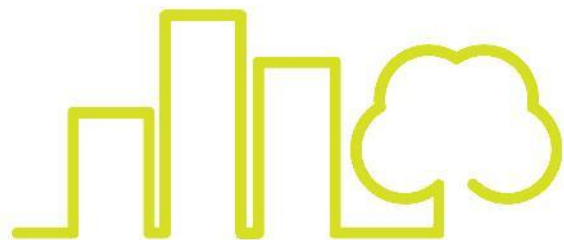




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**SUSTAINABLE  
PLACES**

**2018** June 27-29, 2018  
Aix-les Bains, France

**A sub-zonal PMV-based HVAC  
and façade control system for  
curtain wall buildings**

**Dr. Marco Arnesano**

June 18 - [www.univpm.it](http://www.univpm.it)

# A sub-zonal PMV-based HVAC and façade control system for curtain wall buildings

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A. Calvaresi<sup>a</sup>, O. Casadei<sup>b</sup>, S. Magnani<sup>b</sup>

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# P2Endure - Overview

## Outline

### Who we are

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## UNIVPM - School of Engineering



### Department of Industrial Engineering and Mathematical Sciences (DIISM)

**Sensors and Measurement Research Group:** prof. G.M. Revel (Deputy Rector for European Research, Coordinator ECTP Materials & Sustainability Committee) focuses the research on transversal measurements and service development with focus on smart cities and the built environment

### The group at a glance

2 full professors

3 associate professors

9 FP7 projects

2 lecturers

1 technician

8 H2020 projects

10 Phd students

8 post-doc researchers

# P2Endure - Overview

## Outline

### Who we are

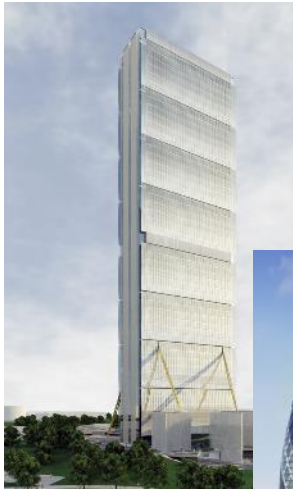
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Focchi S.p.A. is an Italian **leading company in the curtain wall sector** providing design, manufacture and installation of curtain walling with high technological and service content together with the engineering for the external cladding of complex structures ([www.focchi.it](http://www.focchi.it)).



The Technical Department, with more than 40 years of experience in the field of aluminum, relies on a large team of experienced project managers, project design managers, site managers, engineers and surveyors dedicated to each project.

<https://www.focchi.it/>

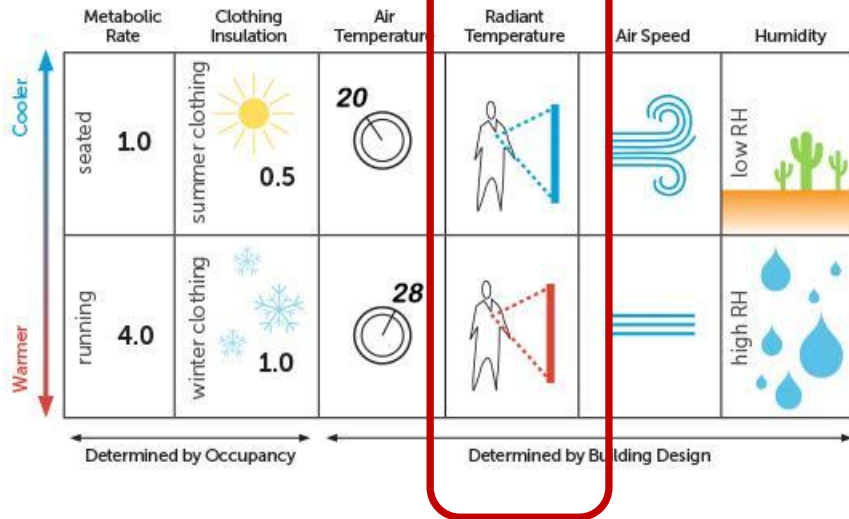
# P2Endure - Overview

## Thermal comfort

### The importance of curtain walls

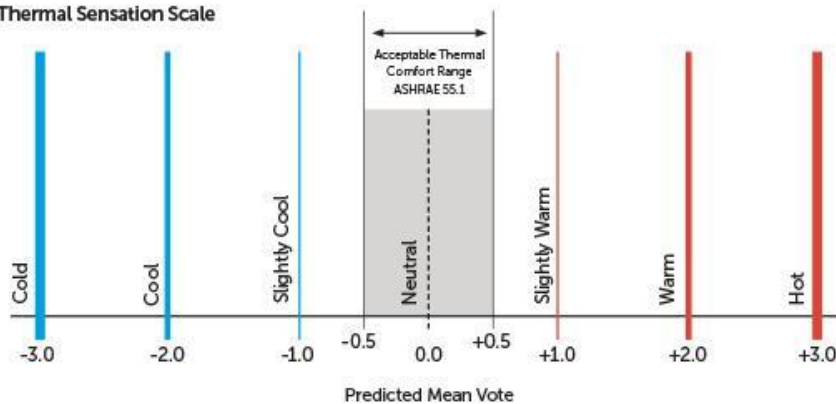
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Thermal Comfort Factors



Thermal comfort is determined by occupants and ambient parameters. Balancing the 6 factors, comfort can be achieved. The glazed facades play a central role in this balance because of the impact of radiant temperatures.

Thermal Sensation Scale





# P2Endure - Overview

## Comfort Eye

### The basic concept

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The Comfort Eye is a low-cost, IR based comfort sensor for the monitoring of thermal comfort in multiple position of the space according to ISO7730 and ISO 7726.

Advanced comfort monitoring with the possibility to **measure maps of radiant temperatures** which affect strongly thermal comfort, especially in case of strong warming of building envelope



- High modularity
- Short and long period monitoring
- Cloud data storage
- Data availability and accessibility

The IR scanning system provides high IR resolution thermal maps and communicates wirelessly with devices. It can be mounted on tripod for short-term monitoring, on the ceiling for long-term or permanent monitoring

# P2Endure - Overview

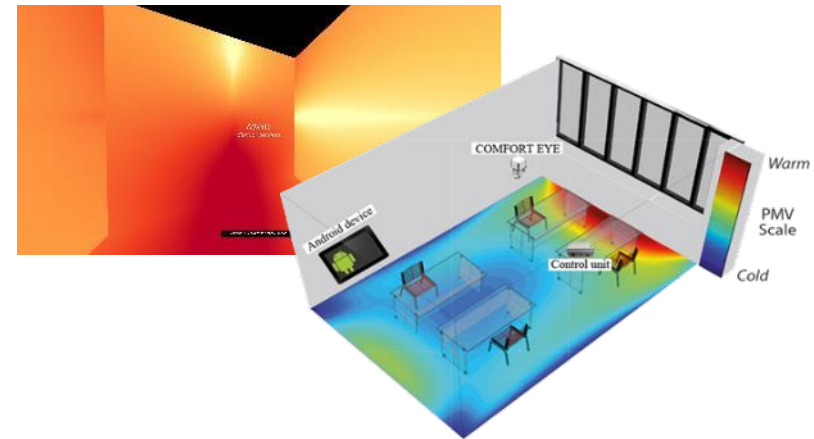
## Comfort Eye

### The basic concept

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The Comfort Eye is a low-cost, IR based comfort sensor for the monitoring of thermal comfort in multiple position of the space according to ISO7730 and ISO 7726.

- In addition to thermal comfort, Indoor Air Quality can be monitored with embedded sensor for CO2 and TVOC measurement.
- Visual comfort can be monitored with light sensor
- 3D thermal images of the room can be extracted to track the thermal performance of the building envelope
- Communication module is interchangeable supporting different standards (WiFi, BLE, Zigbee, LoRa)



Example of 3D thermal scan and comfort maps that can be provided through web service connected with the Comfort Eye



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# P2Endure - Overview

## Concept for curtain walls

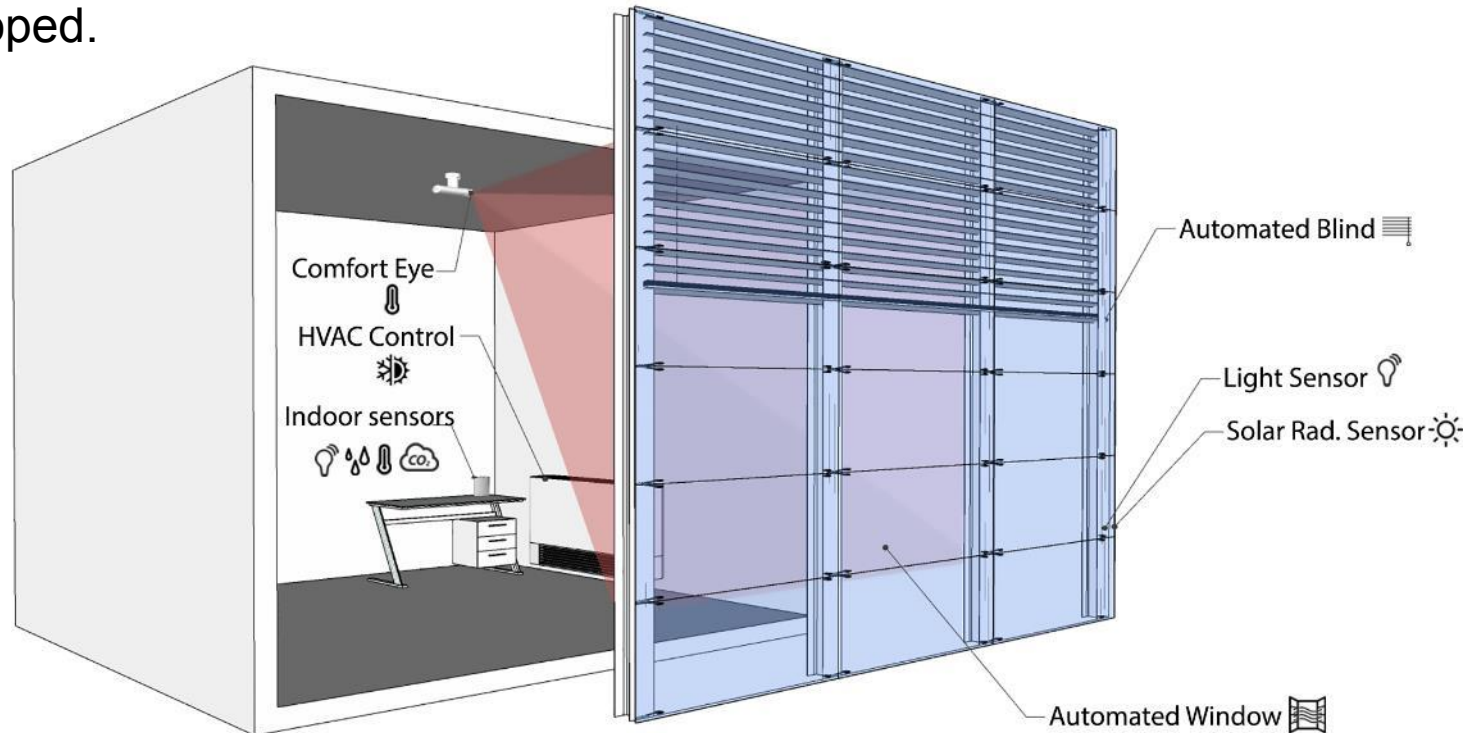
### The Smart Facade



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Given the significant impact of glazed surfaces on occupants comfort and buildings energy performance, the concept of Comfort Eye integrated with the Smart Façade was developed.



Façade module with embedded sensors to measure local outdoor conditions to be merged with the Comfort Eye data and interoperable with the BMS for optimal zonal HVAC, lights and windows management.



# P2Endure - Overview

## Smart Facade

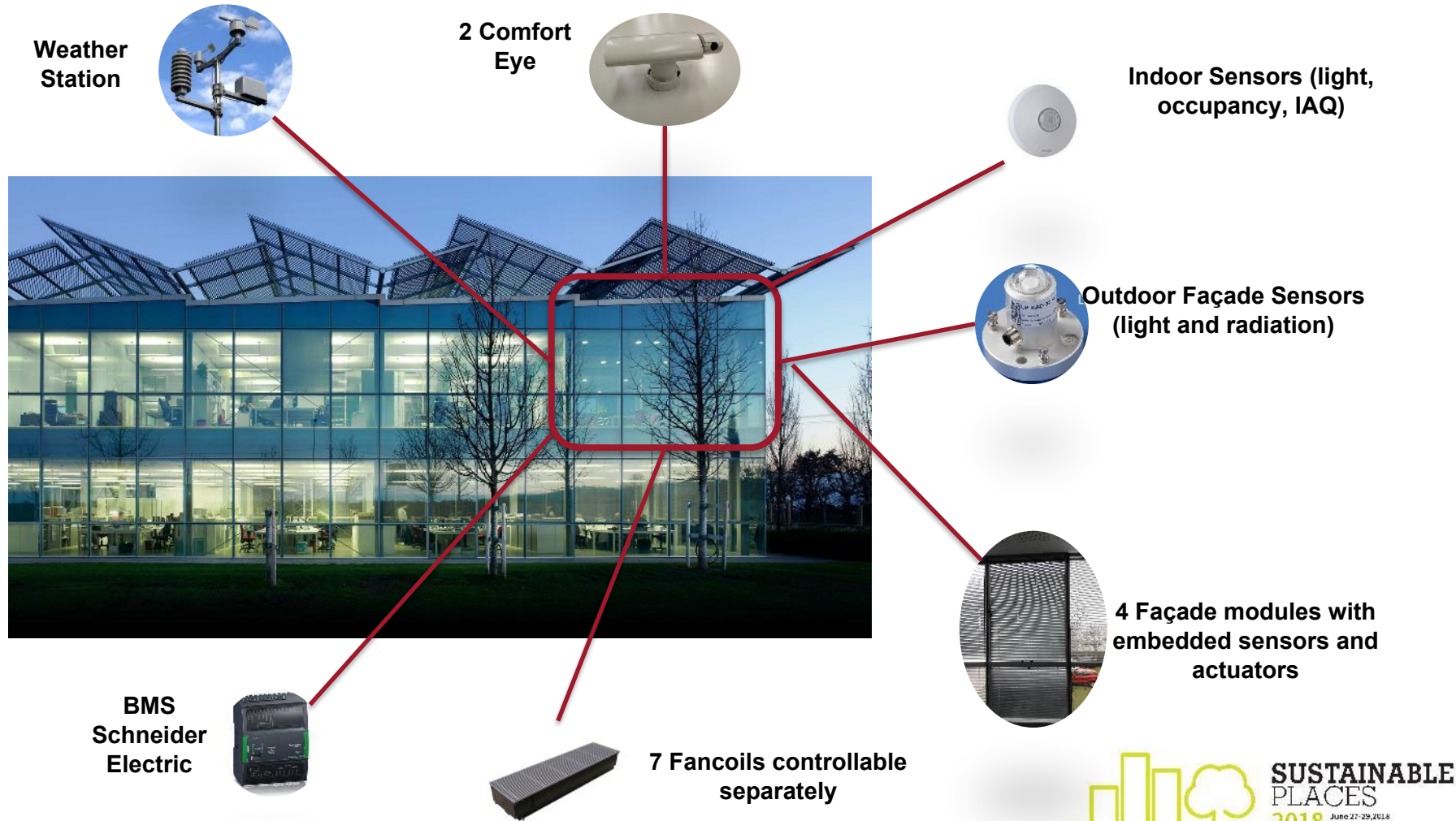
### The case study



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The headquarter of Focchi has been used as case study with the implementation of the proof of concept in the meeting room, called “Demo room”, used as living lab.

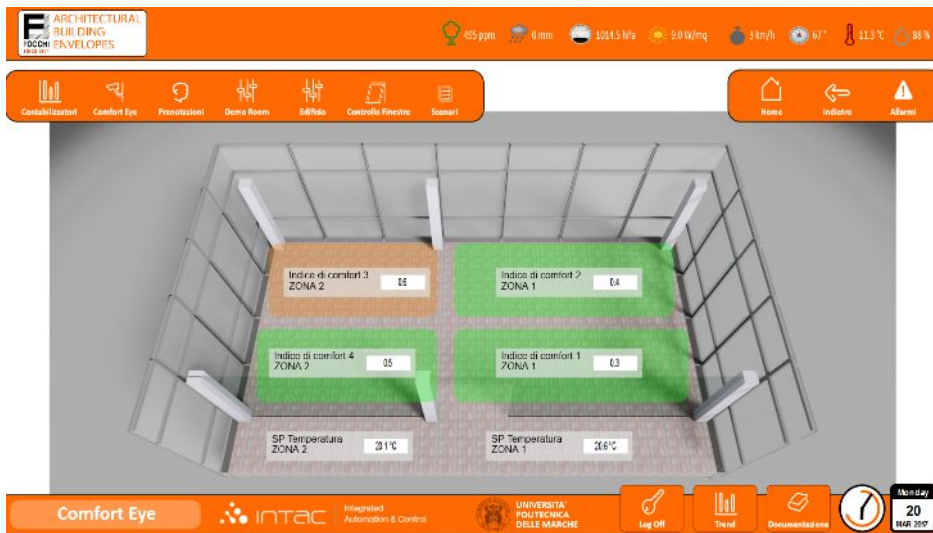




The Comfort Eye was integrated with the BMS to enable the required key functionalities. The BMS gets measured data from the Comfort Eye (PMV and optimal setpoint) and distributed sensors to actuate fancoils, shadings, lights and windows.

## Multipoint comfort measurement

## Sub-zonal HVAC control based on local PMV





# P2Endure - Overview

## Functionalities

### HVAC control



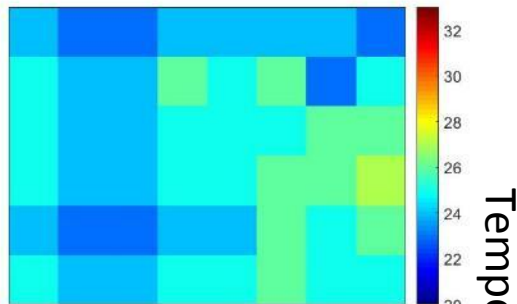
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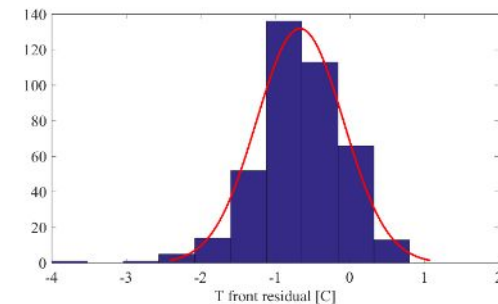
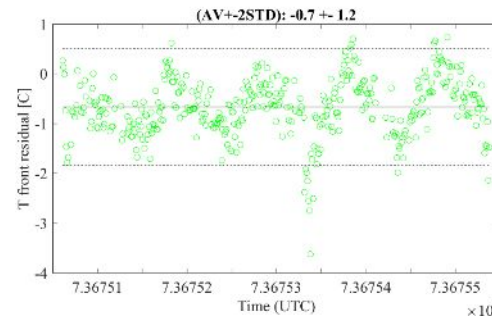
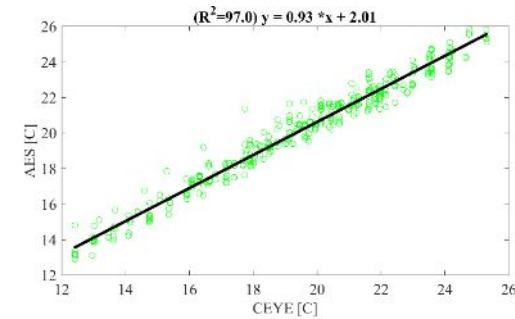
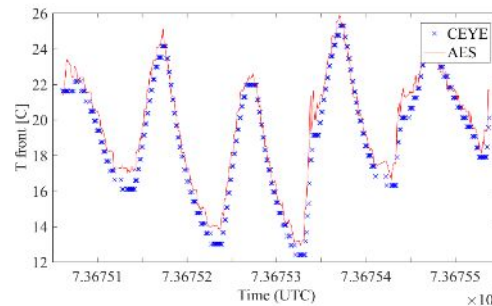
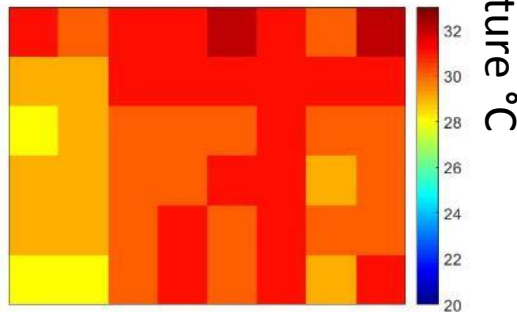
The Comfort Eye allows indoor surfaces temperature measurement to calculate mean radiant temperature deviations due to solar radiation. Thermal maps were extracted to assess the impact of solar radiation on indoor comfort and HVAC set point calculation.

## Comparison with contact sensors

North side



South side



# P2Endure - Overview

## Functionalities

### HVAC control



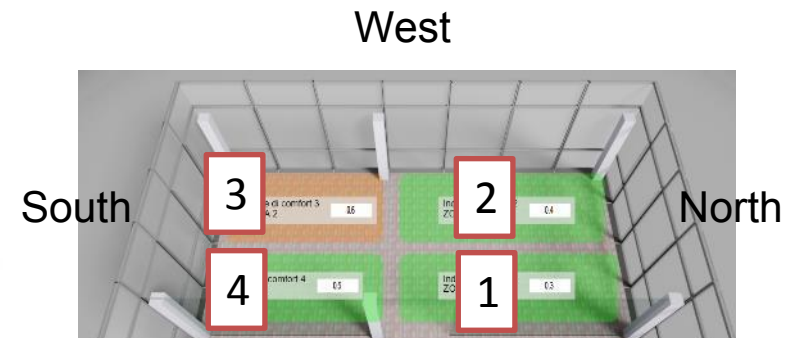
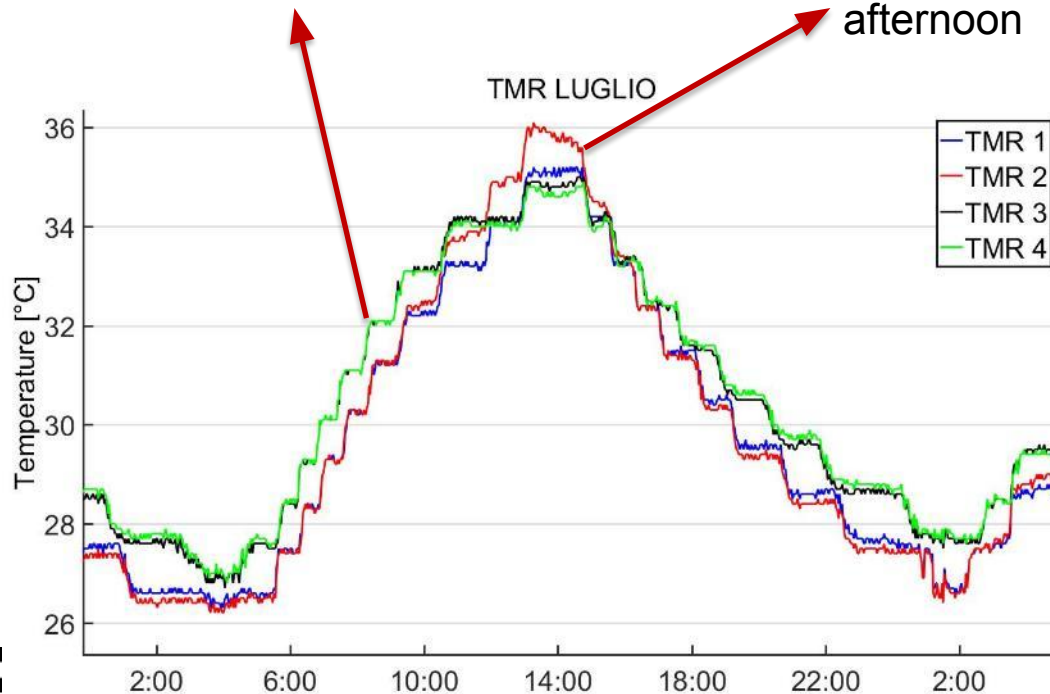
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The Comfort Eye allows indoor surfaces temperature measurement to calculate mean radiant temperature deviations due to solar radiation. Thermal maps were extracted to assess the impact of solar radiation on indoor comfort and HVAC set point calculation.

Zone 3-4 East/South oriented. Radiant temp higher in the morning

Zone 2 West oriented. Radiant temp higher in the afternoon





# P2Endure - Overview

## Functionalities

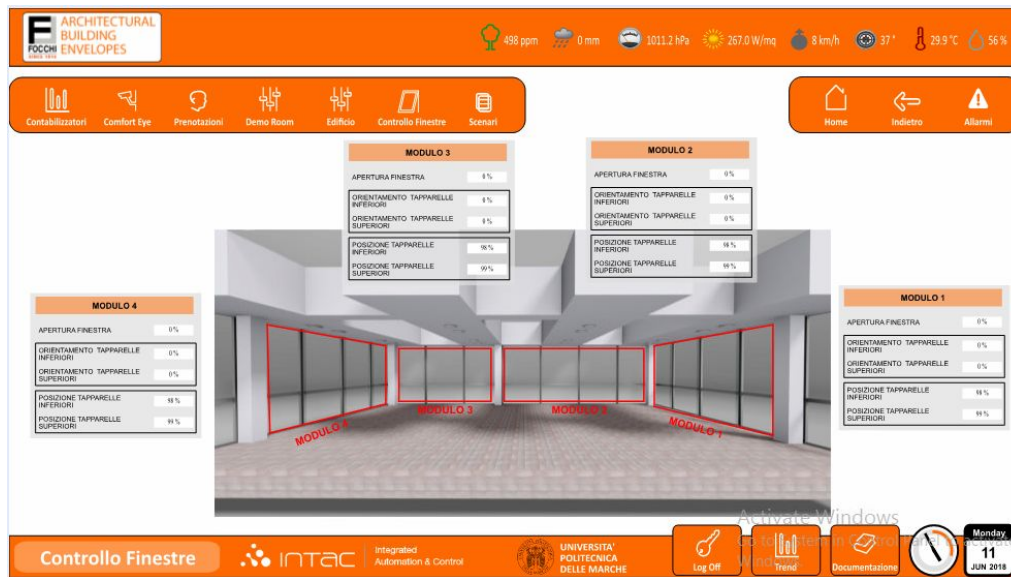
### Shadings control



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Four sensing façade modules provide local visual conditions used to calculate the optimal shading position. Together with average illuminance, the glare is taken into account to avoid local discomfort. Solar radiation is measured to control the solar gain in function of the HVAC mode.



**Sub-zonal shadings control based  
on outdoor/indoor conditions**

# P2Endure - Overview

## Validation



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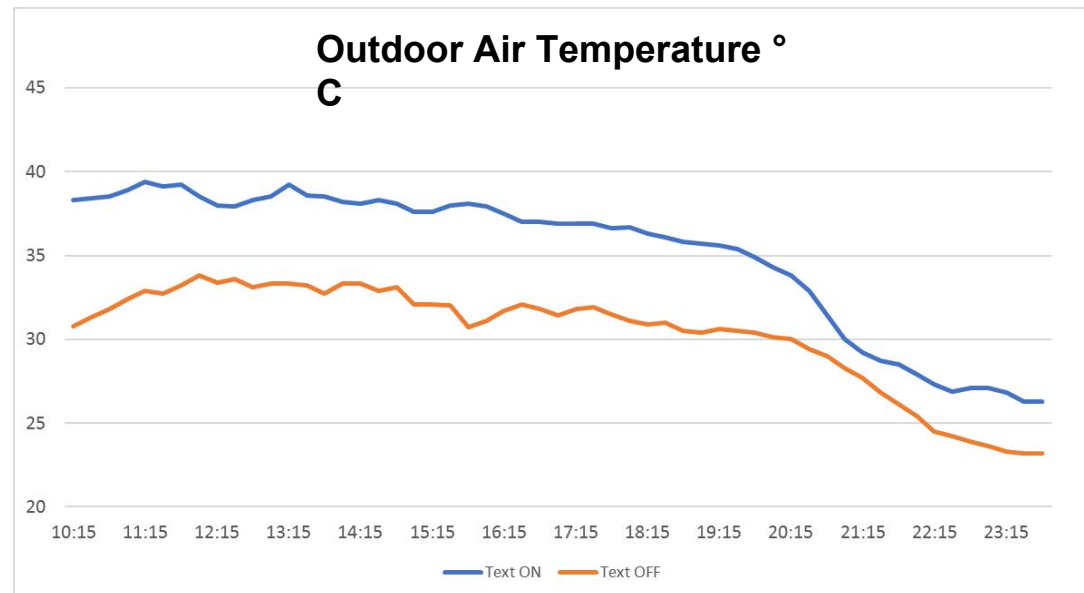
## The reference condition

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The integration of the Comfort Eye with the BMS and facade aims at maximizing thermal comfort with the minimum energy consumption (**heat or cool people, not buildings!**). A preliminary analysis of the Demo Room performance comparing two scenarios:

1. **System ON:** the BMS controls the HVAC making use of the real-time temperature setpoints provided by the Comfort Eye
2. **System OFF:** the BMS replicates the room operation before the installation of the innovative solution. Temperature setpoint fixed at 26°C in all zones and fixed fan velocity.

Two working days have been compared during summer season: 2017/08/04 with System ON and 2018/07/20 with System OFF. The climate conditions were warmer during the day with System ON, leading to a disadvantaged thermal condition.



# P2Endure - Overview

## Validation

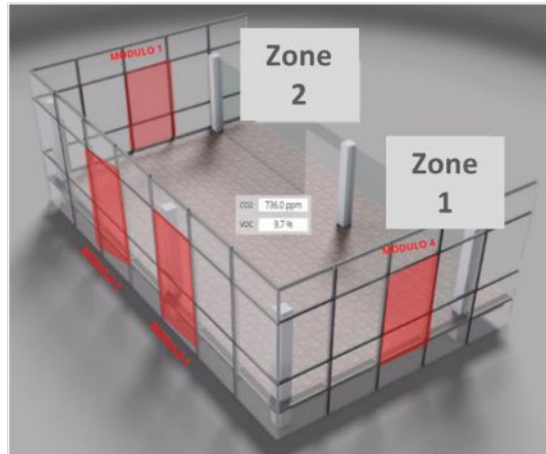
### Energy savings



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Thermal Power W Zone 1 (South Oriented)



Thermal Power W Zone 2 (North Oriented)



Energy Consumption kWh		E norm kWh	Saving by zone	Total saving	Total saving norm.
Z1 ON	12.4	2.9	9.7%	22.2%	42.2%
Z1 OFF	13.7	4.3			
Z2 ON	5.7	1.3	40.1%		
Z2 OFF	9.6	3.0			

The test turned out to provide a total energy saving of the 22%, calculated only in the occupied hours (10-13 with red box). The higher saving is achieved in the Zone 2 (North Oriented) where the Comfort Eye assigned a higher setpoint given the lower mean radiant temperature (colder surfaces).

# P2Endure - Overview

## Validation

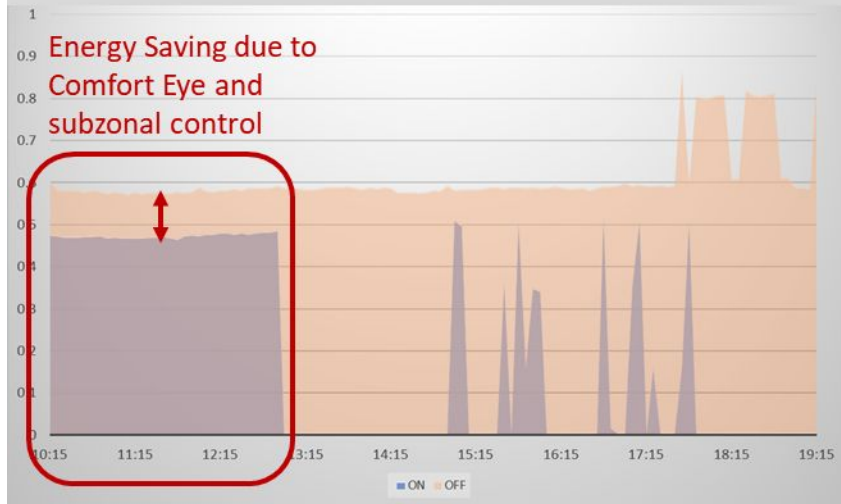
### Energy savings



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Fancoils Electrical Power (kW)



Energy Consumption kWh		Total saving
ON	1.3	23.2%
OFF	1.7	

An electricity saving of 23.2% was registered. The breakdown by zones of the electrical consumption is not available given installation of one meter for the fancoils line. The major contribution to the energy saving is expected to be ascribed to the Zone 2 where the fancoil velocity was reduced given the reduced cooling demand (lower radiant temperature). The energy saving was calculated only for the occupied hours (10-13)

# P2Endure - Overview

## Validation

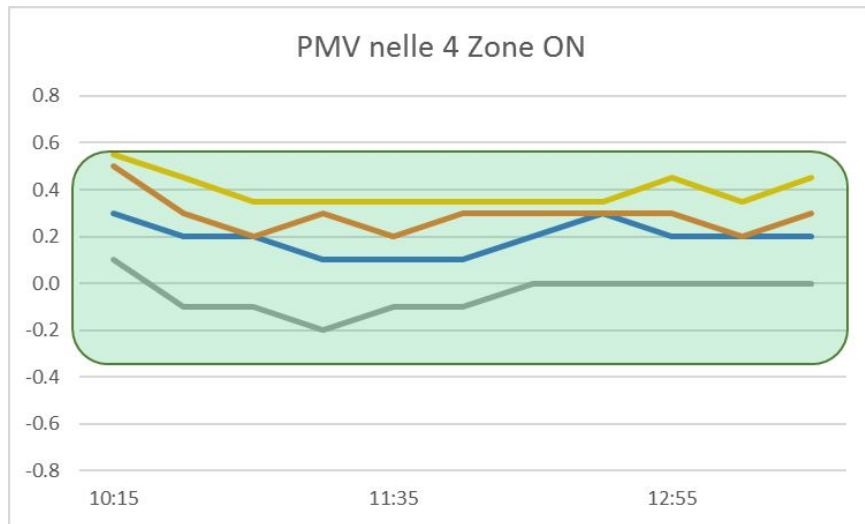
## Comfort



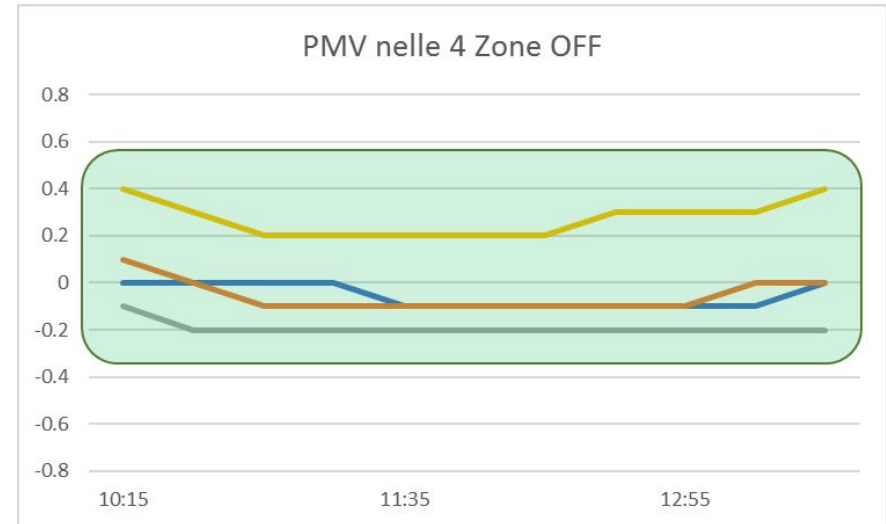
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PMV nelle 4 Zone ON



PMV nelle 4 Zone OFF



During both days the system was able to keep comfort with the optimal range. To be noticed how the System OFF registered negative PMV values (toward cold sensation), mostly in the Zone 2 (North oriented), which is symptom of a non optimal comfort management that cannot balance the different thermal conditions of the room.



# P2Endure - Overview

## Conclusions & Next Steps



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## Thanks



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