MIREO Project: "Comprehensive Methodology for Optimized Energy Rehabilitation"

Annex I. Description of the Challenge

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1. Challenge: Large-Scale Industrialized Energy Rehabilitation System

1.1 Introduction

This document outlines the content of the challenge presented in the Second Open Market Consultation (OMC) for the MIREO Project ("Comprehensive Methodology for Optimized Energy Rehabilitation") launched on 05/06/2025 at this link: https://www.juntadeandalucia.es/haciendayadministracionpublica/apl/pdc-front-publico/perfiles-licitaciones/consultas-preliminares/detalle?idExpediente=248. The project aims to explore innovative solutions for energy efficiency improvements in buildings through industrialized and scalable processes.

Throughout this document, the opportunity to address this challenge is justified, the unmet need that motivates the project is analysed, background information and the state of the art in the field are presented, and the general and specific objectives of the initiative are established. Additionally, the document details the expected functional requirements, estimated budget, and impact indicators to be considered for evaluating the project's success.

Through this Consultation, the contracting authority seeks to inform economic operators of its needs and gather information that will help define the technical specifications for a potential future procurement. The authority considers that the current market does not fully address the project's needs and lacks sufficient knowledge about the feasibility, cost, and other characteristics of new solutions that could be developed to meet these requirements.

The Open Market Consultations are regulated by Article 40 of Directive 2014/24/EU of the European Parliament and of the Council of 26 February 2014 on public procurement, which repealed Directive 2004/18/EC. This regulatory provision has also been transposed into Article 115 of Spanish Law 9/2017, of 8 November, on Public Sector Contracts (LCSP), which implements Directives 2014/23/EU and 2014/24/EU into Spanish law. This law states that:

"Contracting authorities may conduct market studies and consult economic operators active in the relevant market in order to properly prepare the procurement process and inform those operators about their plans and the requirements they will demand for participation in the procedure."

1.2 Justification of the Need for R&D

AVRA requires innovative tools that are currently not available on the market to significantly accelerate and optimize the rehabilitation of residential buildings throughout their entire value cycle. This need is not exclusive to AVRA but affects the entire ecosystem of public and private actors involved in this activity. Its origin lies in the existence of promising technological advances that, although applicable to the sector, have not yet reached the necessary level of maturity for direct implementation.

In this regard, the identified need can be defined as the challenge of bridging the gap between these emerging developments and their transformation into fully operational solutions. Therefore, the objective is to identify high-potential innovations that require further development and technological evolution to become effective improvements in the energy rehabilitation process of residential buildings.

Segmentation of the Unmet Need in the Energy Rehabilitation Value Chain

The unmet need can be broken down into different phases of the energy rehabilitation process, identifying key areas where innovative solutions are crucial to optimizing time, costs, and outcomes.

Diagnosis, Planning, and Prioritization through Predictive Models

Advanced tools are required to enhance the diagnosis, planning, and prioritization of interventions based on multiple criteria. It is essential to have solutions that, given an available budget, can identify the optimal set of buildings to be rehabilitated based on parameters such as:

- Cost,
- CO_2 emissions reduction,
- Improvement of thermal comfort,
- Reduction of energy poverty,
- Support for vulnerable populations, among others.

In this sense, predictive models will play a key role in anticipating the results and efficiencies of interventions. It is necessary to develop tools capable of accurately calculating the required investment, expected benefits in terms of energy efficiency and social well-being, and long-term impact projections.

Project Development

Solutions are needed to drastically reduce the time required for drafting rehabilitation projects and the associated documentation. To achieve this, the following are required:

- Advanced data capture technologies, such as high-precision laser scanning, to generate detailed models of the building.
- Generative artificial intelligence, capable of designing rehabilitation projects automatically based on predefined parameters, promoting collaborative and participatory processes during the design phase.

- Document automation and support tools for architects, optimizing the generation and updating of the documentation necessary for the project's tendering. These solutions will not only streamline document management but also assist professionals in the efficient development of the project.

Construction Solution

It is necessary to develop innovative solutions that optimize construction systems applied to energy rehabilitation, reducing execution times and improving efficacy in terms of thermal insulation, sustainability, and circularity. These solutions must align with the principles of Circular Economy, the DNSH (Do No Significant Harm) principle, and Climate Proofing, which are already incorporated into strategies such as FEDER (European Regional Development Fund) of the Andalusian Government and will be increasingly determinant in project funding.

In this context, the development and scalability of experimental-phase technologies are required, such as:

- Industrialized modular rehabilitation, allowing for reduced intervention times and improved energy efficiency.
- 3D printing and additive manufacturing, applied to building rehabilitation, to develop more sustainable, efficient, and adaptable solutions for different architectural typologies.
- Highly recyclable construction systems, ensuring that materials used can be reintegrated into future construction processes, contributing to circularity and a lower environmental footprint.

Worksite Management

Advanced tools are needed to optimize the control and monitoring of construction execution. Specifically, it is crucial to develop solutions based on:

- Computer vision and artificial intelligence, to detect deviations in real time between the designed project and its actual execution. This will enable more precise and efficient management of ongoing work, ensuring that all involved stakeholders are immediately informed of any changes and can act quickly, reducing delays and optimizing resources.

Evaluation

Innovative solutions are essential for the monitoring and evaluation of the impact of rehabilitation interventions in an efficient, accessible, and low-maintenance manner. These tools must provide accurate information on key indicators such as:

- Energy consumption and its evolution after rehabilitation.

- Thermal comfort, ensuring a real improvement in building habitability.
- Social and environmental impact, including CO_2 emissions reduction and improved quality of life for residents.
- Usability and social sustainability, ensuring that the implemented solutions are intuitive and easy to maintain for users, facilitating efficient use of housing without adding complexity.

Developing and implementing these solutions will close the existing technological gap and promote a more efficient, industrialized, and sustainable energy rehabilitation model, ensuring that benefits are maintained over time without requiring additional efforts from residents.

Need Associated with Design Principles and Criteria

To optimize energy and architectural rehabilitation, it is essential to integrate design principles and criteria in a coherent and effective manner. Currently, their application is fragmented, limiting the impact of interventions. In this context, it is crucial to align solutions with the New European Bauhaus principles, promoting an approach that combines sustainability, inclusion, and architectural quality.

To address this need, the following elements must be considered:

- **Collaboration and Participation**
  - Lack of effective methodologies to involve end-users in the development of solutions tailored to their needs, fostering their participation and ensuring that their opinions and suggestions are considered during the design process.
- **Sustainable Materials and Circularity**
  - Limited use of recycled, recyclable, and low-carbon materials, making decarbonization and sustainability more difficult.
- **Durability and Low Maintenance**
  - Construction solutions that do not guarantee long service life or reduced maintenance needs.
- **Aesthetic Integration and Minimal Intrusion**
  - Difficulty in harmonizing interventions with the urban environment and minimizing their impact on residents' lives.
- **Awareness and Training**
  - Lack of strategies to educate users on the maintenance and efficient use of the implemented improvements.

Addressing these deficiencies will enhance the sustainability, efficiency, and acceptance of rehabilitation projects.

1.3 Identified Problems and Current Situation

AVRA has incorporated the promotion of innovation as an essential objective within its corporate strategy and has extensive experience in participating in and managing innovative projects. Since the approval of its R&D&I Promotion Strategy in 2021, it has developed an Innovation Management System and an Environmental Monitoring and Foresight System, which publishes biweekly bulletins on trends and advancements in rehabilitation. Additionally, it has organized two International Conferences on Innovation and Sustainability in Social Housing (2021 and 2023), further solidifying its leadership in this field.

This commitment has led AVRA to be recognized as an Agent of the Andalusian Knowledge System on January 20, 2022, by the General Directorate for Research and Knowledge Transfer of the Ministry of Economic Transformation, Industry, Knowledge, and Universities. Currently, AVRA is involved in three Horizon Europe projects and is independently developing the nZEISHB Innovative Public Procurement Project (Industrialized Zero Energy Housing System). For this project, AVRA conducted a preliminary market consultation in 2020, which enabled the effective structuring of the subsequent tendering process, recently initiated.

In the field of energy rehabilitation of buildings, AVRA has become a reference point in Spain. Since 2014, it has rehabilitated 9,511 homes in the Andalusian Public Housing Stock, mobilizing an investment of €70 million. Despite these achievements, the challenge remains significant: AVRA manages a housing stock of 75,000 homes, of which 50,000 are rental units, many still awaiting energy rehabilitation.

As recognition for its work, AVRA has received prestigious awards for its recent energy rehabilitation efforts under the REACT EU program:

- EnerAgen Award 2024, Category B - Best Public Initiative in Support of the Energy Transition, for the energy rehabilitation of 1,044 homes in the Public Housing Stock.
- REBUILD REHABILITA Award, Category Energy Rehabilitation in Buildings, highlighting the impact and innovation of its interventions.

These awards reflect AVRA's commitment to sustainability and innovation in residential rehabilitation, reaffirming its leadership in the energy transition and in improving the comfort and efficiency of public housing in Andalusia.

Below, for each phase of the value chain of the rehabilitation process, as well as for the principles and criteria guiding its development, a detailed description of the state-of-the-art technologies and methodologies used in energy rehabilitation is provided, along with the innovative improvements proposed to optimize and transform processes.

Phase of Diagnosis, Planning, and Prioritization Using Predictive Models

The state-of-the-art in this phase is characterized by the use of GIS and BIM technologies, which allow for detailed modeling and management of projects. Through energy simulations and planning tools such as EnergyPlus and DesignBuilder, managers can estimate the impact of interventions on the energy performance of buildings. However, current limitations include the lack of seamless and dynamic integration of all relevant variables (such as intervention costs, thermal comfort, emissions reduction, and energy savings) into a single, user-friendly platform.

Additionally, the available tools often require manual intervention to evaluate and prioritize interventions, which can be time-consuming and error-prone. While some approaches exist for integrating data and simulating interventions, they often fail to provide an accurate and dynamic estimation of the long-term benefits of improvements or to adapt decisions to changes in the environment or the buildings' conditions. This is crucial to ensuring future sustainability and adaptation to changing climatic conditions. These limitations restrict managers' ability to make quick and well-informed decisions on the most cost-effective and efficient interventions.

Another major limitation of existing solutions is the geographic scale of analysis. Most developments so far have been designed to simulate or estimate the behavior of a single building or, in some cases, a municipal-scale estimation with significant constraints on the number of factors considered. However, tools are needed that can analyze, simulate, and estimate interventions across a large number of municipalities. Resource prioritization and planning of housing rehabilitation actions must adopt a supra-municipal perspective, ideally metropolitan or even regional, the latter being the governance level foreseen in the Spanish Constitution for territorial planning, urban development, and housing policies.

Likewise, a comprehensive set of criteria and factors must be considered to optimize decisions and design interventions effectively. However, the current solutions available still present significant limitations in this regard.

Furthermore, while there are existing solutions for simulating energy rehabilitation actions, they also suffer from limitations in scale, the volume of buildings analysed, and the range of criteria considered. This is the case, for instance, with the Building Energy Rehabilitation Measures Simulator developed by the Catalan Institute of Energy (ICAEN), which is designed to assess the technical and economic feasibility of energy rehabilitation measures in residential buildings. Similarly, the IWG5 tool, developed by the EURAC Research Centre, is designed to compare different strategies for energy rehabilitation in residential and office buildings.

It is worth mentioning that projects such as VIOLET, in which AVRA has participated, focus specifically on energy rehabilitation of heritage buildings, providing tailored solutions for these interventions. Similarly, the FuturHist project, led by EURAC with AVRA's participation, researches and tests energy-efficient modernization interventions adapted to historical building typologies. While these projects are more specialized, they contribute to enriching the current landscape of energy rehabilitation, particularly regarding heritage conservation and long-term efficiency.

Finally, it is important to mention the H2020 Re-MODULEES project, completed in 2024, in which the Valencian Institute of Building (IVE) participated. This project adapted and validated various energy rehabilitation solutions, capitalizing on previous European projects and integrating them into a dedicated platform. The platform also includes an automatic diagnosis feature for building energy performance, offering a one-click diagnosis functionality, which requires only the building's address to propose different rehabilitation pathways. Although this project still faces challenges in terms of scale, its contribution is notable in integrating various innovative solutions.

Phase of Project Development

During the project phase of energy rehabilitation, technologies such as 3D laser scanning and BIM modelling have advanced significantly, providing a highly accurate foundation for planning and executing interventions. 3D laser scanning enables the creation of detailed three-dimensional models of buildings, helping to generate precise representations of facades and other architectural elements. These methodologies are complemented by the use of BIM to manage all project information, from design to execution.

However, despite these advanced tools, the current limitations lie in the high dependency on manual labour for project development, budgeting, and documentation. The process of model generation and documentation—while highly detailed—is time-consuming and prone to human errors, which can delay construction start dates and increase costs due to last-minute corrections or adjustments. Additionally, the lack of seamless integration of artificial intelligence for automating these processes remains a barrier to optimizing timelines and reducing design errors.

Development and Testing of Innovative Construction Systems

In contemporary construction, off-site systems and robotic 3D printing have emerged as innovative technologies that promise to enhance efficiency and quality in building interventions. Off-site systems, which involve modular manufacturing in external facilities before installation on-site, help reduce construction times, improve component precision, and minimize errors. However, these systems often face challenges related to transportation costs and limited customization of modular elements.

On the other hand, robotic 3D printing applied to construction offers the ability to manufacture components directly at the intervention site, reducing waste and optimizing the precision of fabricated elements. Although this technology promises unprecedented customization, it still presents limitations in terms of suitable materials and high initial implementation costs, making its large-scale adoption in major projects challenging.

Design Principles and Criteria

Currently, energy and architectural rehabilitation projects focus on integrating sustainability, efficiency, and user benefits, yet often in a fragmented manner, without a coherent integration of all key criteria.

User collaboration and participation methodologies have gained importance, but their implementation remains limited, and in many cases, designs fail to fully meet the specific needs of residents.

While progress has been made in the use of recycled and recyclable materials, circularity in construction is still not fully adopted, and many solutions still rely on traditional materials that do not meet low environmental impact standards or contribute sufficiently to decarbonization.

Additionally, durability and low maintenance of solutions are not always guaranteed, and the use of lightweight and minimally invasive systems remains a challenge for efficiently adapting existing buildings.

Regarding aesthetic integration, many projects tend to prioritize functionality over harmonization with the architectural environment, which can affect the identity of urban areas.

Finally, user awareness and training on maintenance continue to be secondary aspects in most projects, limiting the full utilization of the implemented improvements.

Construction Supervision Phase

In the construction supervision phase, computer vision and image recognition technologies are increasingly being used to monitor project progress and ensure deadlines are met. Currently, tools are available for automated visual inspections using cameras and drones, facilitating site supervision and the detection of visible structural issues.

However, the implementation of these technologies still faces limitations in terms of their ability to accurately and in real-time detect all details related to project progress. Additionally, data analysis and report generation often require manual processing and human interpretation, increasing the risk of errors and delaying decision-making.

Despite advancements, the lack of more advanced and autonomous integration of these tools into a comprehensive project management system remains a major limitation.

Final Impact Monitoring Phase

In the final impact monitoring phase, energy consumption and thermal comfort measurements are typically conducted using traditional methods, such as collecting utility bills or surveying residents on their comfort perception. However, these methods present significant limitations.

Energy consumption measurements often fail to accurately reflect the specific improvements achieved through interventions, while thermal comfort surveys are subjective and do not always provide representative or long-term data.

Moreover, the use of advanced sensors and technological monitoring solutions remains expensive and complex, with high maintenance requirements, limiting their widespread adoption in public housing energy rehabilitation projects.

Although theoretical monitoring can be useful, the main goal should be to ensure that information is accessible and understandable, not only to specialized professionals but also to architectural technicians responsible for designing and supervising the works. This would facilitate continuous and detailed evaluation of the real impact of interventions, allowing for informed decision-making throughout the entire project lifecycle.

Next-generation systems, such as those being implemented in the COSMIC project, in which AVRA is participating, represent a significant evolution in this field, offering more effective and accessible solutions.

1.4 Project Description and Expected Functionalities

The MIREO Project ("Integral Methodology for Optimized Energy Rehabilitation") aims to transform the way energy rehabilitation interventions are carried out in residential buildings by utilizing innovative approaches and advanced technologies to optimize resources, reduce costs, and minimize environmental impact. The project focuses on improving energy efficiency, thermal comfort, and building sustainability through the adoption of industrialized construction methodologies, combined with the use of cutting-edge technological tools such as artificial intelligence, modular construction, and 3D printing.

Below is a description of the expected outcomes in the different project phases:

Diagnosis, Planning, and Prioritization Phase

The proposed innovative improvement, which could be applied to any public housing manager, involves the development of a predictive analysis platform based on AI and Big Data, integrating multiple data sources to dynamically estimate energy efficiency levels, intervention costs, thermal comfort improvements, emissions reduction, and operational cost savings.

This platform would combine historical and real-time data on building energy performance, cadastral information, and climatic conditions, among others, to provide a comprehensive view of rehabilitation needs.

Using predictive models based on Machine Learning, the platform could estimate the impact of various interventions (such as insulation, heating system renovations, window replacements, etc.) and predict both the costs of improvements and the associated benefits in terms of thermal comfort, energy savings, and emissions reduction.

This would allow decision-makers to simulate different intervention options, compare their cost-effectiveness, and optimize planning and prioritization decisions through multi-criteria analysis, considering not only economic costs but also environmental and social impact.

A key feature of this platform would be its ability to prioritize interventions efficiently, taking into account factors such as:

- The urgency of building deterioration
- Availability of resources
- Sustainability policies
- Budget constraints

Additionally, it would allow for the visualization of projected intervention impacts in a 3D BIM model of the housing stock, facilitating more precise and effective decision-making.

Finally, the platform should be capable of handling large datasets to enable regional-scale decision-making. For instance, the city of Zaragoza has developed a digital twin within the European USAGE Project (Urban Data Space for Green Deal) to map urban vulnerability indices. However, as stated in the project’s presentation, it focuses on making environmental and climatic data available at the city level, meaning it has geographic scale limitations (local coverage) and limited criteria considerations (mainly environmental and climatic factors).

Project Development Phase

The project proposes a significant improvement by incorporating generative AI as a tool to streamline and optimize project development and technical documentation generation.

AI will facilitate the creation of preliminary models and drawings, allowing architects to focus on design decision-making and architectural quality. This technology will help optimize resources and reduce time spent on repetitive tasks, improving efficiency without replacing professional expertise.

Furthermore, automation in project documentation management, such as budget preparation and procurement processes, will accelerate project execution, ensuring an efficient use of resources.

This innovative enhancement will make the energy rehabilitation process faster, more precise, and more cost-effective, without compromising creativity and the expertise of sector professionals.

Development and Testing of Innovative Construction Systems

This project introduces an innovative improvement by directly testing and comparing two construction approaches:

- Off-site modular construction
- Robotic 3D printing

This evaluation aims to empirically determine which method offers greater benefits in terms of cost, efficiency, customization, and quality.

- The off-site system will be assessed based on its ability to reduce construction times and enhance material quality through prefabricated modular solutions.
- The robotic 3D printing system will be tested for its capability to fabricate components directly on-site, allowing for a comparison of manufacturing efficiency, waste reduction, and adaptability to project specifications.

Additionally, the use of artificial intelligence (AI) in both systems will enable the optimization of designs and manufacturing processes, leading to cost reduction and greater customization of solutions.

The comparison between these two approaches will help identify the most suitable technology for different types of interventions and provide a solid data foundation to guide future decisions in adopting innovative construction technologies, all while maintaining low implementation and maintenance costs.

Design Principles and Criteria

The project introduces an innovative improvement by systematically integrating all design principles and criteria into a holistic approach tailored to the specific needs of each community and building.

Key features include:

- Active user involvement: A collaborative process that allows residents to contribute their needs and preferences, ensuring that interventions precisely meet their requirements.
- Use of sustainable materials: Recycled, recyclable, and low-carbon materials will be prioritized to promote sustainability and decarbonization.

- Durability and low maintenance: The project will focus on lightweight and minimally invasive systems to reduce structural load and ensure long-term durability.
- Minimal disruption to residents: Interventions will be designed to maintain building habitability during the rehabilitation process.
- Aesthetic integration: Ensuring that interventions respect the architectural identity of the environment, creating visually harmonious solutions.
- Flexible solutions: Implementing features such as additional balconies and thermal comfort improvements to enhance indoor air quality and energy efficiency.
- User training and awareness programs: Helping residents understand, maintain, and maximize the benefits of the implemented improvements.

This integrated approach will result in more sustainable, efficient, and user-centric projects, ensuring that solutions are durable, cost-effective, and adaptable to changing needs.

Construction Supervision Phase

The project introduces an innovative improvement by integrating advanced AI for automatic image recognition and computer vision, enabling real-time construction monitoring with greater precision and autonomy.

Using deep learning algorithms, the system will:

- Identify visible anomalies
- Compare actual progress with 3D BIM models and design plans
- Generate automatic reports on project status
- Analyze resource usage, schedule compliance, and process deviations

This automation will significantly improve supervision efficiency, reduce human errors, and enable quick, data-driven decision-making during construction, optimizing material use and ensuring project development as planned.

Final Impact Monitoring Phase

The project proposes an innovative improvement by integrating low-cost, easy-to-maintain sensors for continuous monitoring of energy consumption and thermal comfort in rehabilitated homes.

- These sensors will be affordable and accessible, facilitating large-scale deployment without significant budget impact.
- They will require minimal maintenance, ensuring a long-term sustainable monitoring system.

- This solution will enable real-time, accurate data collection on energy efficiency improvements without the high costs associated with traditional measurement technologies.

By making impact monitoring accessible and effective, public housing managers will be able to optimize resources and ensure the long-term sustainability of energy rehabilitation projects.

On the other hand, the pursued objectives are:

Specific Objectives

- Identify advanced technological solutions that enable the seamless and dynamic integration of multiple relevant variables (cost, thermal comfort, emissions reduction, and energy savings) into a single, user-friendly platform.
- Explore the development of predictive analysis platforms based on artificial intelligence (AI) and Big Data to facilitate the efficient planning of energy rehabilitation interventions in residential buildings, providing architects with tools to optimize processes without replacing their essential role in design.
- Assess the feasibility of predictive models based on Machine Learning to estimate the impact of different interventions in terms of energy efficiency, thermal comfort, costs, and emissions reduction.
- Determine the possible degree of automation in the evaluation and prioritization of interventions, reducing the need for manual intervention and minimizing decision-making errors, while always maintaining control and oversight by professionals.
- Identify innovative approaches for integrating historical and real-time data (energy performance, cadastral information, climatic conditions, etc.) into simulation and energy rehabilitation planning tools.
- Develop advanced data analysis capabilities to assess thousands of buildings and hundreds of municipalities simultaneously, facilitating the identification of patterns, trends, and intervention opportunities in large-scale energy rehabilitation projects.
- Leverage artificial intelligence to conduct 3D surveys, generate detailed models, and propose solutions, enabling architects to work with more effective tools for informed decision-making.

Specific Objectives for the Project Development Phase

- Explore AI-based generative solutions to optimize and accelerate specific design phases in energy rehabilitation projects, facilitating the generation of models, technical documentation, and data analysis, always as a support tool for architects.

- Reduce manual workload and minimize errors in project planning and execution.
- Investigate the use of high-precision 3D laser scanning for generating detailed building models.
- Develop methodologies for the seamless integration of these models with BIM and advanced automation tools.
- Assess the potential of AI tools for the automated generation of drawings, budgets, and tender documentation.
- Optimize document generation to reduce administrative costs and timelines.
- Determine strategies for personalizing rehabilitation projects based on the specific characteristics of each building.
- Use AI and BIM models to optimize resource allocation and cost reduction.
- Identify innovative approaches that accelerate the planning process, ensuring greater accuracy and efficiency.
- Implement technologies that enhance coordination and project supervision in real time.

Specific Objectives for the Development and Testing of Innovative Construction Systems

- Investigate and evaluate the performance of off-site modular systems and robotic 3D printing in terms of cost, efficiency, quality, and customization in energy rehabilitation projects.
- Identify the main challenges and opportunities for implementing both technologies, considering factors such as transportation, materials, precision, and construction timelines.
- Explore the use of artificial intelligence to optimize design and manufacturing processes, improving efficiency and reducing costs in both construction approaches.
- Analyze the feasibility of on-site 3D printing as an alternative to reduce waste, improve design adaptability, and minimize dependence on transporting prefabricated modules.
- Compare the environmental impact and sustainability of both systems, evaluating their potential to reduce emissions and enhance material efficiency.
- Provide an empirical database to facilitate decision-making regarding the adoption of innovative construction technologies in future energy rehabilitation interventions.

Specific Objectives for the Application of Design Principles and Criteria

- Explore collaborative and user participation methodologies that allow for the development of energy rehabilitation solutions tailored to the specific needs of each community and building.
- Identify recycled, recyclable, and low-carbon materials that actively contribute to sustainability and decarbonization in building rehabilitation.
- Evaluate lightweight and minimally invasive construction solutions that minimize user disruption during rehabilitation, optimizing durability and low maintenance interventions.
- Investigate aesthetic integration strategies that harmonize with the architectural environment, ensuring that interventions are functional without compromising the visual identity of urban spaces.
- Analyze the feasibility of flexible solutions and space extensions, such as balcony additions or thermal comfort improvements, optimizing habitability and quality of life for residents.
- Develop training and awareness strategies to ensure that users understand the operation, maintenance, and benefits of the improvements implemented in their buildings.

Specific Objectives for the Construction Supervision Phase

- Investigate advanced computer vision and AI solutions for automated and real-time monitoring of construction progress.
- Evaluate the integration of deep learning algorithms for image recognition, enabling the precise detection of anomalies and comparison with BIM models or reference plans.
- Explore technologies that allow for automated construction reports, reducing manual intervention and improving accuracy in supervision and decision-making.
- Analyze the impact of automation on the efficiency of construction management, minimizing human errors and optimizing resource allocation and execution timelines.
- Identify construction management systems that integrate computer vision with other digital tools, facilitating a more precise and autonomous control of construction processes.

Specific Objectives for the Final Impact Monitoring Phase

- Investigate the use of low-cost, easy-maintenance sensors for continuous monitoring of energy consumption and thermal comfort in rehabilitated homes.

- Evaluate the accuracy and feasibility of affordable sensor technologies compared to traditional data collection methods, such as energy bills and subjective surveys.
- Explore real-time monitoring solutions to obtain accurate and representative data on the long-term impact of energy interventions.
- Identify strategies to reduce costs and implementation complexity of measurement systems, ensuring their adoption in large-scale rehabilitation projects.
- Analyze the potential for integrating these systems into digital energy management platforms, enabling continuous evaluation and optimization of future interventions.