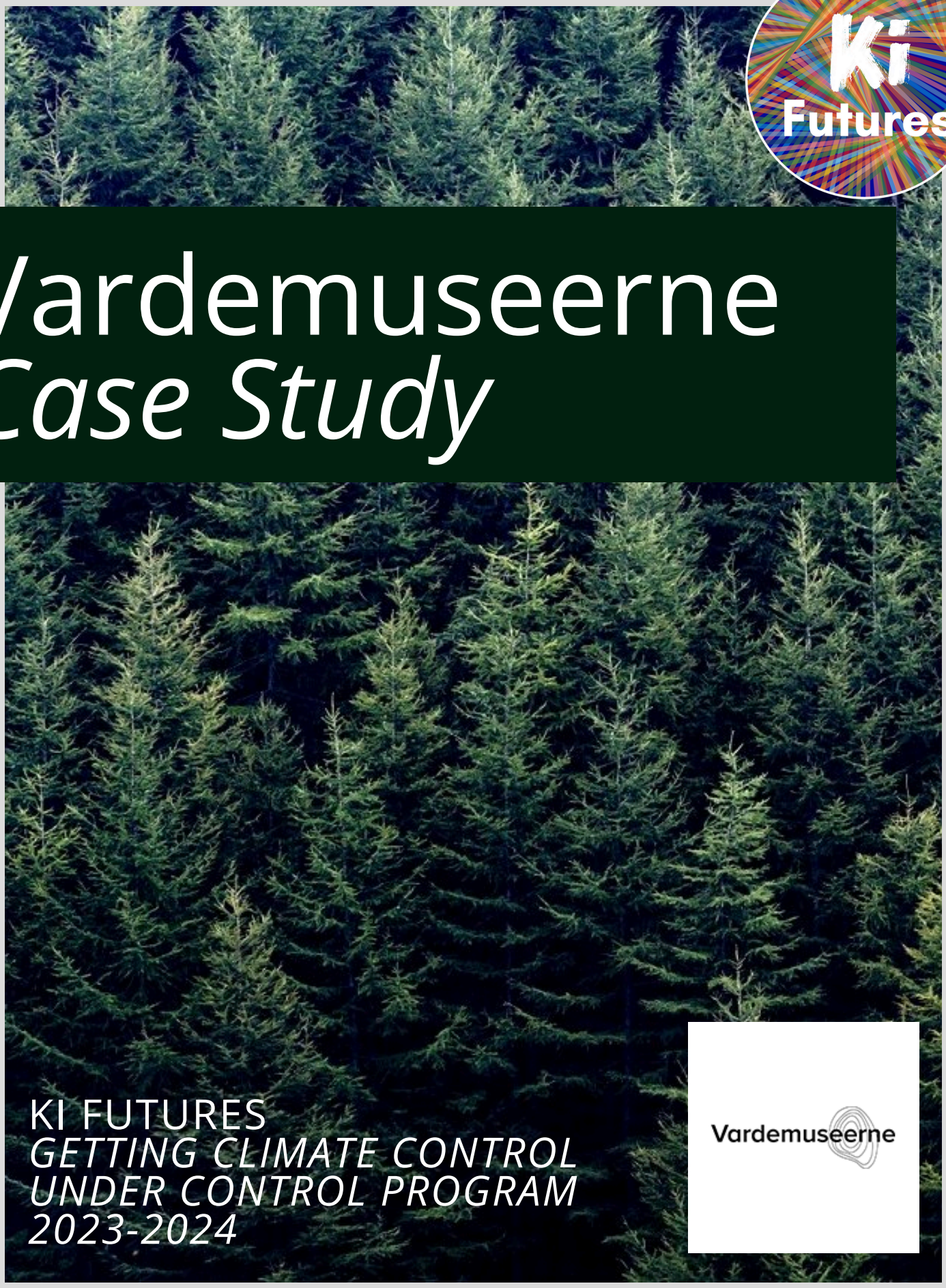

Vardemuseerne *Case Study*

KI FUTURES
GETTING CLIMATE CONTROL UNDER CONTROL PROGRAM 2023-2024

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Introduction & Background

Vardemuseerne is dedicated to:

- Collecting and producing new knowledge about the cultural history of the region.
- Manage the municipality's ancient monuments responsibly.
- Providing relevant, engaging, and up-to-date education and communication about nature, art, and cultural history to the municipality's citizens of all ages as well as to tourists visiting the region.
- Participating in the Ki Futures Climate Control Program aligns with Vardemuseerne’s commitment to the Museum’s Green Charter (Appendix 1). We are working on integrating sustainable practices across museum operations. Our main goal is to contribute to the green transition alongside other museums.

Vardemuseerne is based in Varde Municipality in the Southwest of Denmark. The museum was founded in 1912. Today we have ten exhibition venues and around 335.000 visitors annually. We provide knowledge on several subjects regarding art, nature, archaeology, and cultural history.

Test area

- The building containing halls A and B was built in 2002 and hall C in 2004. The building is freestanding. The outer walls consist of steel on a wooden frame. The interior walls consist of MDF and wood wool boards (træuldsplader). The roof has skylights without UV filters.
- The building is located close to The Northern Sea (15 km) in an industrial area. The building is located low in the terrain with the gables facing north/south. The gates and entrance are facing south. Collection: total area 1187.5 sqm
- Non-collection: 356.4 sqm. The selected test area is in hall C, which is 234 sqm. In the test area, approx. 8.000 smaller museum artefacts of mixed materials (iron, wood, plastic, textile, paper etc.) are stored in Styrofoam and cardboard boxes on mobile shelving.
- The space is only used as a museum storage. Two days a week, two-three employees spend time in the storage area handling artefacts during registration and preparation of artefacts for exhibitions. Cleaning staff are on the premises every Wednesday. On Wednesday afternoons, eight volunteers and two staff members spend time in the building.

HVAC- system

- The climate control system was implemented in late September of 2017. It consists of a COTES C35 dehumidifier. Prior to this project, the values for humidity and temperature had not changed since the setup in 2017.

Previous climate control parameters
The limit values were set to:

- Humidity: Min 48% RH and max 52% RH (Target 50% RH)
- Temperature: min 19 degrees C and max 25 degrees C
- The Danish Agency for Culture and Palaces (Slots- og Kulturstyrelsen) recommends a minimum of 16 degrees C, but as the room shares its temperature control with the painting storage, was set to a minimum of 19 degrees C as recommended by our conservation consultant at Konserveringscenter Vejle.

Collection description

- The collection consists of cultural historical objects of mixed materials (iron, wood, plastic, textile, paper, etc.) and art collected from 1912, when the museum was established, until today. We have approximately 80.000 objects in total in the collection.
- The value of the collection is linked to its provenance and contribution to the story of the Varde area/Varde Municipality. In this respect, the collection has a high value. We collect objects with potential according to research and education.
- The majority of the collection is owned by Vardemuseerne. There is a small loan of archaeological objects from the National Museum of Denmark, which are placed in the museum storage for study purposes, and a larger loan of artillery objects, all of which are on display at the Armor and Artillery Museum in Oksbøl (Panser- og Artillerimuseum).
- Condition/preservation reports are only prepared when deemed necessary, which is mainly in connection with exhibitions. The items are considered stored in a stable manner when they are placed in the museum storage, which is subject to an annual review by a conservator.

The motivation for the Climate Control Program at Vardemuseerne

- In line with Vardemuseerne's commitment to the Museums' Green Charter, we aim to integrate the green transition into all aspects of museum operations, including the collection and its energy consumption. By joining the program, we hoped to gain insights into our building stock, engage in discussions, and share challenges, successes, and knowledge with peers and experts. This will hopefully further qualify and educate employees across various professional groups at Vardemuseerne.

Stakeholder Involvement & Resources Utilized

Karen, Jørn, and Marianne were the project coordinators. They participated in the one-on-one meetings, completed various online courses, and were responsible for the implementation of the project.
Helge contributed data on energy consumption.
Lasse is participating in the last phases of the project communicating the results.
The project coordinators were fully engaged during the project. The rest of the team on an ad hoc basis. We presented the project to our colleagues at a staff meeting and will continuously share our knowledge and results with them.
We hired Kongserveringscenter Vejle to consult on our baseline objects as we did not have the expertise in house.
Salary expenses for the project coordinators.

Project Team

- **Karen Bjelke Fisker, collections archaeology**
- **Marianne Sørensen, collections cultural history**
- **Jørn Nielsen, technical service manager**
- **Helge Asger Wolff, head of finances**
- **Lasse Kjær Hansen, communication coordinator**

Objectives

Training for museum staff

- The project offered climate control and preventive conservation training. Thus, equipping employees across different departments with skills for the green transition. The program includes a forum where challenges and successes can be shared, alongside access to the latest knowledge and advice from experts and colleagues.

Represent historical institutions

- Through our participation, represent cultural heritage institutions with diverse collections.

Assess and improve resource use

- Review and evaluate our energy consumption within our storage area and assess the sustainability of our buildings.

Integrate green practices across museum operations

- Formalize our efforts toward the green transition by embedding sustainable practices in all areas of museum operations, including the collection and its energy consumption. This aligns with our commitment to the Museum's Green Charter. Our main goal is to contribute to the green transition alongside other museums, with a secondary goal of reducing operational costs.

Monitoring Process, Methodology, Implementation

Choosing the test area

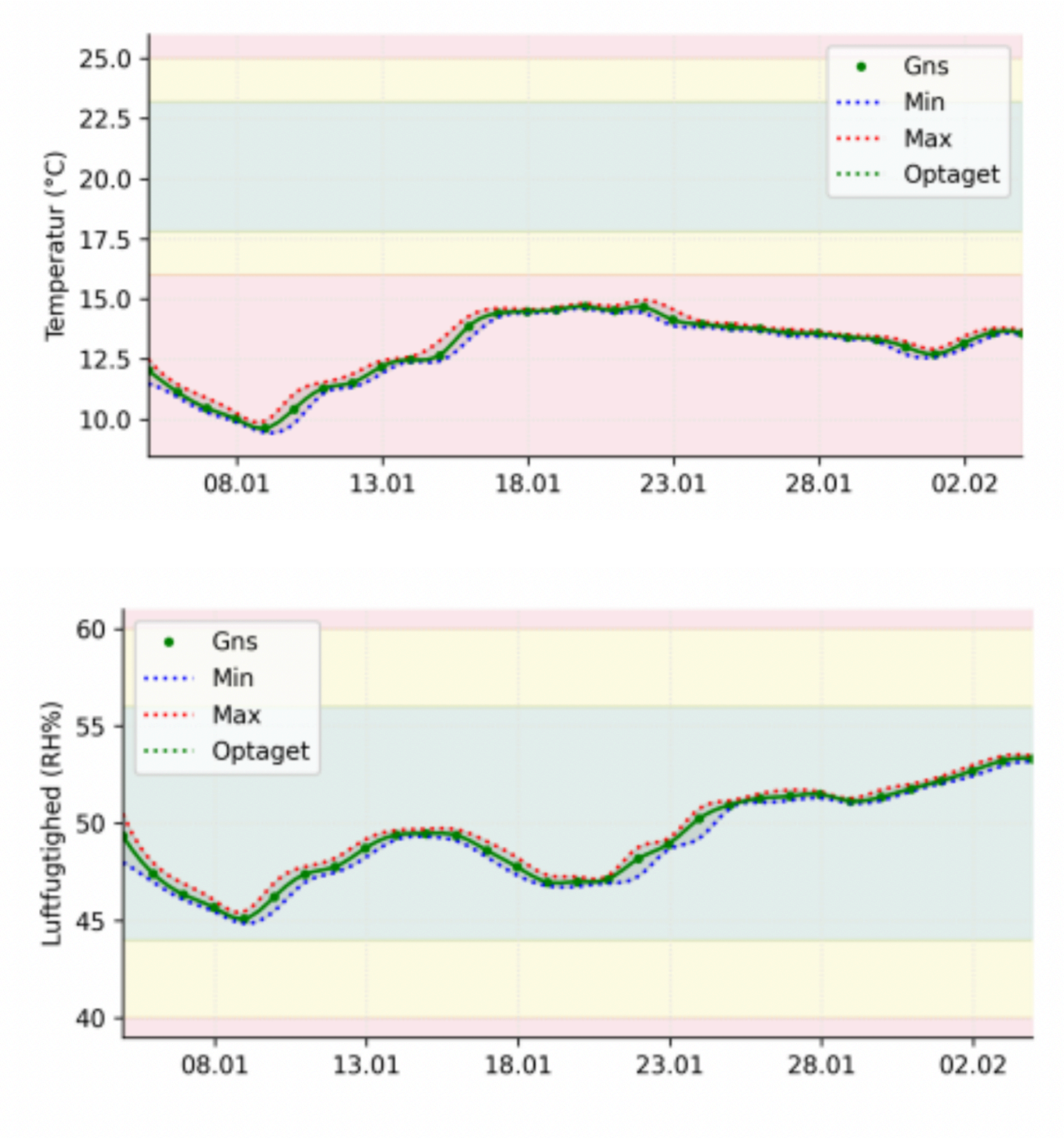
- We chose part of the storage as our test area. We wanted to test an area with objects of mixed materials. And we wanted to test how robust our collections were.
- If we can implement changes in a location with many objects, it is also possible in a place with fewer, like in the exhibitions.
- We were also interested in examining the microclimate for the objects stored in cardboard and Styrofoam boxes.
- We wanted to contribute to the variation of the pilot by choosing the museum storage as our test area.

Microclimate

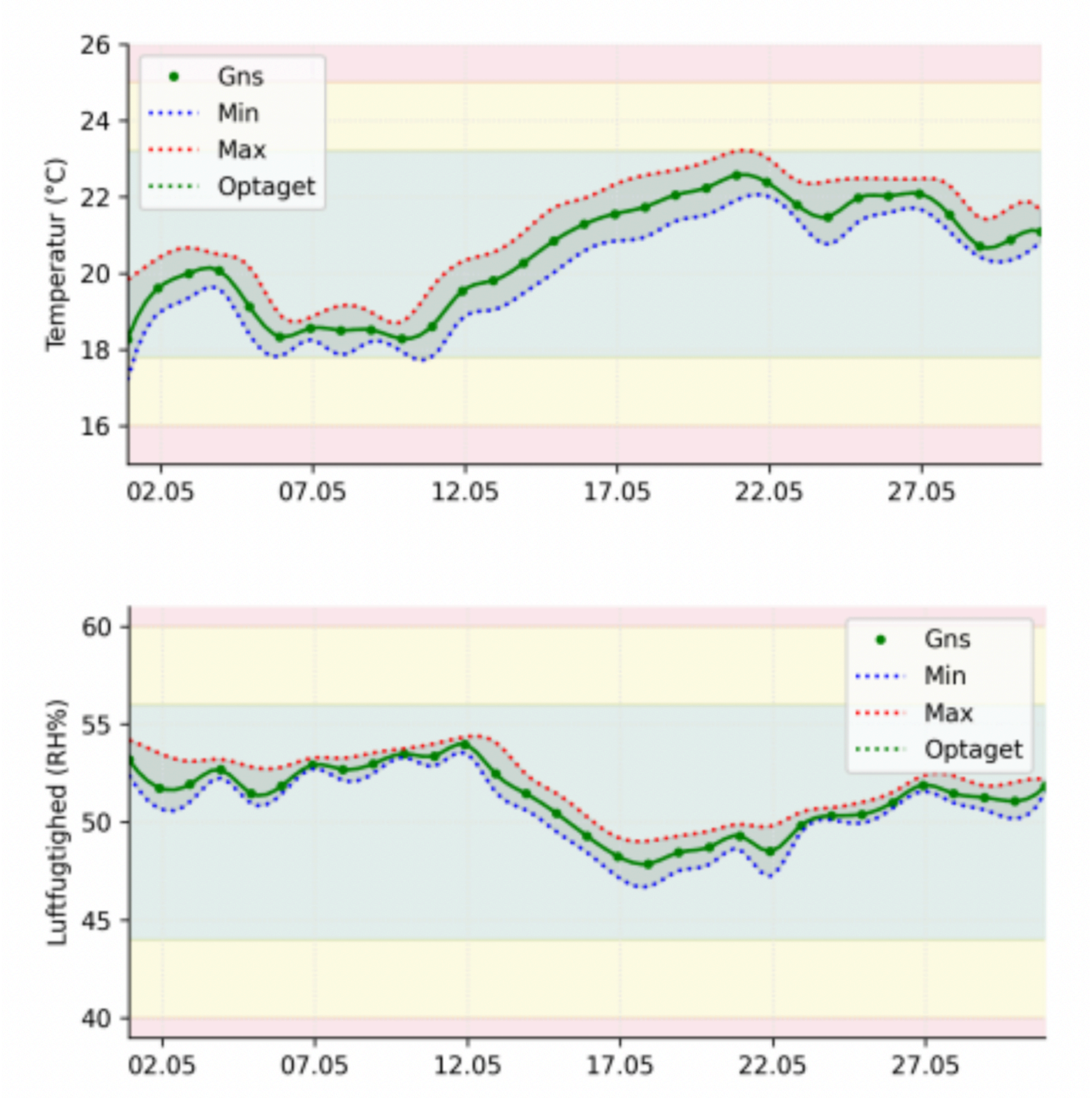
- For many years, it has been standard at Vardemuseerne to store smaller objects in Styrofoam or cardboard boxes. This practice has several advantages. It optimizes space in the storage area, as the boxes can be stacked, and it provides extra protection against mold, as any outbreak would be contained within a single box. This allows the museum staff to detect it before it spreads to the rest of the collection. Previously, the museum had not examined the potential climate-related advantages or disadvantages of storing objects in Styrofoam and cardboard boxes. We had no data showing how humidity in the boxes behaved compared to the rest of the room. Therefore, monitoring the microclimate in the two types of boxes has been part of Vardemuseerne's contribution to this project. Monitoring was conducted by placing a data logger in both a Styrofoam and a cardboard box. The boxes were placed side-by-side on a shelf at a height of 1.20 meters. Another logger was placed next to the boxes to monitor the climate in the surrounding area. The loggers have been active for a little over a year.

Result: The climate data inside the boxes is more stable, with softer curves. Both the Styrofoam and cardboard boxes show a stable microclimate, though slightly more so in the Styrofoam boxes. However, the difference is minimal.

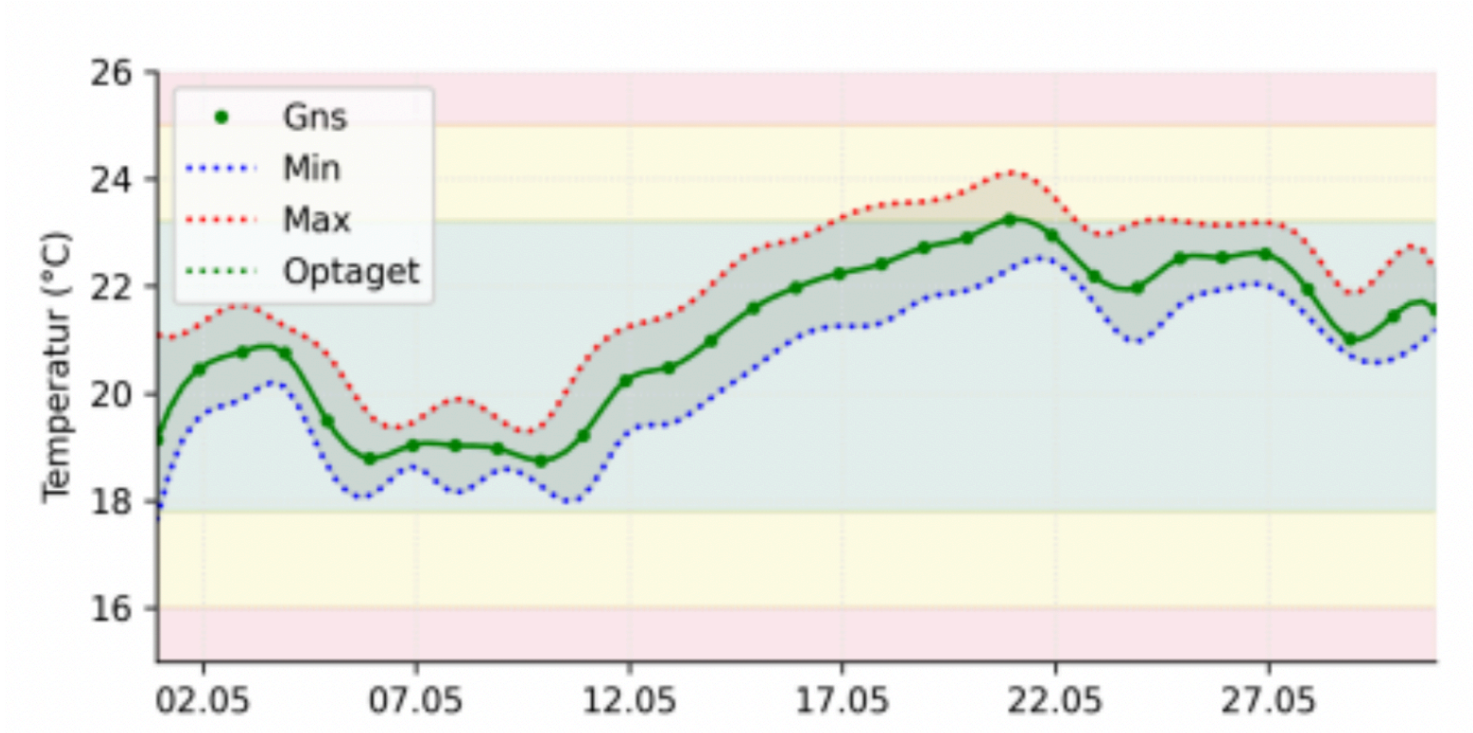
Charts for Styrofoam boxes

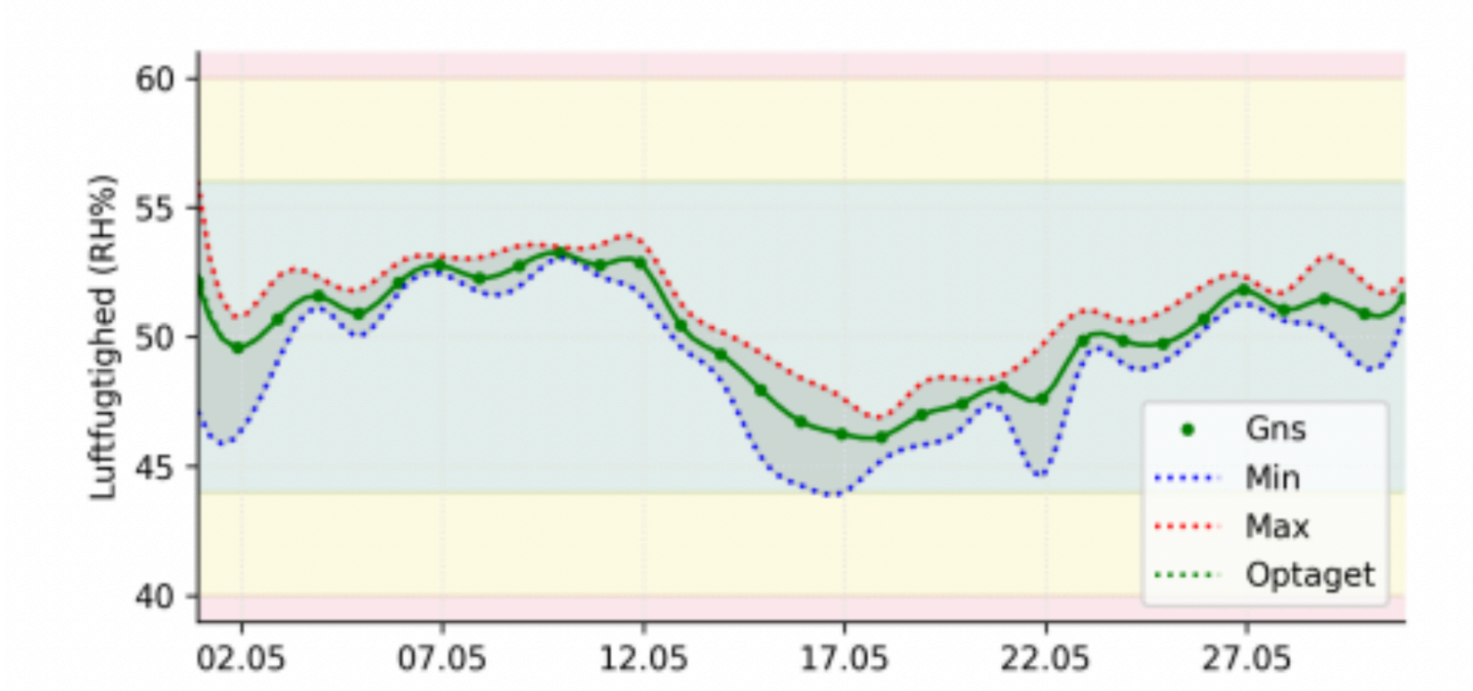


Charts for Cardboard Boxes



Charts for the climate surrounding the boxes





Plastic objects

- One major observation for us has been that while plastic objects require a stable climate to slow degradation, the gases emitted by plastic during the degradation process mean that sealed boxes are not optimal for storing plastic objects. Sealed boxes can accelerate the degradation of plastic objects, and one plastic object can speed up the degradation of other plastic objects. Vardemuseerne store objects made of mixed materials in both cardboard and Styrofoam boxes, unfortunately including plastic objects. We are therefore in the process of removing plastic items from the boxes and storing them in open containers. We have time to address this, as the problem with plastic objects in sealed boxes only becomes significant once the degradation process starts. Until then, they are stable (Appendix 2).

Monitored baseline objects

Results: No visible changes were observed in any of the baseline objects.
Under the guidance of conservator Michael Højlund Rasmussen from Konserveringscenter Vejle, five objects were selected. The objects were placed on a shelf in the middle of the test area. The purpose of these five objects was to monitor any effects of the changes implemented during the project. The objects were chosen based on their materials and design to ensure that any impact from the changes would be as evident as possible. The test area included objects of mixed materials, making it sensible to select items made of different materials. The focus was on leather, wood, iron, veneer, oil paint, and gold leaf. The baseline objects have not undergone any recent preservation

- Baseline Object 1: A drum. Material: Wood and leather. Although the wood was an obvious candidate for monitoring, the focus was on the drum's leather. There is a crack in the leather, which was present long before it arrived at the museum. This crack was measured and photographed at the beginning of the project, and this process was repeated every three months. Additionally, museum staff inspected the items every two to three weeks.
- Baseline Object 2: Mirror A mirror with a wooden frame and veneer front. On the front of the mirror, it was evident that the wooden frame joints had shifted, causing minor damage to the veneer. This damage was measured and photographed at the beginning of the project and again every three months. Museum staff also regularly inspected the item.

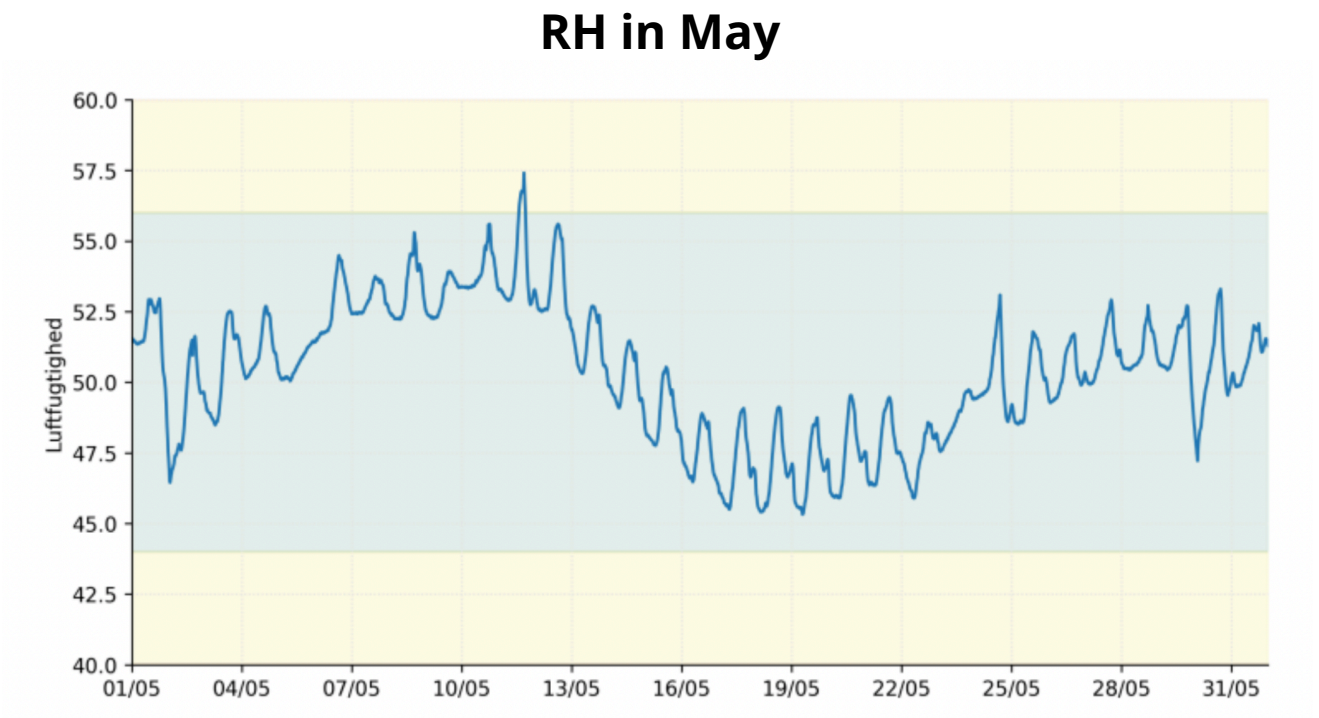
Baseline Object 3: Painting. An oil painting with a wide golden frame. Painting conservator Teodora Boyadzhieva from the Konserveringscenter Vejle prepared a conservation report at the beginning of the project (Appendix 3). Museum staff inspected the painting regularly, and at the end of the project, Teodora prepared a new report. The conservator's examination found no changes in the oil painting or its frame.

- Baseline Object 4: Door. A wooden door made of vertical boards. The small gap between the boards was measured and photographed every three months to monitor any effects of the changes. Museum staff inspected the object every two to three weeks.
- Baseline Object 5: Dagger**.** An iron dagger with a bone handle. At the top of the blade, there is a small area with some rust. The rust is located near an engraving and where the blade is sharpened, making it an ideal iron object to monitor. The rusted area was photographed and measured at the beginning of the project and again every three months. Museum staff inspected the item every two to three weeks.

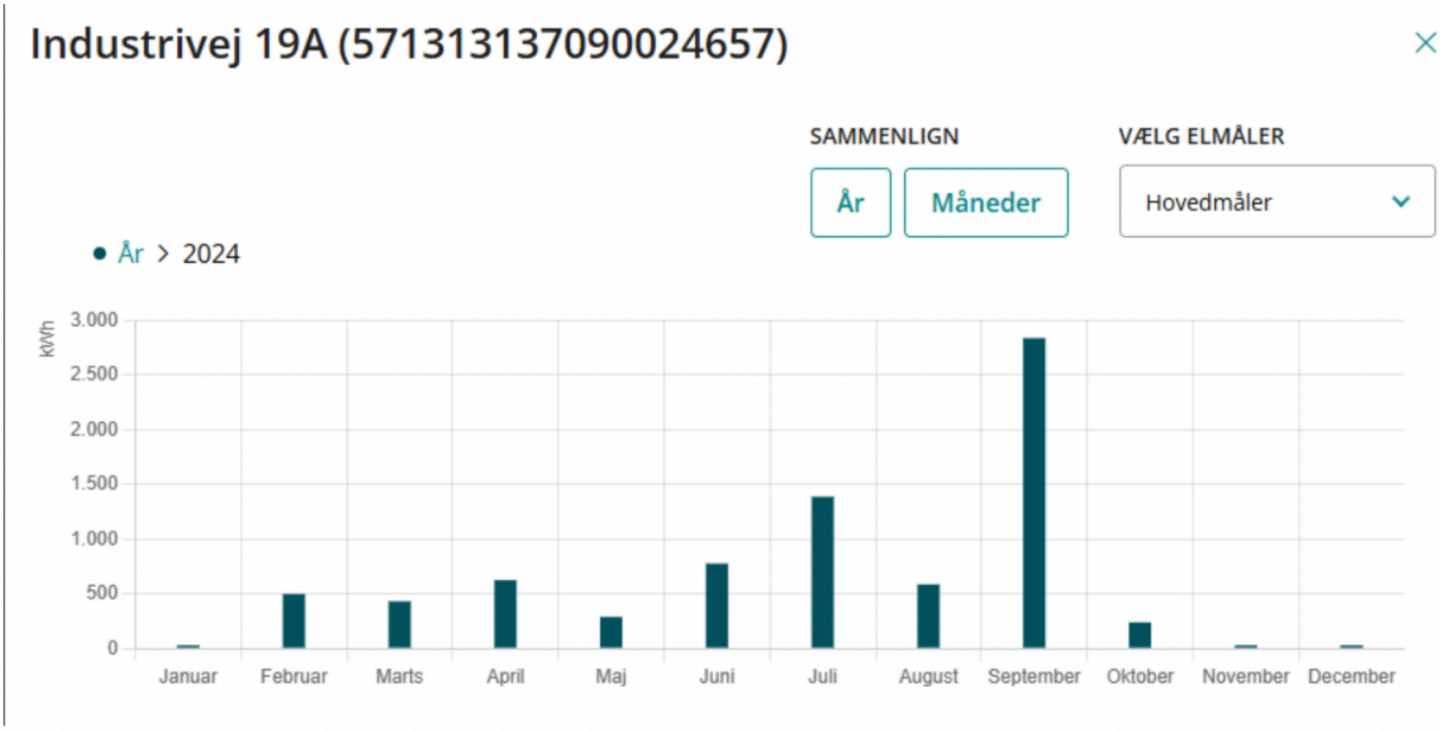
Data, Challenges and Results

- Monitoring the climate in the test area has previously been done with two loggers, but as part of this project, seven additional loggers were installed. Three of them were used to monitor items stored in boxes (see section on microclimate). The remaining four loggers were evenly distributed in the test area. Previously, the museum only looked at climate data if there were alarms. However, as it is a climate-controlled area, there have hardly ever been any alarms. In this project, climate data has been reviewed every month. This has been a way to follow up on the impact of the changes to the dehumidifier settings.

- The changes to the dehumidifier settings have been gradual. First changing from +-2% to +-5%. The result is clearly visible on this graph for the month of May. Once, the dehumidifier was running when the measurement exceeded 55%. If you then look at how often the reading was above 52%, it indicates an energy saving. At the same time, the electricity consumption for May shows a decrease compared to February, March, and April.



Electricity consumption 2024



he experience concluded from climate data has also been that there should be a buffer. This is shown by the fact that the humidity almost reaches 58% before it reverses. This means that the dehumidifier needs a few percentages to adjust. Therefore, we have chosen that the final setting is +-8%. This means that the humidity can reach +-10%, but this is within The Bizot guidelines (Appendix 4), and thus within our guidelines.

We experienced a challenge with the heat over the summer. The heat contributed to a drop in humidity, and since our climate control is only with a dehumidifier, we had to find another solution. We tried air circulation. The fan in the dehumidifier was set to run constantly. We tried this from mid-June and throughout July and September. Unfortunately, this did not solve the challenge of low humidity, and electricity consumption increased. From October, the heat was no longer a problem. We will work on the solution to this challenge in the spring of 2025 to ensure that we do not find ourselves in the same situation next summer. We have an idea that our skylights play a role in this. Even though the light does not hit objects, the windows contribute to the heat and thus the humidity in the area.

Setbacks, missing data and transitioning from gas to district heating

In the middle of the project, some challenges arose that have made it difficult to analyze the collected data.

At the beginning of the project, the test area was heated with gas. From mid-January

2024, the museum switched to district heating. This was an administrative decision made by the museum's finance department and management, which was influenced by both the rising gas prices and the Danish government's goal for Denmark to be independent of oil, coal, and gas. Thus, the calculations on savings in heat consumption are an assessment based on the period February to July 2024 compared to gas consumption in the same period in 2023.

- This gives a saving of 43% or DKK 4,515. This calculation does not consider.

differences in weather conditions in 2023 compared to 2024. The numbers show that we save more during the summer than during the winter period. Based on this, it is estimated that there will be an annual saving of approximately 30% for the whole of 2024, corresponding to DKK 6,112. This gives an average CO2 saving for February to July 2024 of 61% on the test area's heat consumption.

Savings (heating) for February - July

Måned	Fjernvarme_MWh_2024	Fjernvarme_kWh_2024	Naturgas_m3_2023	Naturgas_kWh_2023	Besparelse_kWh	Besparelse_%
feb	3,089	3089	369	4059	970	24%
mar	2,687	2687	397	4367	1680	38%
apr	1,829	1829	295	3245	1416	44%
maj	0,429	429	181	1991	1562	78%
jun	0,431	431	87	957	526	55%
jul	0,286	286	94	1034	748	72%
Hovedtotal	8,943	**8943**	1423	**15653**	6710	**43%**

Savings CO2

CO2_fjernvarme	CO2_naturgas	CO2_besparelse	CO2_besparelse_%
440	835	395	47%
383	898	515	57%
261	667	407	61%
61	410	348	85%
61	197	135	69%
41	213	172	81%
1.247	3.220	1.973	**61%**

Emissionsfaktorerne:

- Natursgas er iht Energinets officielle opgørelse. Her henvist til fra EVIDA: Beregning af CO2-aftryk (evida.dk)
- Fjernvarme er iht. Oksbøl Varmeværks officielle deklaration for 2023 (Appendix 5)

Meter malfunction

- In January 2024, the museum became aware that the electricity meter for the test area was malfunctioning. It has hardly registered any measurements from the whole of 2023, which means that there is no usable data of electricity consumption from the test area for the whole of 2023. This was a setback, as it makes it difficult to calculate precise savings. However, the changes made to the dehumidifier settings only happened after January 2024, so we looked at climate data and our electricity consumption from February to October 2024 and compared this with climate data from the months where changes have been made. This gives an expected or assumed savings since climate data along with changes show that the dehumidifier has not run as often as the year before (see chart p. 9).

New procedures

- As part of the project, new procedures have been introduced and have become standard practice at the museum. A shared schedule was created where changes, agreements, and results were recorded. This document serves as a working document for current and future decisions regarding the test area, including parameters for humidity and temperature. The three primary project staff members (Karen, Jørn, and Marianne) implemented monthly meetings to review primarily climate data and the impact of ongoing changes and actions. During climate data analysis, the museum noticed that the opening of gates caused fluctuations in the climate data. Although the fluctuations were within the set parameters, the sudden changes raised questions. Therefore, a schedule was introduced where employees noted the date and time if a gate was opened, allowing climate data analysis to focus on the impact of planned changes and actions.

Outcome: Impact & Results

This project has helped us formalize our approach to the continuous analysis of climate data, enabling us to make informed decisions on energy-saving measures while preserving the collection. It provides reassurance that, when adjusting parameters, we do not expose the collection to unnecessary stress. None of the baseline objects displayed any changes during the process. Our collection is robust!

During the process we have saved energy, CO2 and expenses thus fulfilling our goal with the project (see p. 11). Participation has given us an insight into how we can approach the process when transferring our experiences from the project to other parts of our institution.

Better informed
Formalized approach
Saved money
Saved energy
Saved carbon
Updated ranges
ROBUST COLLECTION!

Key Achievements

Comprehensive insight into our facilities and conditions.

Understanding how we can use microclimates in storage areas.

Relevant training of staff.

Cross-collaboration established with peers and experts.

New procedures established at Vardemuseerne.

Savings on energy, CO2, and expenses.
Success in testing without damage to the collection.

Plans and ideas for the next steps in the test area.

Ideas for implementing our findings to other parts of museum operations at our institution.

30%
Financial Savings

0
Collection Damage

61%
Carbon Reduction

Recommendations

Go for it! It has been an interesting, giving and at times somewhat frustrating journey. We have gained valuable knowledge into our buildings and conditions. It has equipped us with the ability to make sustainable choices without worrying about damaging our collection. We have learned that we have time to react to problems and changes and that the collections are robust. The project has provided us with communities both locally at Vardemuseerne and among museum colleagues within the project. Find colleagues and partners with whom you can share and discuss your findings, good or bad. Money and energy can be saved in the long run, but you must be prepared to put in work hours in monitoring data and also be willing to invest in necessary equipment.

Next Steps

Retain positive experiences and use them as a steppingstone for further changes at Vardemuseerne.

Work on optimizing the test area further and including the whole storage area.

Create a procedure for data analysis for all museum locations, possibly with the help of AI. We were not able to explore the full potential of AI during the pilot project.

Continue the work with our loan agreements. We do not have many loans, and we have not had climate requirements incorporated in our loan agreements before the project. This has not been a tradition at cultural history museums in Denmark. When revising our loan agreements we will refer to The Bizot guidelines 2023.

KEEP GOING!

OPTIMIZING TESTING AND ROLLOUT

STANDARDIZE PROCEDURE AND AI EXPLORATION

LOAN AGREEMENTS TO INCLUDE BIZOT REFERENCE

Appendices & References

References

Han, B. *et al.* (2024) 'Hygrothermal Performance of Enclosures in a Storage Room and Energy Efficiency in Environmental Control', *Studies in Conservation*, pp. 1–8. Available at: https://doi.org/10.1080/00393630.2024.2375151

Novak, M. *et al.* (2024) 'Evaluation and modelling of the environmental performance of archival boxes, part 1: material and environmental assessment', *Heritage science*, 12(1). Available at: https://doi.org/10.1186/s40494-024-01137-0.

Appendices

1) Charter for grøn omstilling af danske museer. Museernes Grønne Akademi.

2) Manual for håndtering og opbevaring af plastmaterialer: Clara Bratt Lauridsen Konservator, Konserveringscenter Vejle Jonas Hørup Ruskjær Museumsinspektør, Mark | Billund Kommunes Museer Anders Horsbøl Nielsen Museumsinspektør, VejleMuseerne Manualen er en del af projektet "præventiv bevaringsstrategi for plastmaterialer" støttet gennem Slots- og Kulturstyrelsens Pulje til Samlingsvaretagelse 2023.

3) Konserveringsrapport. Baselinegenstand maleri.

4) Andelsselskabet Oksbøl Varmeværk Fjernvarmedeklaration 2023.

5) The Bizot Green Protocol 2023.

Vardemuseerne

OVERVIEW

Geographic Location: Varde, DK
Number of Staff: 64
Number of Annual Visitors: 335.200 (2023)

BUILDING

Description: Modern building (2002- 2004), steel and wood frame with medium density fiberboard (MDF) and wood wool boards (træuldsplader), skylights, set low in local terrain
Size: 1.543,9 m2

COLLECTIONS

Description: 80,000 historical objects - mixed materials (iron, wood, plastic, textile, paper, art etc.). Some objects are stored in microclimates in cardboard and Styrofoam boxes.

ENERGY SAVINGS

Not possible to calculate

Given the lack of data from 2023 it was not possible to calculate precise savings. However, dehumidifier settings were not adjusted until January 2024. When looking at climate data and electricity consumption from February to October 2024 and comparing this to climate data from the months where changes were made it gives an assumed saving. Climate data along with changes show that the dehumidifier has not run as often as the year before.

CARBON REDUCTION

61%

Due to the electricity meter malfunctioning, the carbon reduction is only calculated from the transition from gas to district heating. The reduction is from February to July 2024 compared to the same months 2023.

FINANCIAL SAVINGS

30 %

Due to the electricity meter malfunctioning the financial savings is only calculated from the transition from gas to district heating. The numbers show that we save more during the summer than during the winter period. Based on this, it is estimated that there will be an annual saving of approx. 30% for the whole of 2024.

We have gained valuable knowledge into our buildings and conditions. It has equipped us with the ability to make sustainable choices without worrying about damaging our collection. We have learned that we have time to react to problems and changes and that the collections are robust. The project has provided us with communities both locally at Vardemuseerne and among museum colleagues within the project.

PILOT ACTIONS

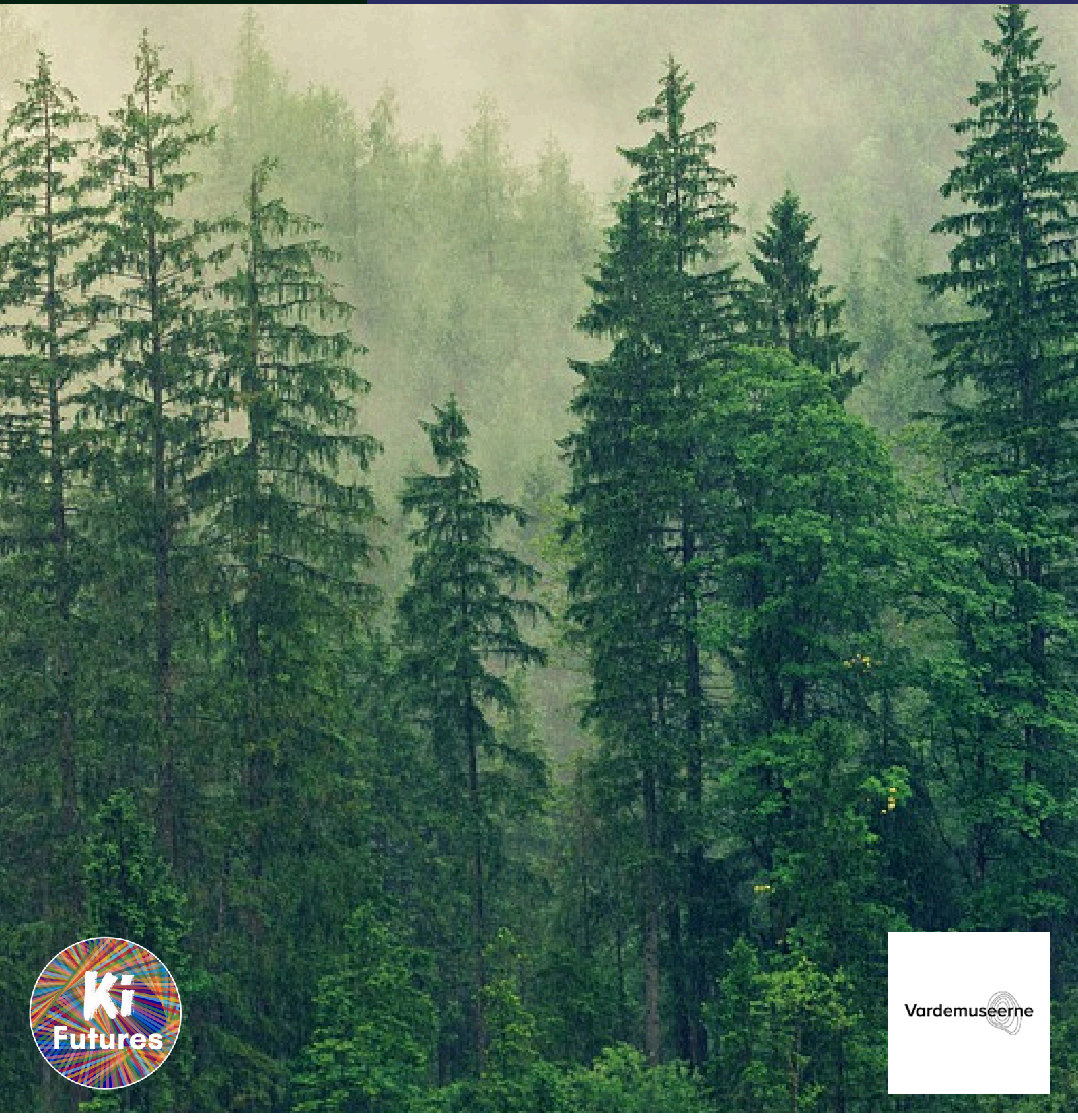
- Changed from natural gas to district heating.
- Moved from +/- 2 to +/- 5 to +/- 8.
- Lowered temperature to min 16 – max 25.
- Implemented monthly meetings to review climate data and the impact of ongoing changes and actions.
- A shared schedule was created where changes, agreements, and results were recorded.
- Implemented a procedure for monitoring baseline objects.
- Focus on objects stored in boxes.

TARGET AREA	BEFORE PILOT	AFTER PILOT
Climate Control Parameters	19 / 50% +/- 2%. (set point) & T / 45 - 55% (actual)	16 / 50% +/-8 set point
Loan Agreements	We do not have many loans, and we have not had climate requirements incorporated in our loan agreements before the project.	When revising our loan agreements we will refer to The Bizot guidelines 2023.
Energy Consumption	Electricity meter for the test area was malfunctioning for most of 2023. The museum became aware of this in January 2024.	From January 2024 the meter was working again.
Facilities	Test area heated by gas	Test area heated by district heating

Retain positive experiences and use them as a steppingstone for further changes at Vardemuseerne.
Work on optimizing the test area further and including the whole storage area.
Create a procedure for data analysis for all museum locations, possibly with the help of AI. We were not able to explore the full potential of AI during the pilot project.
Continue the work with our loan agreements.
Better understanding the behavior of the building.
Contribute to discussions of storage in boxes and the practices and behavior of microclimate in Styrofoam and cardboard boxes.

Carbon Emissions and Energy Reduction

Safe for collections



Ki Futures

Vardemuseerne

Getting Climate Control Under Control

Danish Cohort

May 2023 - December 2024

articheck

DANSKE MUSEER ORGANISATIONEN

AUGUSTINUS FONDEN

Vardemuseerne