Interreg Sudoe

EUROPEAN UNION

IMPROVEMENT

European Regional Development Fund

PROJECT IMPROVEMENT - PRODUCT 1.6.2. IMPLANTATION PLANS

Abstract

This document includes the necessary contents to layout the design of Product 1.6.2. Implementation plans, which includes regional and transnational strategies in the form of a roadmap, aimed at the different authorities and decision makers in the SUDOE regions. The content of this document is based on Deliverable 1.5.3. Implantations Plans, with extended information, which has been written considering the results of different IMPROVEMENT tasks worked out and provided different beneficiaries on the deliverables and specific questionnaires prepared for the project.

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 Política Industrial y Energía · Agencia Andaluza de la Energía · Université Perpignan Via Domitia

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Acronyms.

DHW	Domestic Hot Water
DLC	Direct Load Control
DR	Demand Response
EMS	Energy Management System
IoT	Internet of Things
MPC	Model Predictive Control
nZEB	Near Zero Energy Building
PCM	Phase Change Materials
PEM	Proton Exchange Membrane fuel cell technology
PID/RB	Proportional-Integral-Derivative/Rule-Based control strategy
PV	Photovoltaic
SCADA	Supervisory Control And Data Acquisition

1. Aim of the document.

In recent years, numerous projects have been developed to improve energy efficiency in buildings and to integrate renewable energies into them. However, there are still few projects related to the problems of **integrating distributed energy resources** (DER) in the broadest sense, in environments where high-tech equipment, the so-called "critical loads", is predominant. These can be found in hospitals, airports, universities, and other public buildings.

This kind of environments always particular due to the extreme sensibility of this specific equipment to power disturbances. For scientific considerations in universities and technological centres, as well as, for sanitary reasons in hospitals and for security reasons in railways stations or airports, **power quality and continuity of supply** must be considered as fundamentals aspects. And for that reason, buildings in which guarantee of continuity of the power supply and the quality of the power wave are essential aspects, will be priority targets for IMPROVEMENT findings.

With this consideration, buildings of the following types stand out:

- Hospitals and health centers.
- Security and emergency services buildings.
- Critical transport infrastructures (stations, seaports, airports...).
- Residences of vulnerable people.
- Prisons.
- Research centers.
- Large Sports Facility.
- Military facilities.
- Medium and large auditoriums, concert halls, theatres.

Many of these buildings have the **critical (energy) loads**, that is, energy consumption that under no circumstances can be interrupted, supplied without regularity or with poor quality, very specifically in relation to the electric fluid, since if this were the case, it would put people's health and even lives at risk and/or causes great economic damage.

On the other hand, the implementation of these systems to increase energy efficiency in buildings requires having an adequate regulatory and certification framework, as well as having a business plan that makes it possible to know and guarantee their technical and economic viability.

IMPROVEMENT project aims to convert existing public buildings into **zero energy buildings** by integrating combined cooling, heating, and power (CCHP) microgrids with neutral clamped inverters using hybrid energy storage systems, which will guarantee power quality and continuity of service of sensitive equipment (medical and scientific) while increasing the energy efficiency in this kind of buildings, following the next specific objectives:

1) To improve the thermal efficiency of this kind of public buildings through the production of solar heating and cooling, and the incorporation of active/passive techniques for buildings with zero energy consumption;

2) To enhance the power quality and reliability of supply in public buildings with critical loads developing a fault-resilient power management system for microgrid;

3) To integrate advanced energy management systems for renewable microgrids with hybrid energy storage system under criteria of minimum degradation, minimum cost of use of the storage system and maximization of clean energy consumption.

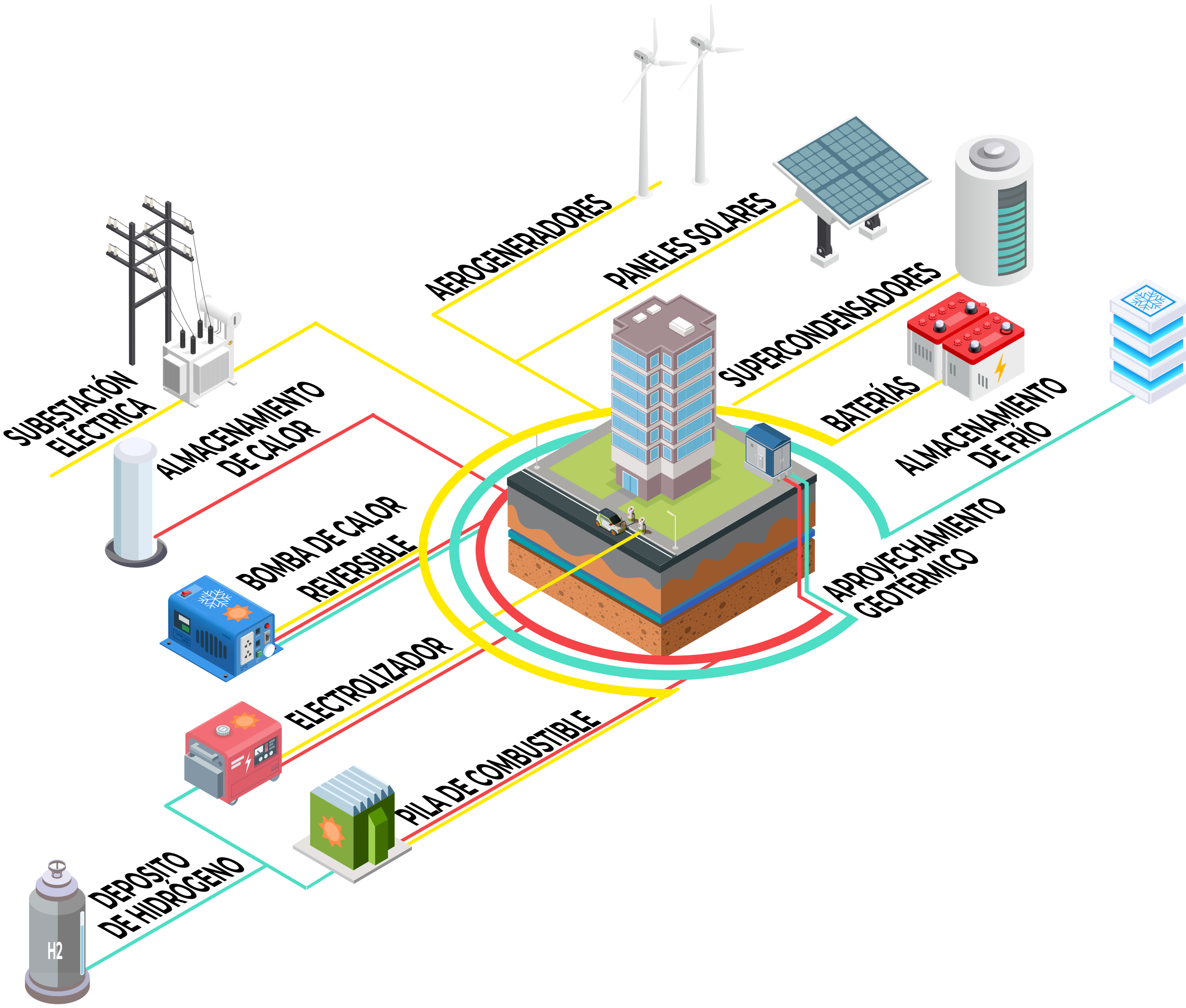


Figure 1.1 Scheme of the IMPROVEMENT System

The IMPROVEMENT project is not limited to seeking the development of its technological proposals within the framework of the member countries of the SUDOE zone, among which are the beneficiaries' nationalities (**Spain, France,** and **Portugal**), but also establishes criteria and recommendations available to countries with similar climatology to SUDOE countries.

Under these goals, the aim of this document is the presentation of **Implantation plans for the IMPROVEMENT system**[1], as a roadmap to pave the way for the implementation of the current pre-commercial phase of the IMPROVEMENT business model and its integration as an energy management solution for public buildings with critical loads.

After analysing the typology of public buildings, the design of the pilot plants, after elaborating a business plan for the IMPROVEMENT system, as well as a *Guide to Good Practices for the application of the system in buildings,* the Andalusian Energy Agency has drafted the present Implantation Plan, to facilitate the starting of a future market launch of the system.

To this end, the results obtained in the work carried out by the different IMPROVEMENT beneficiaries in this project in their respective tasks will be compiled, thereby giving recommendations for the deployment of microgrids in public buildings and facilities that may be of interest to state agencies and the administrative authorities that own them. It will explore the key issues for the implementation of the proposed microgrids and control technology and how these can play a role in implementing the energy policy objectives of the regions.

The beneficiaries in this project are:

- Andalusian Energy Agency **AAE (Spain).**
- Andalusian Government. General Secretary of Energy. **JA-SGE (Spain).**
- Castilla-La Mancha University **UCLM (Spain).**
- Cordoba University U**CO (Spain).**
- Energy and Geology National Laboratory **LNEG (Portugal).**
- National Hydrogen Center **CNH2 (Spain).**
- National School of Mechanics and Aerotechnics **ENSMA (France).**
- Perpignan Via Domitia University **UPVD (France).**
- Technical High School, Lisbon University **IST (Portugal).**

1. For the drafting of this document, the content for Deliverable D1.5.1. Implantation plans has been used. The deliverable includes a more detailed description of the legal, regulatory, and technical status of the constituent elements of the IMPROVEMENT Project for implantation plans.

2. Results of the experiences for the IMPROVEMENT system from pilot plants and laboratories testing.

As a result of the process of research and development of the technologies described for the IMPROVEMENT system, the most relevant results have been determined and collected, as well as the barriers and difficulties to be overcome, to advance in a viable business model in the future. In this sense, a summary of the conclusions expressed by different beneficiaries (**CNH2, ENSMA, IST, LNEG, UCLM, UCO, and UPVD**) on their respective areas of competence in the project is included below.

The results of the experiences with the **pilot plants of the CNH2 and LNEG** beneficiaries will be presented as well as findings relating to power management systems and quality of energy supply (**UCO and UCLM**) developed on CNH2 pilot; and energy management and energy cost forecasts algorithms (**UPVD and ENSMA**) modelled and applied on LNEG pilot. Additionally, information will be added on the experience carried out on the **Alameda campus of the Technical University of Lisbon,** by the beneficiary **IST.** Although this case is not explicitly a pilot plant of the IMPROVEMENT project, it has been thought to be added here because it can offer another vision to the experience and provide interesting information regarding relevant results, barriers encountered, difficulties and formulations to overcome them.

PILOT PLANT CNH2.

At the facilities of the Spanish National Hydrogen Centre (CNH2) in Puertollano (Spain), two separated but interconnected, thermal and electric microgrids have been tested to validate the different goals expected in the project. The microgrids are integrated by equipment for the generation and storage of electricity and heat from renewable sources, coupled by thermal and electrical networks and managed by a central monitoring and control energy/power system. The control system designed by the UCO and the UCLM partners have also been tested and will be able to decide if both microgrids can work interconnected or not.

RELEVANT FINDINGS AND RESULTS

A) ABOUT THE POWER MICROGRID.

CNH2 pilot plant system **main innovation** is based on t**he development of an EMS capable of automatically manage and control the equipment connected to the electrical microgrid through a control algorithm.** Further definition of both **'EMS'** and **'control algorithm'** concepts as well as their functions within the pilot plant, will highlight the innovations they bring to the system:

a. Energy Management System.

Consists of a control system made up of the different physical elements and the communications between them. Is it capable to manage each of these elements or equipment, separately or jointly, thus generating a microgrid.

This EMS will be responsible to keep the algorithm constantly running, to decide which equipment and what power to always use, sending those necessary values through **MODBUS communication to the microgrid SCADA. SCADA will again return real values obtained from the equipment to forward them through MODBUS communication back to the algorithm,** which will use them as input in its calculations.

So finally, **two main innovative aspects arise related to EMS,**

1. Inclusion of a **hybrid energy storage system in our microgrid (HESS) in the microgrid.** This is the combination of different energy storage technologies such as batteries, supercapacitors, or green hydrogen. The use of hydrogen and its inclusion in an electrical micro-

BARRIERS/DIFFICULTIES ENCOUNTERED TO OVERCOME

A) ON THE OPERATIONAL DIFFICULTIES WITH PCM IN THE MICROGRID HEAT GENERATION SUBSYSTEM.

The PCM used in the heat subsystem (during winter mode) was "slurry" type, based on an emulsion of a paraffinic compound on an aqueous base. This has caused difficulties during storage and potential use:

- **Storage:** potential separation of organic/inorganic phase after some time. Coagulation and flocculation phenomena appear. This important unstability resulted in the generation of a high viscosity organic phase and an aqueous phase, and thus a potential loss of its heat storage power.

- **Use:** when the PCM is in motion (flowing) throughout the installation of the pilot plant, its high viscosity and potential phase separation can cause "jams" and important "fouling" of equipment and instrumentation. In case the pumps that drive the fluid (screw pump) are not working, the fluid, after some period laying still can suffer the separation of phases even within the installation. This forces its continuous operation or to remove the said fluid once the tests are finished.

B) ON EQUIPMENT BREAKDOWNS DURING OPERATION.

Several breakdowns occurred in the operation phase of the pilot plant and in different components: failure in the fuel cell of the pilot plant, problems with screw pumps of heat PCMs and breakdowns and problems of fittings / valves grid of this type stands out as an innovation. The key to this HESS is **allowing us to a better use the main advantages of the different storage systems**, thus being able to reduce the disadvantages that they would have separately, e.g., the use of supercapacitors for very fast changes or current peaks, or the use of hydrogen for a longer and more constant power supply.

2. The **possibility of shifting from grid-connected mode to isolated mode** (e.g., in case of power blackout). This shift is **performed automatically** thanks to the operations carried out by the EMS over the SCADA system, keeping critical loads fed while grid blackout lasts, thanks to the energy storage system and the algorithms' resilience criterion.

b. Optimization and control algorithm.

The developed algorithm can control the different equipment and elements of the microgrid, managing the development of the following actions:

- **Buying/selling electricity from/to the power grid.**
- **Battery charge and discharge.**
- **Charge/discharge of supercapacitors.**
- **Electrolyser Hydrogen generation.**
- **Power generation with hydrogen using a fuel cell.**
- **Shutting-down renewable energy generation from the microgrid.**

Regarding this algorithm, t**he most innovative aspect is the costs optimization,** which is achieved considering different criteria, such as:

- **Economic criterion:** decision of when to buy or sell electricity according to the price in the market, or when it is a

/ instrumentation associated with their operation.

C) ON THE NEED TO PRE-CONDITION HYDROGEN EQUIPMENT TO ACHIEVE OPERATING PARAMETERS.

Especially relevant in the fuel cell and electrolyser, for proper operation. This implies the need to devote a certain amount of time to adapting the equipment that, if not carried out, could cause inefficiencies, interruptions, and a decrease in the lifespan of the equipment during its operation.

D) ON THE LIMITATIONS IN THE RESPONSE TIME OF THE ALKALINE ELECTROLYSER.

Having the need to adapt the operating temperature of this type of electrolysers, its hydrogen generation capacity is not as immediate as the ones of other technologies. This results in lesser operation flexibility.

E) ON THE ELECTRICITY CONSUMPTION DURING THE HYDROGEN COMPRESSION PHASE.

From production to the storage phase (pressure increases from 10 to 200 bar) and its subsequent decompression for hydrogen use in the fuel cell, a high electricity consumption takes place.

F) ON THE HIGH EQUIPMENT COST RELATED TO THE HYDROGEN CYCLE.

as well as some of the new technologies implemented, which are still in the development phase, such as PCMs, already mentioned.

G) ON THE COMMUNICATION DIFFICULTIES BETWEEN THE DIFFERENT

better option to use battery or hydrogen storage.

- **Degradation criterion:** minimizing equipment degradation by reducing electrolyser or fuel cell on/off cycles, thus reducing system operating costs.
- **Renewable-energy-generation criterion:** prioritization of renewable energy generated in the microgrid before purchasing electricity from the utility grid. Electricity is only purchased from the grid if it is inevitable, or we do not have enough renewable available at a given time.
- **Resilience criterion:** the algorithm will always have forecast of the possibility of a communication shutdown with the electricity grid, being able to ensure, with the energy stored in the energy storage systems, to feed all critical loads that are in the microgrid for at least 24 hours.

B) ABOUT THE THERMAL MICROGRID.

Currently, the CNH2 facilities have an **air conditioning system based on an air-water heat pump.** This system has two operating modes: cooling mode and heating mode, which allows to meet the needs of air conditioning throughout the year, with a maximum heat output of 273,3 kW (achieved in heating mode). Despite its efficient use and following the recommended air conditioning temperature guidelines, its continuous operation is an important source of electricity consumption from the utility grid. **It is critical to search for measures to minimize it and to serve as a reference to potential public buildings with high energy consumption in air conditioning.**

Reducing energy consumption is where relevant **findings and results** of the thermal part of the CNH2 pilot plant are aimed at:

EQUIPMENT OF THE ELECTRICAL MICROGRID OF THE CNH2 PILOT PLANT.

- The electrical converter, key equipment to start the electrolyser, broke.
- It became necessary to redesign the communication and electrical schemes of the pilot plant.

a. The use of new and disruptive techniques currently applied in a minor way to public buildings:

- **Hydrogen cycle Integration.** Both the electrolyser and the fuel cell are electrochemical devices capable of generating electricity and heat during their operation. Fuel cells can be classified, according to its operating temperature, low or high temperature fuel cells. Depending on the applications one type of technology or the other must be selected. In the case of fuel cells for stationary applications (electricity or heat generation) it makes sense to use polymer membrane technologies (PEM) for small size applications. Molten carbonates (MCFC) or solid oxide (SOFC) in the case of large cogeneration.
- **Use of geothermal energy.**
- **Use of Phase Change Materials (PCMs),** using specific ones for heating mode (**organic slurry**), and others for cooling mode (**inorganic**). PCMs are materials with high latent heat, that is, materials that at the phase change temperature can store or releasing large amounts of energy. During the phase change, temperature remains constant, and the material absorbs or releases energy progressively.

b. Improvement of energy efficiency.

By taking advantage of waste heat from CNH2 facilities implemented equipment: alkaline electrolyzer and PEM fuel cell.

c. Joint integration of innovative technologies.

Geothermal-PCMs and hydrogen cycle-PCMs according to needs and external climatic conditions to increase thermal yields of the microgrid.

UCO and UCLM Power control system or microgrids with high power quality requirements.

Innovations in power management system of this projects are the implementation of IoT submetering system focused on the power quality requirements and specifications (UCO), and the Implementation of inverters with control of the neutral-wire current, to mitigate the harmonic circulation by the neutral wire (UCLM). Proposed IoT sensor will help users to detect most power quality steady-state and events disturbances, while monitoring the power consumption. The main goal of the inverters will be twofold: remove the current harmonics and remove or, at least, reduce current imbalances in the point of common coupling.

RELEVANT FINDINGS AND RESULTS

A) PROJECTION OF IMPROVEMENT SYSTEM RESULTS WITH THE APPLICATION FOR A EUROPEAN PATENT.

The work carried out for this project by the UCO and UCLM, aimed at a development of a Network of Internet of Things Sensors for Power Quality Measurement advanced metering (IoT PQ) capable of implementing Demand Response Direct Load Control (DR-DLC) strategies, as a core development for this project, will involve the application for a European patent.

B) POWER CONVERTER TO ENHANCE MICROGRID POWER QUALITY.

Upon the studies developed by UCLM for the IMPROVEMENT project, one of the goals is to control power quality issues in the microgrid caused by nonlinear and unbalanced loads than can negatively affect critical loads. For that purpose, a power converter that operates in the microgrid, to which all the loads are connected, is controlled by using several control configurations and information provided by IoT sensors. This solution allows to compensate the following dis-

BARRIERS/DIFFICULTIES ENCOUNTERED TO OVERCOME

A) COMPLEXITIES OF SUBMETERING.

Unlike metering building energy consumption in the Point of Common Coupling (PCC), submetering involves measuring energy consumption of individual units or appliances in the building complex. Submeters provide crucial information for more granular measurement of energy consumption data. Unfortunately, **submetering remains limited due to meter costs and the technical complexity of their installation, operation, and disaggregation.**

B) CRITICAL ISSUES AND BARRIERS TO THE EFFECTIVE APPLICATION OF DR THROUGH ENERGY SMART APPLIANCES (ESA):

Cybersecurity: or prevention of unauthorized access to ESAs by third parties.

Data privacy: The secure storage of personal data on the device or anywhere in the EMS.

Interoperability: the ability of ESAs to work operated by any agent in the system.

turbances: current harmonics, current imbalances, and reactive-power compensation. Furthermore, voltage sags and voltage harmonics that can be present in the microgrid can also be cancelled out.

The system is also able to estimate several electric magnitudes in real-time, such as frequency, grid voltage, and current and voltage harmonics.

C) POWER CONVERTER AS A POWER MANAGEMENT SYSTEM.

The proposed solution employs the power converter connected to the microgrid as a current-controlled source or as a voltage-controlled source. This behaviour allows the power converter to operate as a **parallel active power filter** and perform as a current source when the microgrid operates in the utility grid-connected mode, thus compensating current disturbances present in the microgrid. On the other hand, when the microgrid works in islanded mode, the power converter changes to voltage-controlled source setting the voltage and the frequency of the microgrid.

D) POWER CONVERTER WITH ADVANCED FUNCTIONALITIES.

A **four-wire three-phase power converter** (15 kVA rated power) **with control of the neutral point has been built for the IMPROVEMENT project.** The power converter is controlled by a real-time platform, which can carry out the control actions explained above.

Power quality: preventing grid disruptions caused by incorrect or simultaneous operation of ESAs.

C) EXTERNAL FACTORS TO OVERCOME.

not directly related to the project such as the lack of supply for electronic components due to its shortage in international markets or limitations due to geopolitics or sanitary reasons like the CoVid-19 pandemic.

D) LOW DATA AVAILABILITY.

The amount of information provided by the IoT sensors is not completely used by the proposed control topology, as this information is provided in a time scale which is very slow compared to that necessary for the control system. Only in the estimation process of the electrical magnitudes the information provided by the IoT sensors is useful.

This drawback implies that the control system needs the implementation of sensors that provide the measurements of currents and voltages, which increases the cost of the proposed solution.

E) ENHANCEMENTS ARE NEEDED TO BE APPLIED ON TO THE POWER CONVERTER.

Current transition between the grid-connected mode and the islanded mode implemented in the already existing microgrid at CHN2 is very slow, which makes impossible a proper transition with the power converter.

The rated power of the power converter is appropriated for the behaviour of the parallel active power filter. Nevertheless, this value is not sufficient if the converter is required to operate as a voltage-controlled source owing to the rated power of the microgrid.

F) CRITICAL ASPECTS OF NON-COMMERCIAL TECHNOLOGIES.

The **high price** is one of the main issues for adopting a four-wire three-phase power converter with control of the neutral point as solution for microgrids. Another problem is **the lack of companies that are willing to implement this kind of non-commercial solutions. Dealing with expected long delivery periods** considering that the design, construction and putting into service of a customized inverter which must observe several strict operating specifications is always a challenging task. The **maintenance service** of this solution may be compromised for the same reasons.

PILOT PLANT LNEG.

The research activities conducted by LNEG in the Portuguese pilot plant and case study are focused on the investigation of appropriate and reasonable technological solutions for a conversion of an existing public office building located in Lisbon to a nZEB. The retrofit actions applied to achieve the nZEB target consists 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 networks. The overall installation is monitored centrally and managed by a control energy/power system specifically conceived and designed to characterize the improvement in the energy efficiency of the building.

Additionally, partne UPVD has applied the data provided by LNEG's pilot plant and its experience in the field of energy management to develop a model on the LNEG's pilot and to forecast the PV power generation, while ENSMA has been working on the development of systems to forecast energy consumption in buildings and electricity tariffs.

RELEVANT FINDINGS AND RESULTS

A) ABOUT ACHIEVING THERMAL COMFORT.

The Portuguese contribution by LNEG to the project aims to demonstrate a methodology for the renovation of part of an existing public building into a nearly zero energy building while maintaining (and even improving) the level of thermal comfort. One of the initial concerns was the mitigation of energy needs, through the implementation of passive and active solutions and measurement of the improvement achieved for the thermal comfort without being influenced by outside temperature variations. The solutions implemented include maximization of the natural lighting, efficient incorporation of artificial lighting (dimmable LED), replacement of the false ceiling by panels of high thermal and acoustic insulation efficiency, glazing, ventilation, solar shading as well as the application of PCMs for minimising external influences and regulate thermal inertia.

B) ABOUT THE THERMAL MANAGEMENT SYSTEM.

The solution found for the air conditioning of the whole pilot area was a combined heat and cold generation system, based on an air/water heat pump assisted by solar thermal collector for space heating (Winter mode) and the same heat pump to produce cold water for space cooling (Summer mode).

There is a 1000-litter inertia tank whose function is to store heat produced in economical mode, depending on the season. For heat production a circuit composed by a forced circulation solar system is

BARRIERS/DIFFICULTIES ENCOUNTERED TO OVERCOME

A) ABOUT ACHIEVING THERMAL COMFORT.

- In certain extreme climate conditions, it may be difficult to achieve a zero-energy balance in the building while keeping the comfort level at the usual standards. To circumvent this effect, it may be necessary to adopt supplementary measures, such as using adaptive comfort levels.
- Measures applied in the building envelope may result in poor energy consumption reduction and/or thermal comfort increase.
- The cost of the measures to be implemented may not be amortised over the building´s (economic) lifespan.
- The renovation of the building required the work of very skilled professional teams for adequate results. It proved very difficult to find a provider for the spatially dispersed monitoring and electrical load control system, as well as an electrical construction company with experience in the installation of microgrids.
- The development of this niche requires the formation and education of designers and professionals in the two main sectors addressed by the Portuguese Pilot: 1) reforming buildings for increased energy efficiency (turning into nZEB); and 2) installing and operating microgrids on a building's scale

B) ABOUT THE THERMAL MANAGEMENT SYSTEM.

- The definition of requirements for the thermal management system had to used to assist the heat pump. The forced circulation solar system is composed, with two solar collectors together with 16 evacuated tubes with heat pipe, and a 300-litter thermal storage in closed circuit. The heat pump can function in direct mode without the inertial tank. This entire thermal system has a strong monitoring and control components, enabling optimised evaluation and control of the entire process.

C) ABOUT THE ELECTRICAL MICROGRID.

A new electrical circuit **-designed to create a microgrid with PV solar panels, a micro wind turbine, inverters, batteries, and the local loads-** was installed and operationalized. The power management system is capable to automatically switch between microgrid renewable generation (islanding off-grid mode) and the utility grid mode (the default being giving priority to self-renewable generation).

be readjusted in view of the implementation of the recurring thermal comfort options in the renovation of the pilot plant. The deadlines for delivery and commissioning of the equipment were delayed what also postponed the functioning tests of the thermal management system.

- Annual solar thermal contribution is small, making it difficult to justify and amortize the additional cost of the equipment compared to conventional solutions. Another aspect is the variability of the solar resource and the difficulty in matching the needs with the availability of the resource.
- A general lack of competence of companies specialised in thermal energy management in buildings. Poor periodic maintenance of thermal systems.
- Non-existing standardization to define and support the specification of the systems, with a casuistic design and approach, which rises investment and operating costs, requiring highly qualified teams.

C) ABOUT THE ELECTRICAL MICROGRID.

- The main obstacles to for the integration of power microgrids include both financial and technical aspects. The high price of the components to be installed, which represent a long return on investment that is difficult to justify when compared to conventional solutions.
- Poor renewable resources on site. Namely wind energy, in the case of LNEG's pilot.
- Lack of specialized companies with the skills to perform the project requirements.
- Lack of standars to regulate the systems.

UPVD and ENSMA models for energy management and forecasting at LNEG's pilot building.

This section lists the most relevant results achieved by UPVD /PROMES-CNRS (University of Perpignan Via Domitia/Processes, Materials and Solar Energy) regarding the energy management of the LNEG's pilot building in Lisbon (Portugal), evaluate the feasibility of the proposed technical solutions and indicate difficulties and barriers to overcome. The work done by ENSMA (Ecole Nationale Supérieure de Mécanique et Aérotechnique) regarding the forecasting of energy consumption in public buildings and electricity tariffs is summarized. The algorithms developed by UPVD/PROMES-CNRS regarding the PV power generation forecasting are also briefly presented.

RELEVANT FINDINGS AND RESULTS

A) ABOUT THE THERMAL COMFORT/ THERMAL ENERGY MANAGEMENT.

The main contribution of UPVD/PROMES-CNRS to the IMPROVEMENT project is a predictive energy management system (PEMS) for thermal energy and thermal comfort management in public buildings equipped with multi-energy (thermal and electrical) microgrids. The IMPROVEMENT EMS efficiently manages the interconnection of both microgrids. The aim behind this EMS is to take advantage of the photovoltaic (PV) power generation surplus to supply the thermal microgrid.

The LNEG's pilot building in Lisbon (Portugal), which is equipped with an electrical microgrid composed of batteries and PV solar panels and a thermal microgrid which consist in two subsystems, has enabled the design of computationally-tractable control algorithms based on model predictive control (MPC). The first thermal subsystem has solar collectors, a heat pump and thermal storage tanks. The second thermal subsystem

BARRIERS/DIFFICULTIES ENCOUNTERED TO OVERCOME

A) ABOUT THE DESIGN AND VALIDATION OF COMPUTATIONALLY TRACTABLE THERMAL EMS ALGORITHMS.

Precise modelling of the thermal behaviour of the system is quite difficult without penalizing computation time.

Real data are needed to validate the models but, in some cases, such data are missing. Regarding the data provided by LNEG, which are globally consistent, a few data are missing and some key quantities (the temperature of the fluid passing through the solar collectors, its volumetric flow rate and the air flow rate in the fan coil units) are not measured, once the monitoring campaign was designed for energy efficiency assessment, not validation of models.

Generalizing the developed models and the proposed automatic control strategies to other case studies is not an easy task since the energy production and storage systems have specific characteristics and constraints.

supplies heat to different rooms of the building via fan coil units, taking advantage of the heat coming from the first thermal subsystem. All the components of the LNEG's thermal microgrid, as well as the thermal zones in the building, have been modelled.

Two MPC strategies – the first one is optimization based, which is computationally extensive, whereas the second one is optimization free – have been designed and compared to a proportional-integral-derivative/rule-based (PID/RB) control strategy.

All strategies successfully take advantage of the PV power generation surplus, which validate the way multi-energy microgrids are managed. However, regarding this aspect, the PID/RB control strategy is less efficient than the two MPC strategies.

In addition, these control strategies reduce energy consumption, while perfectly ensuring users' thermal comfort, something that the PID/RB control strategy is not always able to do.

With both MPC strategies, the economic cost and carbon dioxide emissions are reduced and the system constraints are satisfied. The optimisation-based PEMS has slightly better performance than the optimization-free PEMS but has a huge computation time, making the optimization-free PEMS the best choice for in-situ implementation.

B) ABOUT MICROGRID ISLANDING MANAGEMENT.

In addition to the algorithms developed for thermal energy and thermal comfort management in public buildings, UPVD/PROMES-CNRS has developed an algo-

Developing energy management strategies capable of handling various scenarios and configurations is not an easy task.

Human behaviour and its impact on energy efficiency in buildings is hard to handle.

Achieving the best compromise between performance and computation time (model complexity) is fundamental to producing good results when developing algorithms, in particular algorithms based on model predictive control.

B) ABOUT MICROGRID ISLANDING MANAGEMENT.

LNEG's thermal resources are not sufficient to cover the whole heat demand in case of islanding. That is why the air temperature setpoint in the different rooms of the building has to be decreased to a lower value so that the thermal microgrid can satisfy heat demand using the available PV power generation surplus.

C) ABOUT FORECASTING ENERGY CONSUMPTION AND ELECTRICITY TARIFFS.

Large datasets are needed when machine or deep learning techniques are used.

Pre-processing the data, which is not an easy task, is needed to achieve good training results and sufficient generalization ability.

rithm to the predictive management of energy resources in hybrid (thermal and electrical) microgrids operated in islanded mode.

Using this algorithm, the islanding ability of the LNEG's hybrid microgrid has been evaluated. A PID/RB control strategy is used as a reference strategy. As an interesting result, the thermal constraints are for the most part satisfied during islanding when using the predictive strategy, something that the PID/RB control strategy is not able to do. The LNEG's electrical microgrid is self-sufficient in terms of energy resources.

C) ABOUT FORECASTING ENERGY CONSUMPTION AND ELECTRICITY TARIFFS.

ENSMA has developed forecasting algorithms with the help of IST for energy consumption and electricity tariffs. UPVD/PROMES-CNRS has developed algorithms for global horizontal irradiance (GHI) forecasting. PV power generation forecasts are inferred from GHI forecasts. All the developed algorithms are machine-learning-based (deep artificial neural networks are for instance used) and computationally tractable. Forecasting accuracy is satisfactory for all quantities. The data used to train and validate the different models are pre-processed for corrupted data and outliers to be removed.

IST ALAMEDA CAMPUS PLANT EXPERIENCE.

The most relevant results of IST Alameda campus pilot plant (Technical University of Lisbon) in Lisbon, is to be described here thus, to add a view of the feasibility of each result and to indicate difficulties and barriers to overcome those results. Alameda campus is not explicitly a pilot of the IMPROVEMENT project. However, it is a set of public buildings with some critical laboratorial facilities for teaching and research, and during the development of the IMPROVEMENT project, the campus had planned some interventions in the thermal and electrical networks. In this way, its analysis is done to identify the feasibility and barriers that public buildings have in regular socio-economic context outside a specific project like IMPROVEMENT.

RELEVANT FINDINGS AND RESULTS

A) ABOUT THE INSTALLATION OF SOLAR THERMAL SYSTEM IN THE CAMPUS SPORT FACILITY.

The IST project aims to replace the consumption of electricity to generate hot water for showers in the locker rooms. Throughout the day, the sport facilities are used by students that belong to different university sports teams. Self-consumption based on solar thermal systems was estimated to be an interesting option to reduce energy bill and to bring the sports facilities of the campus closer to the concept of nZEB.

B) ABOUT THE INSTALLATION OF SOLAR PV PLANT IN THE CAMPUS SPORT FACILITY.

The IST project also aims to install a 0,65 MW solar PV plant to generate electricity for the campus for self-consumption. The Alameda campus consumes more than 14 GWh of electricity per year, with a base power demand throughout the year of 800 kW. All the buildings are connected in a ring-distribution grid

BARRIERS/DIFFICULTIES ENCOUNTERED TO OVERCOME

A) ABOUT SOLAR THERMAL SYSTEM ISSUES.

The intervention was done at the end of 2019. The main difficulty was that due to the CoVid-19 pandemic. For two years (until the end of 2021) the use of the facility was very scarce. Then, the pandemic changed the usage patterns of the locker rooms, especially in the evening, where users tend to leave the facilities without showering, the overall, the demand is significantly lower than expected.

When solar thermal systems are underused, there is an additional thermal stress in the whole installation, as heat is not dissipated. In this way, the collectors, valves, and the insulation of the piping system maintenance is much higher.

The economic feasibility of the project will not be reached. Before the installation it was expected to be above 10 years, but with the underusage and increasing maintenance costs, the breakeven point is not expected to be achieved.

with one connection point to the distribution network at medium voltage. The peak consumption of 3,5 MW is reached in summer times.

B) ABOUT SOLAR PV SYSTEM ISSUES.

The main barrier is the initial investment (estimated to be around 500k€) but more than this is the public financing context, where many public agencies, including universities do not have the autonomy to perform this type of investments with the authorization of central government. Furthermore, the way the public procurement regulation is done takes a significant amount of time. Although IST is using a public fund for public building energy efficiency renovation of buildings, supported by the European Investment Banking which follows the lines of an energy performance contract (the loan is paid based on the savings), after three years the plant is not in operation yet.

In the case of IST campus, where some buildings are classified as heritage, it is not possible to take advantage of the full area of the buildings to install PV systems, so the plant is smaller than required.

3. Recommendations and proposals.

Results of the experiences collected in the pilot plants and testing laboratories were subsequently fed with a study of the state of the art in regulatory and market framework, both for potential buildings receptors of IMPROVEMENT solutions and the technologies involved in them.

Some of these results highlight the need to develop a series of recommendations and proposals to be addressed before bringing the IMPROVEMENT system to market.

ON ASPECTS RELATED TO BUILDING.

The regulatory scenario is becoming increasingly demanding in terms of building and sustainability. **The promotion of quality seals for construction has become a key tool to anticipate future demands.** Buildings environmental certifications have their origin in the need for the building sector, to accelerate its change towards sustainable practices. To put it briefly: what is not defined cannot be measured, what is not measured, can't be improved, if it cannot be improved, it will eventually degrade.

A sustainability certification **gives a building great prestige,** increases its value, leads to greater long-term conservation and, this translates into lower energy consumption, achieve healthier spaces to live and work, while reducing operating costs and a lead to much more sustainable and respectful construction processes of what is required by law.

In the certification process, the certification body issues the certificate after carrying out a control of the building's environmental data. The certifier, apart from preparing this data, can intervene throughout the process to provide environmental advisory.

The **European Directive on the Energy Performance of Buildings** *(EPBD NZEB),*[2] binding on all EU states, stipulates that from 2021 all new buildings must comply with the nZEB standard. **This requirement applies already from 1 January 2019 to public sector buildings.** Technology developed in the IMPROVEMENT project can make it possible to achieve these standards.

In buildings where the IMPROVEMENT solutions will be implemented, both the initial energy-state certificate and the improved energy-state

2. DIRECTIVE (EU) 2018/844 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency

certificate will be necessary. They make it possible to compare initial and final values of energy consumption and demand, to justify compliance with the requirements required to be beneficiaries of energy grants.

Among all the sustainable building certificates, **LEED** and **BREEAM** are the two most well-known and internationally widespread sustainable building certificates. They are the two most successful thanks to their recognition, adaptability, and market penetration. Any type of building can be certified under both systems, whether it is newly created or existing one, and for any type of use: universities, shops, offices, hospitals, homes, sports fields, logistics warehouses, housing blocks, etc.

In Spain, the **VERDE** certification is adapted to Spanish regulations. It contributes to accomplish with sustainability measures in buildings by evaluating environmental, social, and economic aspects. It gives maximum importance to the Life Cycle Assessment of buildings. It is aligned with **Level(s)**[3]- that includes sustainability indicators for construction established by the EU -, with the **Sustainable Development Objectives (SDO),** - getting to know the contribution in each of them -, and with the **European Taxonomy.**

Beyond the technical aspects that determine the energy certificate of a building, there are other important aspects to consider, which intervene in the integration of the IMPROVEMENT system in public buildings with critical loads. All these proposals are set out below:

1. The efficiency of this type of solutions highly depends on the site conditions (e.g., availability of renewable resources, lone building or surrounded by others,...) which may not be suitable in the location where the building of interest is located, therefore it is decisive for the optimal operation of the system, **to previously carry out an analysis of the environmental characteristics and infrastructures of the environment in which lo locate the IMPROVEMENT proposal.**

2. **Development of a taxonomy of critical loads in public buildings** to develop a strategy for the implementation of microgrids, prioritizing according to the criteria of this taxonomy.

3. **Public support** for the development and availability of electronic tools and software for energy management and building control nZEB.

4. **Minimization of administrative and bureaucratic barriers involved in awarding interventions in public buildings,** mainly when the necessary funding is available.

3. https://environment.ec.europa.eu/topics/circular-economy/levels_en

5. **Funding support is highly needed, mainly when considering building refurbishment** where high costs are expected. In the implementation of this type of solutions governments at all levels need to be highly involved. Specific regional grant programs for energy building refurbishment are vital for the inclusion of IMPROVEMENT technologies.

6. **Implementation of EMS in buildings as an ideal tool** for:

   - The improvement of energy efficiency.
   - The reduction and control of energy costs.
   - Legal compliance with regulatory requirements.
   - Reduction of CO_2 emissions and carbon footprint.
   - Improvement public government reputation and image.
   - Assuring energy security.
   - Business opportunities and business credentials.

   and the best guide to implement an EMS is offered by **ISO 50001:2018** Energy management systems - Requirements with guidance for use.

7. **Promotion of the implementation of the energy certificate,** also in those cases in which it is not mandatory to have them. It is proposed to require the need for a certificate when:

   - **Financing of rehabilitation of buildings are available.** The energy certificate could be a document required together with the rest of the documentation necessary for the application of public aid for the rehabilitation of buildings.
   - **Building refurbishment can benefit from local tax exemptions.** Energy certificates could serve as proof to achieve tax credits.

8. **Implementation of a certification system** like the Spanish VERDE seal in the other SUDOE regions involved in the project, since almost half of the registrations of the VERDE certification mentioned in 2021 in Spain, had as promoter a public administration or an entity dependent on them.

9. Enable **mechanisms to disseminate IMPROVEMENT system solutions in a clear way** for decision makers and common citizen to know the existence of this type of solutions and correspondent funding schemes.

10. **Interest shown by companies in this type of solutions for their buildings is limited.** Many companies consider that the implementation of power-quality solutions is very expensive, as they try to save money in their usual activities. They usually disregard these proposals. That is way **it is so relevant to activate the implementation of IMPROVEMENT system on public buildings with critical loads,** as they will work as leverage to wake up private interest on these technologies.

ON ASPECTS RELATED TO TECHNOLOGIES AND EQUIPMENT.

To offer recommendations and proposals to aspects specifically related to the components included in the IMPROVEMENT solution, the grouping of these has been considered in the sections set out below.

This grouping based on the components displayed in the proposed microgrids ranges from aspects that can be improved at the level of technical configuration, based on the experience and resolution of bottlenecks detected by the pilots, to the legal and regulatory aspects, accreditation, quality marking, financing for the final market implementation and environmental aspects.

Technical aspects.

EQUIPMENT AND SYSTEM ARCHITECTURE.

- **On equipment breakdowns during operation.**
    - Upon results achieved in pilots, different design or configurations of the installations should be established to fine-tune system operation and eliminate faults.
    - Adequate operating procedures must be established based on the "know how" acquired with the technologies used in this project.
    - A preventive maintenance plan specific to the technology used must be designed.
- **On hydrogen equipment to achieve operating parameters.**
    - Planning a pre-conditioning and operation of the equipment.
    - The design of a preventive maintenance plan fitted to the used technology.

- **On the limitations in the response time of the alkaline electrolyser.**
  - Evaluation of technological alternatives for the electrolysis process such as PEM technology (Proton Exchange Membrane) if greater production flexibility is required.
- **On high electricity consumption during the hydrogen compression phase.**
  - Assess whether it is possible to store at a lower pressure. Limiting factor in this case is the storage tanks available space.
  - Cover the electrical expenses of compression with renewable energies.
- **On the high equipment cost related to the hydrogen cycle.**
  - Expect further development of these technologies planned for the coming years.
  - Emergence of new economies of scale.
- **On the operational difficulties with PCM.**
  - Selecting other PCM alternatives: PCMs of another nature such as the immobile ones used in the cold part. They have shown an adequate behaviour with not as many operational problems as the “slurry” type.
  - Carry out an in-depth adaptation of the installation: which would imply changing instrumentation and other equipment to adapt them to the fluid, as well as the redesign of the installation itself, due to the possible need to add continuous agitation in the storage tank or to study other possible alternatives.

COMMUNICATIONS PROTOCOLS FOR MICROGRID MANAGEMENT.

- An adequate and robust communication protocol is needed.
- Search for equipment with communication language optimized for this type of applications.
- Design of a maintenance plan.

CONTROL AND FORECASTING ALGORITHMS.

- Real-time access to data, hardware devices, and software services are crucial to the in-situ implementation of the IMPROVEMENT EMS.

- The best solution is strongly site-dependent and related to both the type of equipment to install and the targets of the building owner in terms of electricity savings and thermal comfort needs.
- Machine-learning-based algorithms need large datasets so that an efficient training phase can be performed; this impacts the implementability of such solutions negatively (prior to the implementation of the solutions, enough data must be collected).
- Algorithms must keep running to improve. Poor performance has a negative impact of the dissemination of the solution. (e.g., due to difficulties associated with specific characteristics or constraints).
- Computationally intractable algorithms are hard to implement in situ.
- Achieve an optimal cost vs performance control algorithm. A too expensive solution is hard to disseminate, even if performance is high.

Aspects of legalization, accreditation, and standardization of microgrids and their components.

- First, it is necessary to **legally unify the definition of 'microgrid',** clarifying the legal and regulatory requirements involved, permitted technical schemes, their ownership, etc.

- **Progress in maturity of technologies needs to be set at an early stage.** The technical equipment and components of the architecture of the IMPROVEMENT microgrids have different levels of technological maturity or Technology Readiness Level (TRL). This hinders its development and implementation. The higher the TRL, the more experience and knowledge and the greater the number of certifications.

- **European EN (CEN, Cenelec, ETSI committees) and harmonized standards**[4] are generally voluntary. Manufacturers certify their products with these standards to demonstrate that their products and services possess a certain level of quality, safety, and reliability. It is suggested that for technical specifications for public contracts, minimum standards should be compulsorily.

- Products with a harmonised EN standard must obtain the CE Marking. The **CE Marking**[5] shows that the manufacturer has evaluated the product and considers that it meets the safety, health and environmental protection requirements demanded by the EU. The CE marking is mandatory for certain products, to be marketed in the EU,

4. https://europa.eu/youreurope/business/product-requirements/standards/standards-in-europe/index_es.htm
5. https://europa.eu/youreurope/business/product-requirements/labels-markings/ce-marking/index_es.htm

manufactured anywhere in the world. It ensures that the product complies with current European regulations that affect it. **It is recommended for the equipment used in the IMPROVEMENT system to be previously certified by the supplier.** The Energy Label and the documentation associated with **Electromagnetic Compatibility**[6] are needed to sell the product in the EU. Therefore, **the equipment of the IMPROVEMENT system should also have them.**

- Should there be equipment which does not have accredited compliance with current regulations or CE marking but needed for plant configuration, they could yet be certified. There are entities approved by the International Accreditation Infrastructure conformed by the European Co-operation for Accreditation (EA), International Laboratory Accreditation Cooperation (ILAC), and International Accreditation Forum (IAF), to obtain accreditation for IMPROVEMENT technologies to be exported, reducing barriers to access foreign markets.

Aspects related to public financing and support.

- As said for buildings, funding support is highly needed. Governments need to be very involved, to understand and support to IMPROVEMENT solutions. Public institutions should offer specific public support to microgrid management and optimization systems based on machine learning, IoT, or four-wire inverters formulations, promoted within the IMPROVEMENT system.

- Public administrations agreements to support optimized purchase/sale of electricity to and from the utility grid.

- Public support for the development of electronic tools and microgrid control software addressed to balance the distribution power grid and allowing them to perform other tasks that increase the efficiency, security and reliability of the entire utility grid and electricity markets.

- Public support for **regulatory sandboxes** by regional and national governments, allowing limited pilot projects, laboratories, and experimental operations to allow restricted testing of the IMPROVEMENT system in public buildings with critical loads. Regulatory sandboxes are test benches consisting of experimental environments where tests or trials can be carried out, applying regulatory exemptions in a safe and controlled manner, to favour innovation, research, and regulatory improvement, always guaranteeing the quality and security of supply, the absence of risks for the electricity system and its

6. Electromagnetic Compatibility (EMC) Directive affecting electrical or electronic fixed appliances or installations. Aims to ensure that all electrical or electronic products are electromagnetically compatible with each other.

economic and financial sustainability, as well as the protection of final consumers.

- The characteristics of the product in the pre-commercial phase make the IMPROVEMENT System an ideal project to be financed through **innovative public procurement (IPP).** IPP is a public procurement mechanism to promote the development of new markets which has the public administration as its reference client. This public-private collaboration formula is implemented through tendering, contracting or public procurement processes. Hence, public agencies can incorporate innovative solutions to improve public services, and to find new and better management solutions that allow more efficient responses to the needs of citizens, while positioning the business sector at the head of business innovation processes. It would be desirable to implement this mechanism in those regions/states where it does not exist, so that it becomes a lever for the implementation of IMPROVEMENT.

- The **EaaS (Energy-as-a-Service)** model allows to improve efficiency and productivity without the need for any initial investment, to achieve the objectives of cost, resilience, reliability, and sustainability for the clients. This model shifts the “burden” of installing, managing, and financing energy to a third company, which builds, designs, and manages the energy systems. Energy as a service offers a flexible ownership structure and may represent the best opportunity to reap the benefits of a the microgrid integration. It is essentially a power purchase agreement (PPA) model. the customer pays a monthly fee for operational expenses and a third party owns the microgrid. In this way, there is no need to invest capital and financial risk is reduced.

Environmental aspects.

- **Reduction in waste generation:** regulatory efforts are intensively directed towards increasing waste recyclability in Europe. A good example of this is the recent announcement of new EU battery legislation. The IMPROVEMENT system could consider the way in which the equipment and materials purchased for building refurbishment are installed, as well as their endurance and the possibility of their disassembly at the end of their life cycle. Documents such as a product’s declaration of performance (DoP) sheet help define these aspects.

- **Circular economy:** The European Commission also intends to extend the Eco-design Directive to promote circularity in industrial processes, the use of digital technologies for resource tracking and the achievement of an EU environmental certification mark. Circularity is also reinforced by mechanisms such as the **Environmental Product Declaration (EPD)** that incorporates environmental information on products in part of their life cycle, as well as information on the waste they generate.

→ **The Eco-design Directive:** The ErP (or Energy Related Product) defines the minimum levels of energy efficiency, maximum NOx emissions, noise generation, minimum level of insulation accepted in DHW accumulators, without which it would be impossible to obtain the CE marking to market certain products in Europe. The Eco-design Directive is complemented by the Energy Labelling Directive (ELD) or energy performance of products, which sets out energy consumption requirements and efficiency classes and their label classification from G to A+++ for them.

→ **DNSH principle:** The DNSH (Do No Significant Harm) principle is a condition defined by the Commission that requires a self-assessment to ensure that the investment or reform does not adversely affect one, or several, of the six environmental objectives defined in Regulation 2020/852[7].

→ The **EU Taxonomy of Sustainable Economic Activities Regulation:** A new European regulation that proposes a clear and transparent classification system to identify which activities are environmentally sustainable. This initiative has been proposed as a key instrument for Europe to achieve its ambitious climate and environmental goals, and for future generations to enjoy a more liveable and sustainable world.

7. REGULATION (EU) 2020/852 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 18 June 2020 on the establishment of a framework to facilitate sustainable investment and amending Regulation (EU) 2019/2088.

4. IMPROVEMENT implementation roadmap.

On this chapter a proposal for a roadmap to the placing on the market and its implementation in new or existing public buildings of the IMPROVEMENT system and its components is described. This roadmap can guide the process on areas where action is needed:

- The necessary certification framework for public buildings with critical loads and the legalization that proceeds for its reversion to nZEBs, as well as for the legal incorporation of the subsystems that shapes the IMPROVEMENT system.

- The necessary certification framework for the technologies covered by the IMPROVEMENT system and the proposed kind of microgrid itself.

- In short, this chapter presents a series of roadmaps with temporary milestones, to certify and put on the market the products included in the technology involved in the IMPROVEMENT system addressed to public buildings with critical loads.

ROADMAP FOR THE LEGALIZATION OF NZEB WITH ENERGY MICROGRIDS AND CRITICAL LOADS.

It is necessary to address this issue due to the lack of administrative, technical, and legal regulation required for the **installation of technologies in tertiary buildings located in nonindustrial areas.**

The modification of the legislative framework is usually motivated by a political line or by a market need. In this case, the political line at international, European, and national level, committed to decarbonization, is favourable for the regulatory modification in terms of the promotion of the technologies involved in this project.

Before proposing the phases and actions that would make the legalization of the IMPROVEMENT system viable in Europe, it is necessary to address a series of key aspects prior to the market launch of the system:

1. The boundaries of the project and the cross-border cooperation of the actors involved in the development of the IMPROVEMENT system and the project business model must first be established.

2. Integration of legislation and regulations for the technologies uses present in the IMPROVEMENT system that are not binding for buildings settled non-industrial zones (generation systems with renewables, heat exchange systems (e.g. geothermal energy), storage systems and infrastructures with hazardous materials, electrolysers and fuel cells, ...)

3. **Exploring the creation of a market for thermal energy (district heating/cooling)** in countries where it does not exist.

4. **Promote the adoption of new business models for services that the microgrid can provide to other energy networks: sale of guarantees of origin, auxiliary services** (voltage support, ramp support, reactive power supply, etc.), which themselves will produce additional revenue streams beyond simple energy supply. Energy system regulators should also structure rules that allow for a **fair allocation of the costs of interconnection and maintenance of transmission and distribution networks.** Economic incentives would even be needed **to promote the integration of microgrids into network security of supply measures and long-term system planning.**

As previously stated, the European Directive on the Energy Performance of Buildings (EPBD NZEB)[8], binding on all EU states, stipulates that from January 2019 all new public sector buildings must comply with the nZEB standard.

The technology developed for the IMPROVEMENT project can allow these standards to be achieved. The ***differential*** aspect of the project that adds value as a business model is that the development of proposals is aimed at covering the energy needs that are critical in public buildings, as opposed to what could be called ordinary loads.

The roadmap for the legalization of nZEB buildings with critical loads in which the IMPROVEMENT system can be implemented can be established in the following phases:

Phase 1 Defining the taxonomy framework for critical load buildings.

This phase involves the:

- Analysis of existing regulations that set requirements for public buildings with critical loads.

7. DIRECTIVE (EU) 2018/844 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency.

- Development of regulations that harmonize and set requirements for public buildings with critical loads when missing.

- Setting out a technical standard with taxonomy for buildings with critical loads.

Phase 2. Harmonization of the EPBD NZEB.

Buildings in which the IMPROVEMENT system is to be integrated must be nZEB buildings. In this sense, there must be a technical standard for all SUDOE regions, specifying the requirements that a building must meet to be certified as nZEB. Therefore, a harmonized technical standard with nZEB technical requirements for all SUDOE regions is needed.

Phase 3 Harmonized definition of the concept of microgrids in buildings.

Legally unify the definition of 'microgrid', to clarify the legal and regulatory requirements involved, the technical schemes allowed, their ownership, etc.

A joint definition of microgrids for the provision of cold, heat and electricity for public buildings with critical loads under quality assurance conditions should be proposed and agreed.

Phase 4 Implementation of a nZEB certification seal systems similar to the Spanish VERDE certification seal.

- Review of certification seals in the SUDOE region like the VERDE seal.

- Design and implementation of nZEB certification seal.

Phase 5 Simplification and harmonization of administrative procedures for the implementation of microgrids in public buildings.

- Analysis of administrative procedures for the purchase of products and services in public buildings.

- Simplification and harmonisation of administrative rules for public tenders and other financing mechanisms for the purchase of products and services involved in the integration of microgrids.

Phase 6 Implementation of economic and fiscal support schemes for:

- obtaining nZEB building certificates,
- the design of actions for the transformation of public buildings with critical loads in nZEB buildings through microgrids, and,
- the implementation of microgrids in public buildings with critical loads to transform them into nZEB.

The roadmap for this section is not provided due to the difficulty of estimating the duration of the phases indicated, since their execution involves the intervention of numerous national and international organizations.

ROADMAP FOR THE IMPROVEMENT SYSTEM CERTIFICATION.

The roadmap for the certification and placing on the market of all equipment and systems included in the technology proposed by the IMPROVEMENT project can be settled in the following phases:

Phase 1. Technical development of components and systems in simulation environment (TRL 6).

DESCRIPTION.
The IMPROVEMENT system and its components (equipment, control and power management systems and communications) must reach commercial maturity from their current state in different TRL states to at least *TRL 6 System model or subsystem or prototype demonstration in a relevant environment.*

OBJECTIVE.
Development and validation of the IMPROVEMENT system until reaching the TRL 6 for equipment and components.

ACTIVITIES.
A1. Completion of the analysis protocol of the system and its components in field tests and trials of CNH2 and LNEG pilots for its future implementation on a real scale.

STARTING.
Month 1.

ESTIMATED DURATION.[9]
Two years.

MILESTONES.
M1. Validation of the IMPROVEMENT system in a relevant environment.

Phase 2. Demonstration and validation of the IMPROVEMENT system in real environment (TRL 7).

DESCRIPTION.
Actions for the implementation and validation of the IMPROVEMENT system and its components (equipment, control and power management systems and communications) until achieving level TRL 7 Validation of the system in a real environment.

OBJETIVE.
Implementation and validation of the IMPROVEMENT system until TRL level 7 is reached and the first prototype or demonstrator is available at a non-tradable level.

ACTIVITIES.
A1. Implementation of the IMPROVEMENT system in real environment and its validation.

STARTING.
Month 25.

ESTIMATED DURATION.[10]
Three years.

MILESTONES.
M1. Validation of the IMPROVEMENT system in real environment.

Phase 3. Equipment certification in a real environment (TRL 8).

DESCRIPTION.
The equipment and components that are part of the IMPROVEMENT system technology must be certified with the CE marking, Electromagnetic Compatibility and have the energy efficiency label.

9. The estimated durations at all stages depend largely on the decisions made regarding certification. Timing of the certification body will be the one to mark the duration of the activity.

10. The estimated durations at all stages depend largely on the decisions made regarding certification. Timing of the certification body will be the one to mark the duration of the activity.

Equipment and components used in the CNH2 pilot plant.

- Photovoltaic generator.
- Eolic generator.
- Inverters.
- Polymeric fuel cell.
- Alkaline electrolyser.
- Lithium-Ion batteries.
- Supercapacitor battery.
- Geothermal boreholes.
- Geothermal heat pump (water - water).
- Building heat pump (air - water).
- PCM storage. Heat system.
- PCM storage. Cold system.
- Hydrogen storage tanks.
- System integration components:
    - Heat exchangers housing/tube.
    - Plate heat exchangers.
    - Hot and cold-water storage tanks.
    - Inertial storage tanks.
    - Hydraulic pumps.
    - Screw pumps.
    - Pipes.
    - Measurement, control, and instrumentation systems.

Equipment and components used in the LNEG pilot plant.

- Photovoltaic generator.
- Eolic generator.
- Inverters.
- Batteries.
- Heat pump (air – water).
- System integration components:
    - Sistemas de medición, control e instrumentación.
    - Hot and cold-water storage tanks.
    - Inertial storage tanks.
    - PCM boards.
    - Measurement, control, and instrumentation systems.

OBJETIVE.
Certification of IMPROVEMENT system equipment.

ACTIVITIES.
A1. Identification of the certifications that each equipment and component must comply with.

If a non-certified equipment or product should be integrated in the microgrid, then:

A2. Identify certification bodies to certify uncertified products.

A3. Equipment or product certification.

If previously certified equipment and components should be preferred as to its integration in the microgrid, the activity to carry out should be:

A4. Purchase of previously certified equipment and components.

STARTING.
Month 61.

ESTIMATED DURATION.[11]
Six months, if it is necessary to certify any equipment or component. **If all equipment and components were certified, it would not be necessary to undertake this phase.**

MILESTONES.
M1. Certified products.

Phase 4. Certification of control and power systems (TRL8).

DESCRIPTION.
The control and power systems that are part of the IMPROVEMENT system technology must be certified with the CE marking, Electromagnetic Compatibility label and have the energy efficiency label.

OBJECTIVE.
The control and power systems must be certified in accordance with current regulations and in an appropriate way to be marketed in Europe. Correct integration with the technological components of the microgrid must be ensured.

11. The estimated durations at all stages depend largely on the decisions made regarding certification. Timing of the certification body will be the one to mark the duration of the activity.

ACTIVITIES.
A1. Certification of the control system. Identification of the certifications provided by manufacturer. Starting of a certification process or acquisition of a certified control system in case necessary certification was needed.

A2. Certification of the power system. Identification of the certifications provided by manufacturer and, in case needed, start a certification process, or acquire a certified control system.

STARTING.
Month 61.

ESTIMATED DURATION.[12]
Six months, if system certification was needed. **If all systems were certified, it would not be necessary to undertake this phase.**

MILESTONES.
M1. Certified control system.
M2. Certified power system.

Phase 5. Certification of communications, IT systems, IoT platform (TRL 8).

DESCRIPTION.
Communications, IT systems and IoT platform must comply with all current regulations and European standards.

OBJECTIVE.
Communications, IT systems and the IoT platform must comply with current regulations and standardization in an appropriate way to be marketed in Europe.

ACTIVITIES.
A1. Certification of all communications.

A2. Certification of IT systems.

A3. Standards-compliant IoT platform configuration.

STARTING.
Month 61.

12. The estimated durations at all stages depend largely on the decisions made regarding certification. Timing of the certification body will be the one to mark the duration of the activity.

ESTIMATED DURATION.[13]
Six months, if it is necessary to certify any system. **If all systems were certified, it would not be necessary to undertake this phase.**

MILESTONES.
M1. Certified communications.

M2. Certified IT systems.

M3. Certified IoT platform.

Phase 6. Successful system testing in real environments, and microgrid certification (TRL 9).

DESCRIPTION.
The IMPROVEMENT microgrid supported by renewable energy sources with combined heat, cold and power generation, together with hybridized storage systems, must be certified. To do this, it will be necessary to select certification bodies, request quotes and begin the certification process.

OBJECTIVE.
Certification of the microgrid operation according to the expected performance, functional and technical characteristics.

ACTIVITIES.
A1. Microgrid certification.

STARTING.
Month 67.

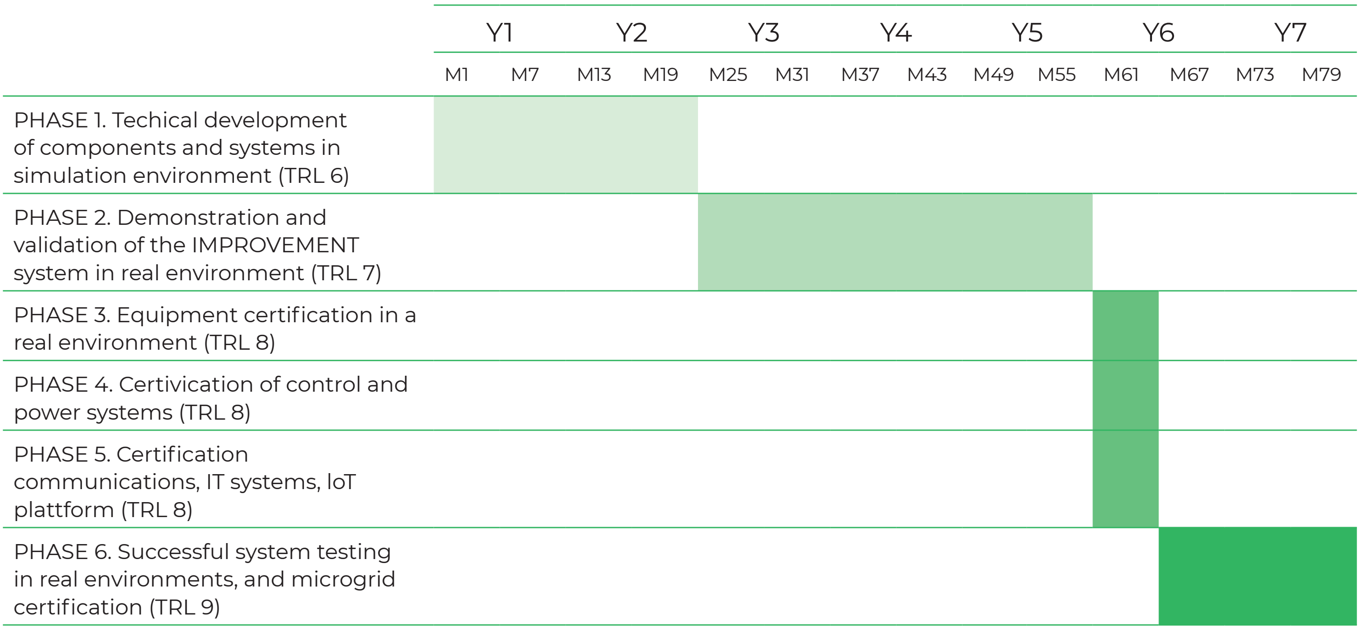
ESTIMATED DURATION.[14]
18 months. Depending on the times estimated by the certification authority.

MILESTONES.
M1. Certified microgrid.

13. The estimated durations at all stages depend largely on the decisions made regarding certification. Timing of the certification body will be the one to mark the duration of the activity.

14. The estimated durations at all stages depend largely on the decisions made regarding certification. Timing of the certification body will be the one to mark the duration of the activity.

A timeline for this roadmap below:



5. Conclusions, lessons learned and potential of the IMPROVEMENT system.

The development of the tasks carried out by the beneficiaries of the IMPROVEMENT project, together with the collaboration of the associated entities, has led to advanced experience and knowledge about the equipment that is part of the technological solution for energy generation and storage, the control and power systems, and elements that make possible the optimal and continuous operation of the microgrid.

The IMPROVEMENT project has as its scope the SUDOE region, an area highly vulnerable to the effects of climate change, with high needs for air conditioning in summer and heating in winter. But it is also called to propose solutions in public buildings with critical loads in countries with similar climatology.

This last section offers a series of conclusions, lessons learned and a proposal to expand the functionalities of the current IMPROVEMENT project, aligned with compliance with current regulations.

CURRENT FAVOURABLE INTERNATIONAL REGULATORY AND FINANCIAL FRAMEWORK.

- Winds are favourable to the international dissemination of this proposal. The European legislative framework marks a path that can be materialised in the Recovery, Transformation and Resilience plans, whose components are fully coherent to the incorporation of the proposals and objectives of the IMPROVEMENT project.

- The current instability of the international geopolitics that reduces the availability of fossil energy resources on which Europe depends, spurs the need to facilitate the means for energy independence and to increase strategies that favour energy saving and efficiency. The volatility of electricity prices is a reality, and to this is added the urgency represented by climate change and the need to decarbonize the economy.

- The promotion of projects to improve energy infrastructures, smart grids, the deployment of flexibility and storage technologies, the need to improve the construction and rehabilitation of existing buildings to reduce rampant energy poverty, support for new business models and innovative projects in smart sector integration, ... they are on all energy policies agendas.

- The Clean Energy for All Package which includes legislative provisions to regulate energy storage, the European Battery Alliance, the EU Hydrogen Strategy launched together with the European Clean Hydrogen Alliance; all initiatives aimed at promoting energy storage technologies in Europe.

- Not only would the IMPROVEMENT system solve the issue of energy supply, the development of hybrid storage systems and the development of active and passive mechanisms to reduce the energy demand of buildings, but it would also comply with other regulatory obligations of the environmental spectrum (waste reduction, circular economy, eco-design, DNSH principle, Taxonomy of sustainable economic activities).

- In this international geopolitical context and the current regulatory framework are evidently propitious. In short, **the systems proposed for the IMPROVEMENT project are fully aligned with the current needs of decarbonization of buildings, a key issue to meet the objectives to 2030 and 2050.**

NICHE FOR THE DEVELOPMENT OF NEW TECHNOLOGICAL PROPOSALS.

- Extending batteries and other equipment to a second life and recycling some of their materials for the manufacture of new components is a challenge as well as an opportunity for new business models. But beyond this, **the IMPROVEMENT system has developed an innovative management strategy that increases the resilience and durability of the equipment,** while guaranteeing the supply in quality and quantity. It can certainly be credited with having considered the circular economy in its conceptual design.

- The IMPROVEMENT system makes it necessary to develop and introduce **cybersecurity protocols** and devices that allow interoperability in the electrical infrastructure, to add greater **security** in microgrids in terms of their architecture, thus reducing the **vulnerability** of this due to technical and service problems.

- The IMPROVEMENT system incorporates submetering, a very innovative formulation of high-resolution monitoring of equipment that in the future will more than likely be the norm.

- The use of smart grids and the Internet of Things (IoT) in the IMPROVEMENT system, opens a door to a new way of optimizing energy microgrids, integrating a learning system that collects information on consumption, generation, storage, from the utility grid, in an autonomous and automatic way, through predictive algorithms.

NEW FEATURES FOR THE IMPROVEMENT SYSTEM.

Below are shown proposals for new features for the IMPROVEMENT system that can increase its added value based on current regulations and market trends.

NEW FEATURES.

The IMPROVEMENT project could develop electric vehicle charging functionality.

Creation of the Demand Aggregator figure if the IMPROVEMENT project technology were installed in a significant number of public buildings (and/or buildings with critical energy loads), a new actor, a Demand Aggregator, could be added to participate in the electricity markets.

IMPROVEMENT Public Building Energy Network. Buildings using IMPROVEMENT technology could act as Grid-interactive Efficient Building (GEB). kind of buildings could share a common Energy Management System so their microgrids could serve as a backup system against power failures in any of the other buildings.

The IMPROVEMENT system incorporates a very innovative formulation of high-resolution monitoring of equipment: **submetering**, which in the future will more than likely be the norm.

The IMPROVEMENT project could promote **future requirements regarding the time regulation for the exterior lighting of buildings** and the luminous level of, infrastructures and roads, whether they are critical loads.

The IMPROVEMENT project could be an optimizing element **for district, heating and cooling** in residential buildings.

European Regional Development Fund