INTEGRATION OF COMBINED COOLING, HEATING AND POWER MICROGRIDS IN ZERO-ENERGY PUBLIC BUILDINGS UNDER HIGH POWER QUALITY AND CONTINUITY REQUIREMENTS (IMPROVEMENT)

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at the Spanish National Centre for Hydrogen (CNH2)

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- Bacground and Motivation
- Main Goal and Specific Objectives
- Consortium and Beneficiaries
- Methodology and Work Packages
- Products and Progressing Indicators

Interreg Sudoe

IMPROVEMENT

INTERREG SUDOE PROGRAMME

- **MAIN OBJECTIVE:** Improving energy efficiency policies in public buildings and housing through networking and joint experimentation.
- **PRIORITY:** Contributing to greater efficiency of energy efficiency policies.
- **THEMATIC OBJECTIVE:** To promote the transition to a low-carbon economy in all sectors.
- **INVESTMENT PRIORITY:** Support for energy efficiency, smart energy management and the use of renewable energy in public infrastructure, including public buildings and housing.
- **FIELD OF INTERVENTION:** 013 - Renewal of the energy efficiency of public infrastructures, demonstration projects and support measures.

• BACKGROUND AND MOTIVATION

Energy efficiency is key to helping reduce serious energy and climate problems. In this sense, the public sector should lead by example in terms of investments, maintenance and energy management of its buildings, facilities and equipment.

In the public buildings sector there is a significant potential for energy savings which, however, is not carried out to the extent that it should. In each of them energy is consumed to meet the needs of heating, cooling, availability of domestic hot water, ventilation, lighting, cooking, washing, food preservation, office automation, etc. The sum of this consumption represents 20% of final energy consumption in Spain, a percentage that tends to increase.

Overall, buildings are responsible for 40% of EU energy consumption and 36% of greenhouse gas emissions, generated mainly during construction, use, renovation and demolition. Improving the energy efficiency of buildings will therefore be key to the ambitious goal of achieving carbon neutrality set by the **European Green Pact** by 2050.

• BACKGROUND AND MOTIVATION

APPROPRIATE POLICIES AND LEGISLATION:

Currently, approximately 75% of the EU's housing stock is energy inefficient. That means that much of the energy consumed is wasted. Renovation of buildings already in use could reduce total EU energy consumption by 5-6% and reduce carbon dioxide emissions by about 5%. On average, however, less than 1% of the national housing stock is renewed each year (according to the Member States, the percentages vary between 0.4% and 1.2%).

In order to better integrate the EU's objective of boosting the transition to clean energy, Directive 2010/31/EU on the energy efficiency of buildings and Directive 2012/27/EU on energy efficiency were revised in 2018 as part of the package of measures «Clean energy for all Europeans».

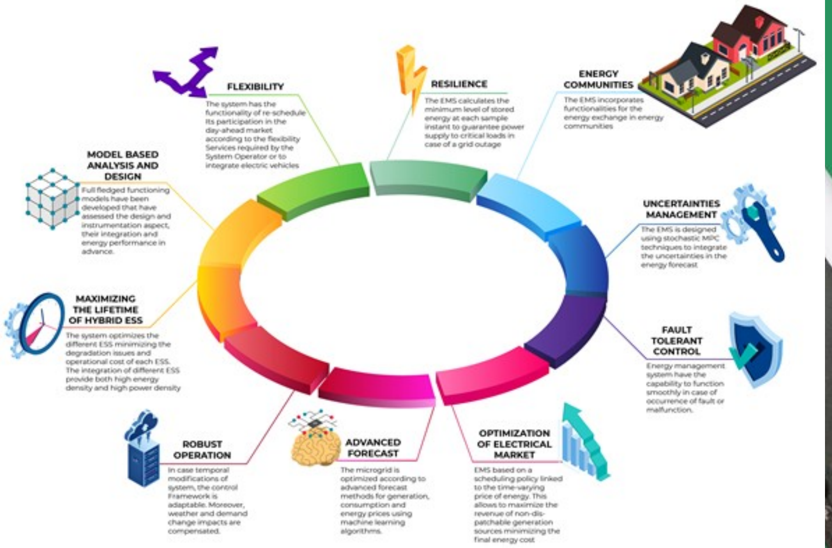
Taken together, these directives contain the following main elements:

- Reinforcement of long-term renovation strategies in EU countries
- Almost zero energy consumption buildings
- Energy efficiency certificates
- Integration into new buildings health and welfare considerations (air pollution), electromobility (charging points) and smart technology (smart meters, self-regulation equipment).

• BACKGROUND AND MOTIVATION

In recent years, numerous projects have been developed to reduce energy consumption in buildings, both from the point of view of energy efficiency and integration with renewable energies.

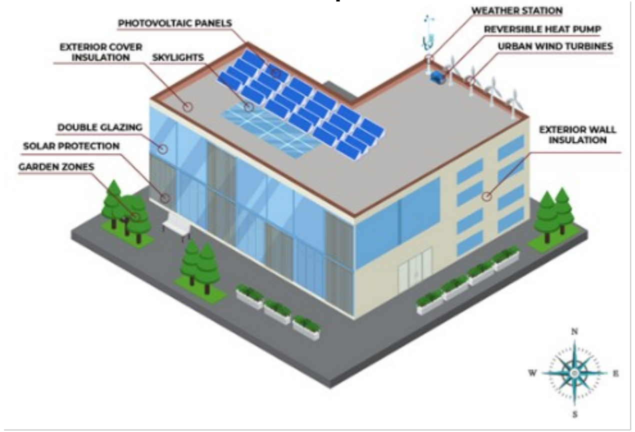
However, the specific problem of integrating this type of energy systems in facilities, is that the reliability of the electricity supply has to be considered as a fundamental aspect.

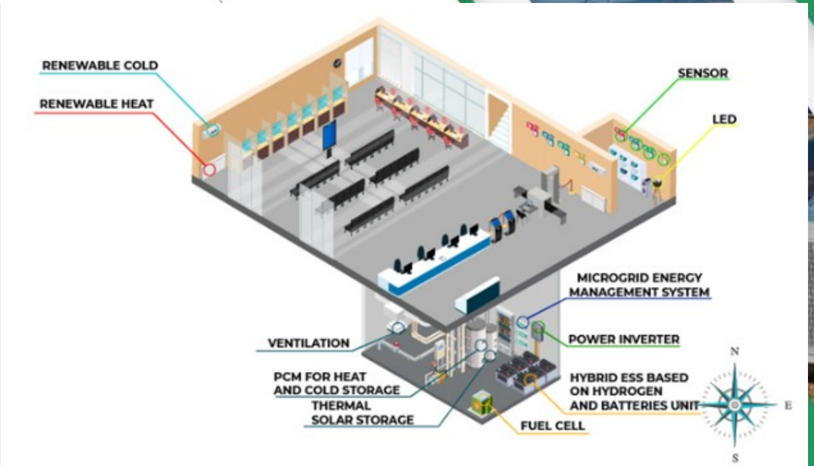


BACKGROUND AND MOTIVATION

There are some places where power outages can mean more than economic losses:

- For health reasons in hospitals
- Scientific considerations in technology centers and universities
- Defense conditions either in military installations
- Security and surveillance in transport stations and airports

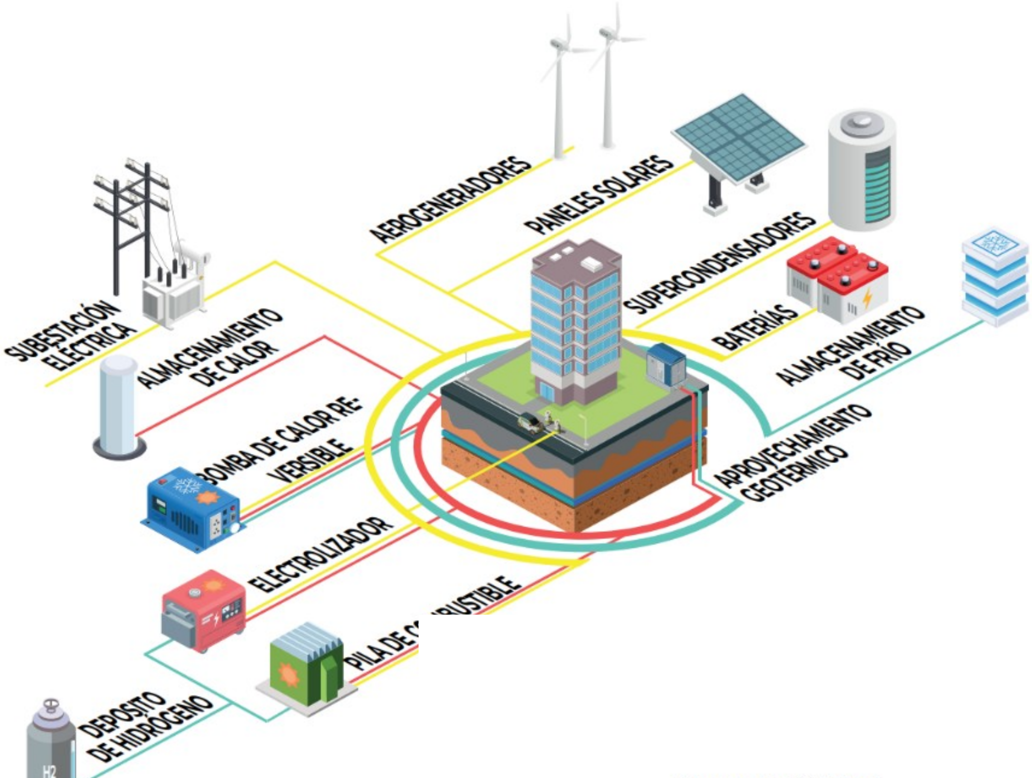




• MAIN GOAL AND SPECIFIC OBJECTIVES

IMPROVEMENT project

To convert **public buildings** into **zero energy buildings** by integrating renewable **energy microgrids with combined heat, cooling and power generation** with inverters with active neutral control using **hybrid energy storage systems (Hydrogen, batteries, ultracapacitor)** that will ensure power quality and continuity of service to equipment sensitive to power quality disturbances (high-tech equipment) while increasing energy efficiency in this type of buildings.



Presupuesto: 2.345.555 €
(Cofinanciado por Interreg SUDOE y FEDER: 75%)

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• MAIN GOAL AND SPECIFIC OBJECTIVES

Specific Objectives

- Development of a system to improve energy efficiency in public buildings through a solar heating and cooling generation system and the incorporation of active/passive techniques for buildings with zero energy consumption.
- Development of a fault resistant power control system for microgrids under high quality design criteria and continuity of supply.
- Development of an energy management system for renewable generation microgrids with a hybrid energy storage system under criteria of minimum degradation, maximum efficiency and priority in the use of renewable energies

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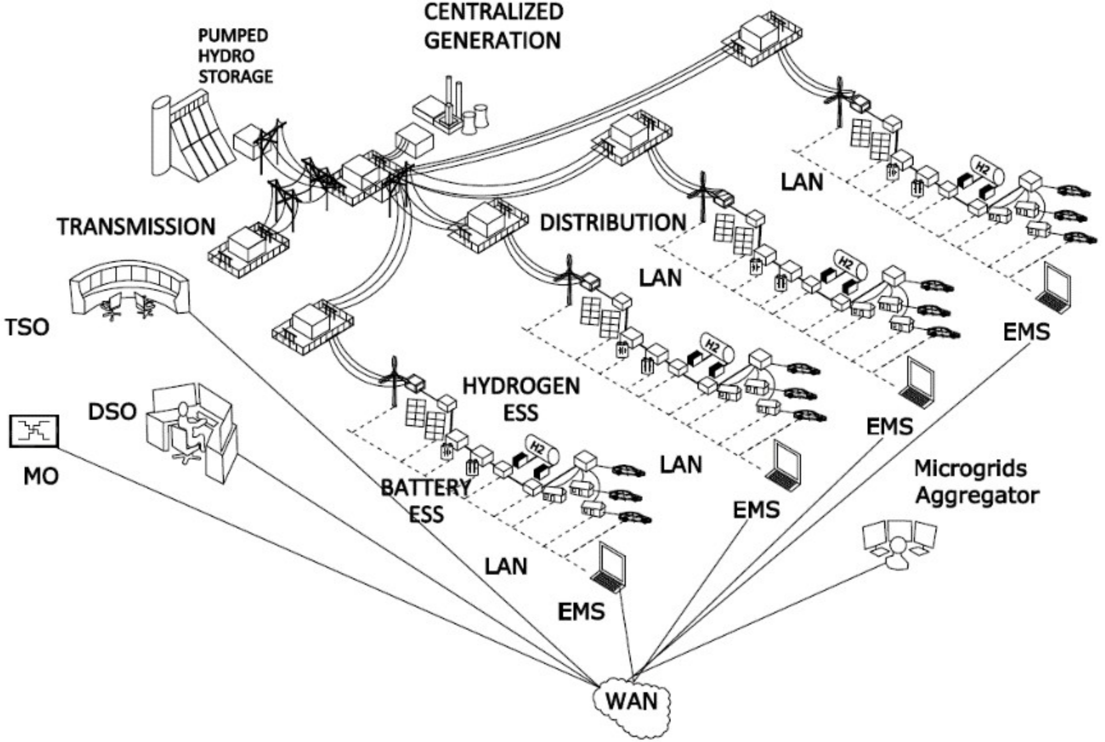
• MAIN GOAL AND SPECIFIC OBJECTIVES

Proposed Innovations:

- Thermal management of public buildings based on renewable energies with cold and heat storage.
- Fault-resilient micro-grids through the development of investors with active neutral control.
- Hybrid storage systems (batteries, supercapacitors and green hydrogen) to improve autonomy and resilience and reduce final energy costs.
- Two pilot plants (Spain and Portugal)
- Solutions to overcome regulatory, legal and financial barriers for such projects.

Microgrid as solution

- Resilience to grid failures
- Flexibility
- Economic optimization of energy prices
- Solve grid congestion problems
- Quality of supply



- **BUDGET**

COSTE TOTAL SUBVENCIONABLE (€):

2.501.926,27 €

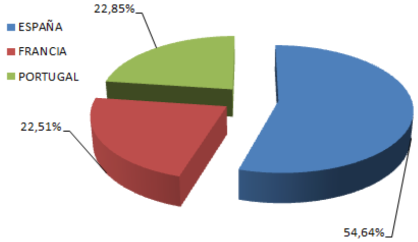
AYUDA FEDER (€):

1.876.444,70 €

Project Reference: SOE3/P3/E0901

The different entities (research centers, universities, agencies and public administrations) that are part of this project, also put at the service of the same, its own experience, facilities and equipment for the correct execution of the different activities foreseen in the IMPROVEMENT project.

Título del proyecto	INTEGRATION OF COMBINED COOLING, HEATING AND POWER MICROGRIDS IN ZERO-ENERGY PUBLIC BUILDINGS UNDER HIGH POWER QUALITY AND CONTINUITY OF SERVICE REQUIREMENTS		
Acrónimo	IMPROVEMENT		
Gasto Total del proyecto	2.501.926,27	Ayuda FEDER solicitada	1.876.444,71
Gasto subvencionable	2.501.926,27	Total Contrapartida nacional	625.481,56
Contrapartida nacional pública	625.481,56	Contrapartida nacional privada	0,00
Tasa de cofinanciación media	75,00	Gasto no subvencionable	0,00
Duración del proyecto	42 meses	Periodo: 01/10/2019 - 31/03/2023	



CONSORTIUM. BENEFICIARIES

BENEFICIARIO PRINCIPAL:	Centro Nacional de Experimentación de Tecnologías de Hidrógeno y Pilas de Combustible
OTROS BENEFICIARIOS:	2. Universidad de Castilla La Mancha 3. Ecole Nationale Supérieure de Mécanique et Aérotechnique (ENSMA) Laboratoire d'Informatique et d'Automatique pour les Systèmes (LIAS) 4. Instituto Superior Tecnico 5. Laboratório Nacional de Energia e Geologia, IP 6. Junta de Andalucía Consejeria de Empleo, Empresa y Comercio Dirección General de Industria, Energía y Minas 7. Universidad de Córdoba 8. Agencia Andaluza de la Energía 9. Université de Perpignan Via Domitia PROMES : Procédés Matériaux et Energie Solaire UPR CNRS 8521 (INSIS)

EURO-FUNDING
FI GROUP
AUREN

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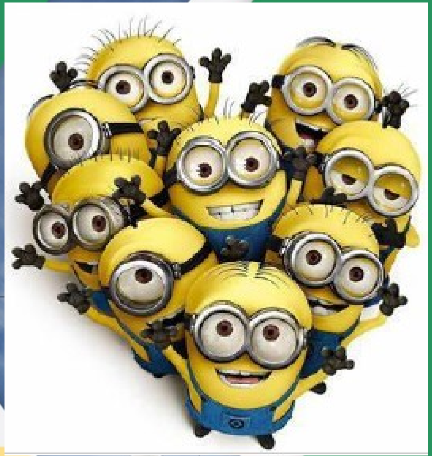
Cooperar está en sus manos
www.interreg-sudoe.eu

Beneficiarios Asociados

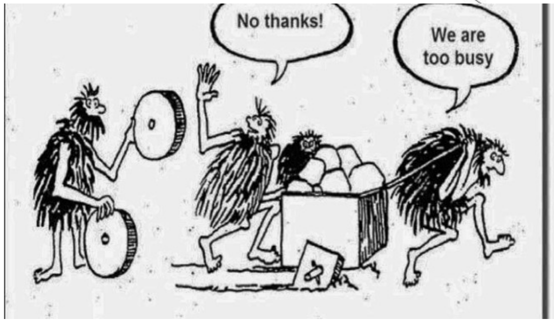
Nº	Nombre de la entidad	País
1	Green Power Technologies, S.L	España
2	NEC RENOVABLES SL	España
3	Área de Gestión Sanitaria Este de Málaga	España
4	Irradia Ingeniería Solar	España
5	Agence Régionale Énergie Climat Occitanie	France
6	Agência Regional de Energia e Ambiente do Algarve	Portugal
7	Associação Plataforma Construção Sustentável	Portugal
8	Intermunicipal Community of Algarve	Portugal



Associated Partners

GPTech
NECRENOVABLES
Irradia Energía
AREC Occitanie

Fuente: Internet



Fuente: Internet

CONSORTIUM. BENEFICIARIES

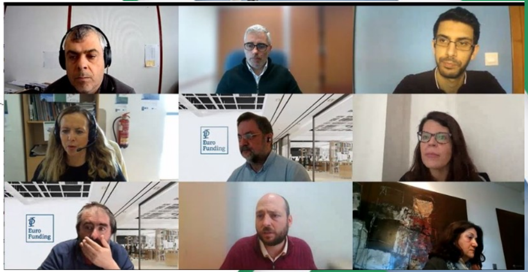
Role of each Beneficiary in the project

It is proposed to carry out 2 pilot plants where to implement and validate the new developments made.

One of them consists of an experimental microgrid platform located at the headquarters of the **Spain's National Hydrogen Center (CNH2)** in Puertollano (Ciudad Real) where the different technical predictive control solutions based on the development of a model of advanced energy management systems, supported by hybrid systems supported by hydrogen, batteries and supercapacitors, will be tested and integrated, ensuring the integration of renewable energy.

The other pilot will be carried out in Lisbon, under the direction of the **National Energy and Geology Laboratory (LNEG)**, with the support of the **Lisbon Higher Technical Institute (IST),** integrating renewable heat/cold generation systems into a microgrid for the conversion of an existing public building into a zero energy balance building.

For its part, the **University of Córdoba (UCO)** will be responsible for developing a power control system for microgrids with high quality supply requirements based on a network of intelligent IoT sensors (Internet of Things). In addition, it will collaborate with **the University of Castilla-La Mancha (UCLM)**, which will develop specific power electronics equipment with active neutral control to improve the quality of supply of such facilities.

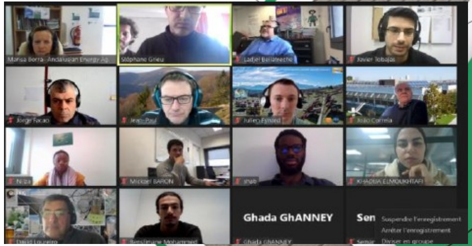


CONSORTIUM. BENEFICIARIES

Role of each Beneficiary in the project

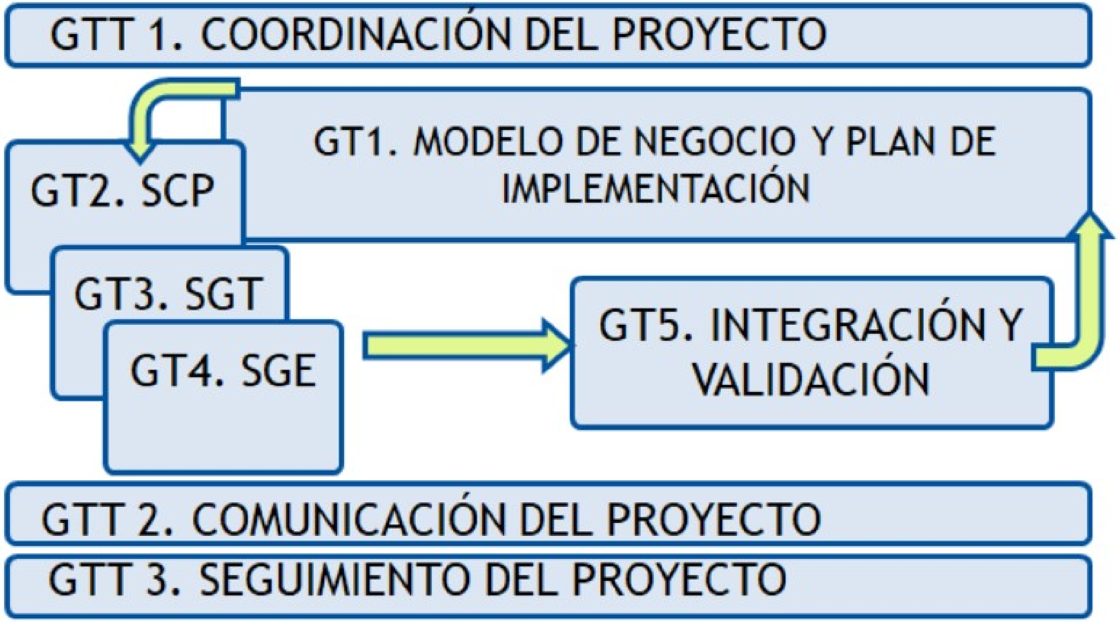
The consortium also involves the **Ministry of Finance and European Finance of the Directorate General of Energy of the Junta de Andalucía (JA)**, which will analyze the regulatory framework proposing the necessary recommendations to facilitate its adoption in the region; and the **Andalusian Energy Agency AEA)**, which will analyze the applicability and requirements of the proposed solutions, will participate in its validation, once developed, and will develop specific plans to implement the results of the project through the Energy Network of the Junta de Andalucía (Redeja).

On the other hand, the **Ecole Nationale Supérieure de Mecànique et Aèrotechnique (ENSMA)** and **the Université de Perpignan (UPVD)** (France) be responsible for the development of energy management systems for microgrids with hybrid storage under minimum degradation criteria and prioritisation of renewable consumption, by performing advanced algorithms that include tools to predict the price of energy and energy both generated and consumed in buildings.



• METHODOLOGY AND WORK PACKAGES

For the correct achievement of the project objectives, the following sequence of activities has been proposed, grouped in turn in different Working Groups (PT).



WORK PACKAGES

Associated Partners

Fuente: Hospital de la Axarquía (Vélez-Málaga)

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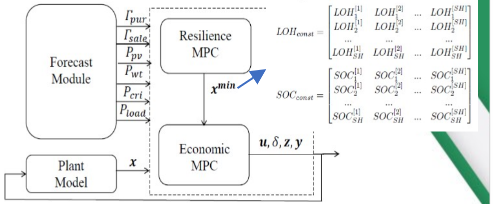
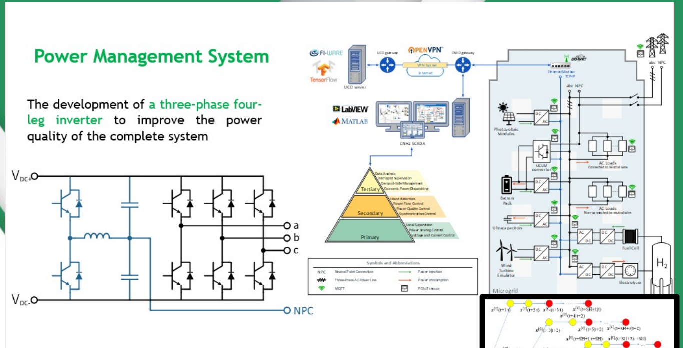
- **PRODUCTS AND PROGRESSING INDICATORS**

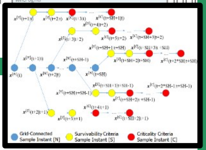
WP	Product
1	Good Practices Guide (1) Regional Plans and Transnational Strategy (4)
2	Fault-Resilient Power Control System for Microgrids (1) Patent (1)
3	Eco-Friendly Comfort System (1) Patent (1)
4	Energy Management System (1) → First indicator of progress Patent (1)
5	Pilot Plants (2) → Second indicator of progress

• PROGRESSING INDICATORS

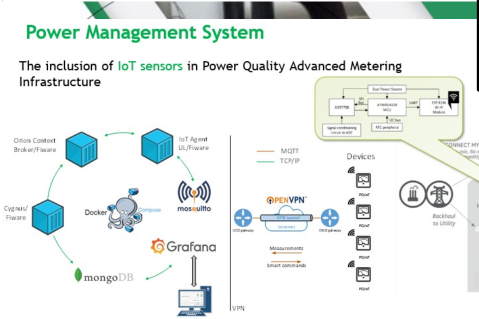


1. ENERGY MANAGEMENT SYSTEM FOR MICROGRIDS



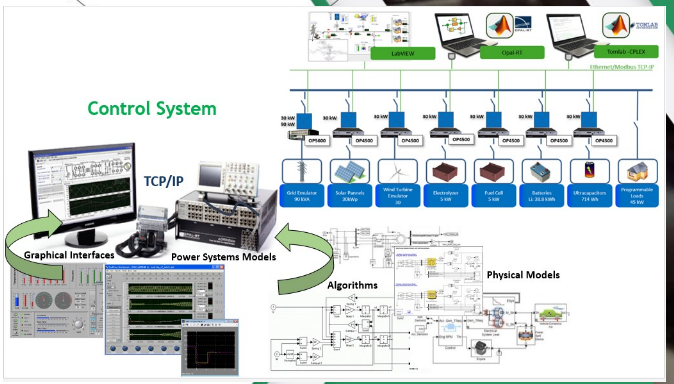


Renewable generation and energy storage systems are technologies which evoke the future energy paradigm. While these technologies have reached their technological maturity, the way they are integrated and operated in the future smart grids still presents several challenges. Microgrids appear as a key technology to pave the path towards the integration and optimized operation in smart grids. Another important solution that will allow buildings to form of energy management is the integration of a number of small production units called thermal micro-grids which does not stop increasing remarkably.



1.1 Electric Energy Management

While most of the technology related to microgrid components such as RES and ESS have reached their technological maturity, there still exist challenges regarding their combined optimization in a microgrid as set of subsystem subjected to uncertainties such as renewable generation, load consumption and energy prices. Besides the aforementioned problems with RES and loads, ESS have to be also optimally controlled by the microgrid according to their operation costs or physical constraints. The complexity of the algorithms is even increased when several microgrids have to be optimized at the same time. Because of the technical and economic benefits that microgrids can bring to the future energy systems, several methodologies have been developed to solve their associated problems and numerous review studies have been developed related to microgrid management from a global perspective such as to particular issues such as power quality in microgrids, stability and control aspects of microgrids, energy management system (EMS), resilience or buildings microgrid.

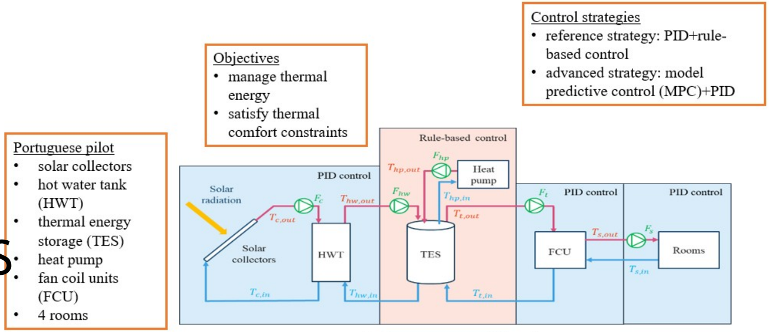


- **PROGRESSING INDICATORS**

1. ENERGY MANAGEMENT SYSTEM FOR MICROGRIDS

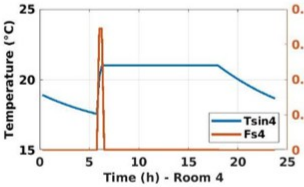
1.2 Thermal Energy Management

Global warming and subsequent climate change has been a strong motivation to reduce overall energy consumption and thus curtail the use of fossil fuels. At the European level, 40% of the energy is consumed by the commercial and noncommercial buildings to serve the functions and comfort of the residing occupants. Consequently, phenomenal research has been contributed to achieve nearly zero energy buildings (nZEB) i.e. buildings or districts joined to smart microgrids incorporating renewable energy sources and storage. These microgrids may or may not be connected to the main utility grid. Over the last few decades, researchers have investigated the goal of optimal operation of the microgrids through a variety of control methodologies to ensure minimum energy consumption while maintaining the comfort of the occupants in the buildings. Among these methodologies, MPC has been most favored technique, thanks to its inherent advantages and flexibility.

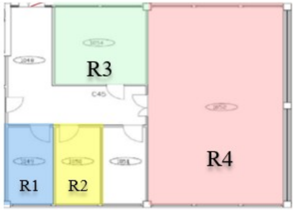


Reference strategy: PID+rule-based control

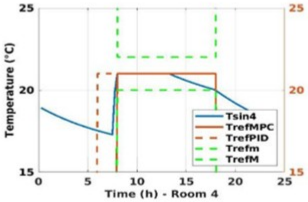
Algorithmic developments have been essential task of this work package as the overall efficiency and operability can be enhanced with an appropriate algorithmic control design. A thorough study was carried out on the simulated environments by considering the pilot plant as use cases, as well defined in the project objectives. The attempt of modeling of these pilot plants have been meticulously accomplished.



Air temperature regulation in room 4 (PID)



Rooms in the building



Air temperature regulation in room 4 (MPC+PID)

T_{sin4}: temperature of the room 4 (°C)

F_{s4}: volumetric flowrate of the air leaving the FCU (m^3/s)

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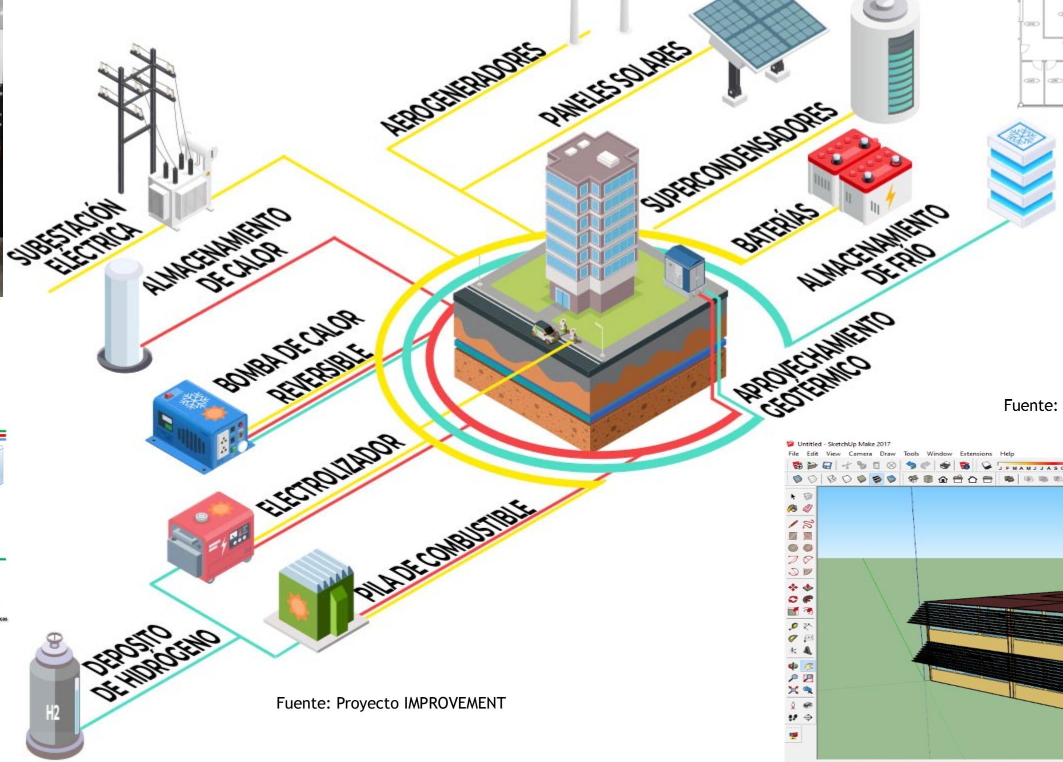
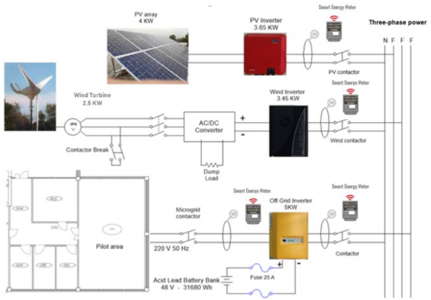
European Regional Development Fund

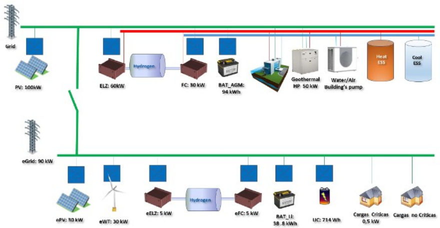
Fuente: Planta Piloto CNH2 (España)

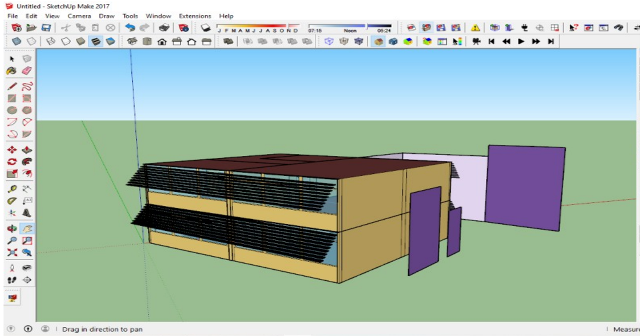


Fuente: Proyecto IMPROVEMENT



Fuente: Planta Piloto LNEG (Portugal)





Centro Nacional del Hidrógeno · UCLM Universidad de Castilla-La Mancha · ISAE ENSMA · TÉCNICO LISBOA · LNEG · Junta de Andalucía · Universidad de Córdoba · Junta de Andalucía Consejería de la Presidencia, Administración Pública e Interior Consejería de Hacienda y Financiación Europea · Agencia Andaluza de la Energía · Université Perpignan Via Domitia

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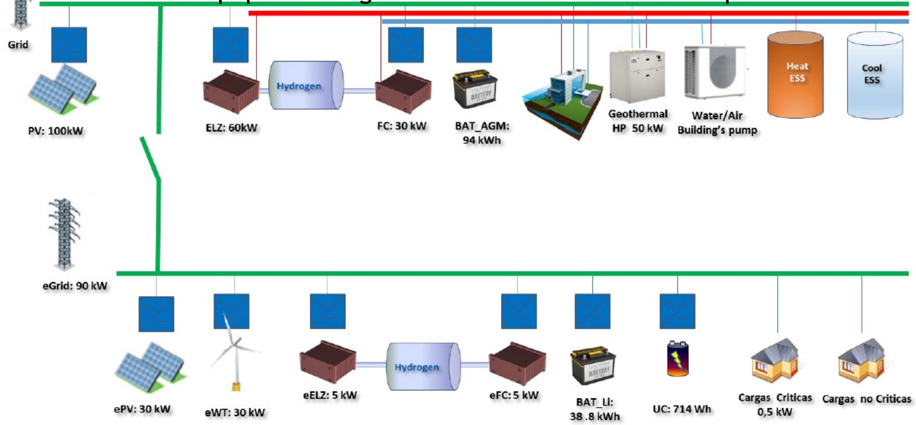
- **PROGRESSING INDICATORS**

2. DEMONSTRATOR PILOT PLANTS

The **IMPROVEMENT system** consists of a **set of techniques and processes to promote the self-sufficiency of public buildings and convert them into practically zero energy buildings**. In order to carry out this process, the **IMPROVEMENT System** as a whole is divided into **2 pilot plants:**

2.1 SPANISH PILOT PLANT (CNH2)

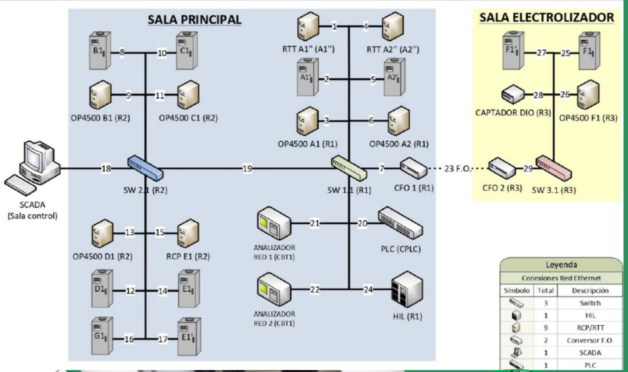
This Pilot Plant is located where systems and solutions for cold and heat recovery will be tested and where the development of an Energy Management System (EMS) composed of a microgrid capable of operating in isolation from the network and guaranteeing quality of supply will be carried out, reduction of equipment degradation and economic cost optimization.



PCM inorganic

- **PROGRESSING INDICATORS**

2. DEMONSTRATOR PILOT PLANTS

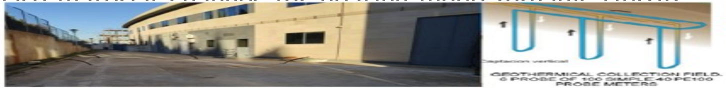


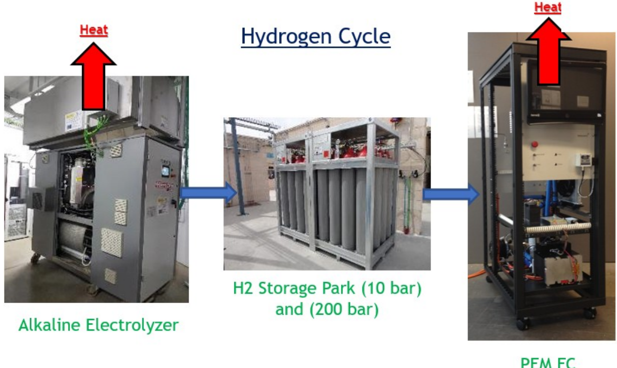
2.1 SPANISH PILOT PLANT (CNH2)

On one hand, **the electrical part**, composed of power electronic equipment, SCADA system, control algorithms and communication system, is located in the Microgrid laboratory in CNH2's building. The elements used in microgrid in order to validate the algorithm and the resilience of the electrical system belong to an experimental laboratory, in which there are emulators, converters and HIL elements that are not conventional equipment.

These elements are the main building grid, emulated 90 kW grid of the microgrid, emulated power wind turbine, emulated 100 kWp solar photovoltaic plant, 5 kW emulated alkaline electrolyzer, 4,5 kW emulated PEM fuel cell system, 30 kW Lithium-ion battery pack, 30 kW ultracapacitor and emulated critical and non-critical loads.

On the other hand, **the thermal part** is located in the CNH2's Demonstrator Building, where are integrated all hydrogen equipment (FC and EZ), heat and cold energy system (HESS and CESS) and geothermal recovery system (GRS). The main purpose of this thermal system is to find an optimal combination of technologies that enable to minimize the energy consumption of the air conditioning building needs, approaching it as close as possible to an nZEB building. It is composed by PV energy production system, hydrogen cycle (electrolyzer, tank and fuel cell), air conditioning, geothermal system, and phase material changes for heating mode (organic slurry) and others for cooling mode (inorganic).

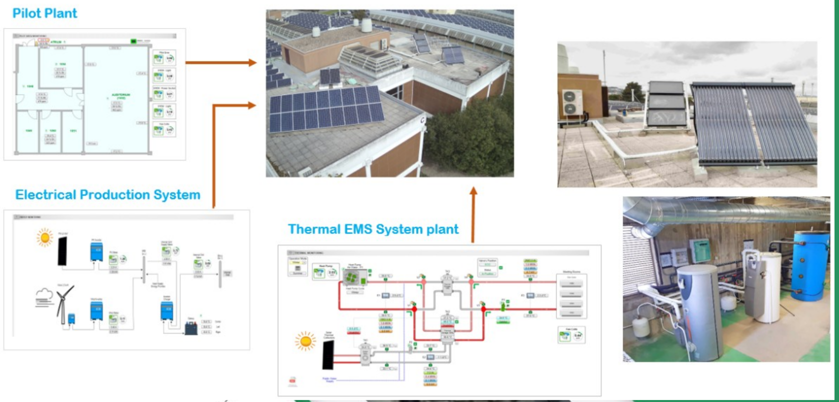




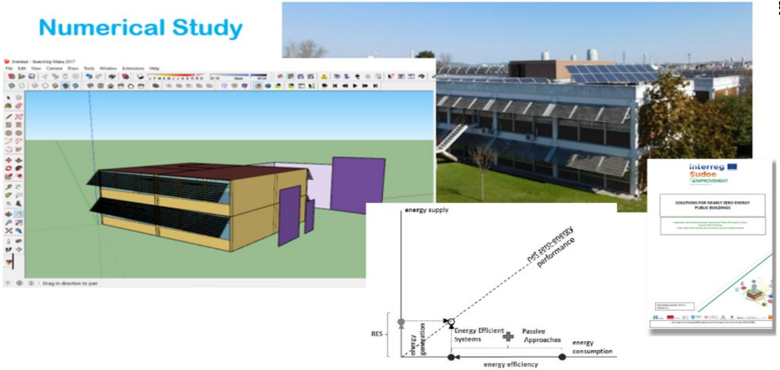
- **PROGRESSING INDICATORS**

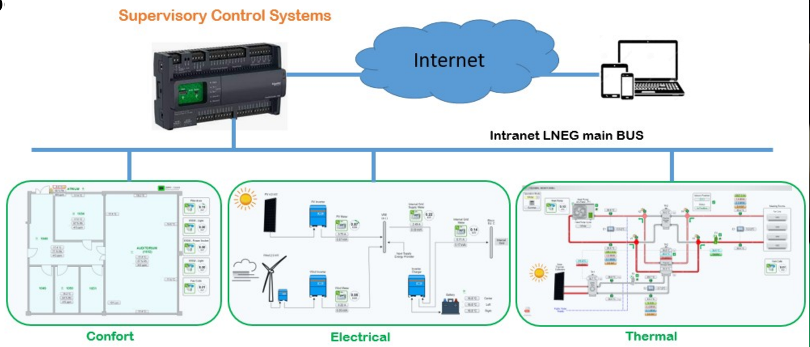
2. DEMONSTRATOR PILOT PLANTS

2.2 PORTUGUESE PILOT PLANT (LNEG)



This Pilot Plant was implemented in Lisbon, for the **conversion of an existing public building with a total area of 170 m² into a near zero energy buildings (nZEB).** The Pilot Plant was ensured by the **renewable generation** produced at the top of the building which integrates **a micro-grid of renewable electrical and thermal generation systems for heating and cooling and electric power** adequate to the **energy efficiency** requirements for **healthy and comfort** public building standards. The retrofit actions applied to achieve the nZEB target consist of a **combination of envelope and technical building systems refurbishment** with the integration of **generation and storage of electricity and heat from renewable sources**, coupled by thermal and electrical ... **ergy/p**





Work done in IMPROVEMENT Project:

European Hydrogen Energy Conference 18-20 May, 2022. Madrid, Spain

Integration of Combined Cooling, Heating and Power Microgrids in Zero Energy Public Buildings with High Power Quality and Continuity Requirements

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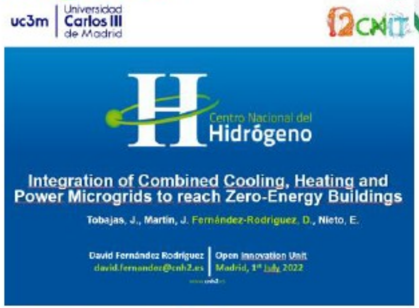

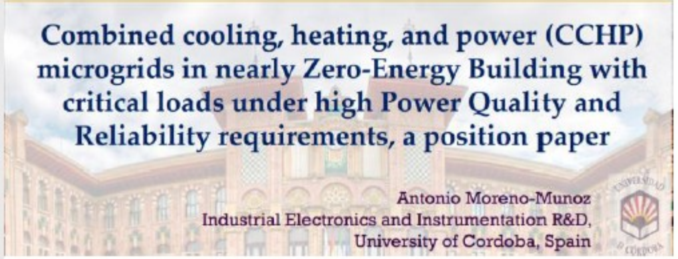

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European Regional Development Fund

Work done in IMPROVEMENT Project:

Scientific Publications

1) F. Garcia-Torres, A. Zafra-Cabeza, C. Silva, S. Grieu, T. Darure, A. Estanqueiro, “Model Predictive Control for Microgrid Functionalities: Review and Future Challenges” Energies 14, no. 5: 1296, 2021. https://doi.org/10.3390/en14051296

2) F. Garcia-Torres, C. Bordons, J. Tobajas, R. Real-Calvo, I. Santiago Chiquero and S. Grieu, “Stochastic Optimization of Microgrids with Hybrid Energy Storage Systems for Grid Flexibility Services Considering Energy Forecast Uncertainties,” in IEEE Transactions on Power Systems, vol. PP, no. PP, 2021, doi: 10.1109/TPWRS.2021.3071867.

3) F. Garcia-Torres, C. Bordons, J. Tobajas, J. J. Márquez, J. Garrido-Zafra and A. Moreno-Muñoz, “Optimal Schedule for Networked Microgrids Under Deregulated Power Market Environment Using Model Predictive Control,” in IEEE Transactions on Smart Grid, vol. 12, no. 1, pp. 182-191, Jan. 2021, doi: 10.1109/TSG.2020.3018023.

4) F. Garcia-Torres, P. Baez-Gonzalez, J. Tobajas, F. Vazquez and E. Nieto, “Cooperative Optimization of Networked Microgrids for Supporting Grid Flexibility Services using Model Predictive Control,” in IEEE Transactions on Smart Grid, vol. PP, no. PP, pag. PP-PP , doi: 10.1109/TSG.2020.3043821.

5) F. Garcia-Torres, S. Vazquez, I. Moreno-Garcia, A. Gil-de-Castro, P.Roncero-Sánchez, A. Moreno-Munoz, “Microgrids Power Quality Enhancement Using Model Predictive Control”. Electronics, vol. PP, no. PP, pag. PP-PP 2021.

6) I. Santiago, A. Moreno- Munoz, P. Quintero-Jimenez, F. Garcia-Torres and M.J. Gonzalez-Redondo, “Electricity demand during pandemic times: the case of the COVID-19 in Spain”, Energy Policy, vol. 48,, pp. 111964, 2020

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Work done in IMPROVEMENT Project:

Scientific Congress

1) “SONDER: A Data-Driven Methodology for Designing Net-Zero Energy Public Buildings”, L. Bellatreche, Felix Garcia-Torres, Don Nguyen Pham, Pedro Quintero Jiménez, International Conference on Big Data Analytics and Knowledge Discovery, 2020.

2) “Conversão de edifícios existentes em nzeb através da integração de energias renováveis, de micro-redes e de soluções de eficiência energética”, David Loureiro, CIES2020, XVII Congresso Ibérico e XIII Congresso Ibero-americano de Energia Solar, 3-5 novembro 2020.

3) “Power Quality of Interconnected Microgrids using Model Predictive Control”, F. Garcia-Torres, S. Vazquez, C. Bordons, I. Moreno-Garcia, A. Gil, P. Roncero-Sanchez, International Federation of Automatic Control World Congress, IFAC 2020.

4) “Current Control of a Grid-Connected Single-Phase Voltage-Source Inverter with LCL Filter”, A. Parreño Torres, F.J. López Alcolea, P. Roncero.Sabcgezm J. Vazquez, E. Molina-Martínez, and F. Garcia-Torres, 22nd European Conference on Power Electronics and Applications, EPE'20 ECCE EUROPE.

5) A Novel Microgrid Responsive Appliance Controller”, J. Garrido-Zafra, A. Gil-de-Castro, R. Saraviego-Fernandez, M. Linan-Reyes, A. Moreno Munoz and F. Garcia-Torres, 2020 IEEE International Conference on Environment and Electrical Engineering and 2020 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe)

6) “Integración de Microrredes de Generación Combinada de Calor, Frío y Eléctricidad en Edificios Públicos con altos requerimientos de Calidad y Continuidad de Suministro”, J. Tobajas, P. Roncero-Sanchez, A. Munoz-Moreno, A. Saez, A. Estanqueiro, S. Grieu, L. Bellatreche, R. Costa Neto, A. Rodríguez, E. Nieto. , XXVII Seminario Anual de Automática, Electrónica Industrial e Instrumentación (SAAEI’20)

7) “Microrredes Cooperativas con funcionalidades avanzadas: Flexibilidad y Resilencia”, F. Garcia-Torres, J. Tobajas, J. Martín y Emilio Nieto, VII Congreso Nacional de Smart Grids.

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Thank you very much!

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