Digital Twins for continuous and accurate energy audits

SUSTAINABLE PLACES 2023

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SUSTAINABLE PLACES 2023

50 AÑOS Desde 1972
cemosa
Ingeniería y Control

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CONTEXT

European Context

- **Reduce energy consumption**: climate change, high energy prices, energy dependence
- Buildings consume **40% energy** and **1/3 CO_2** emissions
- 75% building stock is **not energy efficient**
- Number of **inniciatives** to promote building refurbishing and energy independence: REPowerEU plan, European Green Deal, Renovation Wave, Fit for 55, EPBD, SRI

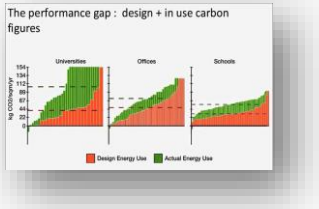
Spanish Context

- 51,42 % buildings > 40 years **old and** has **low energy performance.**
- Many **inniciatives** to promote building refurbishing

Construction Context

- **Digitalization** trend
- Increasing **sensoring and IoT technology** in building sector
- Big amount of **data** available to address energy audits and energy refurbishing problems.

NEEDS AND GAPS ADDRESSED

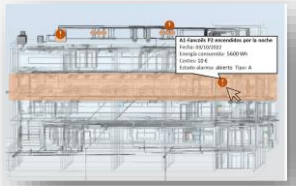


Energy performance gap – difference between estimation and reality

- **Uncertainties** in energy performance and energy saving estimations
- High risk **investments**
- Distrust **clients**

Users´behaviour and awareness

- Users behaviour may increase energy consumption up to **30%**
- Common **inefficient behaviour**: energy consumption with no occupation, non-optimised setpoints
- Users have **lack of information and knowledge**



Building operation and maintenance

- **Energy consumption** is 20-30% of building operation costs
- Building **operation costs** are 75% of building costs
- Difficulties to **identify** energy inefficiencies during building operation

OUR SOLUTION: What do we propose?

Energy refurbishing based on **continuous and advanced energy audits** that use building **digital twin**

Initial Energy Audit

Energy Experts

- Higher automation
- More accurated energy models to evaluate energy conservation measures

Intermediate Energy Audit

Facility Managers and building users

- Higher automation
- More accurated energy models to evaluate energy conservation measures

Renovated Energy Audit

Energy Experts

- Higher automation
- More accurated energy models to evaluate energy conservation measures
- A lot of information to identify problems and potential improvements

DIGITAL TWIN: Concept

Virtual replica of a built asset (building)

- Static data (BIM models)
- Dynamic data (real-time monitoring data)
- Indicators (data processing)
- Scenarios simulation (energy performance models)

Level 1: Descriptive Twin
Editable version of design and construction data – visual replica of a built asset

Level 2: Informative Twin
It has an added layer of operational and sensory data

Level 3: Predictive Twin
It uses operational data to gain insights

Level 4: Comprehensive Twin
It simulates future scenarios and considers "what-if" questions

Level 5: Autonomous Twin
This twin has the ability to learn and act on behalf of users

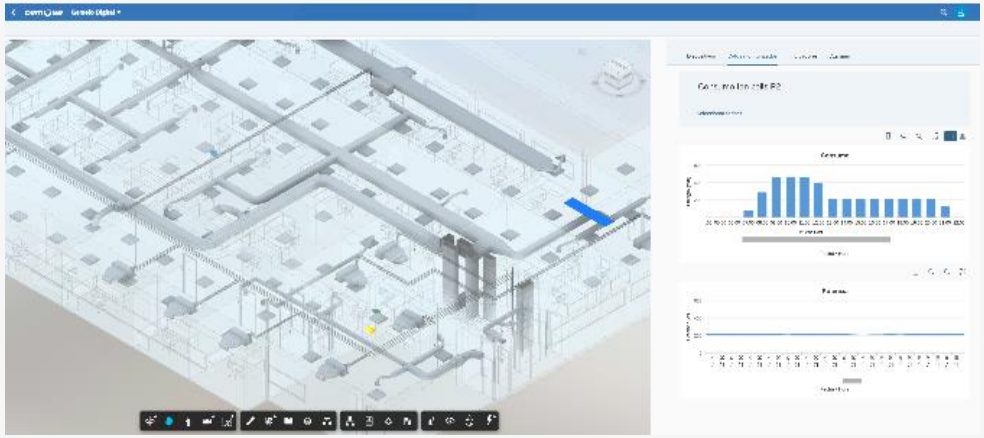
BIM models

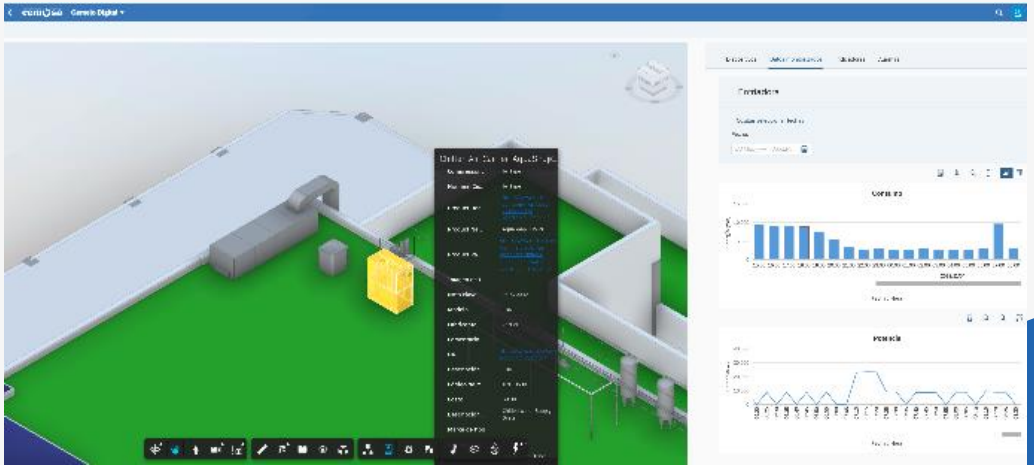
Real time monitoring data

Energy & comfort scores, energy efficiency alarms

Energy models calibrated with real time data to evaluate potential ECMs

DIGITAL TWIN: Technology

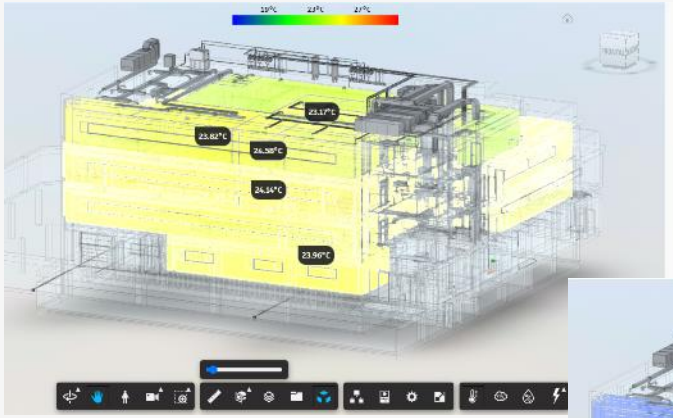


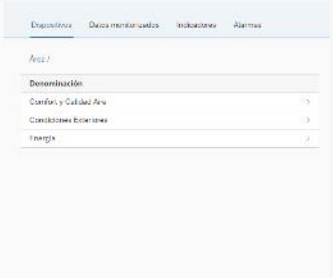


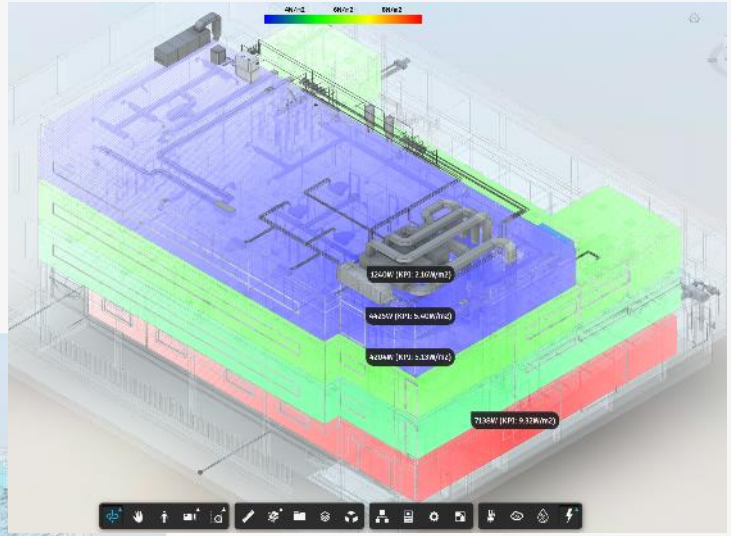
Real time and historical data on energy & indoor environmental quality

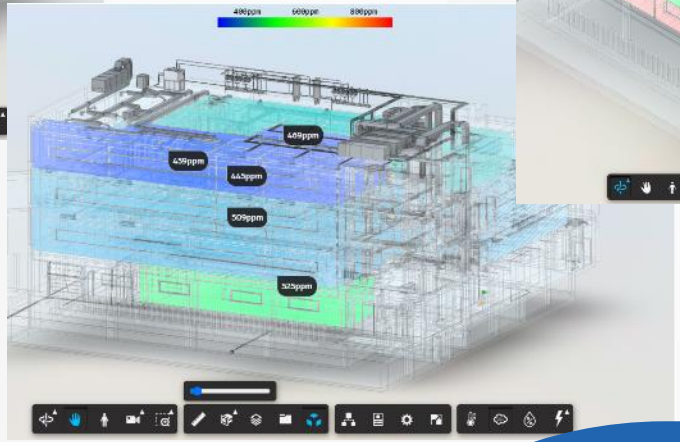
Remote inspection and data visualization

DIGITAL TWIN: Technology









Analisis & control
on energy and indoor environmental quality

DIGITAL TWIN: Technology

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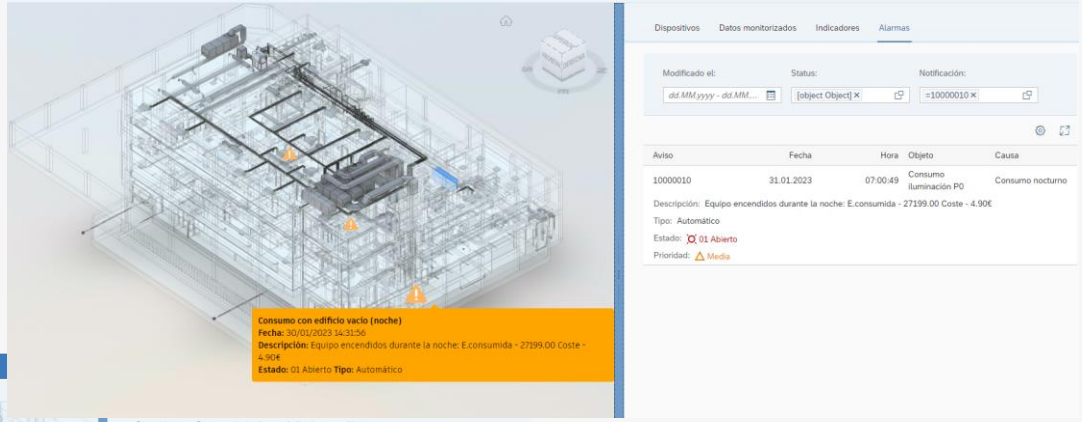
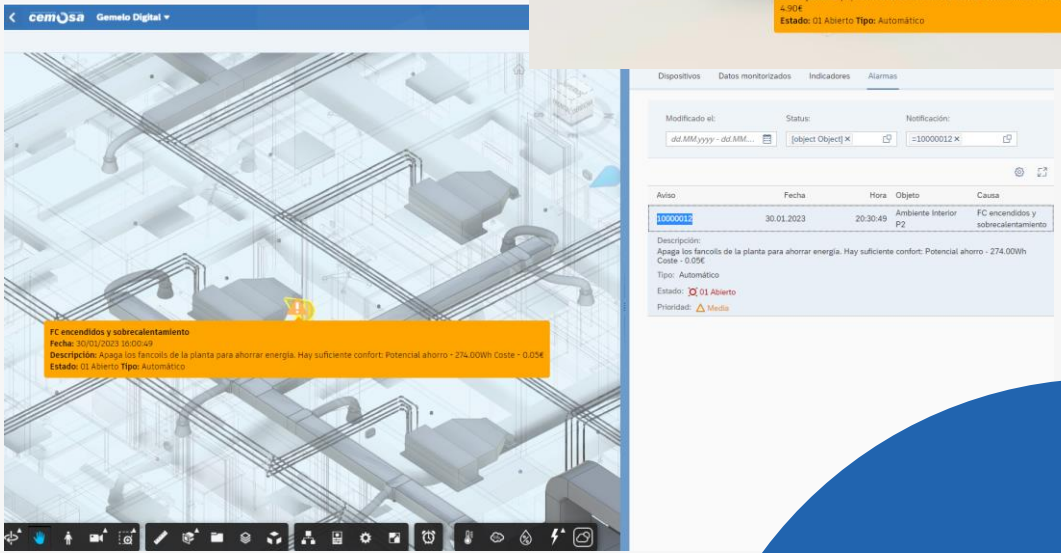
Energy efficiency alarms





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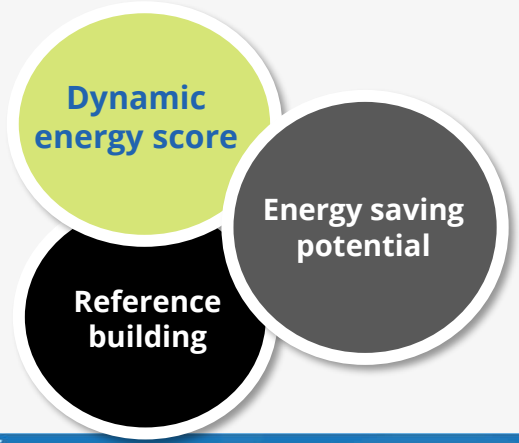
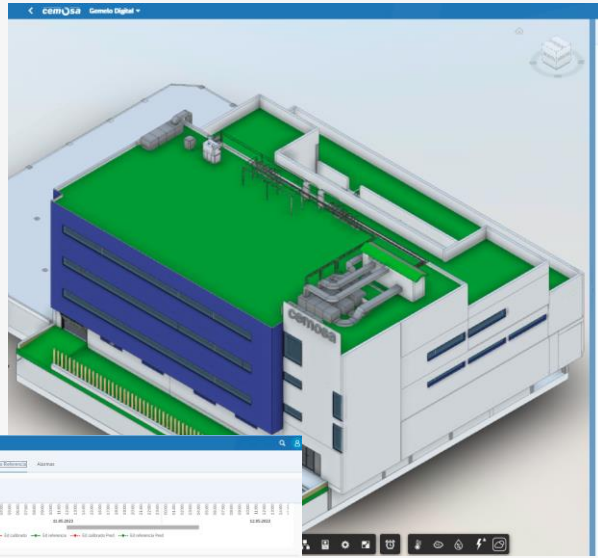
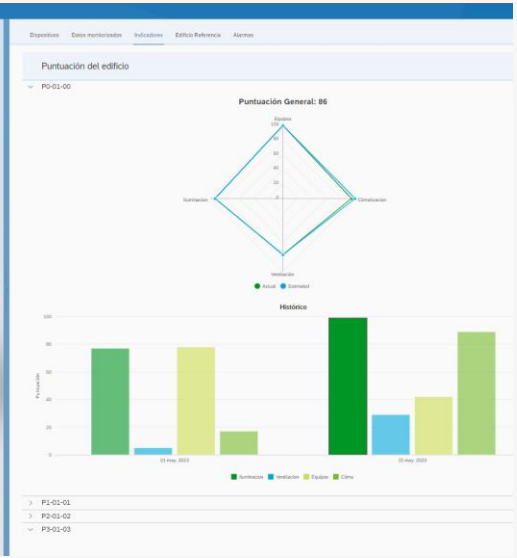
DIGITAL TWIN: Technology







DIGITAL TWIN: What´s behind?

Real-time monitoring

Building

Energy consumption
- Total
- Cooling
- Heating
- Ventilation
- Lighting
- Other equipment

Outdoor environment
- Temperature
- Humidity
- CO_2
- Solar radiation

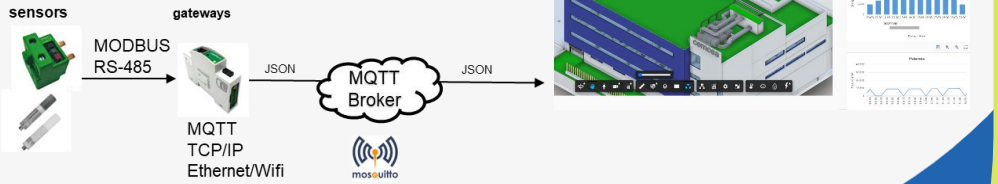
Floor / room

Energy consumption
- Total
- HVAC
- Iluminación
- Otros equipos consumidores

Indoor environment
- Temperature
- Humidity
- CO_2

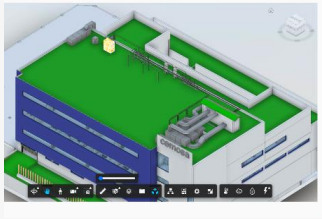
Envelope

Facades
- Tsup,outdoor
- Tsup, indoor



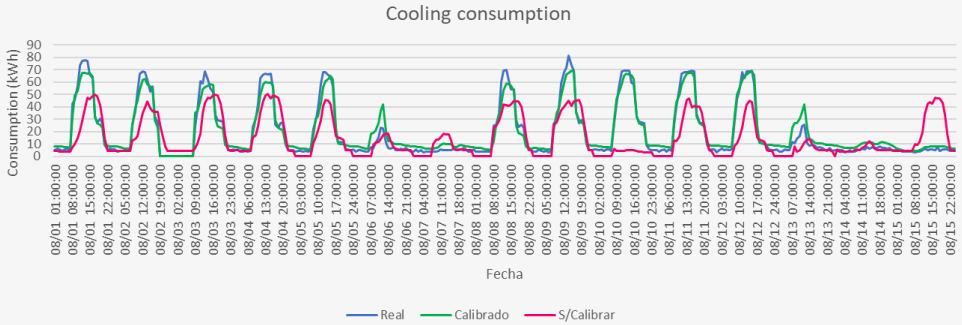
DIGITAL TWIN: What´s behind?

Calibrated energy models



Módulo AICAL

Building energy model

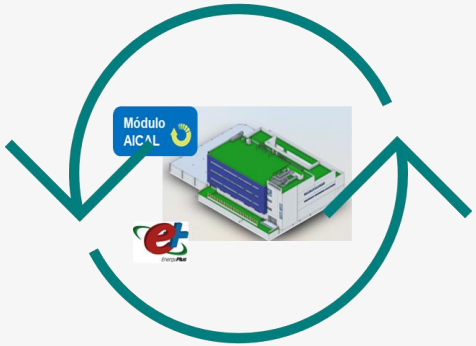


DIGITAL TWIN: What´s behind?

Calibrated energy models

Approach

- **Update models calibrated** during the initial energy audit to ensure accuracy
- **Automated calibration** every 15 day or when alarm
- Reduced number of calibrated **parameters related to the use or degradation:** use factors for lighting and equipment, setpoints, schedules, infiltration
- **Mathematical analytical calibration** – sensitivity análisis & optimisation techniques



DIGITAL TWIN: What´s behind?

Calibrated energy models

Preparation

1. Select calibration **parameters**: COP, infiltration, etc.
2. Define parameters **variation**: COP[1,1.5,2,2.5]; infiltration[1,2,3,4]
3. **Sensitivity análisis** to identify the parameters with higher influence (optional)
4. Generate **sample of input data** that include all possible combinations

Módulo AICAL

$$GOF = \frac{\sqrt{2}}{2}\sqrt{NMBE^2 + CVRMSE^2}$$

$$NMBE = \frac{\sum_{i=1}^{N}(y_i^* - \hat{y}_i)}{N\bar{y}^*}$$

$$CVRMSE = \frac{\sqrt{\frac{\sum_{i=1}^{N}(y_i^* - \hat{y}_i)^2}{N}}}{\bar{y}^*}$$

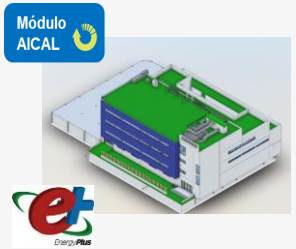
Automitized process

1. Run **simulations** (all combinations of input data) with updated weather data
2. **Read and group monitoring data** from data base to have same timestep.
3. **Normalize** monitoring data and address **data gaps** – skip timesteps with data gaps
4. Calculate **GOF** comparing simulation results and monitoring data
5. Select **best option**

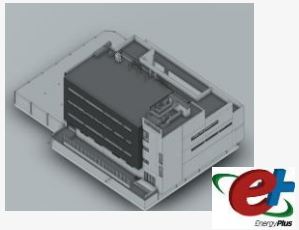
DIGITAL TWIN: What´s behind?

Reference building

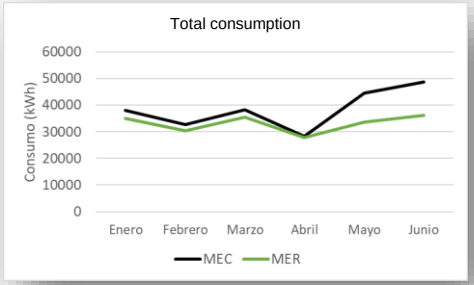
Calibrated building model

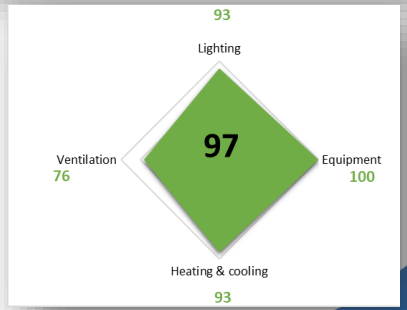


Reference building model



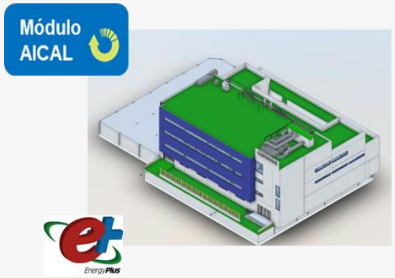
- **Temperature setpoints**
- **Better system maintenance** (COP, Timp)
- **Infiltration control**
- **Adapt lighting and HVAC to ocupation**

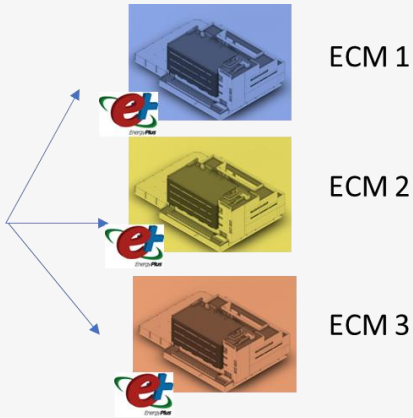


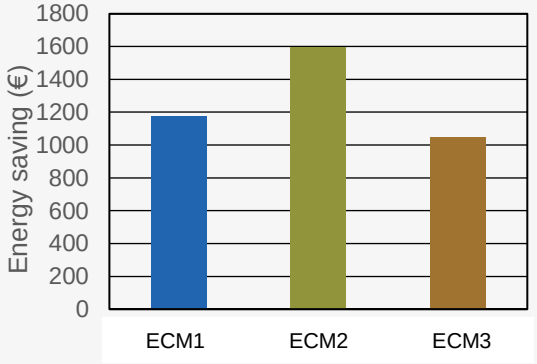


DIGITAL TWIN: What´s behind?

Accurated evaluation of energy conservation measures

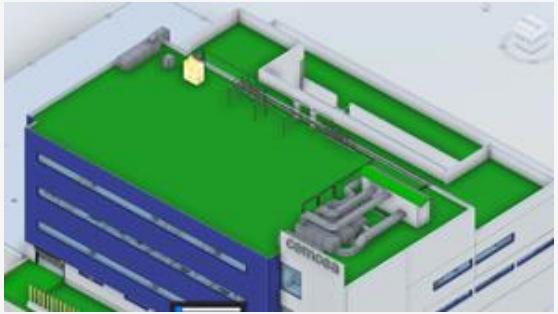






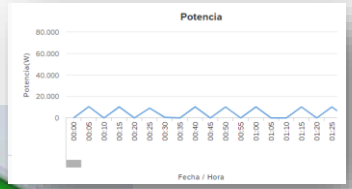
USE CASE – Office building

- Office building CEMOSA Málaga (3000 m2)
  - Ground floor: laboratories & office
  - First & second floor: open spaces - offices
  - Third floor: offices and meeting rooms
- HVAC system
  - Water system: chiller & heatpump
  - 4 Air handling Units
  - Fancoils



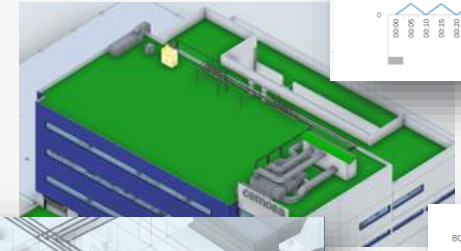
USE CASE – Office building

Inefficiencies detected



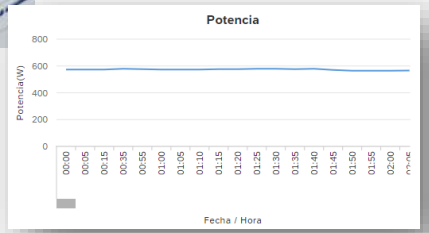
Chiller power at night

Chiller and heatpump stop & start every 5 minutes at night



Energy efficiency alarm

Energy saving potential by using building inertia



Fancoils power at night

Fancoils & lighting consumption at night

CONCLUSIONS

Innovative proposal

- Continuous and advanced energy audits
- Digital twin with user friendly interface for energy experts, building users and facility managers

Advantages

- Energy and comfort problems have been quickly identified
- Highly accurated energy models have been created
- User engagement and awareness towards energy efficiency
- Reduce risk of investment in energy refurbishing

Next steps

- Finish technology and methodology validation in the use case
- Test solution in new pilots
- Extend digital twin scope

¡Thank you!

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