Project Interreg SUDOE Improvement:
LNEG Pilot Plant

Final Event, Sevilla, 7th March 2023

Ana Estanqueiro (Coordinator),

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NATIONAL LABORATORY FOR ENERGY AND GEOLOGY - LNEG

Objectives of LNEG Pilot Plant

LNEG Pilot Plant has the main objectives within IMPROVEMENT Project:

- **Demonstrate** the possibility to increase the energy efficiency in public buildings towards nZEB concept.
- **Design** an energy management system for micro-grids from renewable sources - micro-wind and PV - with a hybrid energy storage.
- **Develop** and operationalize the PT Pilot by the Portuguese partners in this project - LNEG and IST – in order to test, validate and demonstration results.

Concept of LNEG Pilot Plant

Design and concept of LNEG's pilot had three main and different components and areas of intervention:

- **BUILDING**: Improvement of the shadowing and insulation of the pilot rooms. Installation of PCM units.
- **HEATING/COOLING system**: Integration of solar thermal generation with energy storage, installation of a heat pump and fan coils units.
- **MICROGRID**: Integration of solar PV and WT generation and battery unit in a microgrid.

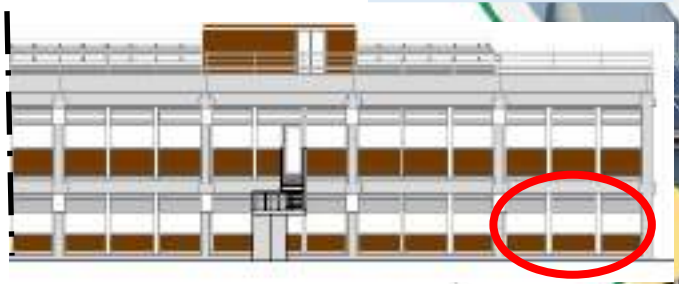
Portuguese Pilot Plant operated by LNEG & IST

Selected public building built in the 1980s (INETI) Lumiar Campus, Lisbon (PT)

Pilot Area (Plan)

Pilot Area (outside view)

Pilot Area (West)



Pilot Area (South)

Portuguese Pilot Plant operated by LNEG & IST

LNEG - Laboratory for Integration of Renewable Energy – Lisbon (PT)

Building

Passive and active solutions applied

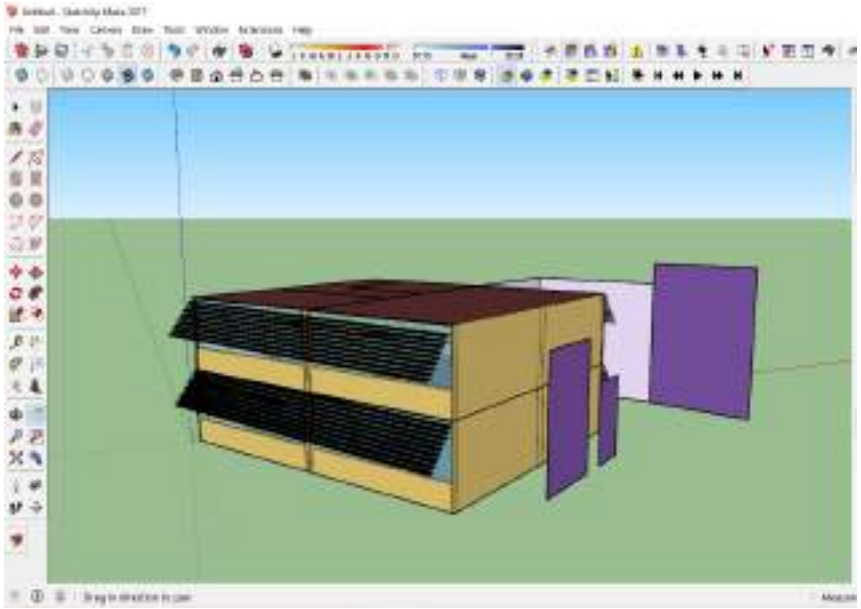
Renovating LNEG Pilot Plant using nZEB strategies

In LNEG pilot, the building was simulated to assess the most cost-effective passive solutions to implement and evaluated experimentally. The options addressed were:

- **Sun Shading** solutions to avoid overheating
- **Natural ventilation** optimization through passive systems
- **Thermal comfort** optimization
- **Phase Change Materials** (PCM) to store passive solar and other heat gains as latent heat

Renovating LNEG Pilot Plant using nZEB strategies

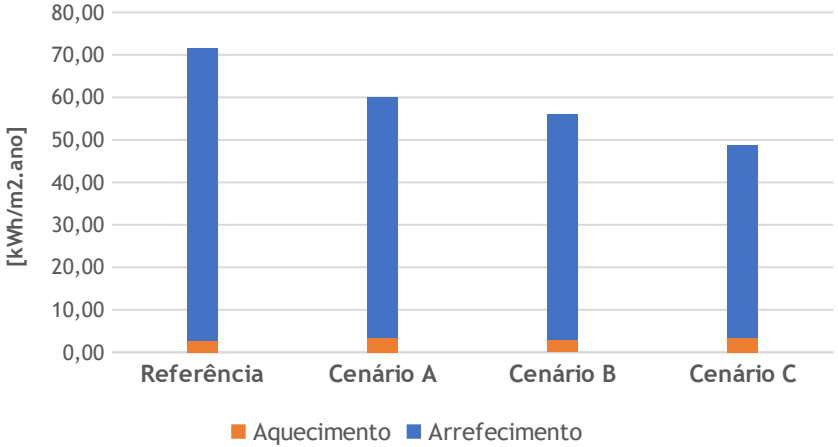
LNEG developed a numerical model of the pilot using the platform EnergyPlus and simulated it to assess the most efficient improvements to the building(*).



(*)LNEG pilot Improvement's simulation model obtained within the MsC Thesis: "*Soluções integradas de eficiência energética, energia renovável e micro-rede num edifício público na perspetiva NZEB*", Gonçalo Pina, FCUL, 2021

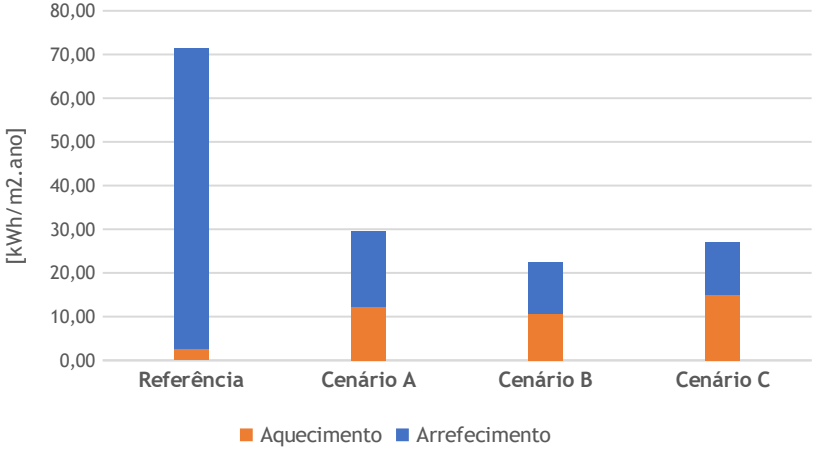
Renovating LNEG Pilot Plant using nZEB strategies

Energy demand – passive solutions



	TOTAL Heating + Cooling) [kWh/m2.ano]	Performance optimization
Reference	71,42	
Scenario A	60,04	15,9%
Scenario B	54,55	21,5%
Scenario C	48,78	31,7%

Energy demand – active solutions



	TOTAL Heating + Cooling))	Performance optimization
Reference	71,42	
Scenario A	29,48	58,7%
Scenario B	22,41	68,6%
Scenario C	27,08	62,1%

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Heating and Cooling

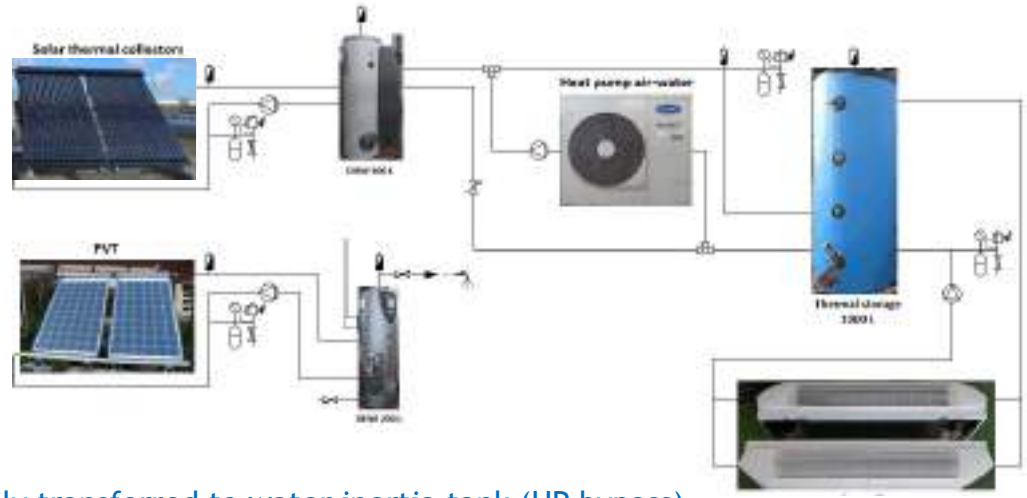
Design of a RES-powered high-efficiency thermal circuit

The heating and cooling RES-powered thermal system

Solar thermal assisted HVAC system strategy

Vacuum tube solar collectors 4m² 350L storage water tank

DHW PVT collectors 3m² 350L domestic water tank

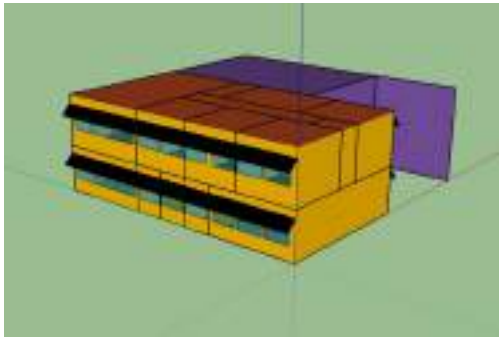


Control strategies:

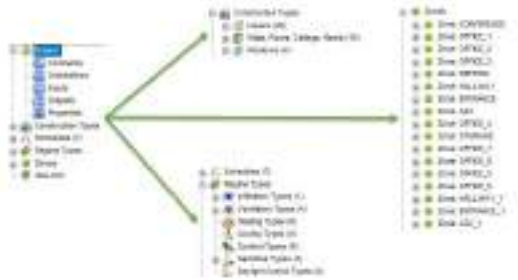
- Solar heat is primarily transferred to water inertia tank (HP bypass)
- Decoupled circulation flows from solar system and inertia system
- Simplified control loading/unloading energy to inertia tank
- Disadvantage when inertia tank temperature is too low which forces HP to pre-load the system
- Direct water heating or cooling supplies to fan coil units
- Simplified control by the three-way valve in the storage circuit

TRNSYS thermal energy simulation

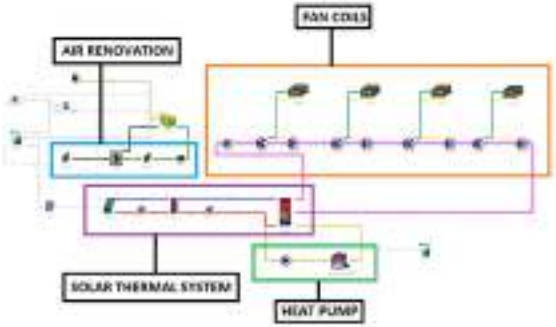
3D Modelling

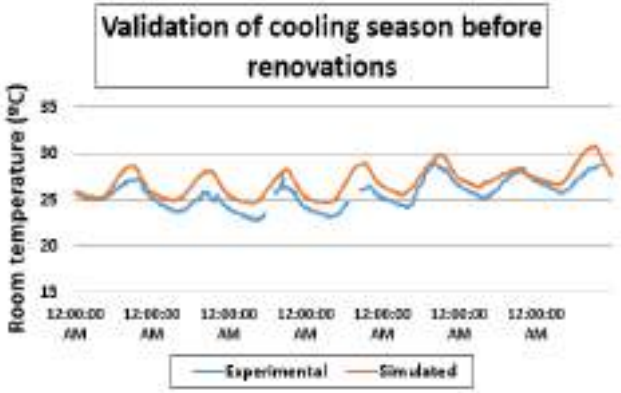


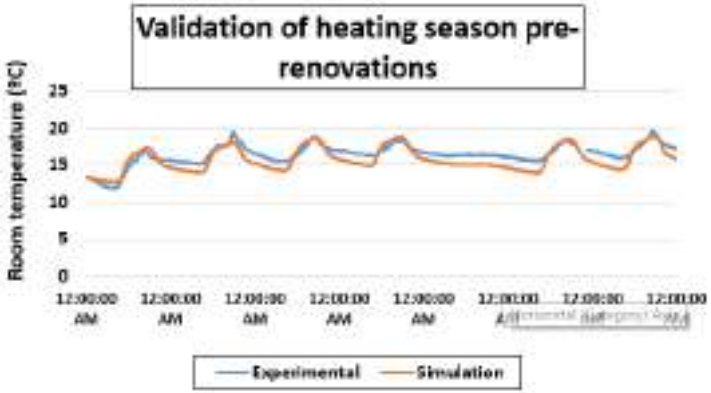
Building Modelling



Thermal simulation setup







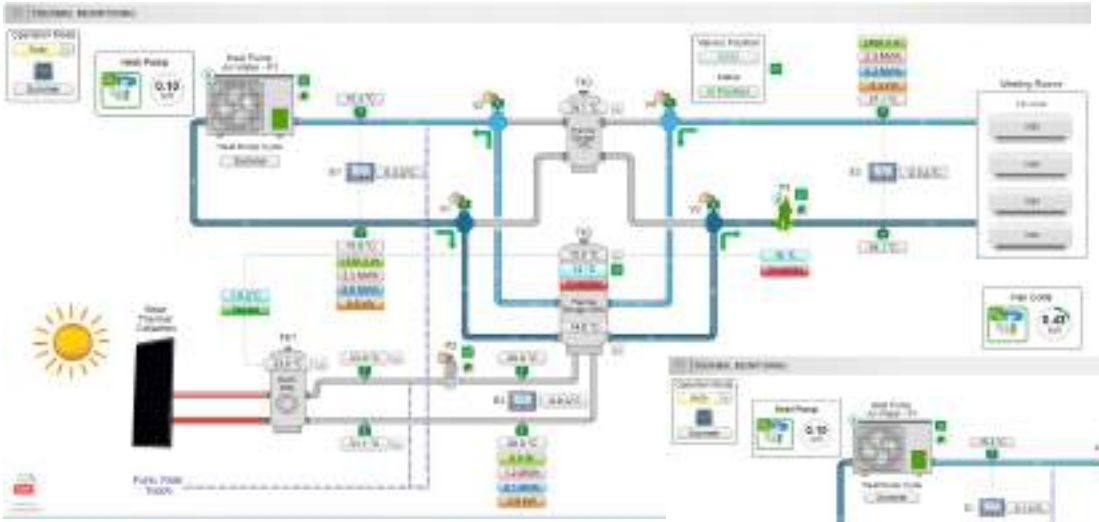
Renovation building to nZEB

Walls and ceiling insulation, LED lighting and PCM insulation Sou*th-West*

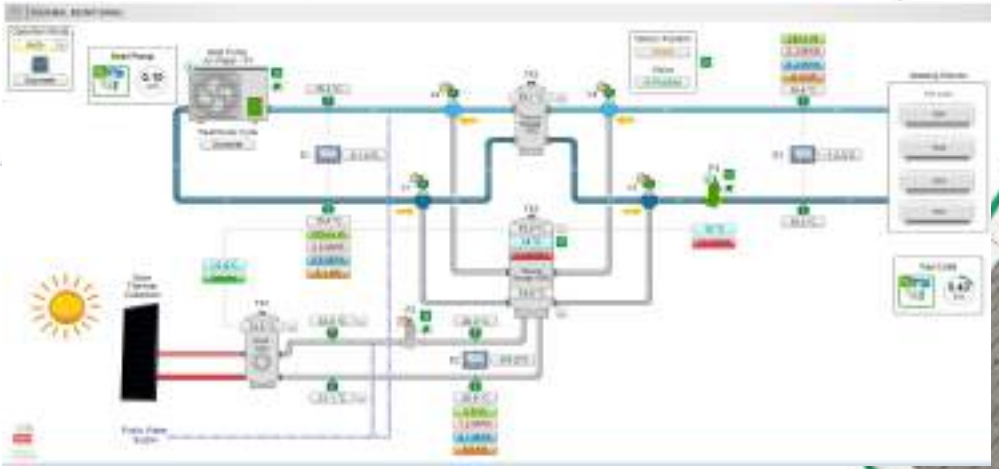
Before

After

Thermal System - LNEG Pilot Final Design



Economic Mode



Direct Mode

Installed/Integrated equipment :

- *Solar Water Heating (SHW) set of solar evacuated collectors with heat pipes (BAXI AR30, 4.8m2) with a storage tank (BAXI FST 300L);*
- *Energy storage system - an inertial water tank (LAPESA G1000 IS_02, 1000L) to delivery heat/cold water to the fan-coils hydraulic circuit;*
- *Air/water Heat Pump (DAITSU CRAD 2 60T, 14.5 kW)*

Renovation building to nZEB - Active solutions

Solar thermal system with storage tank

Before

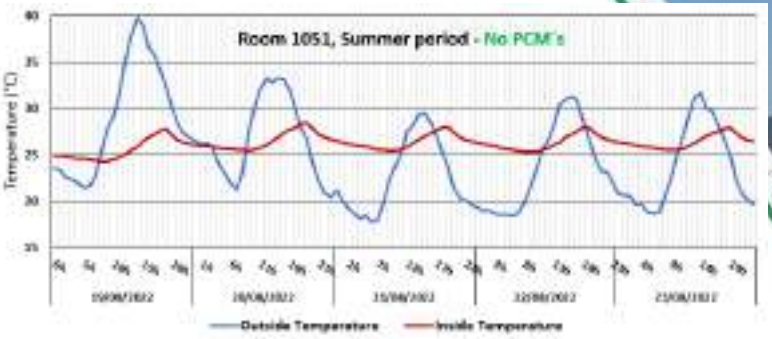
After

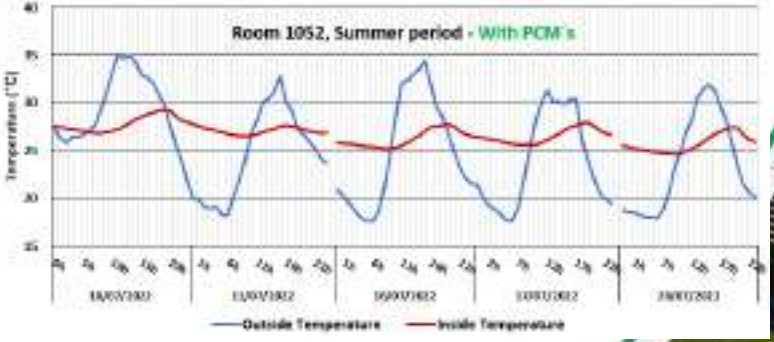
Main results and outcomes

PCM insulation South-West façade data

Heat Pump Thermal Monitoring data

PCM insulation South-West façade data

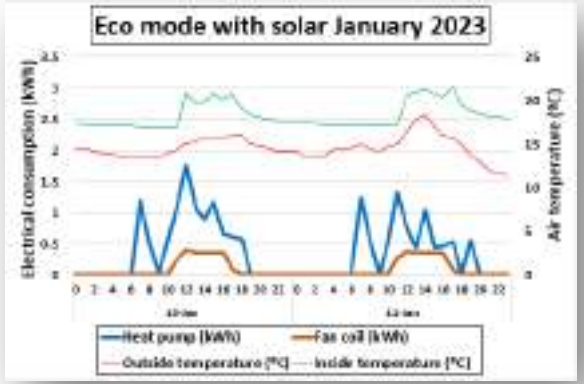




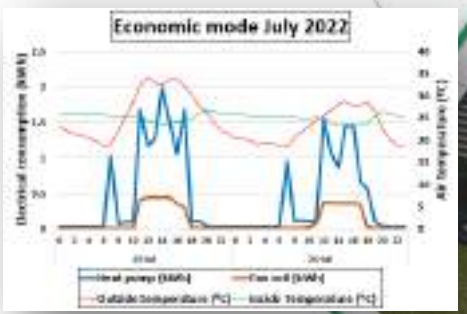
Heat Pump Thermal Monitoring data

Winter (2022/2023)

	Summer		Winter		
	Direct	Eco	Direct	Eco w/o solar	Eco w/ solar
HP total	20.9	21.5	31.4	20.0	18.3
FC total	6.7	5.3	5.4	4.5	4.4
TOTAL	27.2	26.6	36.8	24.5	22.7
IMPROVE		-2%		-33%	-38%
	Evaluation period: **15th and 21st of July** (eco) 2021 vs **20th and 21st of September** (direct), 2022		Evaluation period: **14th and 21st of December 2022** (eco without solar), **10th and 11th of January** (eco with solar) and **1st and 2nd of February** (direct), 2023		



Summer (2022)



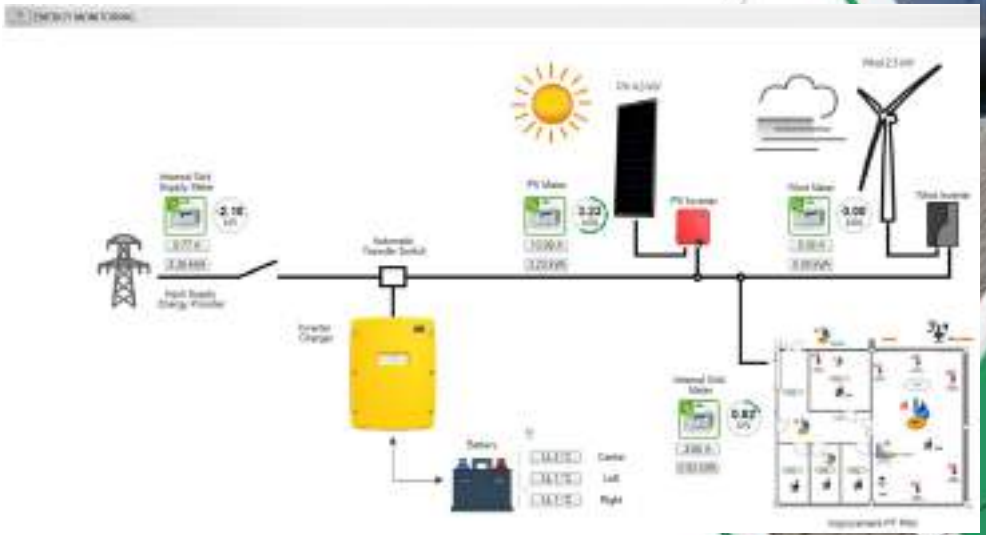
Micro-grid

Wind and solar PV units, battery storage, invertors, controllable loads, and power/energy management system

Microgrid Design & Concept

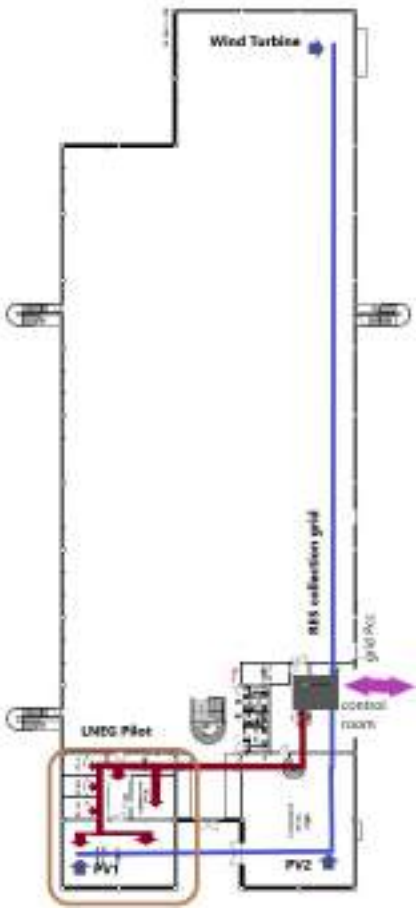
The new microgrid at LNEG Pilot Plant comprehended:

- Integration of solar PV and WT generation and battery unit in the microgrid
- Design & specification, commissioning and installation of new invertors and power/energy system for stand-alone and grid-connected control
- Definition of hierarchy of loads and installation of controllable relays for loads management
- A new set of electrical circuits was designed and installed to create an autonomous microgrid
- Adaptation of electric switchboard and protections
- New led lighting was installed
- Automatic switch between internal priority RES generation and mains supply – the microgrid enters in isolated mode of operation in case of grid failure.



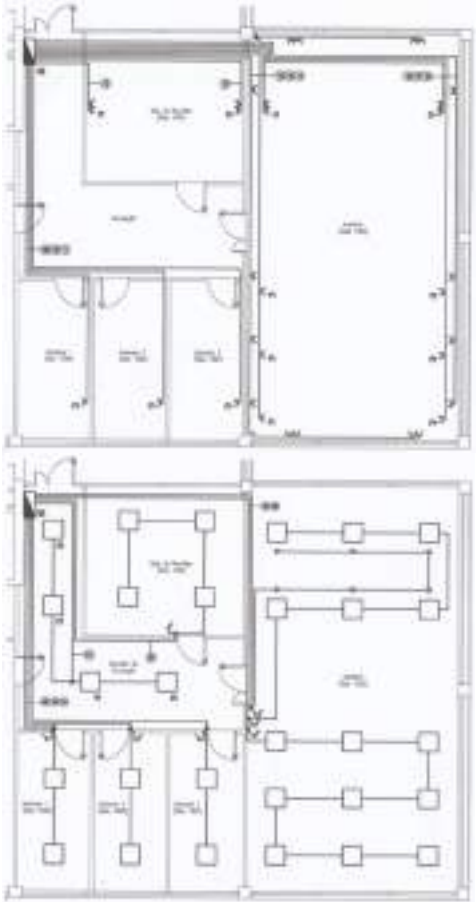
Microgrid Design & Concept

Power control and energy storage room



Microgrid layout (blue circuit – generation; red circuit – consumption)

LNEG Pilot Plant controllable loads



Hierarchy of loads:

A. Priority circuits

Always on: Lights, Desktop-connected office *shuck* plugs, projector's plugs in meeting rooms); priority lightning;

B. Non-Priority circuits

may be turned off: all other *shuck* plugs (e.g. laptop charging and coffee machines in meeting rooms, ventilation,…); additional (comfort) lightning.

Lightning:

- 1st generation fluorescent lights replaced by high performance LEDs
- Dimmable LEDs (0-10V control) installed in meeting rooms
- Motion sensors installed in corridors

LNEG Pilot:
Outcomes & Main Conclusions

Building

- Measures applied in the converted building's envelope may be insufficient to effectively reduce consumption reducing and/or increase comfort;
- The cost of the active measures to be implemented may not be amortised over the building´s intervention (economic) lifespan;

Heating and Cooling System

- Heat pump testing (underway) will enable to identify the periods when direct mode is more efficient than economic mode, depending on the season and the time schedule occupation.
- The set-point temperature of the inertial tank will be optimized through testing. In periods of excess of renewable generation, this set-point will be adjusted for maximizing thermal energy storage.
- Outcomes of control simulation will be implemented in LNEG Pilot EMS. E.g. in Summer, the storage set-point temperature may be lower at night, forcing the heat pump to operate with lower air temperature, improving its performance.

Microgrid and RES generation

- The implementation of a microgrid in a public building with sensitive loads, as in LNEG's pilot represents a paradigm shift, from classical diesel emergency systems to RES-powered systems with battery storage and demand-side management. The conversion is totally feasible although it requires a great effort in the adaptation of exiting equipment – and the substitution of other.
- Not withstanding some difficulties (e.g reduced number of companies offering products and services) microgrids are the privileged path to designing sustainable autonomous public buildings.

THANK YOU

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Project SUDOE Improvement: Monitoring and LNEG's Pilot Plant control

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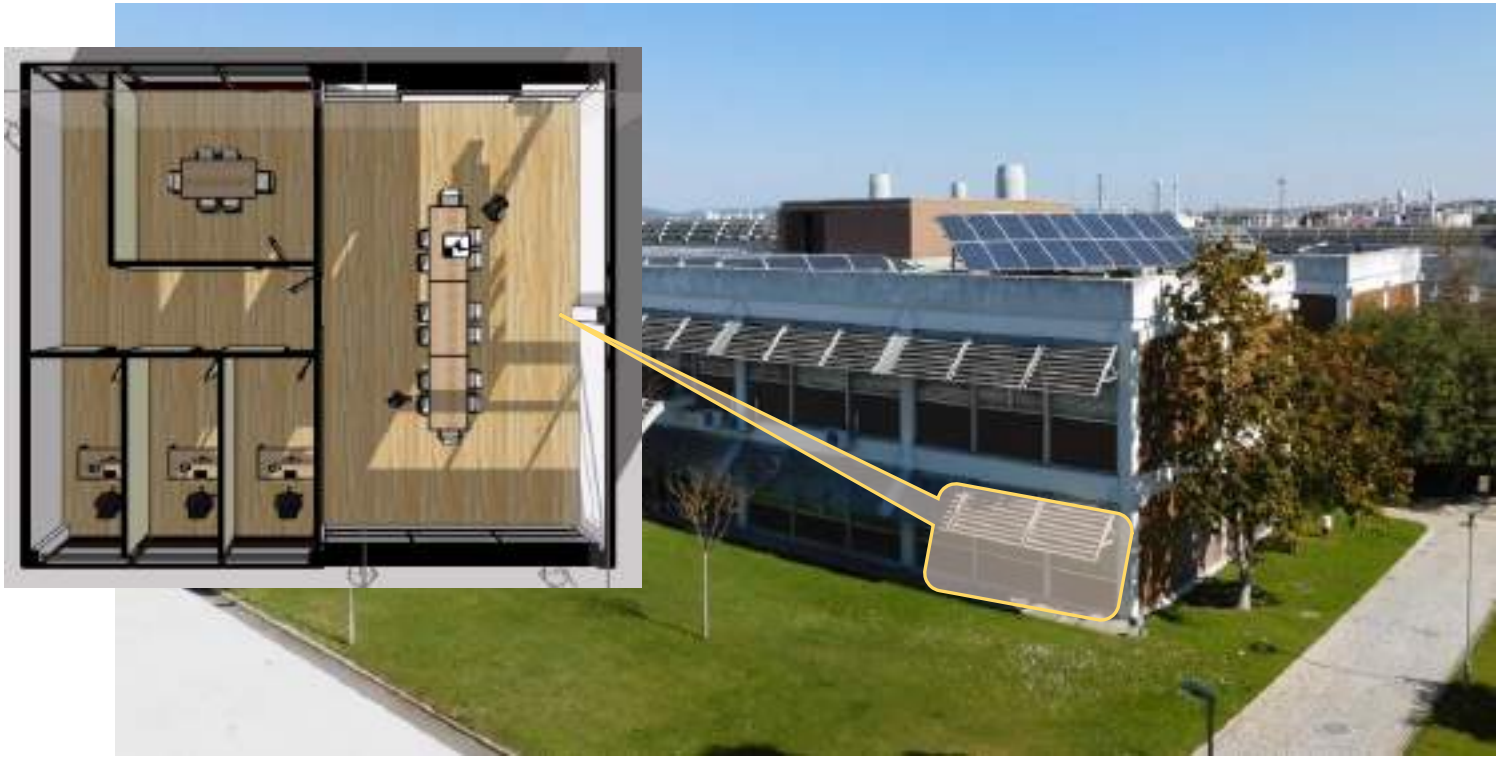


Integration of endogenous renewable generation in a nZEB building

Monitoring system: Quantities & parameters

Comfort

- Air temperature and relative humidity, C02, and lightning;
- Surface walls temperature;

Thermal

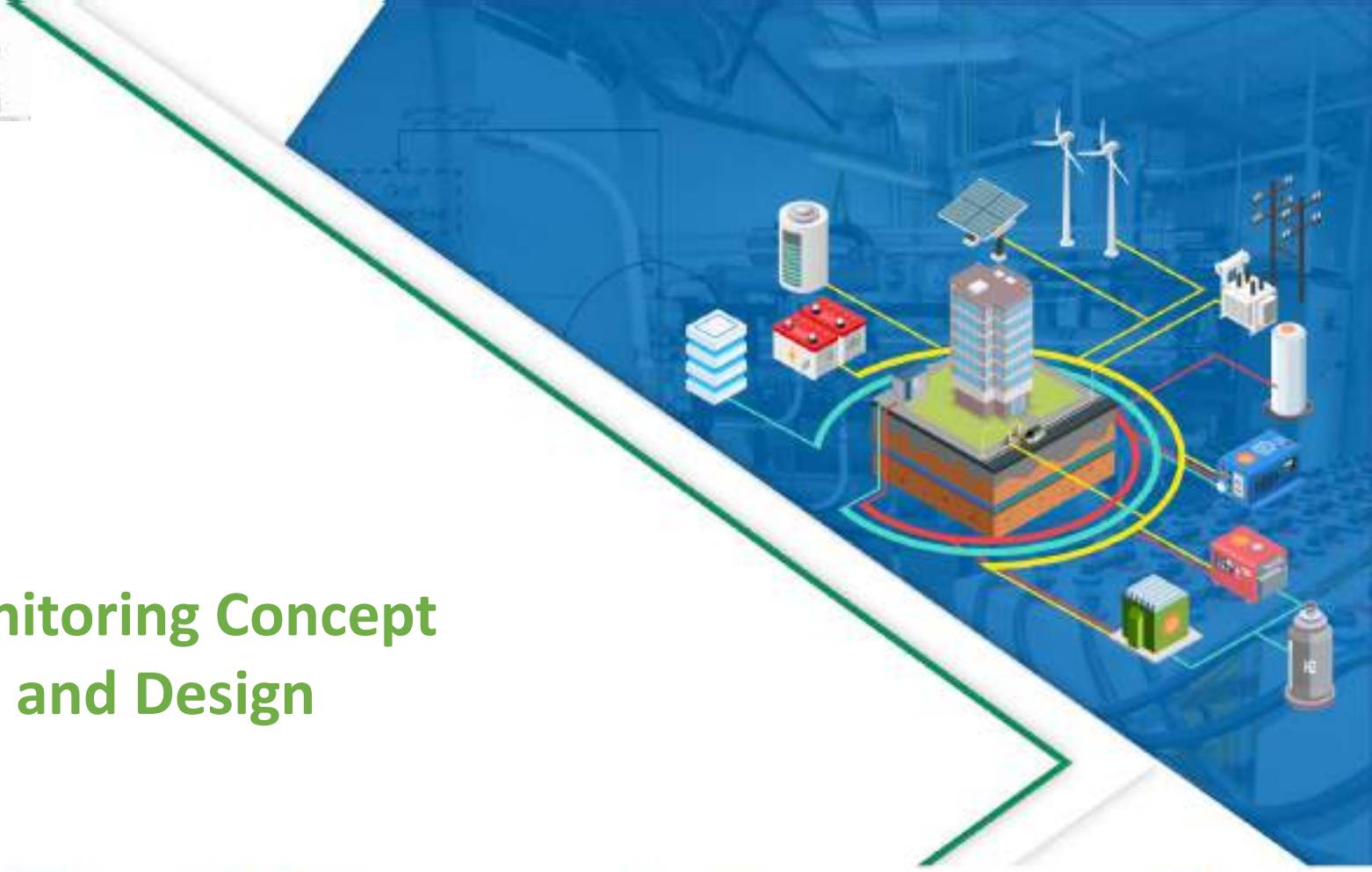
- Heat Pump operation and power consumption;
- Energy Enthalpy Meters;
- Water (hot/cold) water pumps operation parameters (time schedule, temperatures, flow);
- Thermal water storage tanks temperatures;
- Fan Coils time schedule and power consumption;

Electrical

- Pilot area energy consumption by the existing loads (Ex. Lights, Schuck plugs, Climatization);
- Energy produced from renewable sources in building “C”;

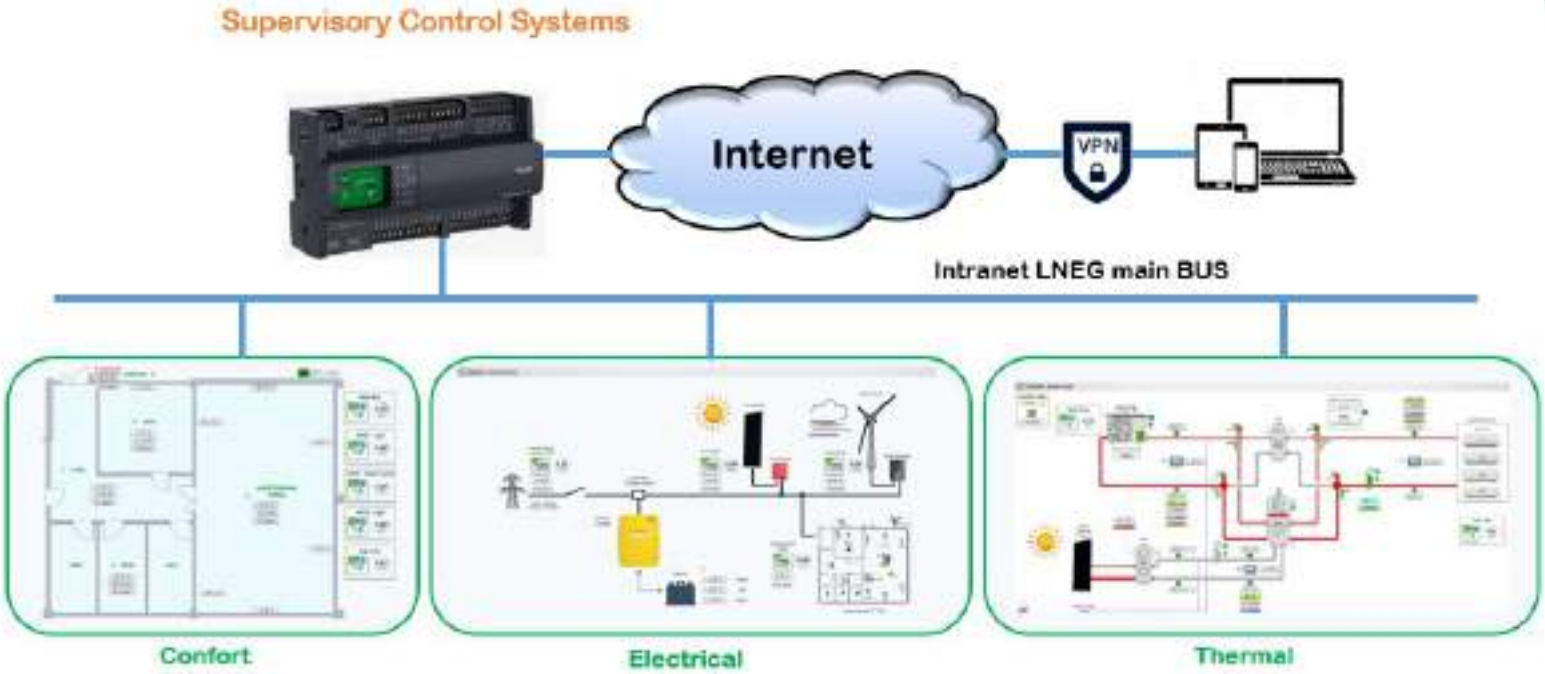
Weather Station

- Solar irradiation; Air temperature and Relative Humidity; Wind velocity and direction.



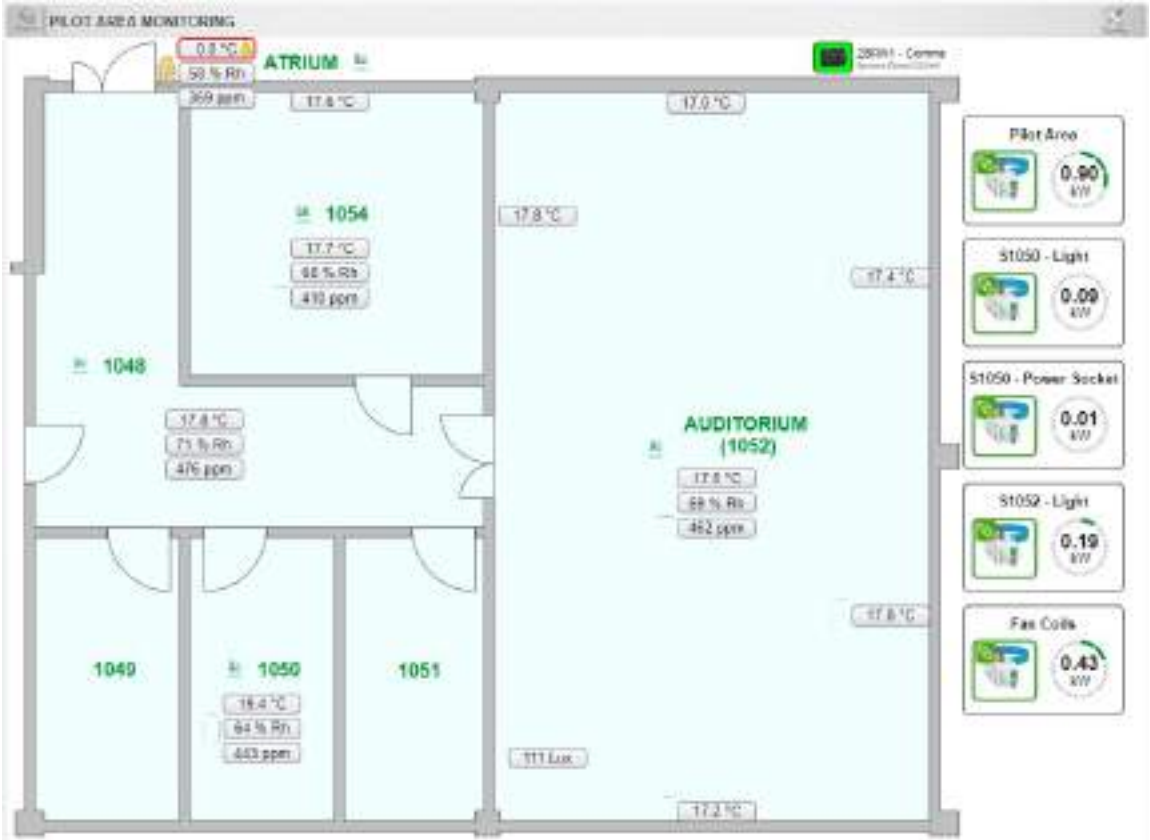
Monitoring Concept and Design

Monitoring - Global System



Monitoring system homepage (web interface)

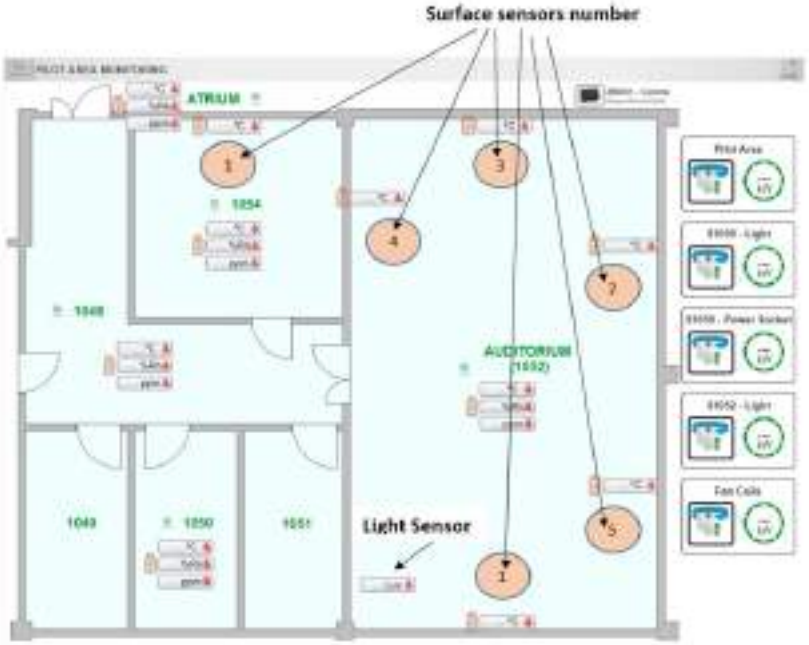
Pilot Area – Comfort and Consumption Monitoring (web interface)



Assessment of comfort:
Measurement of wall surface temperature

Monitoring the comfort levels and air quality

- Set of wireless sensor
  a. air temperature,
  b. relative humidity and
  c. CO2 concentration levels.



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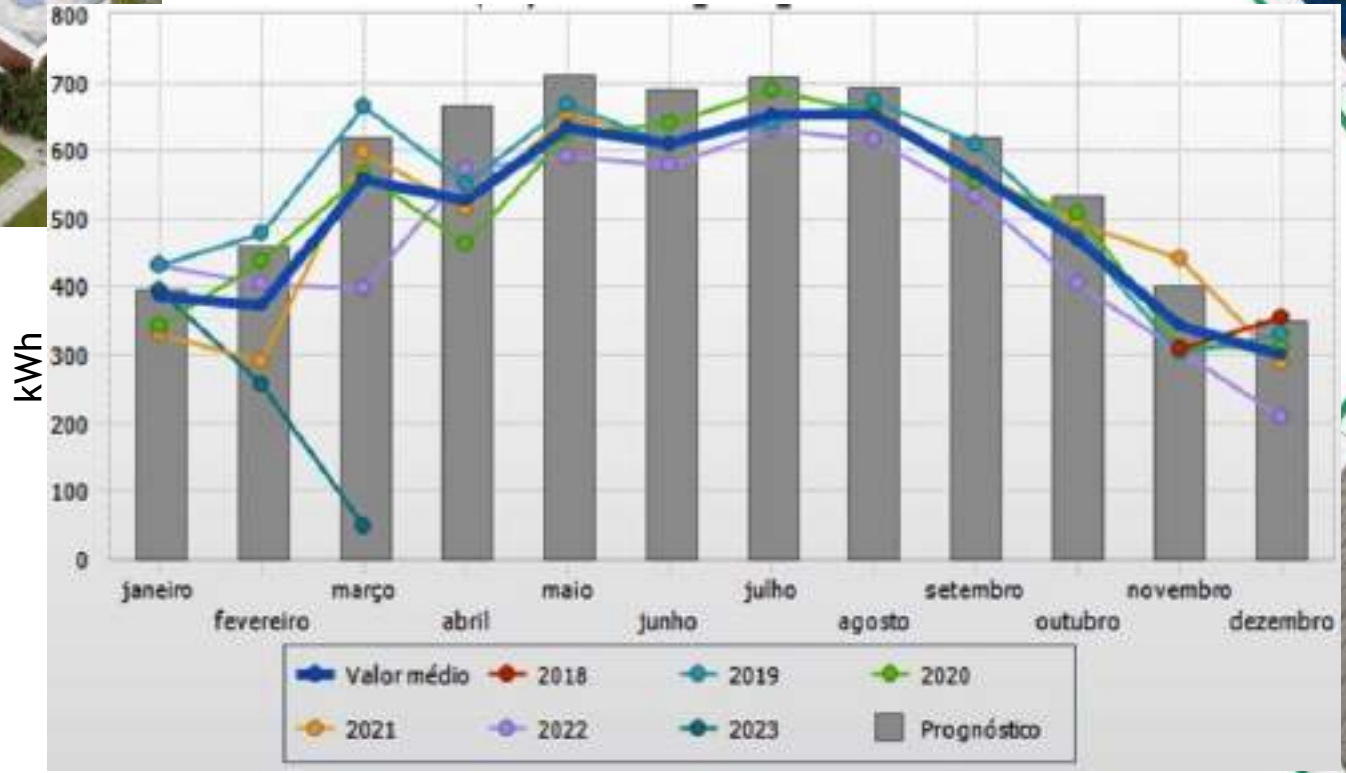
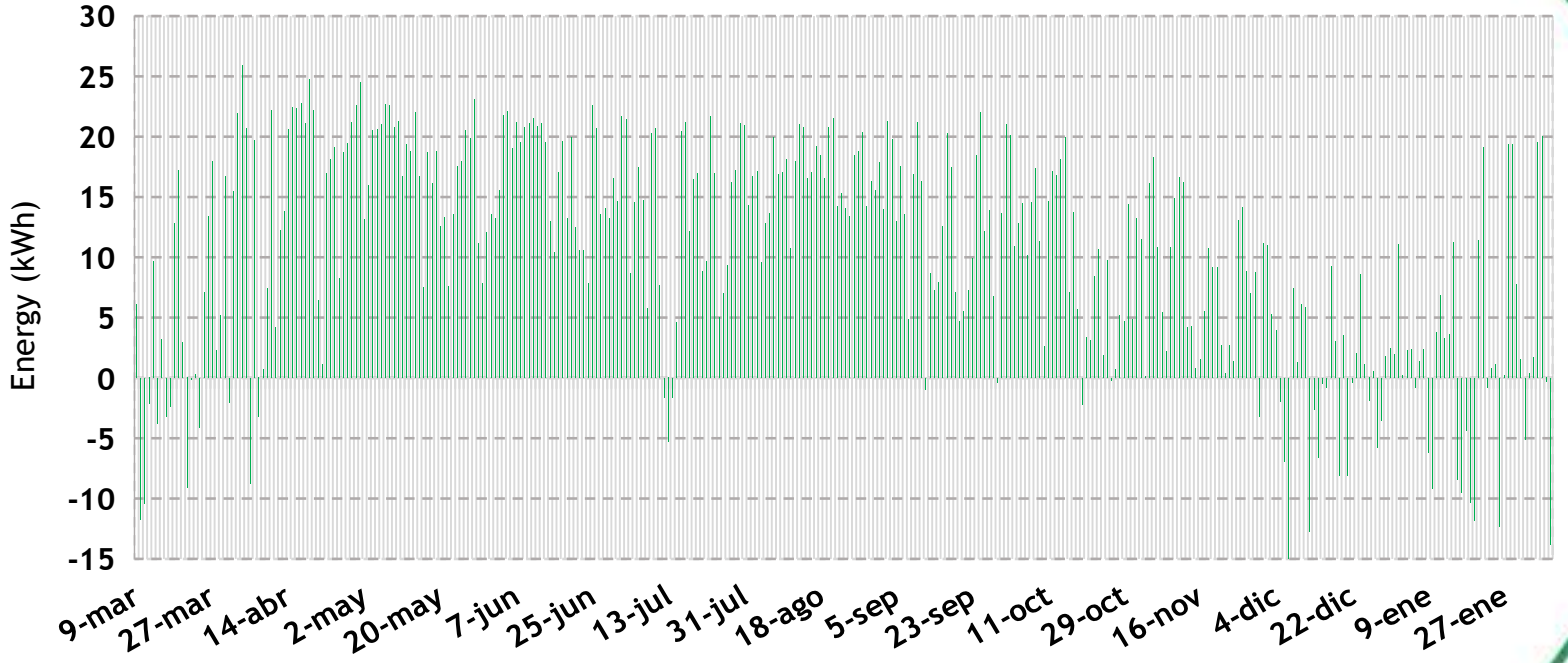
Monitoring of RES generation

Annual profile
RES generation [2018/2023] LNEG's Pilot



Electric energy production vs consumption
Daily surplus/shortage of energy (March 2022 to February 2023)



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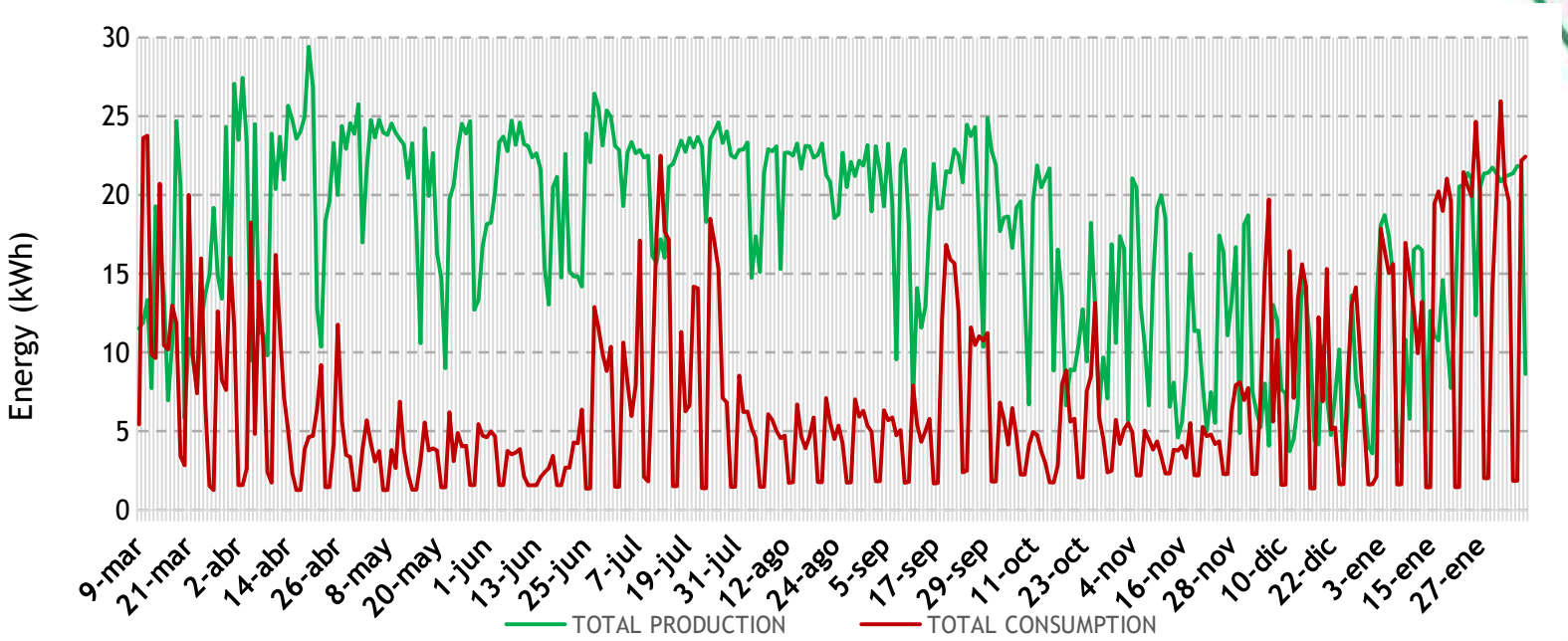
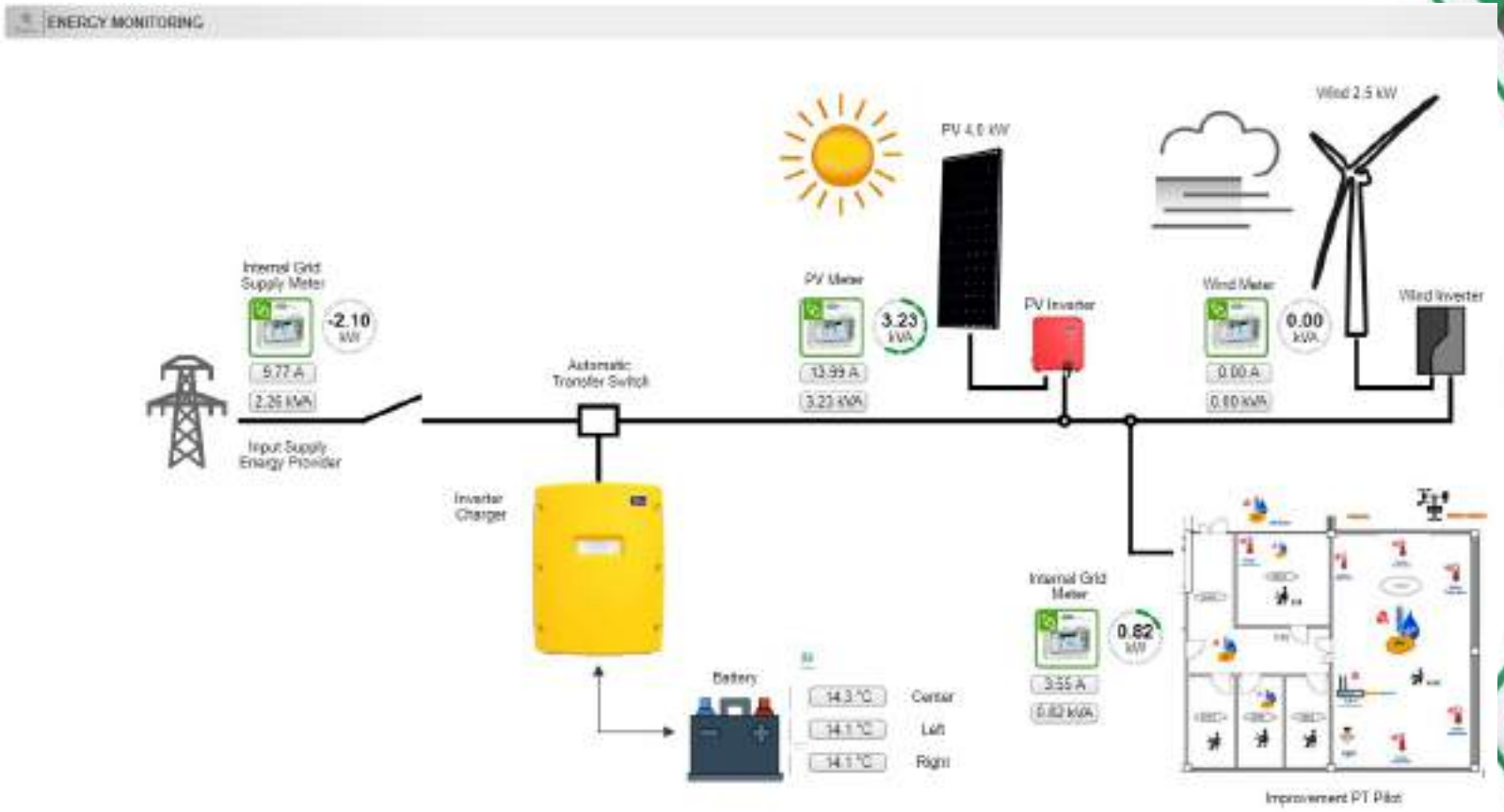


Average Daily	
Production	Consumption
17 kW	7 kW

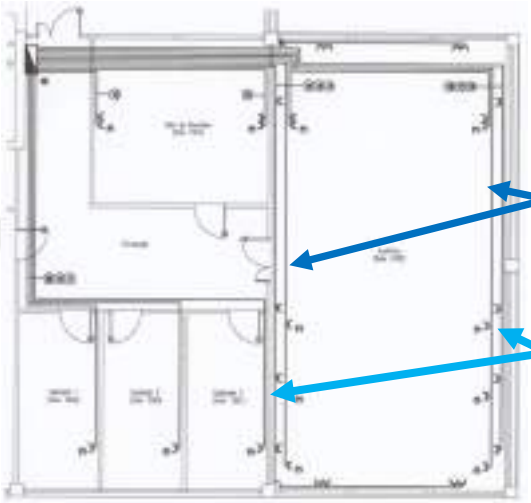
Load Management at LNEG Pilot

Microgrid parameters monitoring (web interface)



Microgrid and RES control area

Load Management System



::Priority::
Circuits that not be turned off
(Ex. Lights, office Schuck plugs)

::Non- Priority::
Circuits that can be turned off
(Extra Schuck plugs)

Synthesis

The specification and commissioning of LNEG's pilot monitoring and control system concluded successfully and included:

- the required parameters for building comfort assessment;

- all relevant quantities of the thermal system including, heat pump schedules and consumption, enthalpy meters, conditions of the heat/cold tank storages and the overall parameters requested for energy efficiency assessment;

- all power/energy relevant quantities for assessment of performance (and control) of a microgrid composed of PV solar panels, a micro wind turbine, batteries and controllable loads;

THANK YOU!

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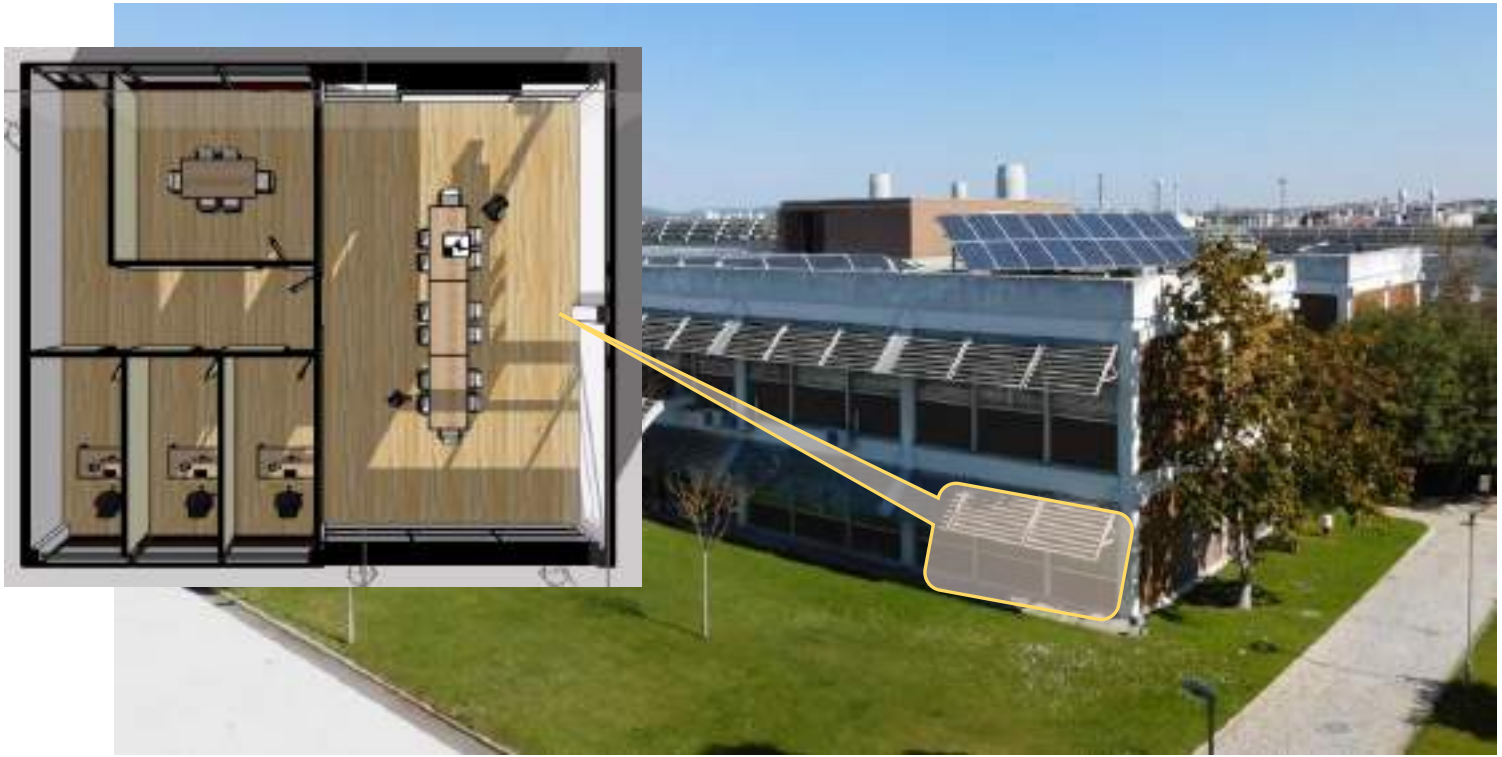

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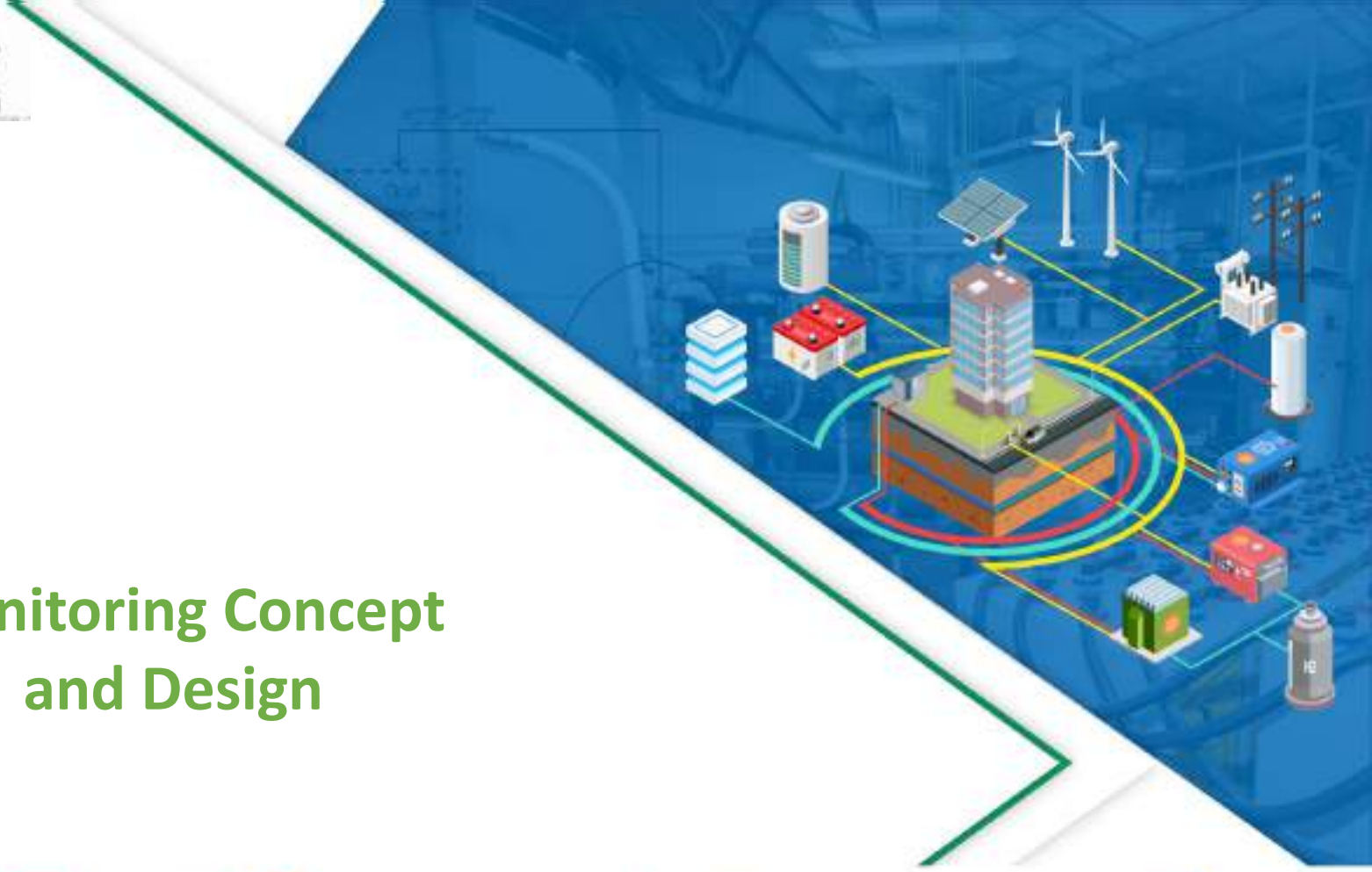
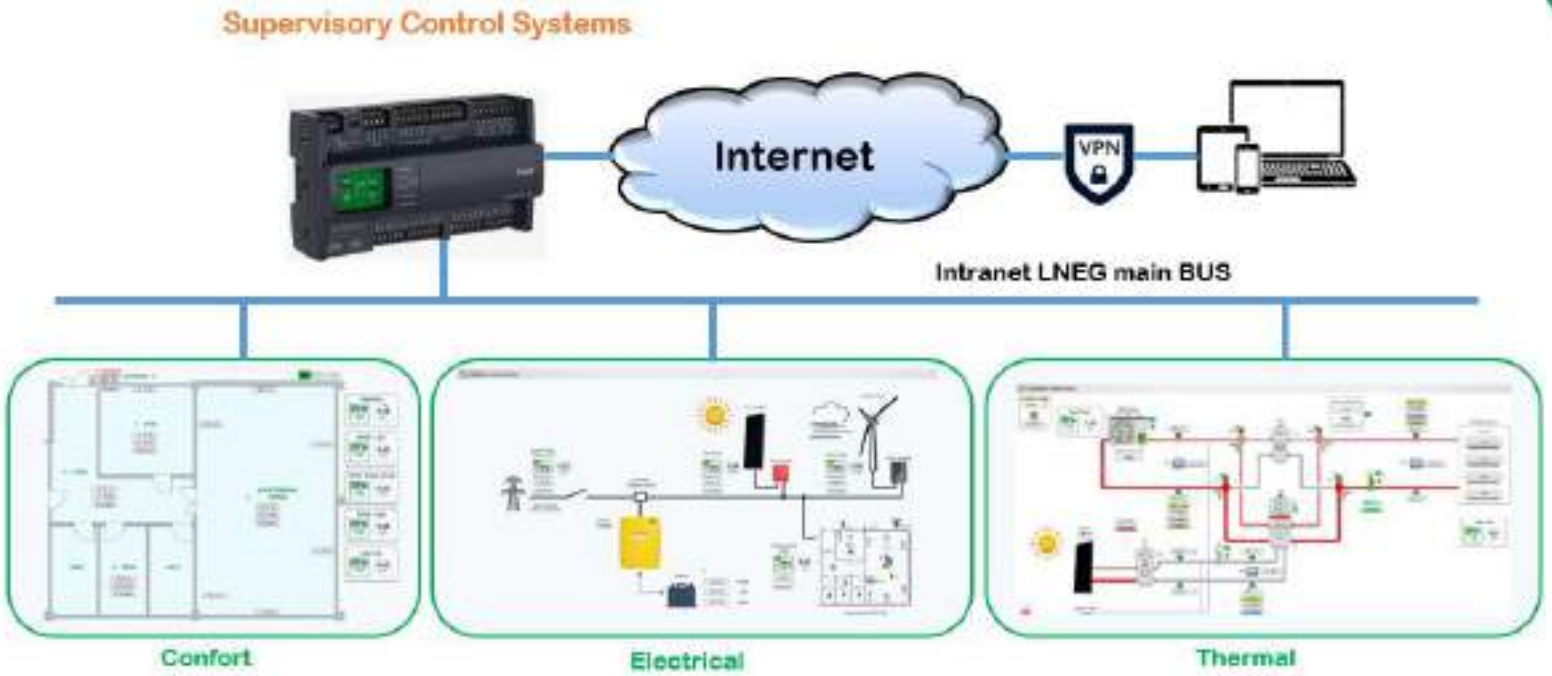


Monitoring Concept and Design

Monitoring - Global System



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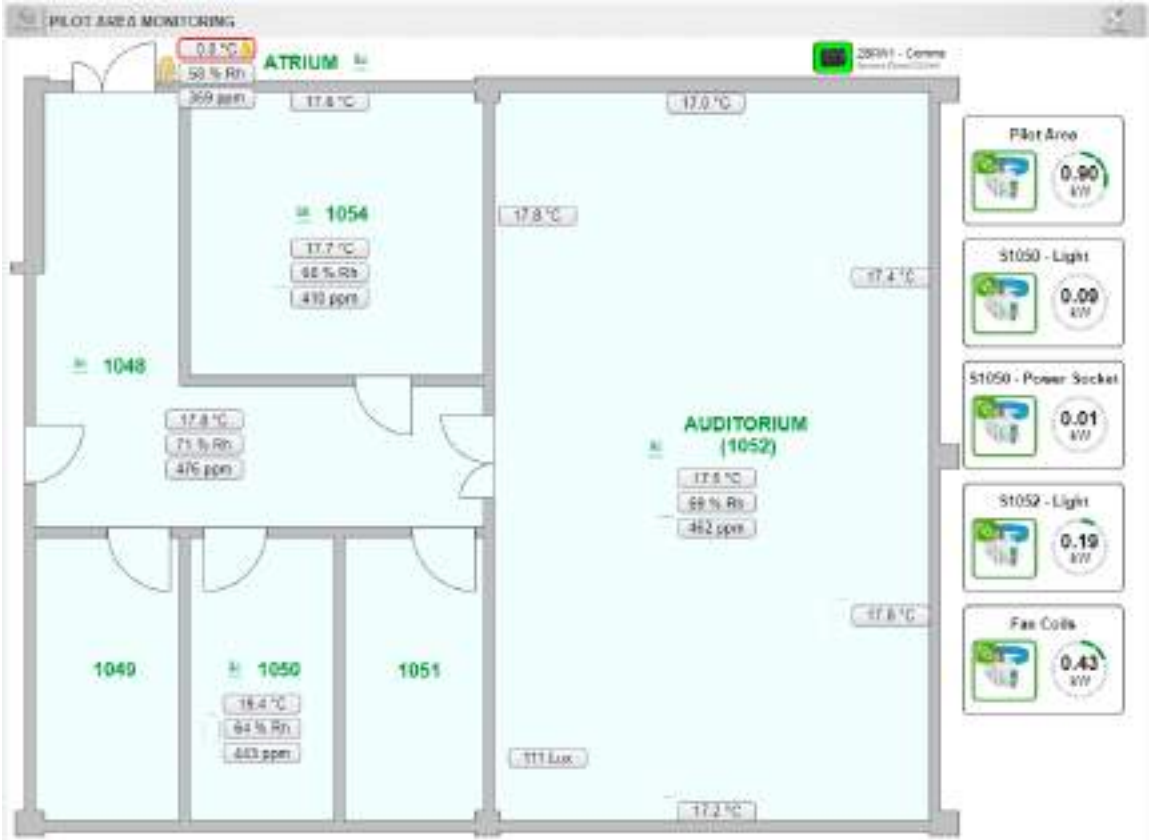

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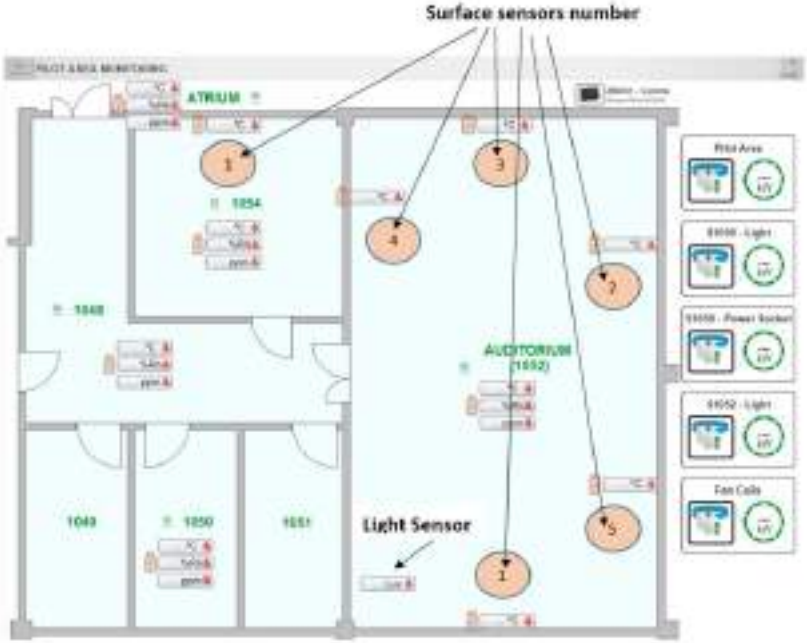

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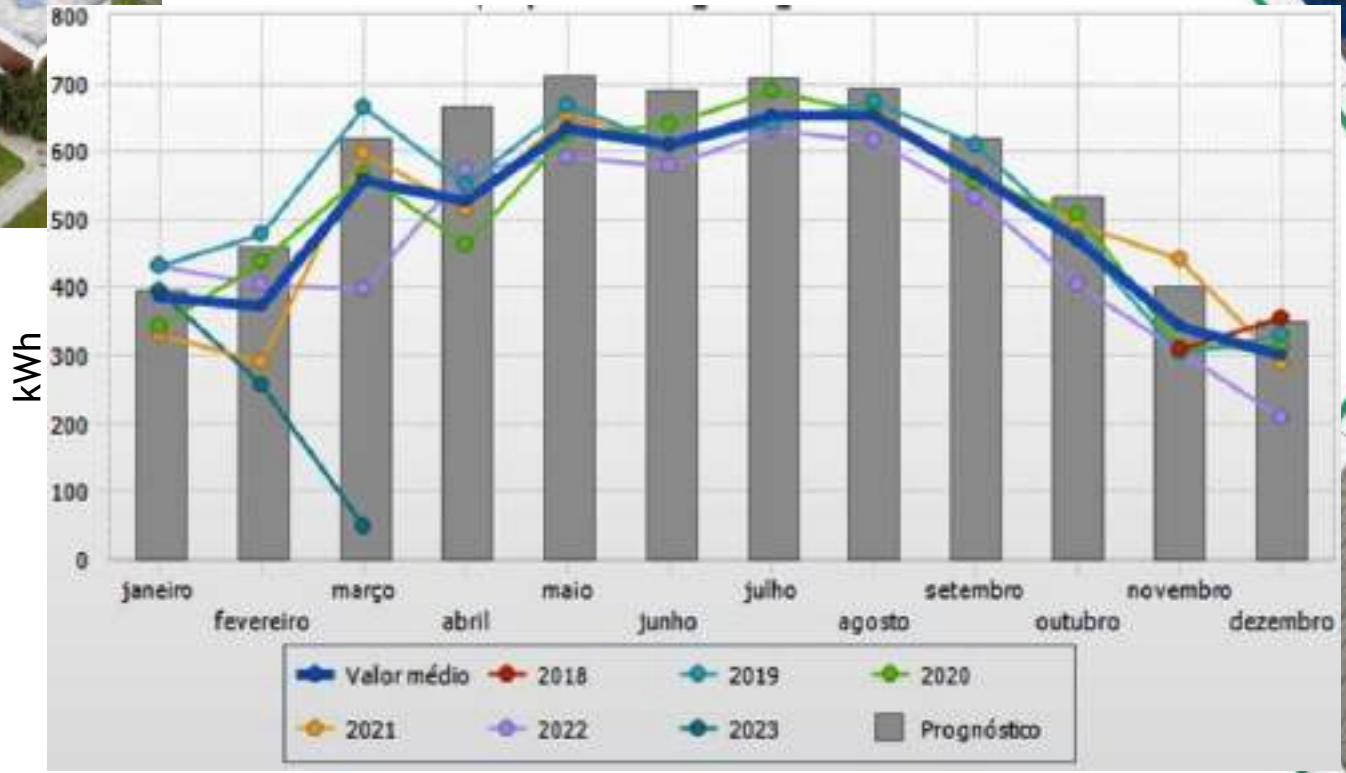

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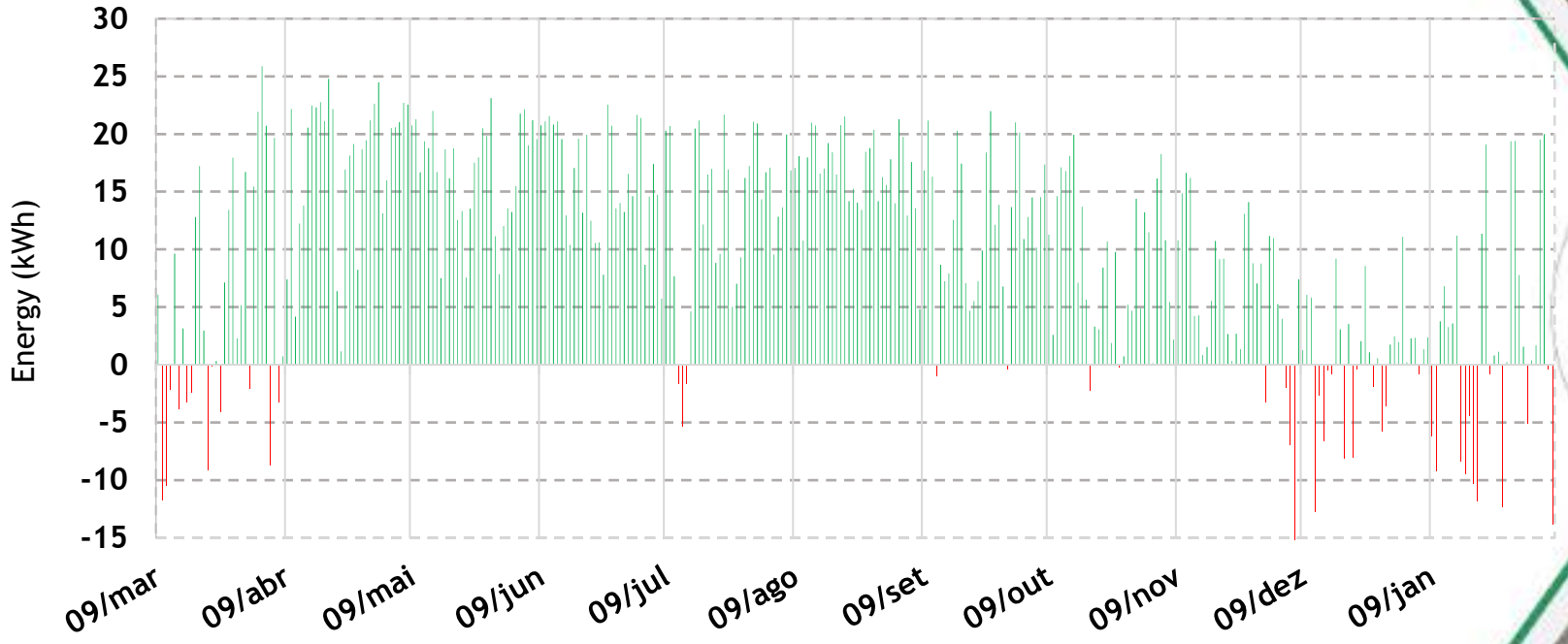
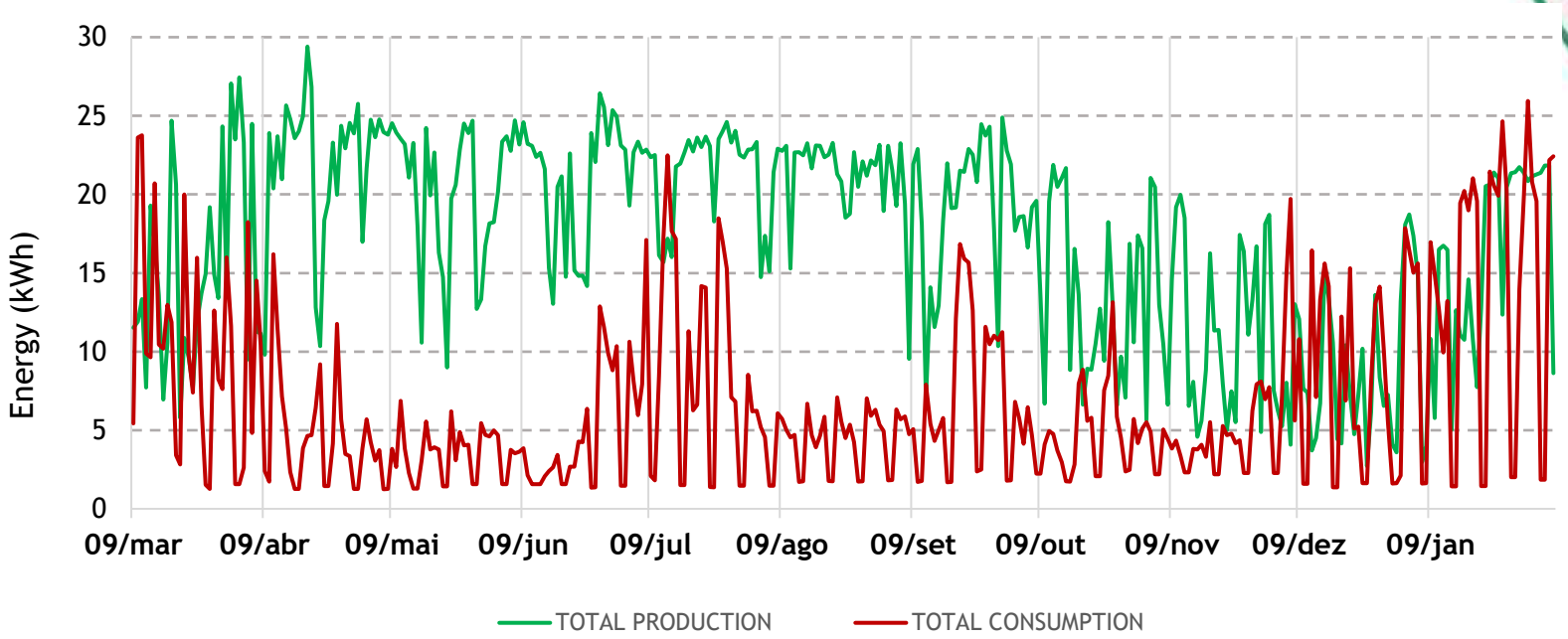


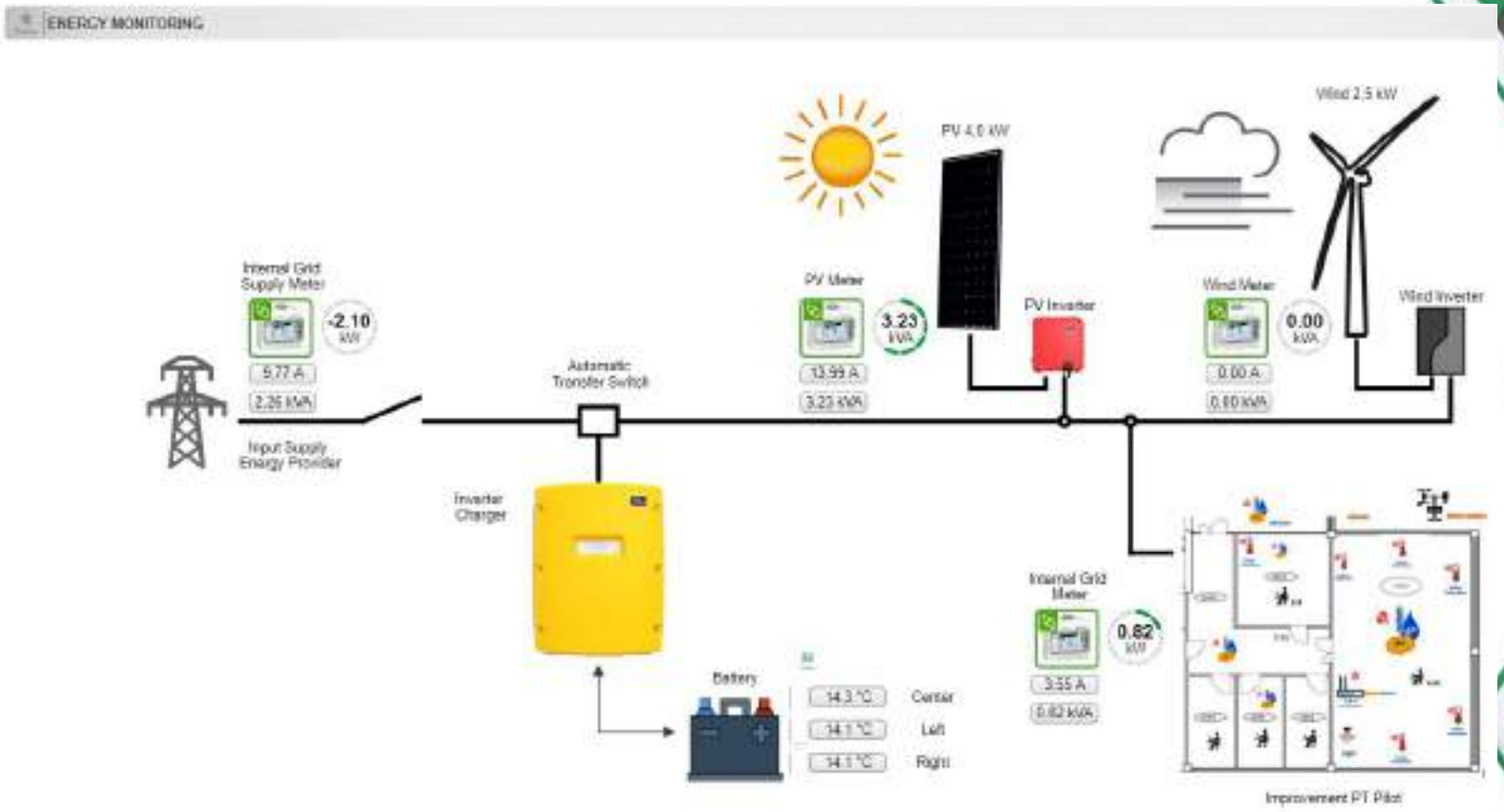
Production vs Consumption
(March 2022 to February 2023)



Average Daily	
Production	Consumption
17 kW	7 kW

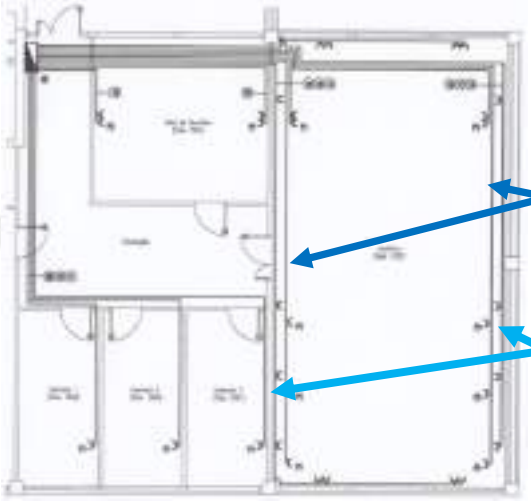
Load Management at LNEG Pilot

Microgrid parameters monitoring (web interface)



Microgrid and RES control area

Load Management System



::Priority::
Circuits that not be turned off
(Ex. Lights, office Schuck plugs)

::Non- Priority::
Circuits that can be turned off
(Extra Schuck plugs)

Synthesis

The specification and commissioning of LNEG's pilot monitoring and control system concluded successfully and included:

- the required parameters for building comfort assessment;

- all relevant quantities of the thermal system including, heat pump schedules and consumption, enthalpy meters, conditions of the heat/cold tank storages and the overall parameters requested for energy efficiency assessment;

- all power/energy relevant quantities for assessment of performance (and control) of a microgrid composed of PV solar panels, a micro wind turbine, batteries and controllable loads;

- specification/design of a new microgrid's power management system for automatic switching between the two modes of operation of the microgrid: grid-connected and isolated/stand-alone mode.

THANK YOU!

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