramics and stone
    - Damage functions for glass
  - Assumptions built into models
  - Sources of uncertainty and variability

**Applied learning activity: assessment tool case study** (35 minutes)

- Learners will work individually or in small groups to review and utilise one of the methods on a provided case study (Full activity detailed below)

**Key Takeaways** (5 minutes)

- Inorganic materials are sensitive to multiple interacting factors
- Identifying vulnerable objects enables targeted, object-specific preventive conservation by predicting deterioration rates under defined conditions

**METHODOLOGY**

**Delivery Format**      Blend of lecture and practical exercise

**Activity**                **Vulnerable Object Identification Case Study** (30 minutes)

Learners will work individually or in small groups to review and utilise on the assessment methods on a provided case study and recommend preventive conservation strategies. The activity integrates material sensitivity, environmental variables, and sustainability considerations.

**By the end of the activity, learners will:**

6. Predict object vulnerability for ceramic, stone, or glass under given environmental conditions
7. Identify the environmental and material factors influencing decay risk
8. Recommend environmental guidelines or preventive strategies tailored to the object
9. Evaluate trade-offs between preservation, sustainability, and resource-use
10. Reflect on the broader impacts of their recommendations on the green parameters (climate, resources, human health and well-being, and cultural heritage)

**Materials:**

- Assessment tools for ceramic, stone, and glass
- Case study datasets which include (RH, temperature, pollutant levels) and object specific details (composition, surface ion concentration, preservation state)

**Tasks:**

- Review the relevant software for the material type
- Input environmental and object material data from case study

- Record predicted object vulnerability, risk levels, and critical contribution factors
- Compare predicted rates to object's current state
- Identify which environmental factors contribute most to risk
- Propose environmental guidelines and preventive strategies using both predicted and observed damage

**Questions:**

- What environmental change would have the biggest impact and at what cost?
- Where might resource constraints force compromises?
- How does the preventive strategy support both preservation and sustainability?

**Discussion and analysis:**

- As a group, discuss findings and how material composition, deterioration rate, and preservation state influence preventive conservation strategies, analysing impacts across four areas:
  - Climate:
    - Energy demand of environmental control
    - Carbon implications of stricter vs targeted parameters
  - Resource Use
    - Costs of air filtration and environmental management
    - Long-term sustainability of proposed strategies
  - Human Health and Well-Being
    - Indoor air quality
    - Staff and visitor comfort and exposure
  - Cultural Heritage
    - Risk tolerance and significance
    - Preventing loss of material and cultural value
- Compare outcomes across different material types and assessment methods
- Reflect on how damage functions influence environmental decision-making
- Discuss trade-offs between preservation, sustainability, and operational constraints
- Identify acceptable compromises in preventive conservation practice

**Facilitator notes:**

- Keep returning to the idea of “appropriate” rather than “ideal” environment
- Highlight the assessment methods as tools rather than absolute predictors. They help quantify risk not eliminate it
- Emphasise that each method has its own model and assumptions
- Encourage learners to articulate why they would accept certain risks
- Key prompt: What do we gain and what do we lose by trying to control everything?

## 6. Analysing Paper, Canvas, Dyes: Composition, Rate of Deterioration, and Preservation

Author: Łukasz Bratasz

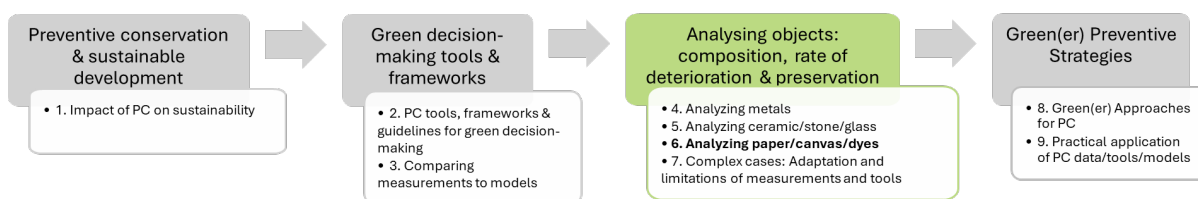
This session introduces the freely available web-app HERIE (<https://herie.pl/>) and explores its applications in decision-making regarding collection care and environmental management in heritage institutions. In particular, the *Chemical degradation* and *Radiation* modules will be introduced. Participants will use specific tools to evaluate the objects' lifetime and discuss possible climate control strategies in an institution.

Key Concept 1      **Agents of deterioration**  
Key Concept 2      **Lifetime and fading calculators**

### OBJECTIVES

Objective 1      Describe how environmental parameters affect the deterioration rate.  
Objective 2      Use the web-app modules to assess environmental risks to the collection materials (paper, canvas, dyes).

### Module placement in Determining Material Sensitivities learning trajectory



### SESSION OUTLINE (total 2 hours)

#### Introduction (15 minutes)

This session concerns risk assessment for materials susceptible to chemical degradation and fading. The concept of 10 agents of deterioration and the effectiveness of conservation measures will be introduced.

#### Chemical degradation of low-stability materials (20 minutes)

An introduction to the chemical degradation of low-stability organic materials will be presented.

- Overview of materials prone to chemical degradation (paper, polymers, leather, silk, dyes).
- What are the environmental parameters affecting the degradation rate?
- Activation energy of degradation.
- Concept of the relative lifetime of an object.

### **Hands-on exercises: chemical degradation** (40 minutes)

Learners will work individually on their own laptops/tablets to review and utilise a *Lifetime – paper* calculator on a provided case study (full activity described below).

### **Light-induced fading** (20 minutes)

An introduction to light-induced colour fading will be presented.

- Overview of materials prone to fading (dyes, inks, wood).
- What are the environmental parameters affecting the fading rate?
- Commercial standards for luminous exposure of materials of various stability.
- Colour change  $\Delta E$ , CIE Lab colour space and colour descriptors.
- Quantification of ‘just noticeable colour change’ and ‘different colour’.

### **Hands-on exercise: light-induced fading** (20 minutes)

- Learners will work individually on their own laptops/tablets to review and utilise a *Light damage calculator 1* on a provided case study (full activity described below).

### **Key takeaways** (5 minutes)

- Benefits and limitations of calculators for decision-making support.
- Chemical degradation of organic materials depends on temperature and RH.
- The effect of previous exposure on dye fading.

## METHODOLOGY

**Delivery format**      Lecture and hands-on exercises

**Activities**              Hands-on exercises (40 + 20 minutes)

Learners will work individually to utilise calculators on the provided case studies. In particular, participants will be asked to:

- evaluate the lifetime of the books produced post-1850 and evaluate various preservation methods:
  - active lowering of temperature,
  - deacidification,
  - lowering the temperature for winter without energy use;
- evaluate the ‘time to lining’ of Salvador Dali’s painting;

- develop a lighting policy for a light-sensitive object – a 19th-century Japanese print with crystal violet – for the next 50 years.

**By the end of the activity, learners will:**

1. Predict the lifetime of paper, canvas and the fading rate of dyes under given environmental conditions.
2. Identify the environmental factors affecting the degradation/fading rate.
3. Evaluate various preservation methods in terms of cost-efficiency and sustainability.

**Materials:**

- *Lifetime – paper* calculator, *Light damage calculator 1* (single-point data).
- Case study datasets which include environmental measures (RH, T, UV, LUX) and object-specific details (degree of polymerisation, acidity, type of dyes).

**Tasks:**

- Download exemplary environmental data from *Demonstration data*.
- Review the relevant tools: *Lifetime – paper* and *Light Damage Calculator 1*.
- Run calculations for a case study based on the provided descriptions.
- Compare the efficiency of various preservation methods (chemical degradation).
- Identify factors bringing the highest risk (chemical degradation).
- Propose long-term storage conditions for case studies.

**Questions:**

- Which measure impacts the rate of chemical degradation and fading the most?
- Are there any myths about preventive conservation to debunk?

**Discussion and analysis:**

- In groups, discuss outcomes of calculations for each case study and possible preventive conservation measures.
- Reflect on how lifetime and fading calculators influence environmental decision-making.
- Discuss the pros and cons of different preventive conservation measures, bearing in mind the costs.

**Facilitator notes**

- Point out the limitations of calculators.
- Emphasise that the calculation outcomes are approximations, not exact values (should be treated as years, decades, hundreds of years, etc.).

- Highlight multiple options of preventive conservation measures (there is no ‘one proper decision’).

#### **ADDITIONAL RESOURCES**

- Manuals and tutorials at the HERIE website (<https://herie.pl/>)

## 7. Complex Cases, Adaptation and Limitations of Measurements and Tools

Author: Łukasz Bratasz

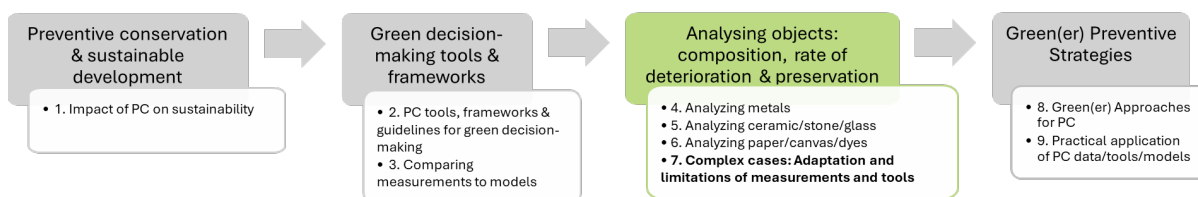
This session explores the use of the web-app HERIE (<https://herie.pl/>) in decision-making regarding complex cases of collection care and environmental management in large heritage institutions and historic buildings. Participants will use this tool to evaluate the risk of mechanical damage to wooden objects transferred from a naturally unstable climate (historic building) to an air-conditioned environment and develop the lighting policy for the painting gallery.

Key Concept 1	<b>Worst-case scenario</b>
Key Concept 2	<b>Acclimatisation concept</b>
Key Concept 3	<b>Risk analysis</b>

### OBJECTIVES

Objective 1	Explain how environmental parameters influence the mechanical response of wooden artefacts.
Objective 2	Describe how the current state of an artwork affects the decision-making process.
Objective 3	Use the web-app modules to assess environmental risks to the collection.

### Module placement in Determining Material Sensitivities learning trajectory



### SESSION OUTLINE (total 2 hours)

#### Introduction (25 minutes)

An introduction to mechanical damage due to environmental variations will be presented.

- Three approaches to assessing whether climate variability is acceptable:
  - Understanding the mechanical behaviour of objects,
  - The acclimatisation ('proofed fluctuation') concept,
  - Non-destructive methods of in-situ tracing damage development.
- The worst-case scenario approach.
- Guidelines overview.
- Real environmental data from various institutions.
- How does the *Mechanical damage* tool work?

**Hands-on exercise: mechanical damage** (40 minutes)

Learners will work individually on their own laptops/tablets to review and utilise the *Mechanical damage* tool for a provided case study (full activity described below).

**How to develop a lighting policy for a large institution?** (20 minutes)

- Overview of the painting collection (age distribution of paintings) and luminous exposure in different areas of the building, defining the risk zones.
- An approach based on the estimation of past exposure will be discussed for various groups of paintings in the collection.

**Hands-on exercise: lighting policy** (30 minutes)

Learners will work individually on their own laptops/tablets to review and utilise *Light Damage Calculator 1* on a provided case study (full activity described below).

**Key takeaways** (5 minutes)

- How digital tools support decision-making.
- Module predictions for undamaged objects vs. acclimatisation concept.
- The effect of previous exposure on dye fading.

**METHODOLOGY**

**Delivery format**      Lecture and hands-on exercises

**Activities**              Hands-on exercises (40 + 30 minutes)

Learners will work individually to utilise the *Mechanical damage* tool and the *Light damage calculator 1* for the provided case studies. In particular, participants will be asked to:

- assess the risk of pictorial layer cracking due to moving a panel painting from the natural microclimate of a historic building to an air-conditioned conservation studio in a museum;
- develop a lighting policy and discuss a set of measures for the painting gallery (British art), where light levels are significantly above the recommended.

**By the end of the activity, learners will:**

4. Evaluate the risk of mechanical damage due to relative humidity variations.
5. Assess the fading due to past exposure and predict future colour change.
6. Identify the risk groups for painting collection.
7. Evaluate various preservation strategies in terms of cost-efficiency and sustainability.

**Materials:**

- *Mechanical damage* tool (case study 1) and *Light damage calculator 1* (case study 2).
- Case study datasets which include environmental measures (RH, T, UV, LUX), object-specific details (wood type, panel cut and thickness, ground type and water vapour transport), and painting collection description.

**Tasks:**

- Case study 1:
  - Download exemplary environmental data from *Demonstration data*.
  - Merge microclimate datasets.
  - Review the relevant tool: *Painting on wood*.
  - Run calculations for a case study based on the provided description.
  - Compare the obtained deformation results with the critical values.
- Case study 2:
  - Upload light intensity data from a file.
  - Estimate colour change based on past exposure and assess the amount of remaining colour.
  - Predict colour change for a 50-year perspective.
  - Propose a lighting policy, considering the pros and cons of the approach.

**Questions:**

- What are the consequences of various decisions regarding the conservation of a panel painting from the historic church?
- Which dyes are the most prone to fading?
- Are there any myths about preventive conservation to debunk?

**Discussion and analysis:**

- In groups, discuss outcomes for each case study and possible preventive conservation measures.
- Reflect on how risk assessment tools influence environmental decision-making.
- Discuss the ‘acceptable damage’ in the context of the entire painting collection.

**Facilitator notes**

- Emphasise that the worst-case scenario overestimates the risk.
- Remind about the acclimatisation concept.
- Key prompt: risk assessment vs. safety analysis.

**ADDITIONAL RESOURCES**

- Manuals and tutorials at the HERIE website (<https://herie.pl/>).

## 8: Green(er) Approaches for Preventive Conservation

Author(s): David Thickett and Cathryn Harvey

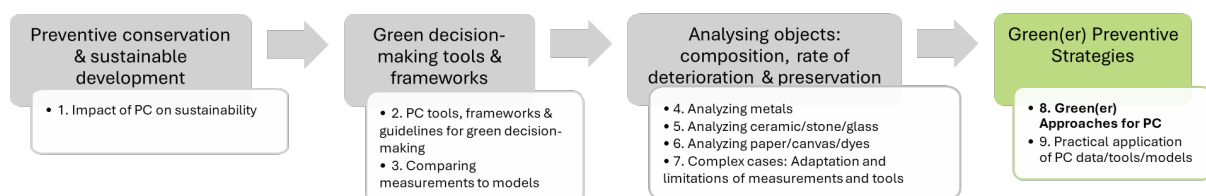
This session explores the impacts informed limits of temperature and relative humidity can make to the sustainability of preventive conservation. It explains the effectiveness of microclimates compared to entire room conditioning, and the importance of working with existing building envelopes to mitigate external environmental change. It also explores the adjustment of air conditioning systems to use less energy while still providing the same internal environment.

Key Concept 1	<b>Limits of T/RH can massively impact energy use</b>
Key Concept 2	<b>Advantages of microclimates</b>
Key Concept 3	<b>Building envelopes can give significant protection</b>
Key Concept 4	<b>Approaches to reducing HVAC energy use</b>

### OBJECTIVES

Objective 1	Understand how object response and T/RH limits massively affect G3 (indoor climate control impacts) of the Green Parameters for Green Conservation ( <a href="https://gogreenconservation.eu/defining-green-conservation/#definition">https://gogreenconservation.eu/defining-green-conservation/#definition</a> )
Objective 2	Understand that microclimates are much less energy intensive than controlled room environments
Objective 3	Building envelopes can be used to reduce energy demand

### Module placement in Determining Material Sensitivities learning trajectory



## PREPARATORY MATERIALS

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## SESSION OUTLINE (total 2 hours)

### Introduction (5 minutes)

This session expands on the concepts introduced in Session 1 (Impact of Preventive Conservation on Sustainability) by exploring how different approaches in preventive conservation can impact energy use. Brief recap of 'Traditional Environmental Guidelines' and 'Other Preventive Strategies' sections from Session 1.

**Impacts of preventive conservation (25 minutes)**

Provides outline of thought process behind the evaluation of environmental impacts of preventive conservation activities.

- G3 Green parameters for conservation: Energy – indoor climate control impacts
  - Considers the energy use related to indoor climate control for the object / collection, considering general guidelines, existing controls in place and the prevailing outdoor location: also considering any change in the climate control needs of the object as a result of the approach/treatment under contemplation. Considers the energy sources being used (carbon-based, non-renewable, renewable).
- Discussion questions: Looking at the data from this paper (Simon 2023), how would you rank these results for their impact using the G3 green parameter framework? How do the results of Modules 2,4,5,6 (Green Decision Making, Material Sensitivities) feed into required conditions?
- Activity: Review Artigas MSc graph on how allowable T and RH fluctuations impact energy consumption.

**Applied learning activity: HERIe painted wood module (30 minutes)**

- Learners will work individually or in small groups to determine a suitable environment with the most appropriate conditions using sample data sets and the HERIe painted wood module (full activity detailed in **Activities** section)

**Microclimates: use of enclosures (25 minutes)**

Provides an overview on the influences on microclimates, how to assess them and examples of use

- Influences:
  - Volume of enclosure
  - Air exchange rate (AER)
  - Volume of air to be conditioned
  - Conditions of surrounding environment
- Examples of use
  - Glazed paintings, print frames
- Assessment
  - Cannot be done through inspection
  - Measuring AER
  - Monitoring condition in enclosure
  - European standard tables provide guidelines (EN BS15999 part 2)

**Building Envelopes: the building as a buffer (30 minutes)**

Provides an overview of different building types, how they can serve as a buffer for environmental conditions, and how to evaluate and predict the buffering effect

- Heritage building types:
  - Historic buildings
  - Churches
  - Museums
- Mitigation
  - Heating
  - Humidistatic heating
  - Smart ventilation
  - Seasonal drift
  - Shutdowns
  - Reduction of AC load
  - Reduction of external air intake
- Measuring and predicting buffer effect
- Limitations and issues with approach.

#### **Key takeaways (5 minutes)**

- Traditional preventive conservation methods have significant impact on energy usage
- More informed T/RH limits can make preventive conservation approaches less energy intensive
- The use of microclimates, adjustment of HVAC systems, and exploitation of existing building envelopes can make efforts more impactful and sustainable

## **METHODOLOGY**

**Delivery Format**      Blended approach

**Activities**              Using HERIe modules and Artigas graphs to determine suitable environments (30 minutes)

Learners will work individually or in small groups to use the HERIe painted wood module and Artigas graphs to assess 3 demonstration datasets to assess and predict risk levels, fluctuations and energy usage per m<sup>2</sup> for the preservation of a painted wood object.

#### **By the end of the activity, learners will:**

- Be comfortable uploading data to HERIe and using the painted wood module
- Be familiar with the use of Artigas graphs to determine energy usage per m<sup>2</sup>
- Reflect on the broader impacts their recommendations have on the G3 green parameters

**Materials**

- HERle website (<https://herle.pl/>)
- Case-study datasets which include RH & temperature, and object specific details

**Tasks**

- Ensure all students have a HERle account and access to the sample datasets
- Input environmental data to HERle and how to set up painted wood module
- Interpret HERle output
- Record predicted object vulnerability, risk levels, and critical contribution factors
- Compare predicted rates to object's current state
- Calculate energy consumption per m<sup>2</sup> for different preventive approaches
- Use results and calculations to propose preventive conservation strategy for example object

**Questions**

- How does the preventive strategy support both preservation and sustainability?
- How might resource constraints force compromises?

**Discussion and analysis**

- Discuss trade-offs between preservation, sustainability, and operational constraints
- Identify acceptable compromises in preventive conservation practice

**Facilitator notes**

- Informed limits of temperature and RH can help make more informed preventive conservation choices with regards to energy consumption
- There are more energy efficient approaches than whole room conditioning, such as microclimates
- It is important to work *with* the building
- Accurate measurements are key to informed decision making
- Tools like HERle can help visualise and present data for decision making and communication

## 9. Practical Application

Authors: David Thickett, Lukasz Bratasz and Sonia Bujok

This session explores the use of the web-app HERIE (<https://herie.pl/>) and an excel spreadsheet on Zenodo (forthcoming) in two practical applications: a) adjusting the amount of silica gel to stabilise the relative humidity in a showcase at a certain level, and b) using dehumidifiers to dry rooms to certain RH levels.

Key Concept 1

**Passive environmental control**

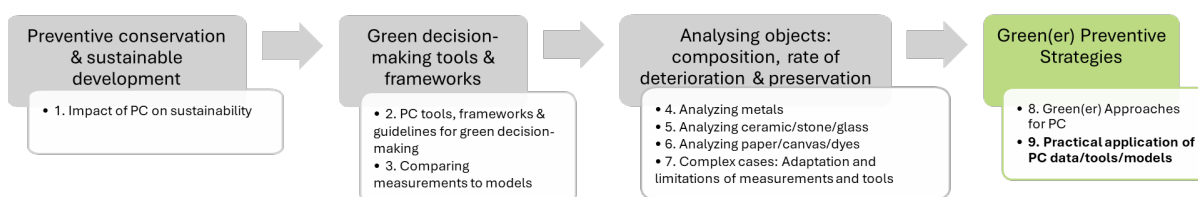
Key Concept 2

**Active environmental control**

### OBJECTIVES

- Objective 1 Adjust the amount of silica gel in the showcase for specific relative humidity conditions.
- Objective 2 Predict the energy use for dehumidifying a room to certain RH values.
- Objective 3 Use the web-app modules and Zenodo spreadsheet to compare environmental control options.

### Module placement in determining material sensitivities learning trajectory



### PREPARATORY MATERIALS

Fife, G., Wagner, J., Goncalves, B., Southwick, C., & Katrien Keune. (2025). *DEFINING GREEN CONSERVATION - GoGreen*. GoGreen Conservation.

<https://gogreenconservation.eu/defining-green-conservation/>

Students should register an account with <https://herie.pl/> prior to teaching.

**SESSION OUTLINE** (total 2 hours)**Introduction** (30 minutes)

A short theoretical introduction to relative humidity control will be presented.

- The air exchange rate (AER) – parameter determining the airtightness of showcases and rooms.
- The protocol for estimating the AER for showcases and rooms/buildings.

**Hands-on exercise: the amount of silica gel** (30 minutes)

Learners will work individually on their own laptops/tablets to review and utilise the *Showcase tool* for a provided case study (full activity described below).

**How to determine energy use of dehumidifier** (20 minutes)

A short theoretical introduction to room climate control

- Methods of control.
- Different needs, different environments and buildings.
- Dehumidifier is one of least complex, provided full information available.
- Approach to calculations.

**Hands-on exercise: dehumidifier use** (20 minutes)

Learners will work individually on their own laptops/tablets to review and utilise the *dehumidifier tool on Zenodo* on a provided case study (full activity described below).

**Discussion and analysis:** (20mins)

- In groups, discuss the pros and cons of active and passive environmental stabilisation methods. Compare the results from silica gel control to whole room control. Discuss impact of changing AERs
- Reflect on how risk assessment tools influence environmental decision-making at the strategic level.

**Wrap-up/Key takeaways** (10 min)**METHODOLOGY**

**Delivery Format**      Lecture and hands-on exercises

**Activities**              Hands-on exercises (30 + 30 minutes)

Learners will work individually to utilise the *Showcase tool* and the *dehumidifier tools* (Zenodo) for the provided case studies. In particular, participants will be asked to:

- determine the parameters of the showcase to keep the relative humidity:
  - below 30% to avoid corrosion,
  - around 60% to provide stabilisation of the RH demanded in a loan agreement,
  - high to avoid the risk of mechanical damage to an object acclimatised to high RH.

**By the end of the activity, learners will:**

- Explain how to determine the air exchange rate (AER).
- Estimate the amount of silica gel required for stabilising specific RH conditions in the showcase.
- Evaluate the energy use of dehumidifiers.

**Materials:**

- *Silica gel lifetime* calculator (case study 1) and the *dehumidifier tool* (case study 2).
- Case study details, which include required RH levels and showcase characteristics (case study 1), and the costs of drying room air (case study 2).

**Tasks:**

- Case study 1:
  - Review the *Silica gel lifetime* calculator.
  - Select the silica gel type and adjust its amount in the showcase of predefined size for a case study based on the provided description:
    - Use the ‘Keep RH low’ option for RH below 30% and adjust the initial RH of the silica gel.
    - Use the ‘RH around 50%’ option for RH around 60% and adjust the initial RH of the silica gel.
    - Use the ‘Keep RH high’ option for RH above 75% and adjust the initial RH of the silica gel.
  - Evaluate how often to replace (regenerate) the selected amount of silica gel and how AER affects the ‘silica gel lifetime’.
- Case study 2:
  - Review the dehumidifier tool.
  - Compare the predicted energy use for rooms with different air exchange rates.

**Questions:**

- What are possible improvements in the showcase design?
- Are there any myths about preventive conservation to debunk?

**Facilitator notes**

- Remind about the cost-effectiveness of preventive conservation actions.
- Highlight that there is no ‘one proper decision’, but tools may support it.

**ADDITIONAL RESOURCES**

- Manuals and tutorials at the HERIE website (<https://herie.pl/>).
- Zenodo (<https://zenodo.org/communities/gogreen/>).