Define sustainable indoor climate for cultural heritage preservation

in an existing building

1 Reality check

What is needed / what is possible

START

- Consider **collection risks**: light, water (infiltration), fire,...
- Current state of the **collection**. What (type of) damage is visible?
- What is the (natural) buffering capacity of your **building envelope**
- Capacity and state of your **climate control system(s)** (if present).
- What is your **outdoor climate** in relation to your potential **energy cost**
- **Budget** available for energy consumption and **technical staff** (maintenance).

YES → Try to **link the damage to your current climate.**

NO → Identify the needs based on your **space use** and material **sensitivities of the (permanent) collection**

2A Identify and understand damage / change

Existing and past damage to classic mixed heritage collections

	RH ↓	RH ↑	RH ↑↓	T ↓	T ↑	T ↑↓
Mechanical	**deformation, cracking,** shrinkage, flaking, embrittlement, loss of flexibility	**swelling, warping, delamination,** softening	**weakening, deformation**, fatigue, separation, delamination	**retraction,** adhesive failure, increased, chipping, flaking embrittlement, **frost damage**	**expansion,** dehydration, dissication	**Expansion and contraction,** leading to cracks and **delamination,** loss of mechanical properties
Chemical	**acidification,** desiccation, salt crystallization, degradation, color fading	**oxidation, hydrolysis, corrosion,** efflorescence (salt migration), staining	efflorescence (salt migration), chemical reactions, accelerated aging	increased **embrittlement,** efflorescence (salt migration)	**speeds up chemical processes**; hydrolysis, oxidation, darkening, emission of VOC's, softening,... leading to **accelerated natural aging**	loss of strength and other phenomena related to high T
Biological	generally decreases insect and mold development and growth	**increases mold and bacterial growth** causing staining, weakening, discoloration, **higher presence of insects**	**increased release of fungal spores,** cycles of dormant and active mold (can go unnoticed)	generally decreases insect and mold development and growth	**increases mold and bacterial growth** causing staining, weakening, discoloration, **higher presence of insects**	condensation leading to increased risk of **local mold growth**

! Establish the link between damage and indoor climate (e.g.: cracks can also be caused by bad air handling, discoloration by light and mold by a temporary leak.

2B Compare to climate data

Review your climate **data** and logbook. Are there any **damages / changes linked to climate** (step 2a) and / or **are your goals realistic** (step 5a)?

- YES → **MECHANICAL**: **Avoid** constant high RH (+70% and -30 % RH), avoid 24h RH and T fluctuations (+10%) and 5°C
- YES → **CHEMICAL**: **Avoid** constant high T and constant high RH (material dependent)
- YES → **BIOLOGICAL**: **Avoid** constant high T and constant high RH (+70%) and create ventilation.

NO → While taking these **basic tips** into account, it is still important to go through the **following steps**

YES → Do you want / have to think about **energy savings**?

NO → Your **current indoor climate** is probably **suited** for your collection

OK, YOU'RE DONE

5A Determine set-points

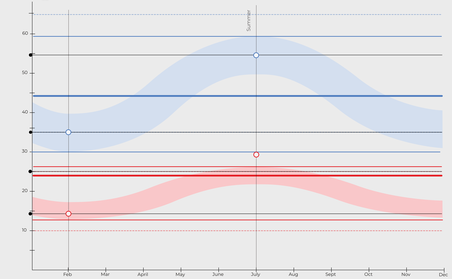
It's time... First, a small checklist.

YES / NO / NA

- ❶ Are your goals **realistic**?
- ❷ Is there is **collection damage**?
- ❸ Have you identified the **type** of damage?
- Is it **related to unsuited indoor climate**?
- Have you identified your **different zones** and their needs?
- ❹ Have you **chosen which guideline or current institutional set-point** to use as a reference for the different zones?
- Have you calculated your historical average?
- Do you understand that choices are not only dependant on the **needs of your collection**, but also the **building envelope capacity** and the **systems** present (different systems can control different rooms).
- Do you understand that a strict indoor climate can have severe **implications on your energy use** and (subsequently) your budget.
- ❺ Consult all **stakeholders** and verify again: are your goals still realistic?

5B Create time plot

SI (metric) units



4.1 **Historical building, Belgium**
RH Annual average: 44%RH
T Annual average: 24°C

4.3 **ASHRAE 2019, Climate Class A1:**
RH Long term outer limit: 35-65% RH
T Long term outer limit: 10-25°C
4.2 RH Seasonal Fluctuations: +- 10%RH
T Seasonal Fluctuations: +5°C, -10°C
4.4 RH 24h Fluctuations: +- 5% RH
T 24h Fluctuations: +- 2°C

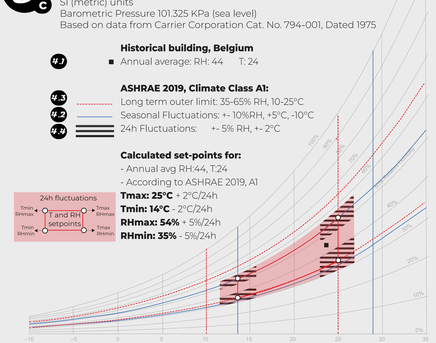
24h fluctuations: Tmax, Tmin; T and RH setpoints

Calculated set-points for:
- Annual avg RH:44, T:24
- According to ASHRAE 2019, A1

Tmax: 25°C + 2°C/24h
Tmin: 14°C - 2°C/24h
RHmax: 54% + 5%/24h
RHmin: 35% - 5%/24h

5C Create psychrometric Chart

SI (metric) units
Barometric Pressure 101.325 KPa (sea level)
Based on data from Carrier Corporation Cat. No. 794-001, Dated 1975



EXAMPLE

ASHRAE 2019 - A1

❶ **REALITY CHECK:** Collection: paper, main other risk: light building envelope: historical building - old warehouse - large glass roof, climate system: heating in winter, outdoor climate: temperate, budget and staff: private museum, limited resources, 1 technical FTE on staff.

❷ **DAMAGE / CHANGE:** embrittlement, accidification

❸ **ZONE:** Main exhibition room, open space, mezzanine on 1st floor. Most works in modern (not airtight) display cases.

❹ **GUIDELINE:** Chosen to compare existing climate to ASHRAE A1.

EXAMPLE

Conclusion

❺ **DETERMINE SET-POINTS:**

- **4.1. Annual average:** T is very high, RH rather low
- **4.2. Seasonal fluctuations:** annual avg. ± seasonal fluct.
- **4.3. Long term outer limit:**
  Seasonal T + is higher then long term outer Tmax.
  Seasonal RH ↓ is equal to long term outer RHmin.
- **4.4. 24h Fluctuations:** on top of the seasonal fluctuations
  T +: around long term outer limit because seasonal Tmax too high
  RH ↓: around long term outer limit

Annual avg. T is too high to realistically obtain a ASHRAE A1 Climate. This, partially, due to the large glass surfaces of the building envelope.
Annual avg. RH is low in winter due to heating without humidification.
ASHRAE B (often used for historical buildings), might be **a more realistic choice**. Combine less heating in winter and light blocking materials in summer.

CONSIDERATIONS / IMPACT

on the choice of guidelines

BUILDING
(description of the typical building envelope)
- purpose built / low energy / passive
- well insulated / historical building
- badly insulated / open stucture

CLIMATE SYSTEM REQUIRED
(except low-energy / passive build)
- HVAC in non temperate climates
- Partial climate control possible
- No climate control possible

BUDGET: ENERGY USE
(except low-energy / passive build)
- low
- medium
- high

! OUTDOOR CLIMATE
the bigger the gap between your outdoor and indoor climate, the higher the cost.

ANNUAL / HISTORICAL AVERAGE

How to interpret historical average in relation to your indoor climate

- **No climate system** → correct representation of the natural capacity of your building envelope
- **Heating only** → T ↑ and RH ↓ in winter
- **Cooling only** → T ↓ and RH ↑ in summer
- **Mechanical / natural ventilation** → ↓ chances of mold development
- **(De)humidification** → RH ↑ when humidifying, RH↓ when dehumidifying then naturally
- **HVAC** → climate is result of impact of natural building envelope quality + system perfomance

3A Define zones

Collection preferences per materials

- **Collection / public:** define your needs based on the collection composition and comfort
- **Collection, not public:** define the needs based on the collection
- **Non collection, public:** focus on comfort temperature

MOVING
Moving from one place to another can require time for an artwork to **adapt to another climate.**

PERMANENT
This is usually the dominant institutional climate, **acceptable for the bulk of the collection**

STORAGE
Take into account **natural buffering capacity**: cellulose based and large mass collections.

COMFORT
Typically desk area's or working area's. Create a comfort temperature.

Is it a **working space**

YES / NO → For **chemically unstable objects** (metals, unstable glass, plastics, ethnographic objects, mixed media,...) consider small scale solutions.

Is the institutional **climate similar** to the original climate?

NO → YES

3B Understand systems and collection

Collection preferences per materials

- **'Classic museum climate'**: organic collections and classic mixed collections
- **Microclimates** (e.g. display cases): natural buffer RH fluctuations. Passive and active control possible
- **Climate chambers and quarantine rooms**: loans and collection mobility
- **Cold, cool, frozen and dry** storage: photography, metals, chemically unstable materials
- **Low oxygen** storage: beneficial for all collections. Added benefit: reduces risk on pests.

YES

3C Locate System

Which rooms are conditioned by which system(s)?

Can you identify for every room how they are conditioned?

- **Heating**
- **Cooling**
- **Humidification**
- **Dehumidification**
- **Mechanical ventilation**

4 International guidelines

Existing guidelines can serve as a reference for your institutional climate

Typical use / Impact	4.1 (Annual / hist.) average	4.2 Seasonal fluctuations	4.3 Long term outer limits	4.4 24h Fluctuations
	T and RH averaged of a representative year or a longer period. It's an important starting point for collections that have resided in the same building / climate for a long time. If unknown, an educated guess can be made. Be open to revision after measurements.	Fluctuations **starting from the annual / historic average** allowing for seasonal variations. Seasonal fluctuations will reduce the energy consumption and can relieve stress from mechanical systems. Seasons can be determined regionally (e.g. including monsoon).	Represent the **minimum and maximum values that should not be surpassed** (with a possible exemption of 24h or short term fluctuation). These outer limits are mainly determined to reduce the risk of mechanical response and mold germination	Are related to the **response time of object** or the time an object needs to respond to environmental changes. Lesser daily / hourly / weekly changes will cause lower stress and strain. E.g. unframed paper will respond faster to RH ↓↑ then a wooden sculpture.
2014 - ICOM-CC & IIC Environmental guid.	Series of remarks endorsing the 'Bizot Green Protocol' (international), AIC (American, national) and AICCM (Australia, national)			
2019 - ASHRAE Climate class A1	T: annual avg. exhibition rooms: human comfort	T: +5°C, -10°C; RH: +10%, -10%	T: 10 - 25°C	T: ±2°C; RH: ±5%
2019 - ASHRAE Climate class A2	RH: annual avg.	RH: no change	RH: 35 - 65%	RH: ±10°C
2019 - ASHRAE Climate class B		T: +10°C, -20°C; RH: +10%, -10%	T: < 30°C, T: < 40°C; RH: 30 - 70%	T: ±5°C; T: rarely > 30°C
2019 - ASHRAE Climate class C	T: usually < 25°C; RH: between 25 - 75%		RH: > 25 %, < 75%	not continually above 65% for x days
2019 - ASHRAE Climate class D	RH: reliably < 75%		< 75%	
2019 - ASHRAE Loans	Loans are not tied to a climate class. They are the result from a negotiation between two parties taking into account their respective climates.			
2014 - Bizot Green Protocol		T: 'stable'; RH: ±10%	T: 16 - 25°C	T: 'stable'; RH: ±10%
ISO 18934:2011 Cool storage	T: 12°C (fixed avg.)		T: 8 - 16°C; RH: 45 - 55%	
ISO 18934:2011 Cold storage	T: 4°C (fixed avg.)		T: 0 - 8°C; RH: 30 - 50%	
ISO 18934:2011 Frozen storage			T: -20 - 0°C	

6 Implementation

Aftermath

- Indicate the zones and the related set-points in the **facility report**
- **Inform all stakeholders.**
- Ask max. for a similar climate to your own in **loan agreements**
- If needed, set some **exceptional set points during hottest, coolest, most humid and driest moments** of the year. Set **alarms** accordingly.
- Keep on **testing** and measuring your **energy use, T and RH**

CLIMATE2PRESERV
Collections · Buildings · Systems

LEGEND

RH: Relative Humidity (in %)
T: Temperature (in °C)
↑: high(er), will increase, upper
↓: low(er), will decrease
↑↓: fluctuations, will fluctuate

Climate2Preserv (C2P) is a project coordinated by the Royal Institute for Cultural Heritage (KIK-IRPA), realised with the help of the Catholic University of Leuven (KUL), the University of Liège (Ulg), International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM) and the Academia Belgica. The project is funded Belspo.

This graph was created for the C2P summer school and is part of a larger protocol about energy saving practices for cultural heritage institutions. Want to know more? visit: https://www.kikirpa.be/en/projects/climate2preserv

CLARIFICATION

This flowchart does not represent all factors that can be taken into account when considering the aspects of indoor climate and it's influence on collection preservation. It merely highlights the most influencial factors and aims at being an **aid for descision-making** for a broader group of stakeholders. Note that **many national institutions provide guidance based on your local climate**.

For more information, more detailed sources can be consulted:

- **Agent of Deterioration: Incorrect Relative Humidity, Agent of Deterioration: Incorrect Temperature** & **Environmental guidelines for museums**, Canadian Conservation Institute (CCI - ICC, 2017) - Available in English and French
- **Managing indoor climate risks**, Cultural Heritage Agency of the Netherlands (RCE, 2018) - Available in English and Dutch
- **ASHRAE Handbook 2019** - HVAC Applications, Chapter 24: Museums, Galleries, Archives, and Libraries, American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) - English