Climate Control Program

Louisiana Museum of Modern Art

Case Study

LOUISIANA

Content

Introduction

Louisiana Museum of Modern Art is a place for international modern and contemporary art. Established in 1958 by Knud W. Jensen the museum continuously strives to be a place where people meet to create community across time and space.

Louisiana was invited into the Ki Futures Climate Control Program by The Association of Danish Museums (ODM). Louisiana entered the project with a hope to gain knowledge and experience on studies concerning the climate range impact on exhibited artworks and how to optimize the climate control system in order to save energy.

For the 10 Louisiana Museum of Modern Art has worked to increase focus on sustainability in all departments. Different actions and improvements in Louisiana's operations have led to energy-savings and reduced CO2-emissions.
In 2023, Louisiana instituted a sustainability strategy, in which climate (CO2-emissions), circularity, biodiversity and social responsibility are important focal-points for the museum the fourth-coming years with goals for 2030 and 2050.
Louisiana participates in different networks and projects both nationally and internationally to support the journey towards the sustainable museum.
Louisiana is a member of The Bizot Group and has been an active part in developing . The museum contributes to the network, while also working on implementing the different guiding principles for exhibitions, climate control, transport, etc. updated in 2023.

The KI Futures Project

- a goal to explore energy-savings, new systems, and CO2-reductions

Louisiana envisaged to challenge the existing climate control requirements, including climate control systems (and further the guiding principles in the Bizot guiding principles).
Louisiana has several exhibition spaces, and as a modern art museum many diverse exhibitions during the year, including architecture, paintings / drawings, installations, and sculptures. Therefore, Louisiana regulates the climate control system, to fulfill loan agreements and known requirements in relation to preservation.

The KI Future Project 2023-2024

Quick Overview of Goals, Tests and Implementations

2023 /

Louisiana had a wish to:

- Gaining knowledge across organizations and with colleagues, sharing and exploring.
- Rebuilding and testing new measures to improve energy efficiency (without changing the temperature).
- Changing the temperature/conditions/climate control during storage and in the galleries to reduce energy consumption.

With the objektives towards:

- Revising own loan agreements with the possibility to have tailored object climate settings in different loan agreements.
- Reducing own energy consumption through energy efficiency initiatives.

Louisiana have tested and implemented the following during the project-period:

First year of the project 2023

- Broaden the climate systems to RH 50% ± 10 % (before 50% ± 2%).
- Reduced air speed (20%).
- Test and observation on object / watercolor and crayon on paper.

Continuing the project - 2024

- Reduced air speed was supported and tested by an AI implementation to the BMS-system (4i4 AI programming).
- Parallel project to the KI project: Installed new damper on two locations within in the BMS-system allowing us the keep existing amount of heated air in the system.
- Implemented an AI solution to support the BMS system and hourly regulations.
- Agreed on RH 50% ± 8 % (before 50% ± 2%) as a standard range in galleries (RH 40-60%).

Project

The KI Futures Climate Control Program was presented at a kick-start meeting at Louisiana, at the early stage of the project period (May 2023). Representatives present from the departments: registrars, conservators, facility and operations, sustainability and BMS technician. Project lead and Head of Facility facilitated the meeting in which focus, and goals were discussed.

Goals and scopes were identified and paired with areas of responsibility and staff involvement. Our focus on loan agreements and climate system narrowed the project team down to a team of:

- Bo Heinrich Kristensen – BMS[1] technician
- Sofie Laier Henriksen– Collection Registrar
- Ulrik Staal Strange Dinesen, Head of Conservators and Exhibition Producers
- Anette Hansen – Director of Facilities and Security (project-owner)
- Carina Hammer – Sustainability Manager & project lead (Maternity leave January-September 24)
- Laila Dalgaard – Sustainability Manager & project lead

Roles:

- The BMS technician monitors the HVAC system and assures all technical components are running accordingly at all times.
- The Director of Facilities and Security monitors the financial management, addresses related issues and monitors the security of own collection and borrowed art pieces. The Director also participates in the Bizot-Group.
- The Sustainability Manager monitors the project-flow and addresses proposals for CO2-saving initiatives, cross-disciplinary possibilities.
- The Collection Registrar, who is a conservator, monitors the art pieces in our collection.

[1] The BMS technician monitors the HVAC system and assures all technical components are running accordingly at all times.

Methodology & Process

Scope 1 June - August 2023

- Identification of team and areas of responsibility
- Selection of goals, target points: galleries, art and BMS-system
- Identification of measuring points
- Ordering IOT-system (indoor climate monitoring sensor)

Scope 2 August - December 2023

- On-site meeting with energy consultant
- Set-up of IOT monitors
- First data from IOT meters / Baseline
- Selection of monitor areas in storage and galleries
- Comparison of data results and tests on an ongoing basis
- Identification of possible energy saving projects

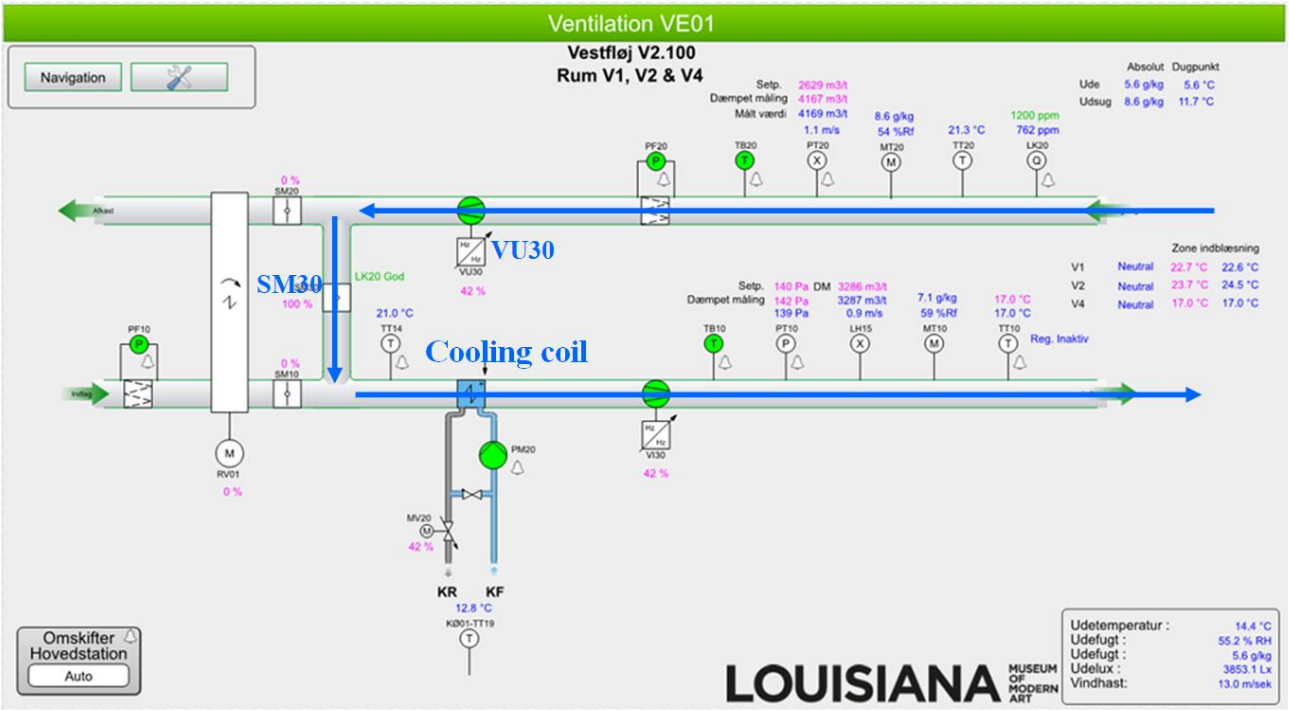
Scope 3 December 2023 - October 2024

- Test on reduced air speed: experiments of airflow, in storage areas and galleries
- Look into own loan agreements and the requirements placed on borrowers.
- Data from IOT (moved from one area to another due to missing connection, IOT monitor sent back for testing)
- Data and observation of artwork in adjusted climate window
- Test with AI on BMS-system towards implementation
- Installed new damper on two locations

Test and results on the BMS-system.

New Bypass Damper

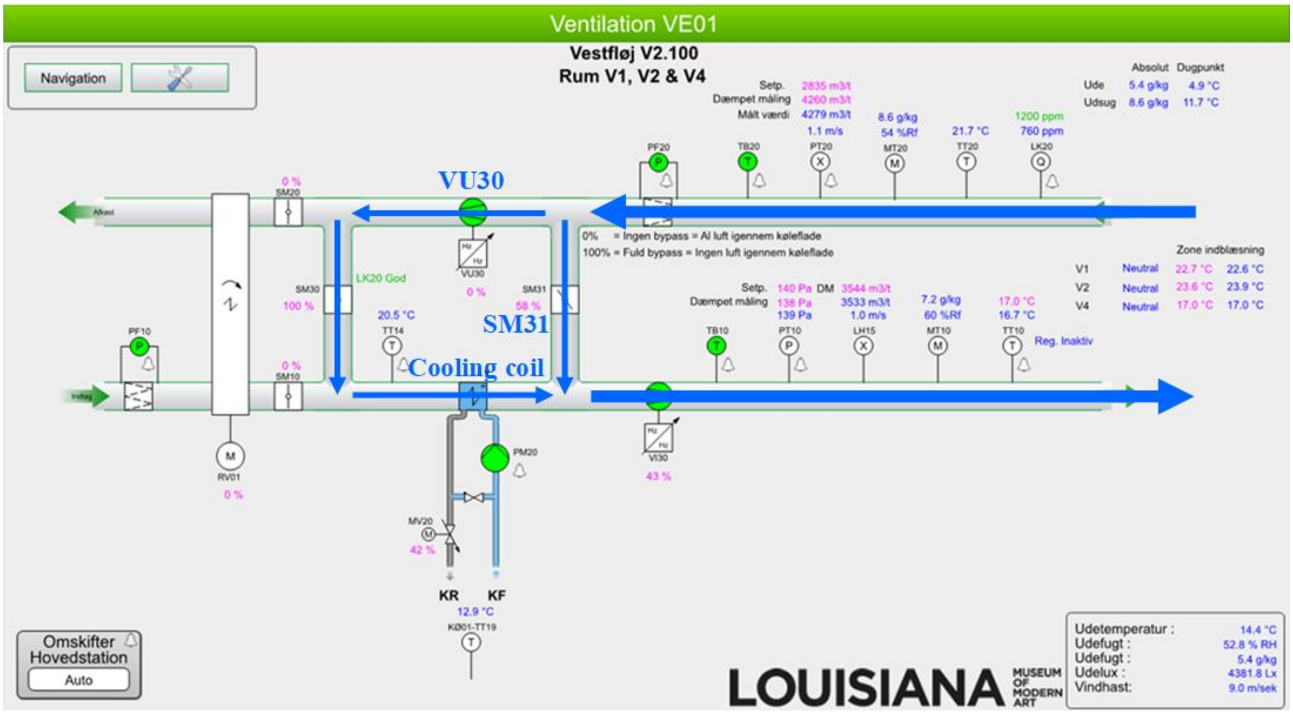
Original Setup:



How it worked before the renovation:

On a regular basis, all the air from our galleries were extracted by an exhaust fan (VU30) and then reintroduced through a cooling coil. Therefore, when we needed to dehumidify, the entire air mass had to be cooled to the dew point, removing humidity from the air. Subsequently, the air had to be reheated to the desired climate.

After the modification:



A new damper, SM31, has been introduced.

Normally, SM31 is fully open (see illustration above). This means that it is not necessary for the entire air volume to pass through the cooling coil when cooling is needed. A few advantages:

Economic Benefit 1: A cooling coil provides high resistance, requiring the fan to use more energy to pull the air through. When the air does not have to pass through the cooling coil, we save electricity and reduce wear on the motor.

When there is a need for cooling - e.g., for cooler supply air or dehumidification, the damper SM31 will gradually close and direct more air through the cooling coil.

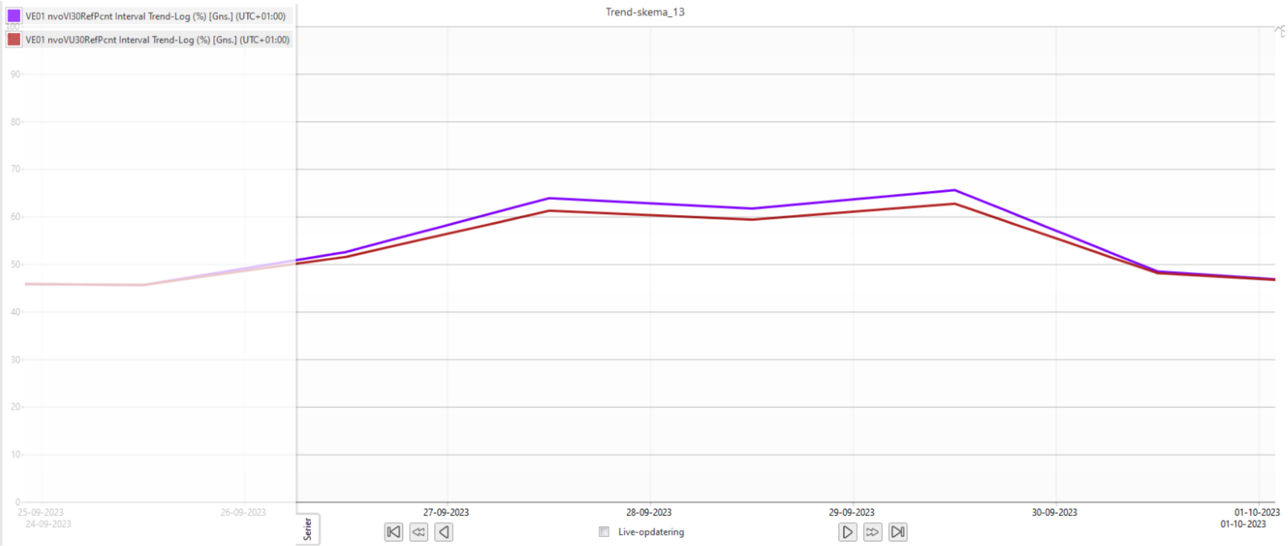
Economic Benefit 2: When humidity needs to be removed from the air, it is now done on a smaller air volume, which requires less cooling. This means that we also need less heating to warm the air to the desired climate range, as only a smaller portion of the air is being cooled.

To maintain the air balance between supply and exhaust, we now control it based on the air volume measured in cubic meters per hour. We aim to maintain a controlled overpressure within the galleries to mitigate the infiltration of contaminated air. This means that the air in the galleries is clean, filtered through the ventilation system's filters, and humidity and temperature are regulated.

Economic Benefit 3: The exhaust fan (VU30) hardly needs to run as the supply fan (VI30) handles most of the air volume. This reduces both energy consumption and wear.

Before the renovation (average per day):

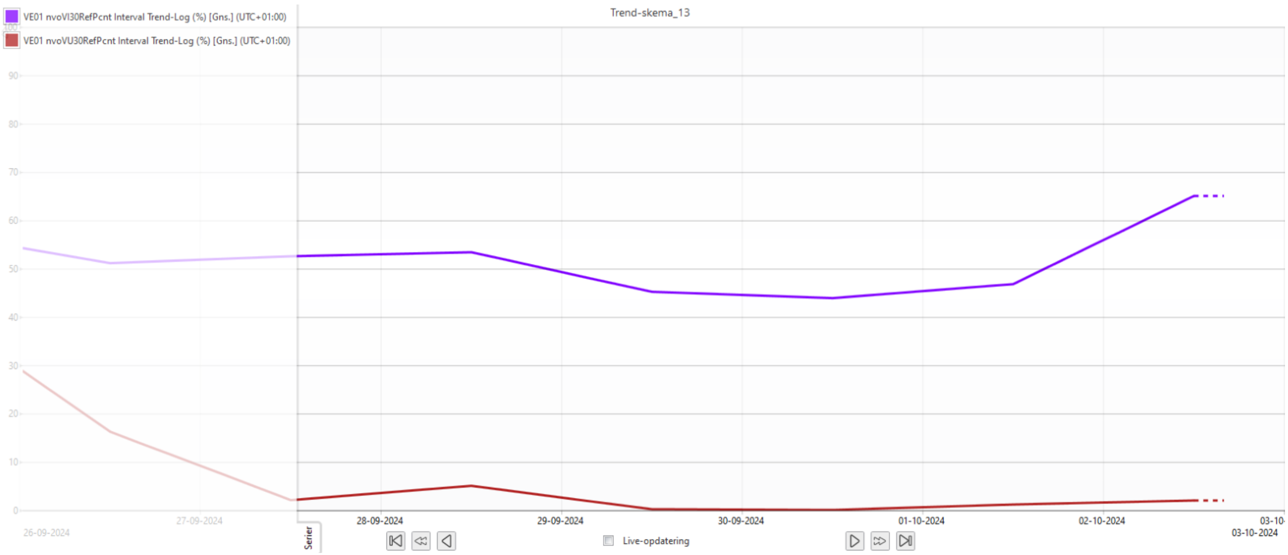
Below are graphs illustrating the speed of the supply air fans (VI30) and exhaust air fans (VU30) prior to the renovation. Both fans operated between 46% and up to 67%.



After the renovation and the introduction of AI (average per day):

Here are graphs showing the speed of the supply air fans (VI30) and exhaust air fans (VU30) fans after the renovation. Now, the supply fan (VI30) regulates between 45% and 65%.

The exhaust fan (VU30) now regulates between 0% and 29%.



Use of AI in Airflow Regulation

Before AI:

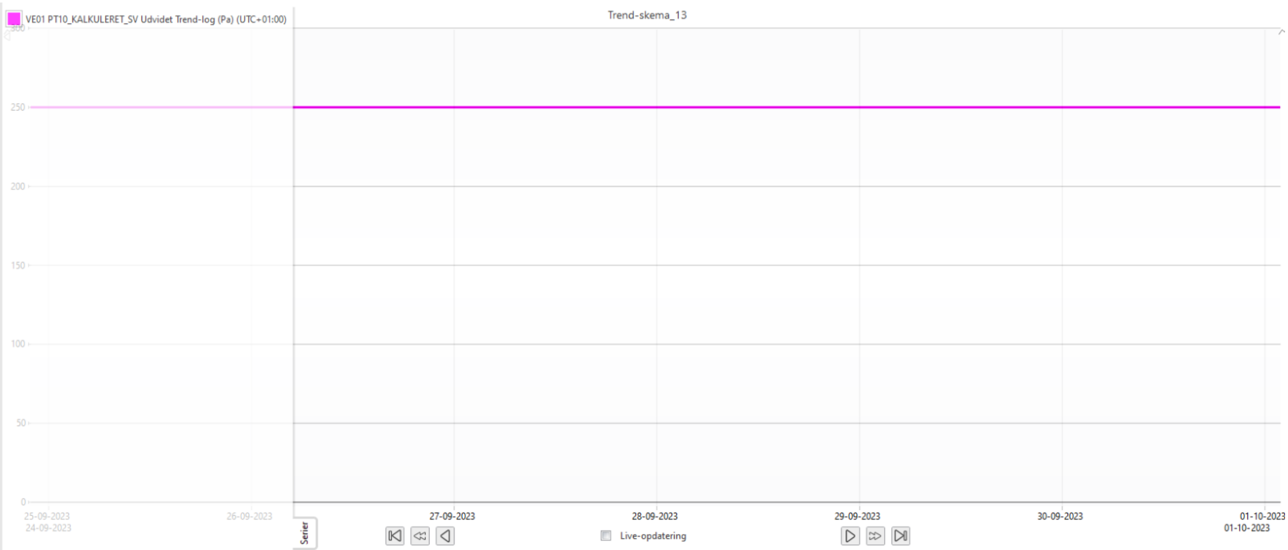
We controlled the airflow based on a fixed pressure in the supply air fans.

When a gallery requires changes in humidity levels, we open the zone dampers from 50% to 100%. For higher or lower temperature demands, we also gradually open the zone dampers from 50% to 100%, depending on the need. This increases the airflow and thus speeds up the change.

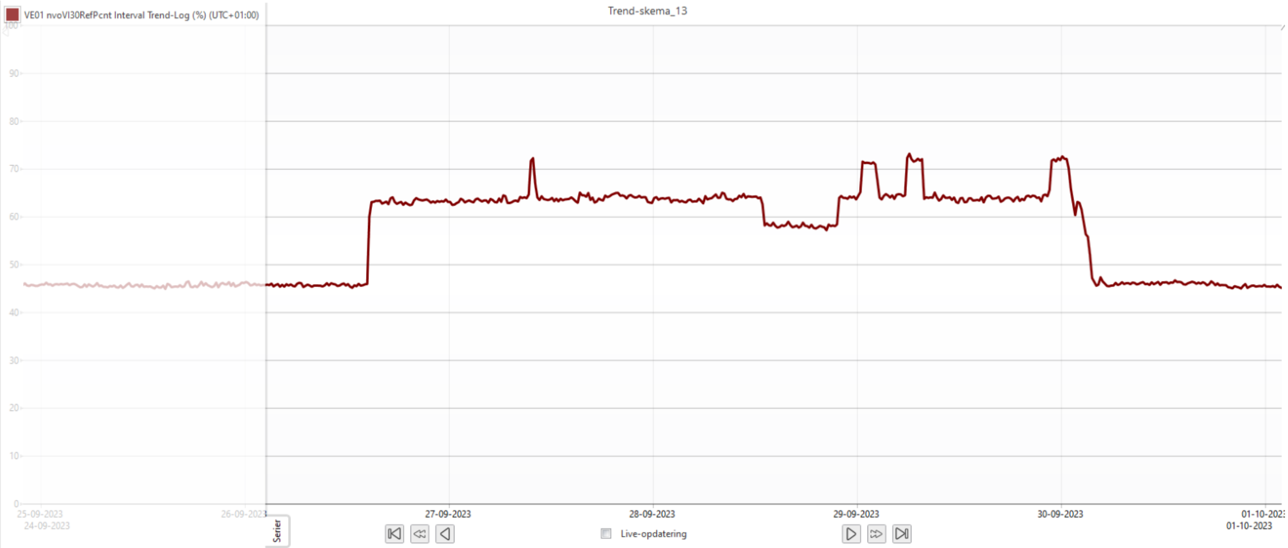
Note: We maintain this control principle even after the implementation of AI.

Before AI:

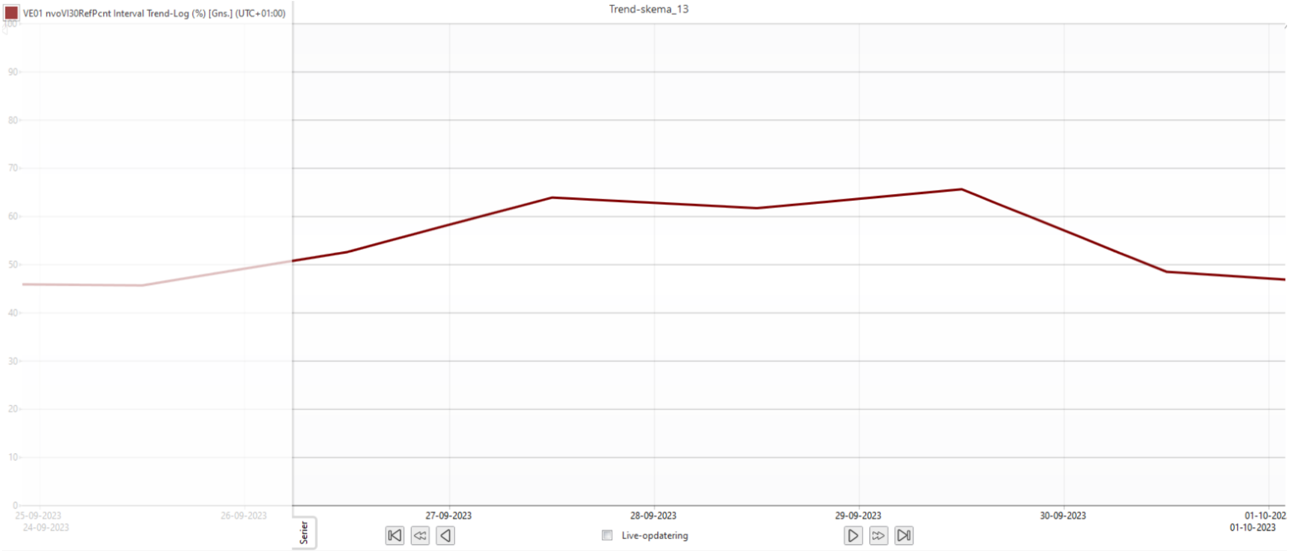
Here is the setpoint for the supply air pressure (PT10) in Pa (period 25/9 - 1/10-23):



Here is the speed of the supply fan (VI30) in %:

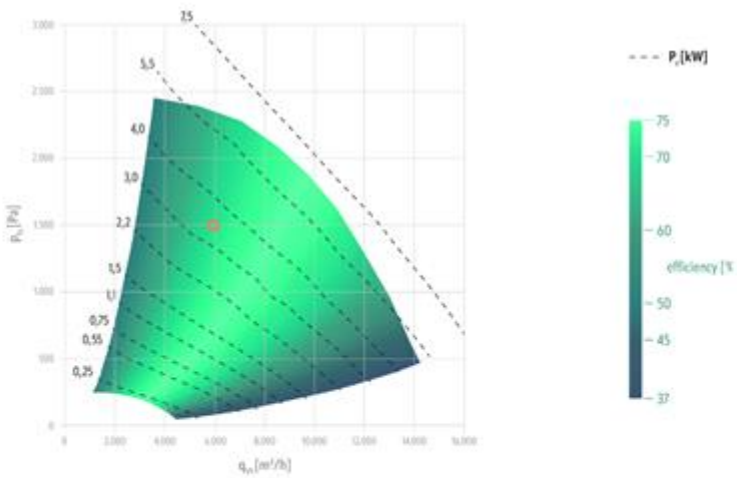


Here is the speed of the exhaust fan (VU30) in %:



Before the introduction of AI, we had a fixed setpoint for the pressure, which was achieved by adjusting the fan speed. This resulted in the fan sometimes running at optimal speed and efficiency, while at other times it ran less efficiently. The diagram below shows the connection between pressure, airflow and power.

For the fan to work efficiently, it is important to stay within the light green area.

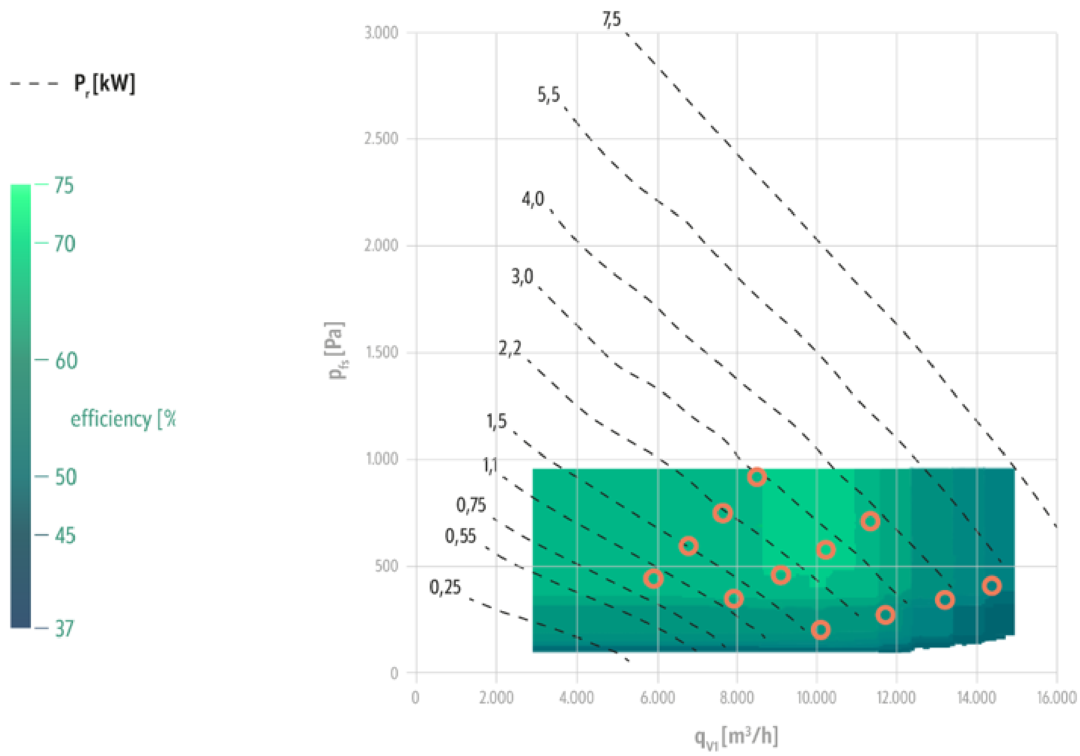


After the Introduction of AI

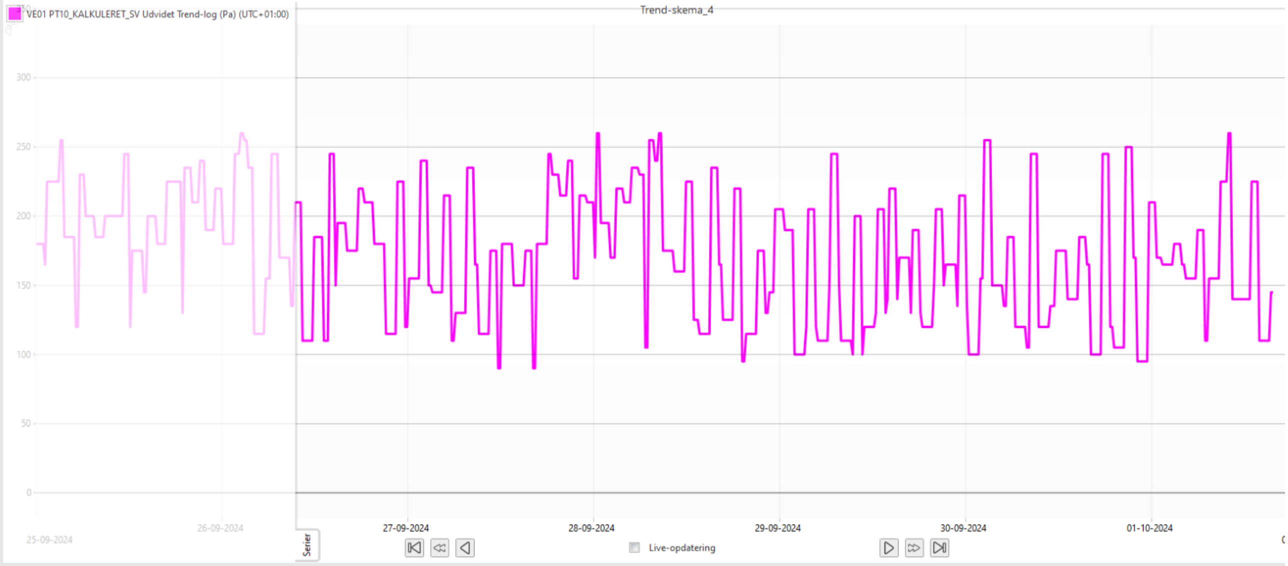
After implementing AI, the desired supply air pressure (PT10) is automatically adjusted up and down as the AI gains day-to-day experience. During the start phase, the AI dynamically adjusts the pressure to assess the system's responsiveness to fluctuations in temperature and humidity within the galleries. The AI combines this information with data on the air quality in the exhaust air, the number of visitors, electricity prices (in the long term), outdoor temperature and humidity. Additionally, the AI adjusts the pressure setpoint based on when the motor operates most efficiently.

Each dot represents a point where the motor delivers maximum airflow with minimal energy consumption. The AI uses these airflow rates to maintain the desired conditions when changes are needed in the galleries.

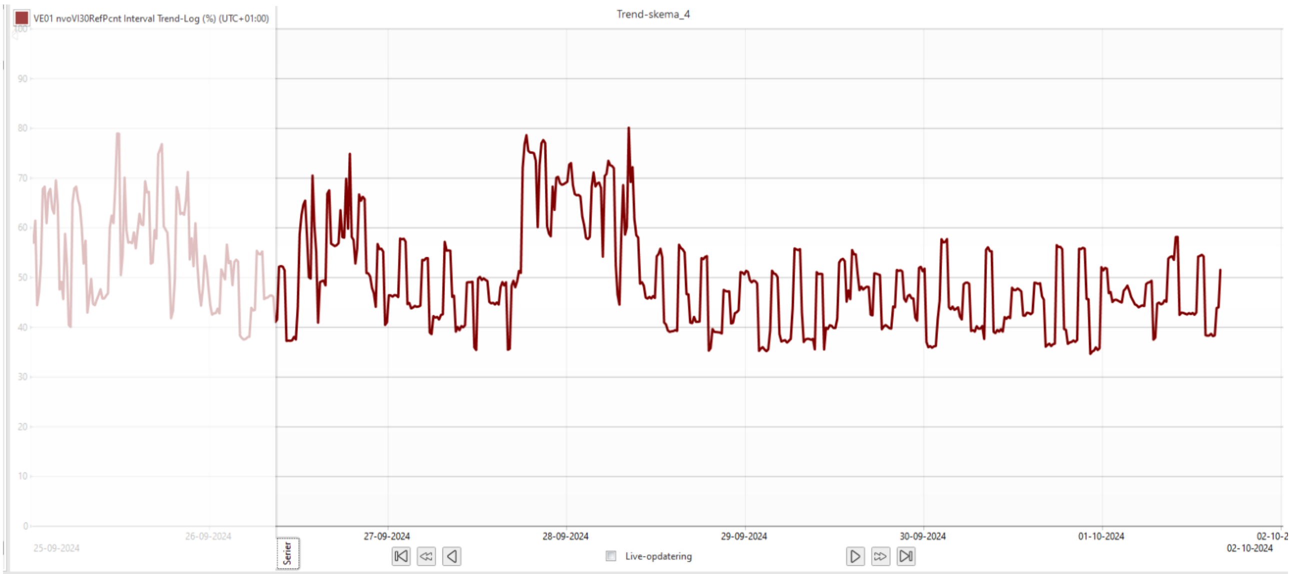
EcoVent by 4i4



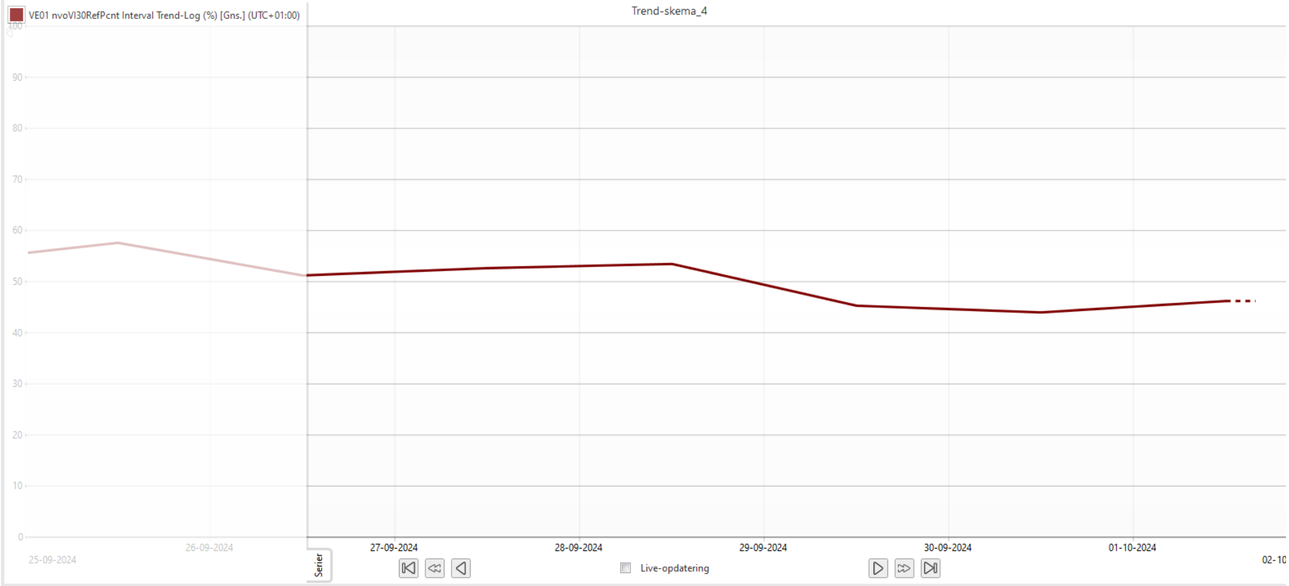
Here is the setpoint for the supply air pressure (PT10) in Pa (period 25/9-1/10-24):



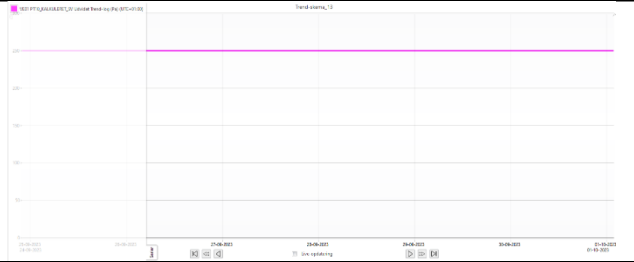
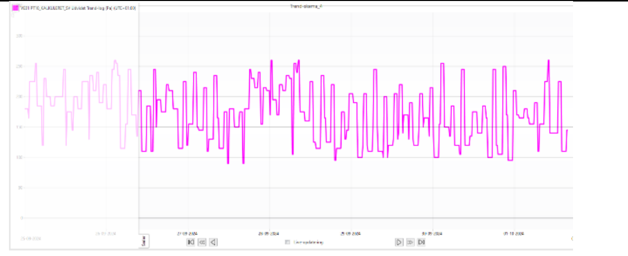
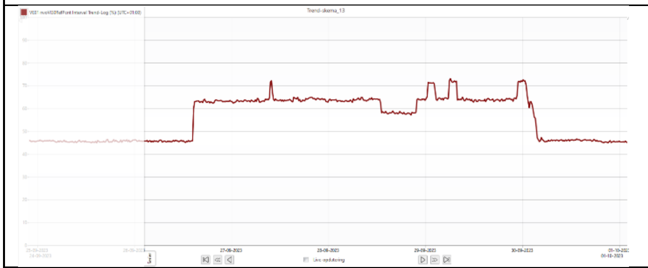
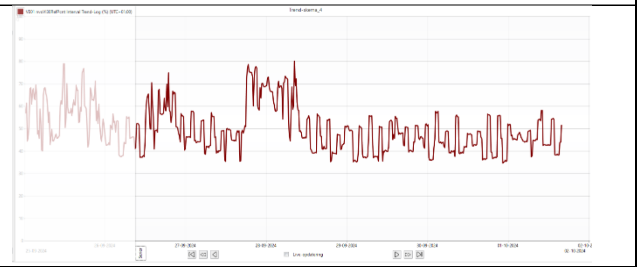
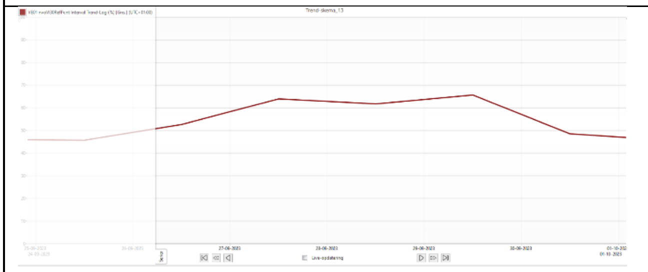
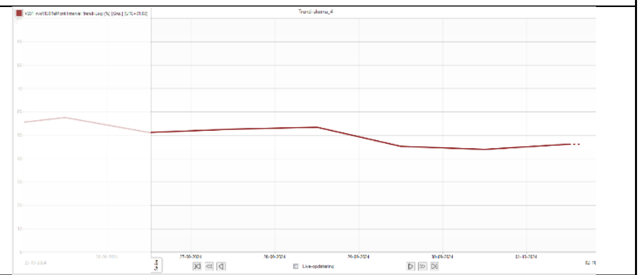
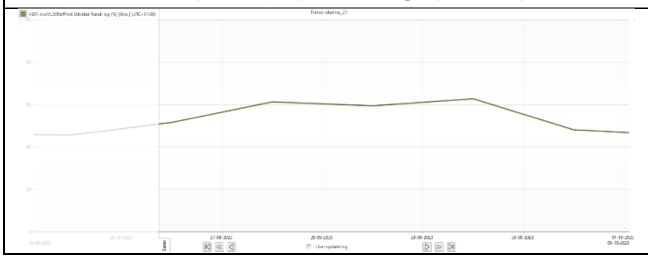
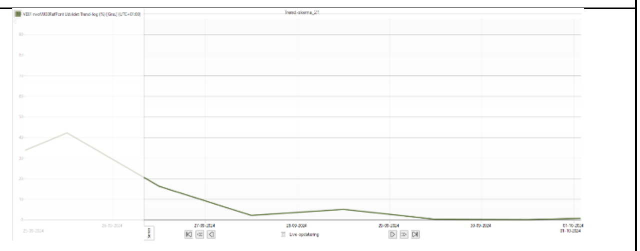
Here is the speed of the supply fan (VI30) in % real values:



Here is the speed of the supply fan (VI30) in % average per day:

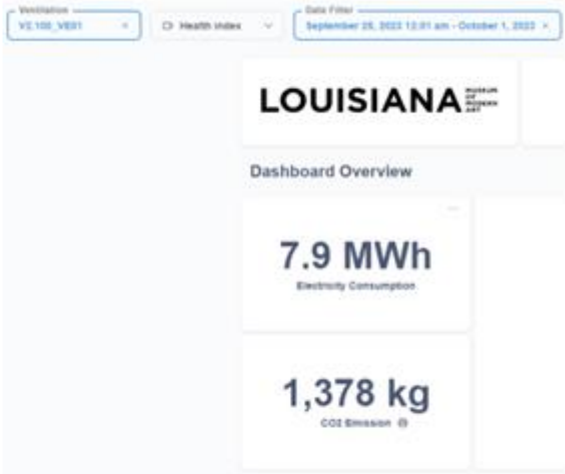
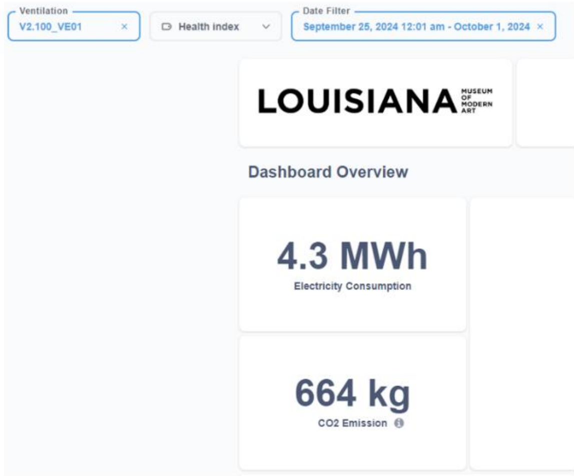


Comparison of Curves:

Before AI	After the Introduction of AI and New Damper SM31
Supply Air Pressure Setpoint (Pa):	
	
Supply Fan Speed (%):	
	
Supply Fan Speed (%) - Average per Day:	
	
Exhaust Fan Speed (%) - Average per Day:	
	

Energy Savings

Data on electricity consumption retrieved from the same AI tool for the respective periods for the system.

2023:	2024 (after renovation and AI implementation):
	

Louisiana is still in the early stages with AI. Therefore, there are many precautionary processes in AI regulation as the work progresses. As the AI and the BMS-technician get familiar to the system, we can adjust parameters, which will certainly provide us with further savings.

Preliminary calculations for savings

Ventilation Unit	Previous Pressure (Pa)	EcoVent Pressure range (Pa)	EcoVent Average pressure	Save in %
V2.100	250	90-260	175	51
V6.03_VE01	430	200-380	275	49
V6.03_VE02	125	45-125	80	53
V6.07	1950 m3/h	1000-1800 m3/h	1300	56
V6.13	430	200-370	310	48
S3.100	305	220-300	255	30
S12.01	350	200-330	275	38
S14.100	190	135-200	165	25
N24.10	80	40-100	65	33
N26.10	145	95-145	120	32
O3.01	265	160-260	210	37

These savings only show the energy consumption for the operation of the fans themselves. Additionally, there are savings from reduced cooling and heating consumption as well as less wear and tear when the ventilation system runs slower.

Summary and Recommendations on BMS system

System Optimization:

- Ensure heating and cooling are only provided when necessary.
- Review the entire system to avoid conflicting parts.
- Reprogram for better synergies.

Art Protection:

- Follow the Bizot Group's recommendations.
- Expand humidity control to achieve energy savings while protecting the art.

Temperature Control:

- Raise the temperature when dehumidification is needed.
- Lower the temperature when humidification is needed.

Hardware Improvements:

- Replace circulation pumps for better efficiency.
- Replace fans to reduce energy consumption.
- Review and optimise filters for energy savings and good air quality.

New Bypass Damper

Original Set-up:

- All air from the exhibition areas was extracted by the exhaust fan (VU30) and reintroduced through the cooling coil.
- For dehumidification, the entire air mass was cooled to the dew point and then heated to the desired supply temperature.

After Renovation:

- A new damper (SM31) was introduced, which is normally fully open.
- It is not necessary for the entire air volume to pass through the cooling coil when cooling is needed.

Economic Benefits:

1. Reduced Energy Consumption and Wear:

- The cooling coil provides high resistance, requiring more energy.
- When the air does not pass through the cooling coil, electricity is saved, and motor wear is reduced.

2. Efficient Dehumidification:

- Humidity is removed from a smaller air volume, which requires less cooling than if it were the full air volume.

- Less heating is needed to warm the air to the desired temperature.

3. Optimized Air Balance:

- Air volume is controlled in cubic meters per hour to maintain a slight overpressure in the galleries.
- Clean, filtered air in the galleries.

4. Reduced Energy Consumption and Wear on the Exhaust Fan:

- The exhaust fan (VU30) runs less, as the supply fan (VI30) handles most of the air volume.

5. Fan speeds before and after renovation:

- Before Renovation:
    - The supply fan (VI30) and exhaust fan (VU30) ran between 46% and 67%.
- After Renovation and AI:
    - The supply fan (VI30) regulates between 45% and 65%.
    - The exhaust fan (VU30) regulates between 0% and 29%.

Use of AI in Airflow Regulation

Before AI:

- Fixed pressure in the supply air, resulting in inefficient operation.

After AI:

- AI automatically adjusts the supply air pressure based on experience and data.
- This optimizes energy consumption and maintains the desired conditions in the exhibition areas.

- AI uses data on:
    - Indoor temperature and humidity
    - Setpoints for indoor temperature and humidity
    - Air speed
    - Air quality
    - Supply pressure
    - Setpoint for supply pressure
    - Supply and exhaust motor speed
    - Humidifier control signal
    - Heating and cooling valve control signal
    - Visitors
    - Outdoor temperature and humidity
    - Electricity prices (in the long term)

- AI ensures the motor operates most efficiently by delivering maximum airflow with minimal energy consumption.

Conclusion on Energy Optimisation

After optimising the system, significant energy improvements have been achieved.

Heating and cooling are now only provided when necessary, reducing energy consumption.

The system has been reprogrammed for better synergies and new circulation pumps and fans have been installed to increase efficiency and reduce energy consumption.

Additionally, the filters have been reviewed and optimised for further energy savings.

With the new bypass damper (SM31), it is no longer necessary for all air to pass through the cooling coil, saving energy and reducing motor wear.

Test and Observations in Conservation

Since the beginning of this project Louisiana decided to broaden the climate systems relative humidity range to be 50 % ± 10 % RH. This was a change from ± 2 % RH within exhibition areas and storage facilities at the museum. The decision was based on the large amount of scientific, conservation-related research made prior to this project. Condition reporting was balanced throughout the project with scientific research and data driven evidence.

Louisiana did a few observations and condition reports on objects in storage, after implementing the new, expanded range, and found the changes insignificant. As expected, we cannot conclude any significant changes from the visual observations.

The team also did a test with very large, traveling artworks packed in travel frames with lids instead of the regular climate crates. This was to see if we could reduce material, size and possibly number of trucks. The humidity and temperature were logged by installing a datalogger in the travel frames. The artworks going on loan were subjected to different climates during travel, which showed both large fluctuations in % RH and visible changes in the objects' condition. Therefore, no changes were made within future loan agreements regarding travel frames and climate crates. Climate crates are still necessary in most cases.

Conclusion conservation

We will continue to follow the Bizot Green Protocol. We incorporated this already before the project in our loan agreements, so when artworks are on loan, we also recommend the lending institution to follow the Bizot range of 40-60 % RH. With the observations made during this project, consequently we will have a greater focus on observing artworks for any change. There are still certain criteria for traveling artworks that need to be complied with in order to not jeopardize the condition of the artworks.

Key Achievements

Louisiana has worked intensely on improving the climate control system, in order to create energy savings. This work was initiated before the KI project and will continue after the KI project. In short, the key achievements for Louisiana are

- Improved the climate system with new installations with dampers.
- Have tested and implemented AI in the BMS-system with a drop of 45 % in energy use.
- The Bizot guiding principles of RH 40-60 % range for climate is standard.
- Interdisciplinary meetings and learnings across the organization: The project has enabled dialogue in which conservators and BMS-technician have gained learning, from both sides on the climate control system and reasons for energy savings.

Lessons Learned

The project has reinforced wishes to keep challenging existing climate set points and energy optimising initiatives. Through different tests and measurements, we have discovered new, innovative ways to save energy and have disproved some earlier assumptions for energy saving initiatives.

Throughout the project period it has shown beneficiary to have interdisciplinary meetings between BMS-technician, sustainability manager and conservators. We hope to continue these interdisciplinary meetings across the organization.

We found continuous learnings through the IOT data, AI implementation, newly purchased ventilations. Therefor it makes sense to keep on challenging the BMS system. We have seen significant savings in energy, and therefore CO2 emissions in the BMS-system. Louisiana will keep working with reducing and optimizing energy systems.

Recommendations

Louisiana recommends that other museums open up to challenge the climate control system, no matter the state and efficiency. There are savings to find if you open for an outside assessment. Louisiana had success by inviting an energy-engineer from another sector.

Louisiana recommends that other museums take part in the Bizot-guidelines and open the climate range to RH 40-60 % when possible and in loan agreements. Furthermore, the guiding principles have other initiatives such as online couriers, design of existing buildings and storages, transport and more which can be inspirational.

Conclusion

The project has enabled a platform from which Louisiana has obtained different learnings in operations, particularly regarding the climate control system and loan agreements. Through various angles and analyses, it has become clear that the climate control system has opportunities for optimization. Before, during, and continuing after this project, Louisiana will keep testing and challenging the system to enable further energy reduction and CO2 reduction. Louisiana will furthermore continue to use the Bizot guidelines when managing both its own loans and borrowing from other institutions.

Other beneficial insights on energy savings 2018-2023

Changes in operations at Louisiana from the years 2018-2023, before the KI project.

Several years ago, we decided to take a thorough look at heating, cooling, and ventilation systems to identify potential energy savings. Louisiana also replaced all lights to LED, which also lead to an energy reduction. Insights, decisions, and programming on climate control:

System Coherence

- Our first focus area was the control of the systems. We started by ensuring that the systems only provide heating and cooling when necessary and in the precise amounts needed. This required us to review the entire system - from domestic hot water and heating to cooling and ventilation - and see how the different parts affected each other.
- Often, these systems have been built over time without a comprehensive plan, which means they can end up working against each other. For example, we might have a heating circuit that overheats an area while the ventilation system tries to cool it down. Or, we have cooling water that is colder than necessary for dehumidification, even when there is no need for dehumidification.
- Once we identified these areas, we reprogrammed the systems to create better synergies and avoid them working against each other. This meant we could optimise operations and ensure that all systems work together instead of against each other.

Setpoints

- Our main task is to protect the art. Therefore, it is important to look at the research and recommendations available for different art materials when deciding the humidity and temperature conditions we want in our exhibition areas.
- We have decided to follow the recommendations from the Bizot Group whenever possible. This has allowed us to expand our humidity control and ensure that we can preserve the artworks best.
- Bizot recommends maintaining humidity levels within the range of 40-60%. To ensure compliance with these limits, our BMS system is configured to regulate according to setpoints of 42% and 58%.

Using Outdoor Humidity to Control Indoor Humidity

We use outdoor air to help maintain the right humidity levels indoors.

- For Humidification: When the indoor air is too dry, we bring in fresh air if the outdoor humidity is higher.
- For Dehumidification: When the indoor air is too humid, we bring in fresh air if the outdoor air is drier.

Temperature Control Helps with Humidity

- We control our room temperature within a certain range based on humidity control.
- If dehumidification is needed, we slowly raise the room temperature, as this helps reduce humidity. Conversely, if humidification is needed, we slowly lower the room temperature to increase humidity levels.

Hardware

Circulation Pumps

- Next, we focused on the "hardware" itself - the components that make up the systems. One of the most important measures was to replace the circulation pumps in our heating and cooling circuits. Calculations showed that this investment would have a very short payback period, making it obvious to replace 74 of our 77 pumps. The payback periods ranged from 0.6 to 7.7 years, making it economically sensible.

Fans

- We also analysed the potential of replacing the old, belt-driven fans with modern and energy efficient EC direct driven fans. By replacing all 44 fans, we could reduce energy consumption by as much as 33%, and this investment had a payback period of just 2.6 years.

Filters

- Additionally, a review of filters in the ventilation system can provide an overview and possibly savings.
- First, it is important to check that the correct filter class is selected for each filter.
- If they have too high a filter class, they use unnecessary energy to push air through the filter.
- If the filter class is too low, you do not get the air quality you want.
- Then you can look at the size of the filter - whether the filter is physically as long as the system allows. There can be significant energy savings by using the longest filters possible. This provides more filter area for the air to pass through, thus lowering energy consumption. Whether it is economically viable to buy a longer filter can be determined with the help of your filter supplier. The longer filter is slightly more expensive to purchase, but there can be energy savings due to lower resistance in the filter which may outweigh the extra material costs.
- These measures have been important steps towards more energy efficient operations and have led to a significant reduction in our energy consumption.

If any questions, please don't hesitate to contact

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Ulrik Staal Strange
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The AI system Ecovent by 4I4 / Intelligent ventilation control
See case on 4I4 website press here.
Contact CCO Milad Ansari
milad@4i4.dk

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