



Guideline

Med-EcoSuRe

Mediterranean University as Catalyst
for Eco-Sustainable Renovation

Guidelines for the implementation
**of Energy Efficiency projects
at Mediterranean universities.**

This document has been produced with the financial assistance of the European Union under the ENI CBC Mediterranean Sea Basin Programme. The contents of this document are the sole responsibility of Med-EcoSuRe partners and can under no circumstances be regarded as reflecting the position of the European Union or the Programme management structures.



Med-EcoSuRe

About Med-EcoSuRe project:

Starting in September 2019 and ending in August 2023, Mediterranean University as Catalyst for Eco-Sustainable Renovation (Med-EcoSuRe) project is funded by the EU under the ENI CBC Med programme.

The total budget of Med-EcoSuRe project is 2.9 million euros and has received a co-financing of 10% of the total amount (2.6 million euros) from the European Union.

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The consortium is composed of:



And the associated members are:



Mediterranean University as Catalyst for Eco-
Sustainable Renovation

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1. Introduction



Low-energy educational buildings are now the norm in European and Mediterranean countries. While universities continuously develop technical solutions for eco-sustainable building renovation, there remains a gap between theoretical models and practical implementation. This is primarily due to barriers such as limited collaboration among key stakeholders and a lack of efficient tools from the public sector to drive solutions.

To address this issue, partner universities from Italy, Tunis and Palestine have undertaken the Mediterranean University as Catalyst for Eco-Sustainable Renovation (Med-EcoSuRe) project. Med-EcoSuRe project aims to provide innovative approaches to cost-effective energy renovation within university buildings, with the goal of extending these solutions to the wider public buildings sector in the long term. The project's general objectives include environmental protection, climate change adaptation and mitigation, enhancing energy efficiency in university buildings, and implementing on-grid PV generators with and without energy storage.

By reducing the energy demand from the local electrical network, the project not only helps to decrease operational costs of the universities but also ensures a sustainable, reliable, safe, and cost-effective electrical energy supply. Additionally, the Med-EcoSuRe project seeks to raise awareness about the advantages of utilizing renewable energy sources and the application of energy efficiency measures.

Universities are an ideal place to innovate due to their innate nature of education, research, and technological transfer, as well as the opportunity to capitalize the academic knowledge, the know-how of the local network of stakeholders, such as companies and public administration), and to provide a place in the renovation process to young generations of students.

One notable outcome of the project is the Med-EcoSuRe Toolkit of Innovative Retrofit Processes. This is a comprehensive output produced by the UNIFI-DIDA partner (Department of Architecture - University of Florence). The toolkit is the result of the WP3 related to the Living Lab initiative to experiment with innovative collaboration schemes between academics, decision-makers, and stakeholders.

Several new and retrofit actions have been implemented. These actions have been selected based on the following criteria:

- The energy audit performed which led to a list of recommendations including passive and active measures.
- The survey that was launched by SOLARTYS which resulted in the selection of innovative technologies, tested in the pilot projects (PV glass used in the pilots at UNIFI and ANNU).
- Numerical simulations using a decision aid tool developed by the University of Seville (US)¹

¹ The tool was designed to support energy management staff in the university in identifying and implementing the best options for building refurbishing and improving operation control to achieve energy savings, while maintaining the occupant's comfort. Tool link: <http://tmt2.us.es/Medecasure/src/index.html>

2. Methodology



Toolkit for
Innovative and
Eco-sustainable
**Renovation
Processes**

Toolkit



The general methodology followed during the implementation of the Med-EcoSuRe project consists of setting-up a Living Lab and implementing new and renovation projects that arise from it. This methodology for the implementation of innovative and eco-sustainable energy renovation solutions for Mediterranean higher education institutions is contained in the document elaborated by UNIFI-DIDA: Toolkit for Innovative and Eco-sustainable Renovation Processes.

The contents of the Toolkit derive from the exchange of experience occurring in the Med-EcoSuRe Mediterranean cross-border Living Lab “Med beXLive”, connecting an excellence network of experts in the field of renovation of Mediterranean public buildings, as well as from the local experience of the pilot retrofit project and Living Lab developed in the spaces of the School of Architecture in the historical centre of Florence (Italy).



The core concept behind this project revolves around the notion that universities can function as real-world testing grounds for pioneering retrofitting methods and solutions by utilizing their physical infrastructure within the university campus. This infrastructure serves as a model for cutting-edge practices and technologies, fostering innovation and promoting education geared towards more sustainable retrofit solutions.

Establishing Living Labs within universities situated in the Mediterranean region can facilitate the adoption of more inventive and environmentally conscious renovations for public buildings. Within these Living Labs, the university community, akin to a miniature society, collaboratively experiments with innovative renovation processes, strategies, and technologies.

The retrofit process has been divided into 5 main phases (knowledge framework, analysis of criticalities, planning and design, intervention, and post-management), introduced by a phase zero related to the setting up of the university Living Lab, and followed by a parallel part on the digital twin implementation, considered as the best path to approach the whole retrofit process.

The central part of “planning and design” has been focalized with an analysis of case studies related to recently renovated and new constructed university buildings adopting energy efficiency solutions and with an Abacus of Retrofit Design.

2.1. Project Motivation

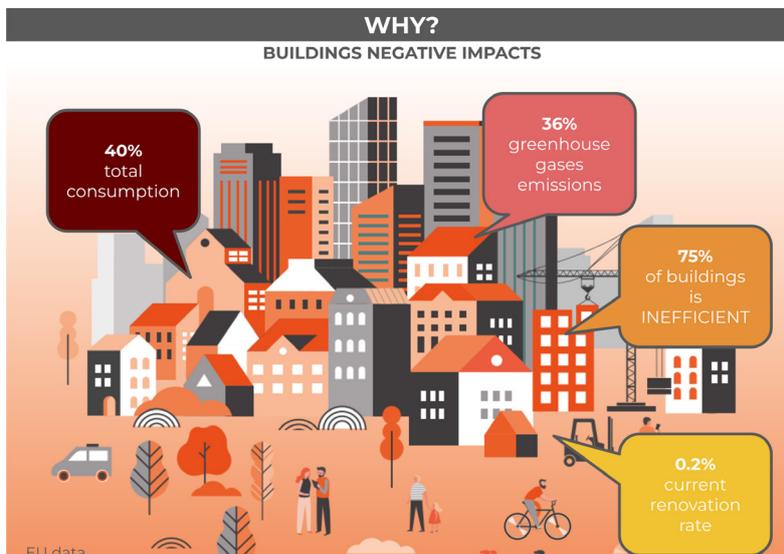


Figure 1: Buildings negative environmental impact. (Source: UNIFI)

2.2. Objectives of the project

Renovation objectives			
Energy	IEQ	Building	Environmental impact
Reduction of energy demand	Improvement of indoor comfort and wellbeing	Improvement of architectural quality	Reduction of building's carbon footprint



Figure 2: Four main components of the project. (Source: UNIFI)

2.3. Implementation Process of the Living Lab

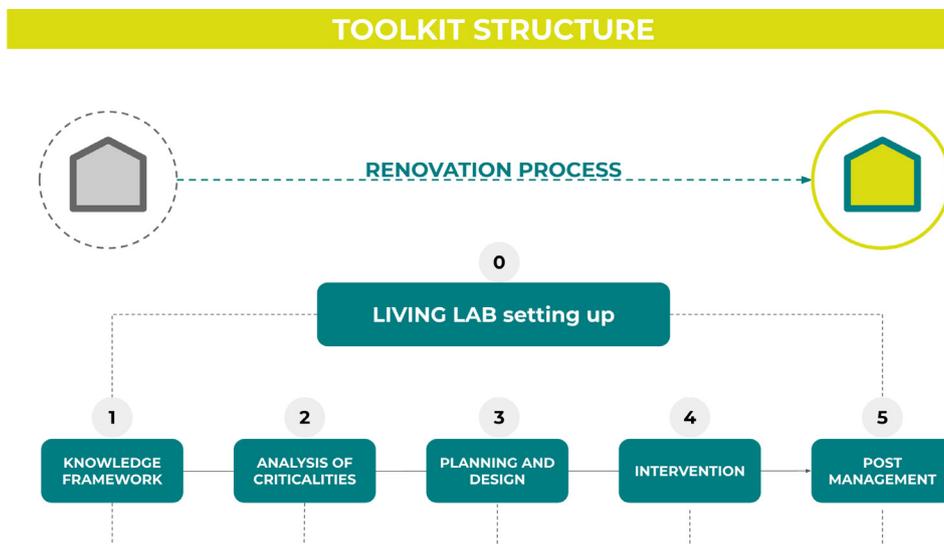
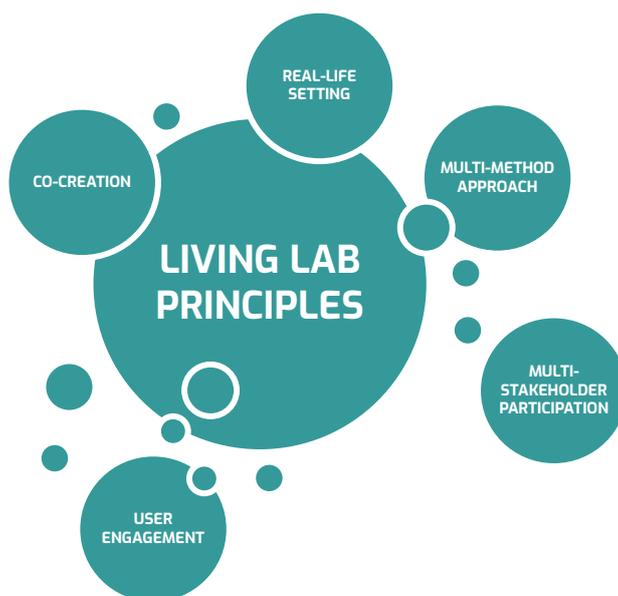


Figure 3: Implementation process of the Living Lab. (Source: UNIFI)

2.3.1. Phase 0: University Living Lab

This phase is intended to provide guidance in the setting up of university-based Living Labs working on the innovation of energy renovation processes.

2.3.1.1. What is it? University Living Lab to innovate building renovation.



- **Living Lab:** multi-stakeholder organization set up to carry out innovation projects focused on real-life experimentation.

- **The aim** is to create a collaborative platform for real-world product and service innovation using specific methods, tools, and projects.
- **Co-creation perspective** to turn building managers into active players contributing to renovation.
- **Innovation Phases:** The innovation project follows three phases: exploration, experimentation, and evaluation.
- **Exploration (Understanding the Current State):** Understand the current state and envision future possibilities.
- **Experimentation (Testing Future States):** Prototypes are developed and tested in real-life settings, aiming to understand user reactions and behaviors.
- **Evaluation (Measuring Impact):** Measures the post-intervention impact compared to the pre-intervention benchmark, emphasizing market readiness.
- **Open innovation:** Exploration and exploitation align with capturing external knowledge and market readiness.
- **Cross-Border Living Labs:** Collaboration networks among local Living Labs enable research at a larger scale, promoting innovation.
- **University-Based Living Labs:** Universities host Living Labs for sustainable building renovations, engaging students and international networks to improve Mediterranean buildings.

2.3.1.2. Who is involved?

Living Lab’s success relies on enhanced communication and collaboration among participants, fostering innovation co-creation through synergies.

- (At least) four main roles are required:
 - » Promoters: activate the Living Lab.
 - » Stakeholders: involved in the process.
 - » Users: involved in real-life testing.
 - » Customers: beneficiaries from the Living Lab’s results.

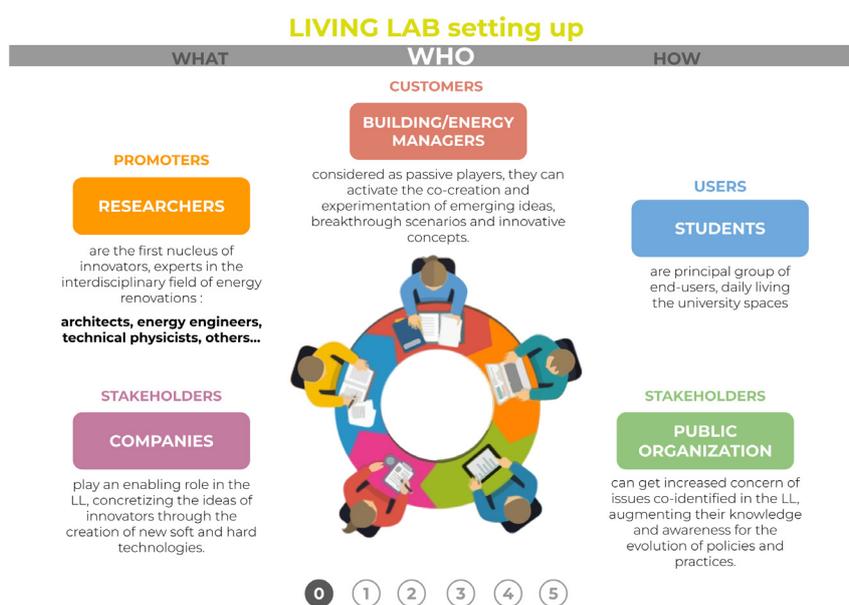


Figure 4: Main roles and participants of a Living Lab. (Source: UNIFI)

- Same figure can have different roles:
 - » Example: Stakeholder can be a User and a Customer simultaneously.
- In the case of LL for energy renovation in university buildings:
 - » 5 main figures involved: researchers, building managers (promoters), companies, public organizations (stakeholders), and students (users).
- Each figure has roles, contributions, and benefits in the Living Lab:

	Roles	Contribution	Benefits
Researchers and building managers (Promoters)	Promoter	Co-creation of innovation	Advancements in energy transformation
Companies and public organizations	Stakeholders	Input and collaboration	Solutions for energy renovation
Students and university community (Users)	Users	Testing and feedback	Improved university buildings and learning environments
University managers (Customers)	Customers	Passive technical or administrative support	Active participation in the LL

2.3.1.3. How? Setting up the Living Lab

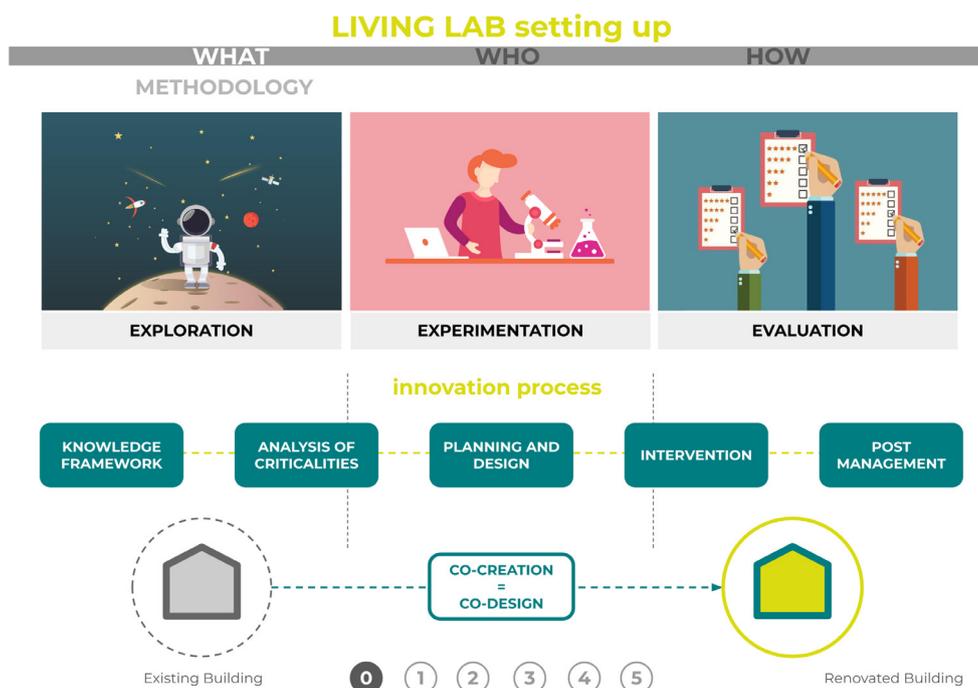


Figure 5: Setting up a Living Lab. (Source: UNIFI)

- Successful Living Lab implementation involves four key steps: defining a mission, establishing governance, securing a physical space, and creating an action plan.
- Six activities are usually realized to realize this:

1. Define the mission

- Preconditions for creating a Living Lab (LL) include a common mission shared by promoters and initial participants.
- Sustainability is a common theme in LLs, focusing on addressing environmental and social issues.
- LLs in the Mediterranean area prioritize energy efficiency, quality of living environments, and renewable energy.
- The first step in LL development is defining a clear mission, which guides the innovation process.
- A well-defined mission helps maintain the LL's core nature, inspires activities, and communicates its purpose.
- Periodic evaluation and updates are essential to keep the mission realistic and valid.
- The mission statement should be easy to remember and can include a captivating graphic image or manifesto.
- Key questions for defining the mission: the problem to address, the core innovative idea, the scope, and main beneficiaries.
- The mission can align with sustainability initiatives in the university context to engage new stakeholders.

2. Structure governance and management

- Governance and management are crucial for both local and cross-border Living Labs.
- Local Living Labs (LLs):
 - » Directed by a Technical Director (TD).
 - » Managed by a Multidisciplinary Team (MD Team) with researchers and a university manager representative.
 - » TD coordinates the team, has scientific responsibility, and approves LL activities.
 - » MD Team covers various roles including relationship management, physical infrastructure, digital infrastructure, and scientific production.
 - » Effective communication is vital for LL activation and future success.
 - » Strong relationships with university managers and local stakeholders are essential.
 - » Engagement with users, especially students, is a key aspect.
- Cross-border Living Labs:
 - » Managed by a Steering Board consisting of representatives from local LLs.
 - » Directed by a LL Coordinator who oversees cross-border LL activities.
 - » Cross-border LLs aim for harmonization, larger experimentation, and involvement of national or international stakeholders.

3. Manage the LL

Management processes for both local and cross-border LLs:

- **Connecting:** Agree on common goals, identify innovation opportunities, define intellectual property principles, explore collaborations, and involve new stakeholders.
- **Planning:** Define action plans, leverage LL competencies, assign responsibilities, establish collaboration infrastructure, and plan activities.

- **Supporting:** Facilitate dialogue between local LLs, guide implementation, support negotiations, and conduct collaborative testing.
- **Sustaining:** Communicate results, promote LL activities, and expand LL impact.

4. Outline an action plan

- An Action Plan is essential for both local and cross-border Living Lab (LL) activities to plan and control outcomes while supporting teamwork.
- Operative Plans are formulated by the Multidisciplinary Team for local LLs and by the Steering Board for cross-border LLs.
- An Action Plan, rooted in project management, is a document listing steps to achieve goals, aiding in obstacle prediction and maintaining focus on objectives.
- Advantages of an Action Plan include defining a clear roadmap, organizing priorities, monitoring progress with milestones and deliverables, and clarifying resource requirements and timelines.
- The Action Plan comprises key elements:
 1. Define LL Objectives: Specific objectives congruent with competencies and resources, following SMART criteria.
 2. List Steps: Internal steps aligned with the LL methodology's phases (exploration, experimentation, evaluation) to prioritize activities and dependencies.
 3. Define Outputs: Activities yield deliverables and milestones, tracking LL progress.
 4. Attribute Roles & Responsibilities: Assign roles and responsibilities to LL members based on their competencies.
 5. Allocate Resources: Define resource allocations, including financial and instrumental, to create a reliable budget.
 6. Set a Timeline: Estimate timeframes for completing activities and steps, creating a timeline (e.g., Pert chart).

5. Select strategic physical and virtual locations

- Strategic Physical Location for Local LLs:
 - » Local LLs need a pilot-building for real-life experimentation and physical setup of the LL.
 - » Selection of the pilot-building should consider characteristics of the university building stock (e.g., construction time, functions).
 - » The pilot-building must host university functions, including didactics, research, and study.
 - » Consider pedestrian flows to enhance the visibility of the renovation project.
- Requirements for the Pilot-Building:
 - » The pilot-building should have space for research activities, facilitating LL member meetings and experimentation.
 - » The pilot-building should have space for research activities, facilitating LL member meetings and experimentation.
- Virtual Location for Cross-Border Living Lab:
 - » Cross-border LLs require a virtual platform for management.
 - » A digital infrastructure/platform supports cooperation activities and disseminating results to a wider audience for greater impact.

6. Pilot-building renovation target:

- Phase 0's final activity is defining quality renovation targets for the pilot-building, related to OROs.

- Renovation targets represent ambitious project objectives and highlight key challenges.
- These targets are influenced by economic-financial factors and the vision for a sustainable university.
- Quality targets establish a shared vision and quantify improvements in relation to OROs.
- Quality targets can be based on international or local assessment protocols.
- Examples of quality targets include EU NZEB, EU Positive Building, national targets, and environmental protocols (e.g., LEED, BREEAM, ITACA).
- Well-defined targets in existing protocols simplify project assessment.
- Researchers, university managers, and renovation experts collaborate to define quantitative, reliable targets.

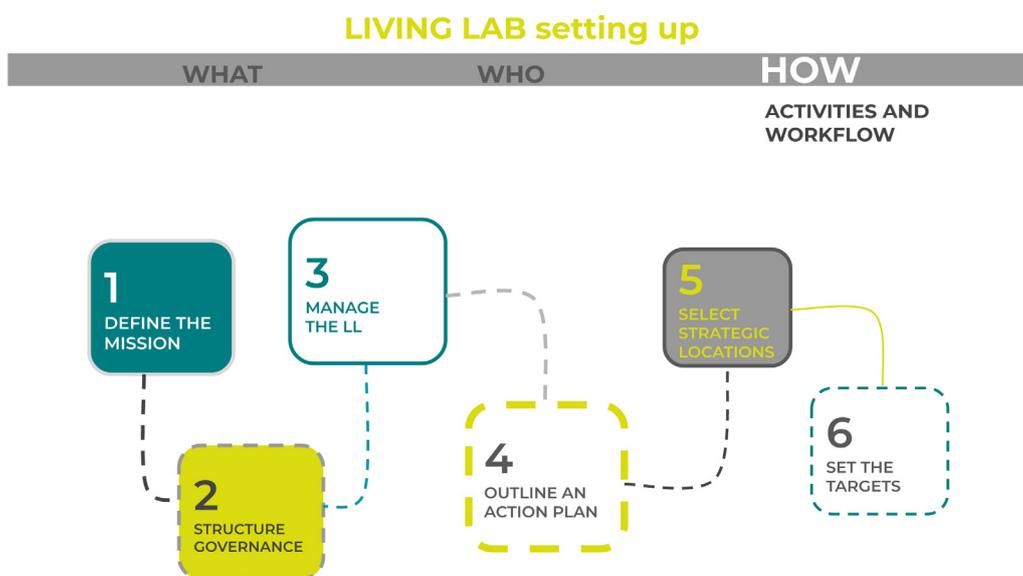
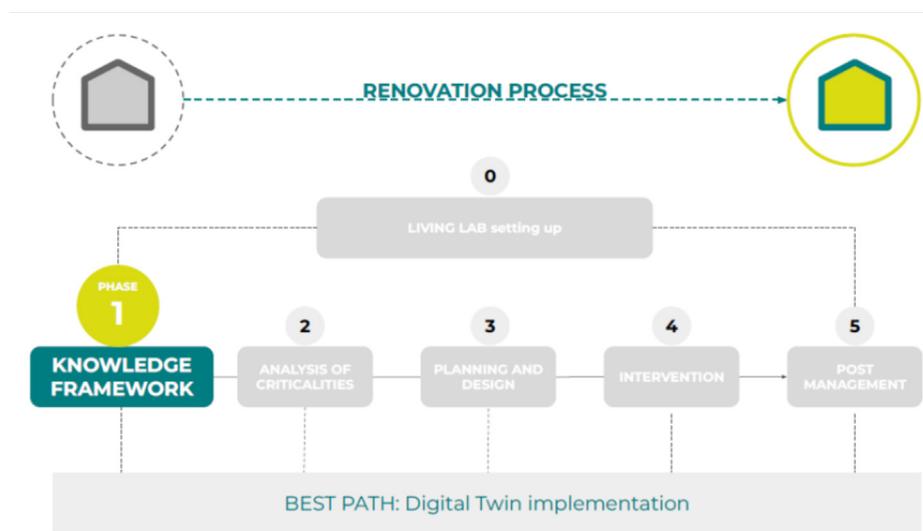


Figure 6: Steps to set up a Living Lab. (Source: UNIFI)

2.3.2. Phase 1: Knowledge Framework



- A robust Knowledge Framework (KF) is essential for successful university building renovation.
- The KF acts as a comprehensive “building ID card” for the pilot-building, supporting its life cycle.
- Four types of data are relevant for the KF: architectural quality, energy efficiency, comfort and wellbeing, and environmental impact.

2.3.2.1. What is it? Knowledge Framework

- The Knowledge Framework (KF) is an organized collection of data and information related to a pilot-building.
- It is used to analyze critical aspects of the building in Phase 2.
- Four types of data are relevant for the Knowledge Framework:
 - » Architectural quality, including physical attributes, history, and materials of the building.
 - » Energy Efficiency, covering heating/cooling systems, ventilation, lighting, and energy consumption.
 - » Comfort and wellbeing, encompassing parameters like thermo-hygrometric, visual, acoustic, and air quality in indoor spaces.
 - » Environmental impact, including renewable energy systems, environmental protocols, and the use of recycled materials.

2.3.2.2. Who is involved?

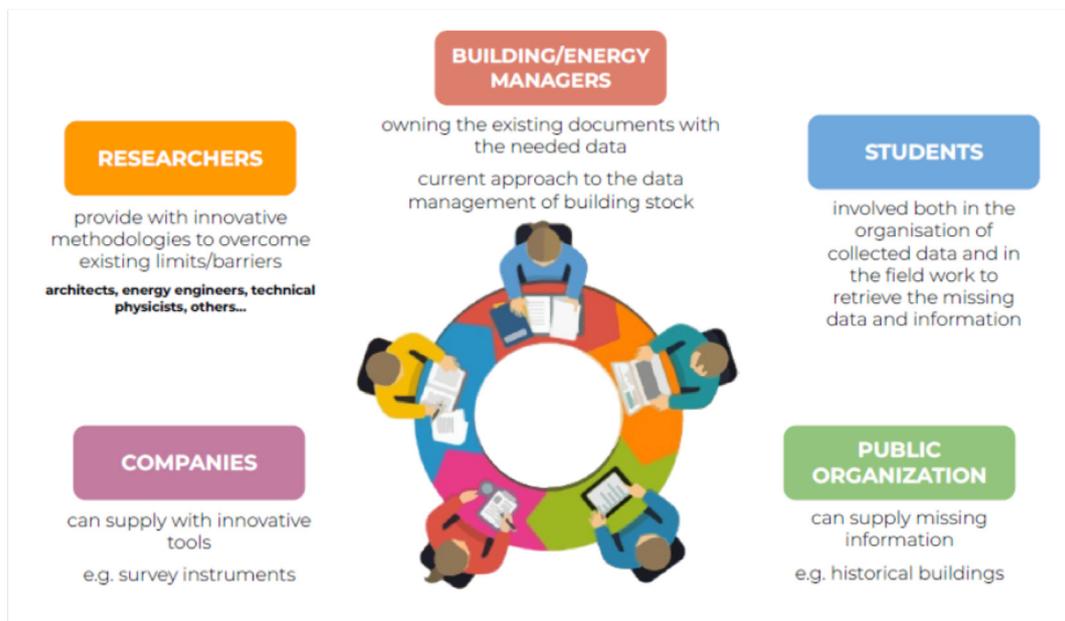


Figure 7: Participants in the Knowledge Framework. (Source: UNIFI)

- Interdisciplinary groups of researchers and university managers collaborate to create the KF.
- Existing data often lacks completeness and may be distributed across various offices.
- Students can help gather missing information and organize data.
- Collaboration with technology companies and public organizations is possible.

2.3.2.3. How is it conducted?

1. Collect existing documents related to architecture, energy efficiency, IEQ, and environmental impact.
2. Verify data completeness to ensure all necessary data is available.
3. Organize a building survey to collect architectural data, involving researchers, students, and university managers.
4. Conduct an energy audit with interdisciplinary teams and university members.
5. Measure IEQ and conduct surveys to gather data on indoor comfort.
6. Organize the KF by structuring and consolidating all collected data efficiently, potentially using innovative data management tools and technologies.

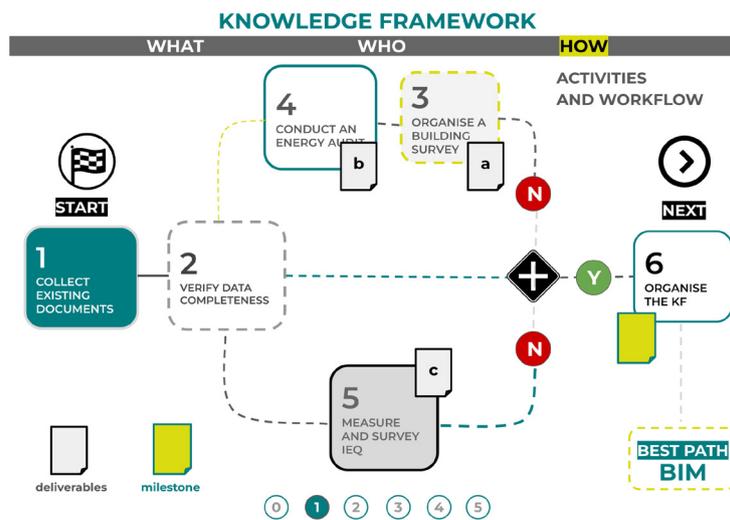


Figure 8: Steps to realize the KF activity. (Source: UNIFI)

2.3.3. Phase 2: Analysis of Criticalities (AC)

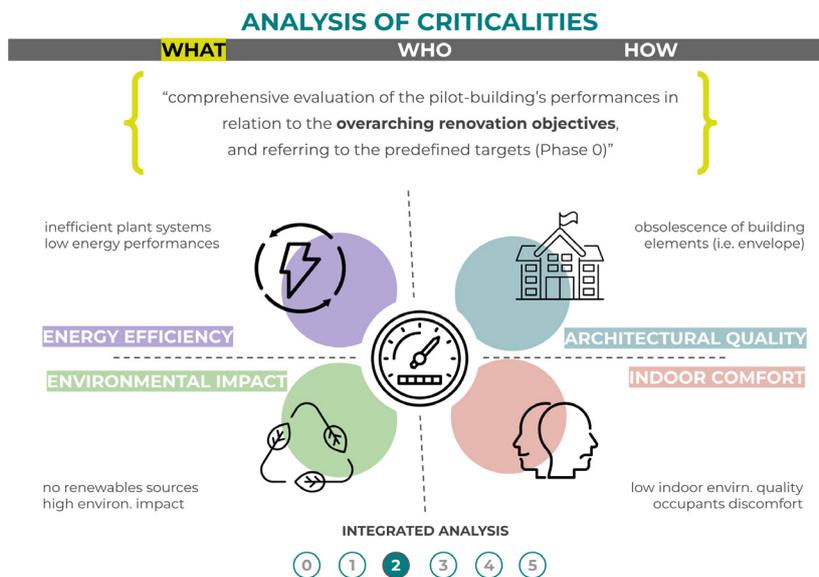


Figure 9: Main objectives of the AC phase. (Source: UNIFI)

- The Key Framework (KF) defined in Phase 1 is crucial for this analysis.
- Data from the KF is used to identify critical issues that the renovation project must address in Phase 3 to meet overarching renovation objectives (OROs).
- Collaboration of all Living Lab (LL) participants is encouraged, including researchers, external stakeholders, and final users.

2.3.3.1. What is it? Analysis of Criticalities

- AC assesses pilot-building’s criticalities concerning OROs, ranging from legal compliance to ambitious renovation targets.
- AC results in a map and report of criticalities, which becomes input for Phase 3 planning and design.

Types of criticalities related to OROs:

- Architectural: Issues with the physical asset, spaces, configuration, and building elements.
- Energy: Inefficiencies in energy systems (heating, cooling, lighting) and low energy performance.
- Comfort: Problems with indoor environmental quality (thermal discomfort, inadequate daylight, noise, air quality).
- Environmental Impact: Lack of renewable energy sources.

2.3.3.2. Who is involved?

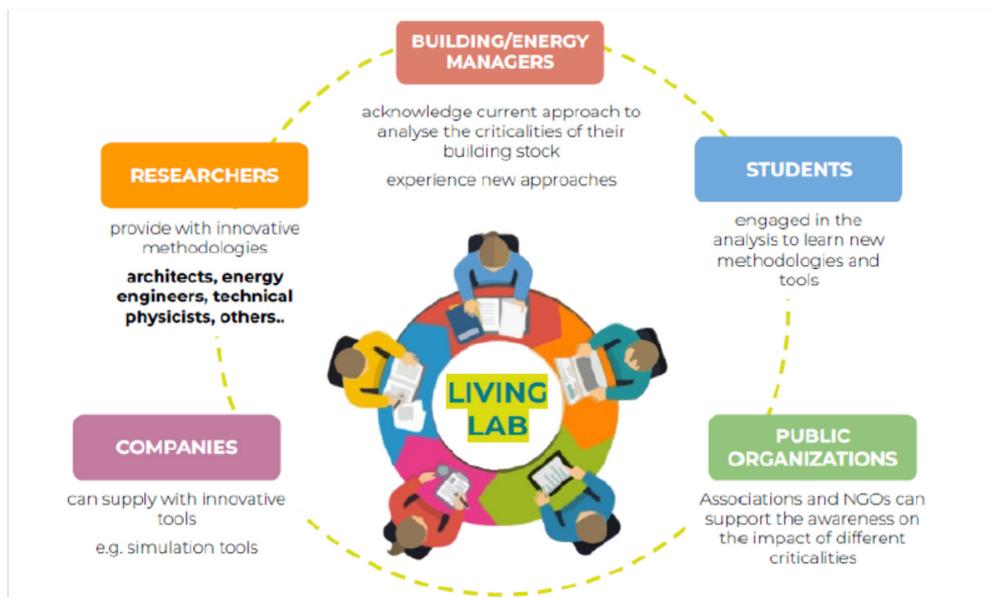


Figure 10: Participants in the AC activity. (Source: UNIFI)

- Interdisciplinary group of researchers manages AC but includes all LL participants.
- Researchers work on innovative analysis methodologies and tools.
- Collaboration with companies or experts in energy and environmental analysis is possible.

2.3.3.3. How is it conducted?

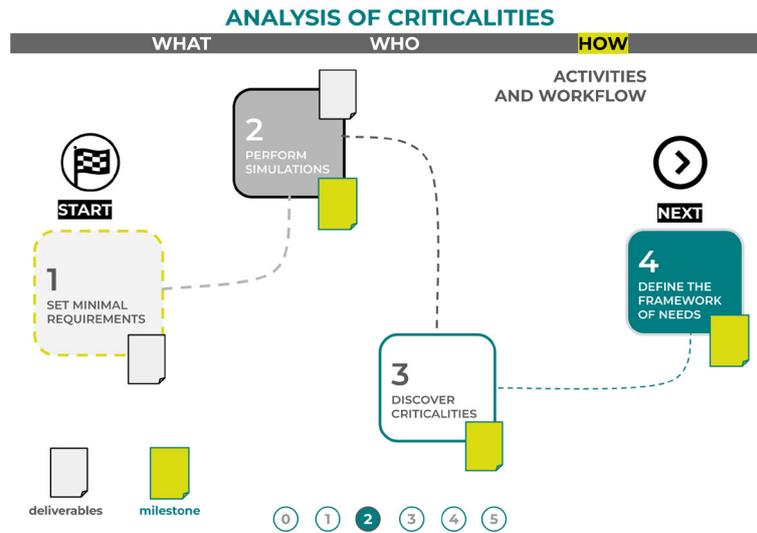
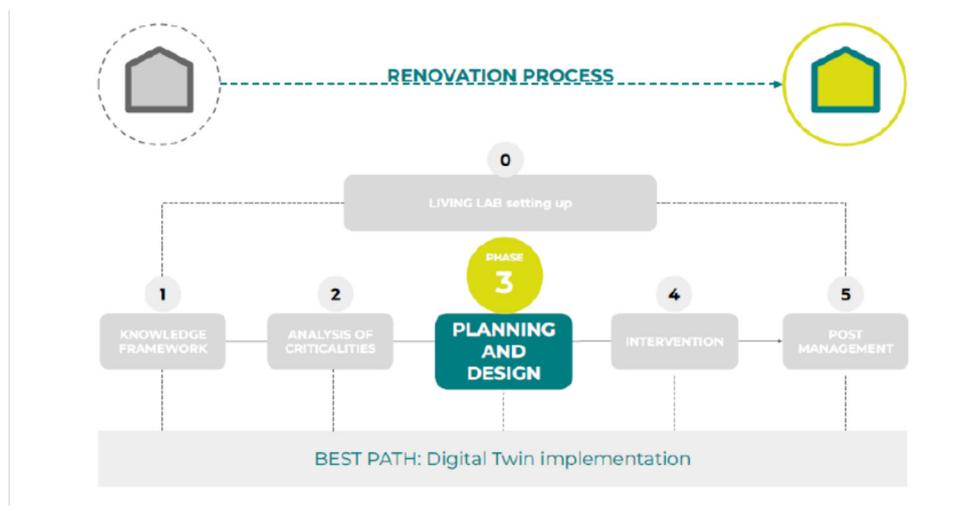


Figure 11: Steps to conduct AC. (Source: UNIFI)

1. Set minimal requirements: Collect legal requirements and standards related to university building transformations.
2. Perform simulations: Use computational tools to assess building conditions and energy efficiency.
3. Identify criticalities: Combine KF data and simulation results to pinpoint critical issues.
4. Define the framework of needs: Prepare a list of necessary interventions to address criticalities and meet OROs. This guides Phase 3 design and involves key stakeholders.

2.3.4. Phase 3: Planning and Design



- This phase encourages creative solutions to address existing building issues.
- It builds upon information from Phase 1 (KF) and Phase 2 (AC).
- It integrates architectural solutions for the pilot-building in Phase 4.
- The Living Lab (LL) environment enhances co-design processes with stakeholders and users.

- Activities focus on finding the best technology to address energy, environmental, and architectural concerns.
- Early simulation of building energy performance is emphasized to influence design modifications.
- The KF dataset allows preliminary energy and environmental simulations, identifying critical points.
- Criticalities guide the calibration of renovation objectives and key performance indicators (KPIs).
- The BIM asset model, synchronized with performance simulation tools, acts as a benchmark.
- It assesses improvements resulting from renovation technology integration in various scenarios.
- Collaboration between designers, specialists, owners, and end-users is fostered through a shared BIM model, supporting co-design processes.

2.3.4.1. What is it? Planning and Design

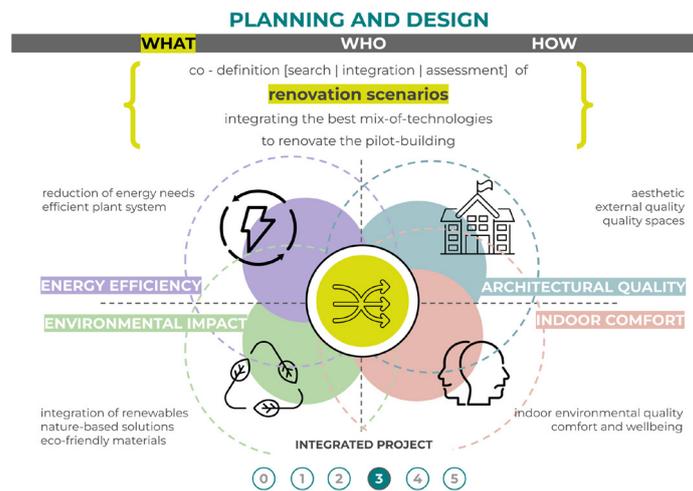


Figure 12: Main objectives of the P&D phase. (Source: UNIFI)

- The Planning and Design phase (P&D) focuses on finding, integrating, and testing the best technology mix for renovating the pilot-building.
- It analyzes strategies and technologies based on the Framework of Needs to address recognized issues and explore ambitious improvements.
- The core of the P&D phase involves defining various improvement scenarios and a methodology for selecting the most effective one while considering predefined quality targets.
- A renovation scenario includes for main aspects: Architecture, Energy efficiency, Indoor environmental quality (IEQ), and Environmental Impact.
- Architecture examines how renovation strategies and technologies enhance energy efficiency.
- Indoor environmental quality evaluates how renovation strategies and technologies improve IEQ.
- Environmental impact considers how renovation strategies and technologies minimize environmental impacts.
- P&D also encompasses the development of a coherent renovation program and projects, whether single or partial, to achieve the ORO (Objectives of the Renovation).

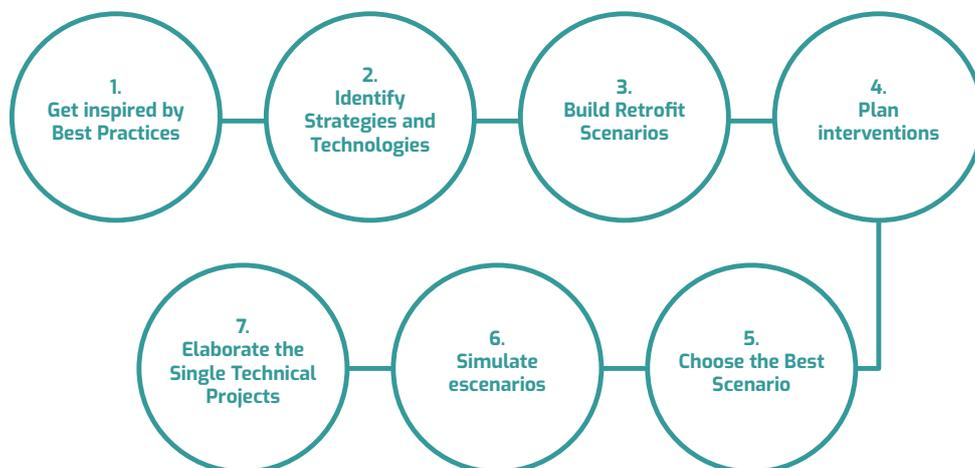
2.3.4.2. Who is involved?

The P&D phase is managed by an interdisciplinary group of researchers, including architects, involving both internal and external participants within the university context.



Figure 13: Main participants of the P&D phase. (Source: UNIFI)

2.3.4.1. How is it implemented?



1. Get Inspired by Best Practices

- Provide LL participants with an overview of innovative and eco-sustainable technologies for future building alignment.
- Define a collection of best practices related to Mediterranean European university building projects (renovation and new construction).
- Encourage local LLs to add local experiences to enrich the best practices collection.

2. Identify Strategies and Technologies

- Identify renovation strategies, technologies, and materials using the Abacus method.

- Engage local companies and experts to evaluate technological solutions.
- Evaluate appropriateness through dialogues with local entities, especially for historical buildings.
- Enrich the abacus with local technologies and materials.

3. Build Retrofit Scenarios

- Develop renovation scenarios integrating technologies to improve building performance.
- Construct scenarios based on satisfaction of renovation targets, costs, and various aspects.
- Configure three intervention scenarios (Low, Medium, High) to address critical aspects and transform them into strengths.

4. Simulate Scenarios

- Use simulation tools to analyse environmental and energy performance.
- Visualize building transformation with renovation technologies for different scenarios.
- Evaluate improvements in architectural quality, energy efficiency, indoor environmental quality, and environmental impact.

5. Choose the Best Scenario

- Perform Cost-benefit analysis and Multi Criteria analysis.
- Consider shared needs and effectiveness in achieving project goals.

6. Plan the Interventions

- Optimize economic resources for renovation projects over time.
- Choose between Whole-building approach or Staged approach based on system influence.
- Distribute retrofit interventions over time based on economic considerations.

Living Lab

- Requires coordination between university offices and building-equipment (b-e) managers.
- Provides technical knowledge and know-how to evaluate feasibility and convenience of interventions.
- Defines a renovation program with flexibility based on fund availability.

7. Elaborate the Single Technical Projects

- Finalize renovation projects following national or local procedures.
- Collaboration with managers, students, and stakeholders.
- Benefit from prior contacts with public organizations to facilitate the authorization process.

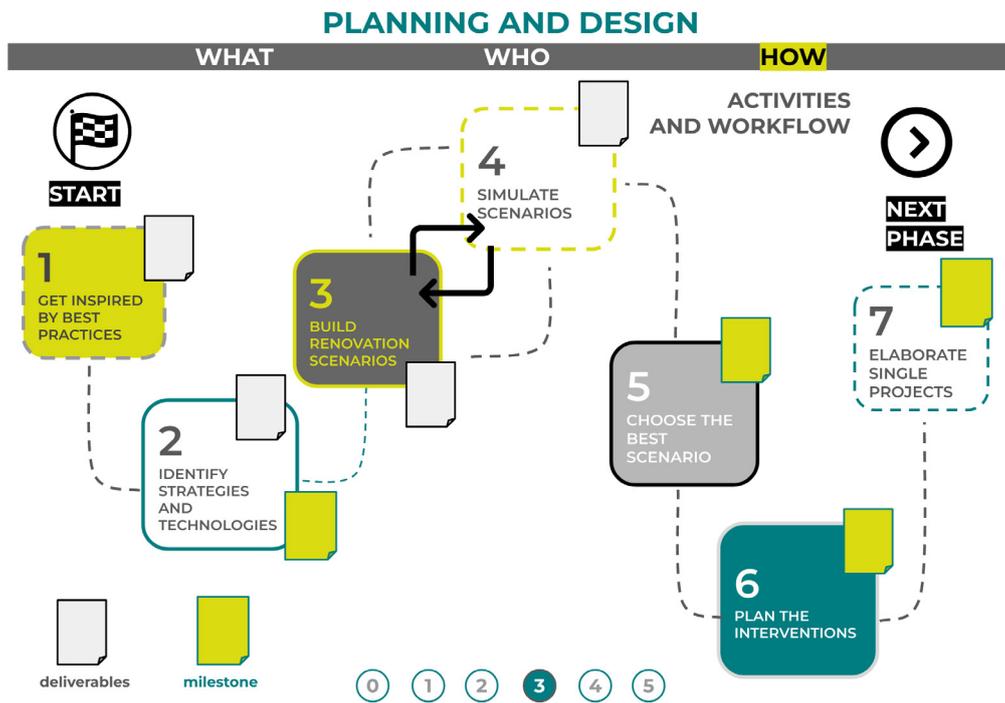
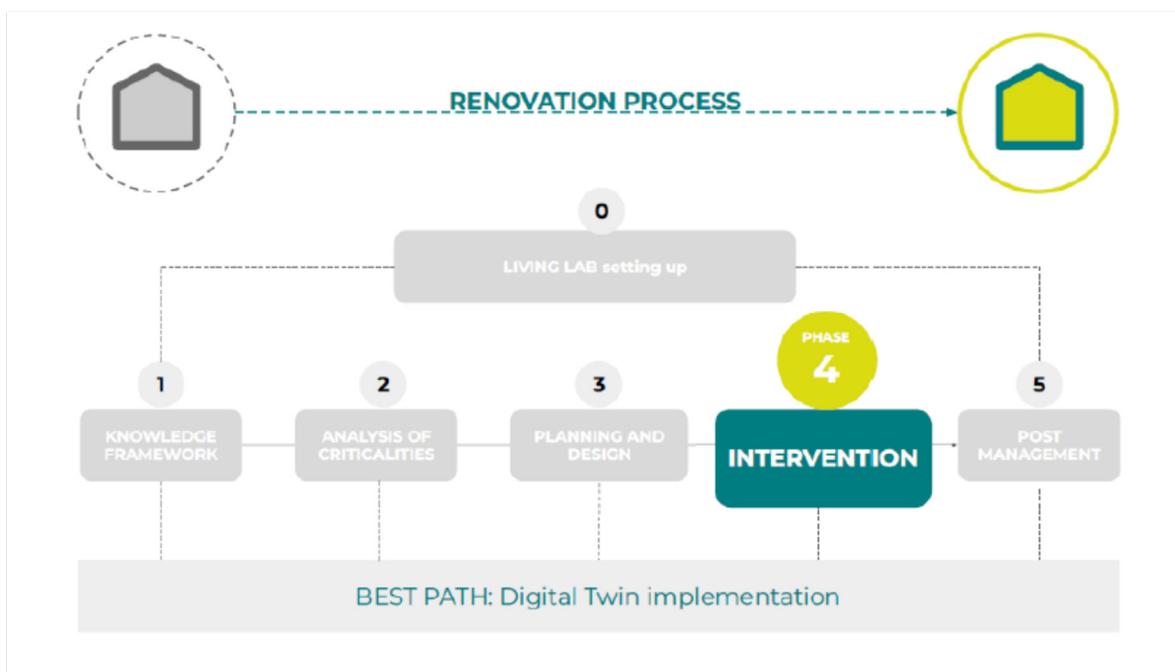


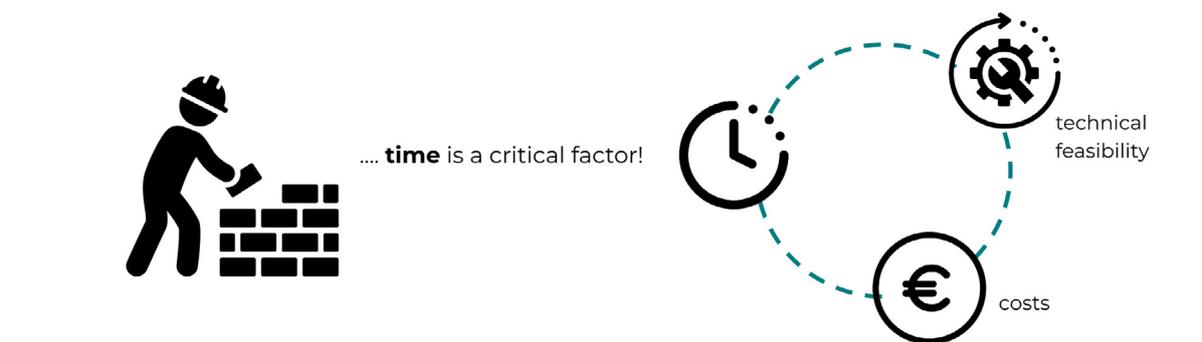
Figure 14: Steps in the P&D phase. (Source: UNIFI)

2.3.5. Phase 4: Intervention



- This phase follows the Planning and Design Phase 3 and involves construction to integrate selected technologies into an existing pilot building.
- It prepares the building for Phase 5 (post-management).

2.3.5.1. What is it? Intervention phase



- Activities range from project approval to physical renovation through technology integration.
- Retrofitting existing buildings can be complex, especially if the site is partially occupied, and time is critical.
- Planning is essential to optimize cost, time, and feasibility.

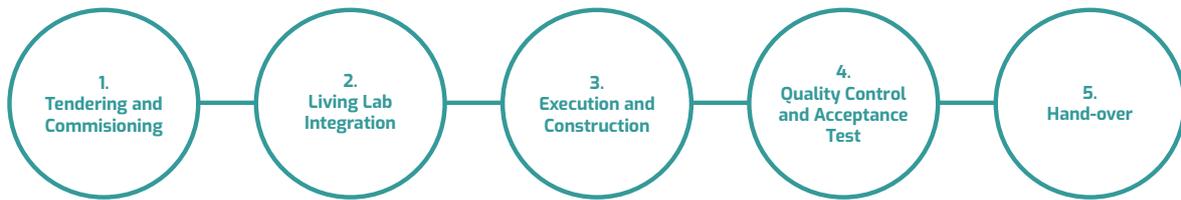
2.3.5.2. Who is involved?



Figure 15: Participants in the Intervention phase. (Source: UNIFI)

- Managed externally, mainly by stakeholders/contractors responsible for renovation.
- All Living Lab (LL) actors are engaged, aligning with LL's mission to support innovative renovation.

2.3.5.3. How is it implemented?



Activities in the Intervention phase:

1. Tendering and commissioning

- Selecting contractors for renovation works based on executive projects.
- Types of tendering: Open, Selective, Negotiated.
- Single-stage and Two-stage tendering methods.
- Commissioning process to ensure systems and components meet operational requirements.

2. Living Lab integration

- LL supports tendering document preparation and data collection.
- Construction companies involved in LL for quality and environmental impact awareness.

3. Execution and construction

- Delicate execution phase, ensuring correct installation.
- Careful integration of new technologies.
- Supervision required to mitigate risks.
- Focus on low environmental impact and waste management.

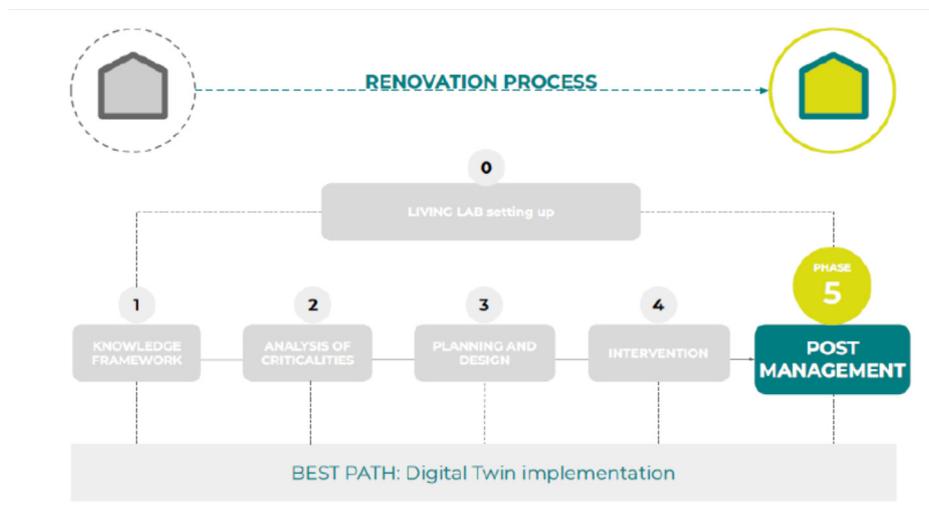
4. Quality control and Acceptance Test

- Ensuring correct renovation implementation.
- Visual and instrumental inspections for performance testing.
- Proper installation and testing of equipment like renewable technologies.
- Defect recognition, reporting, and corrective actions.
- Maintenance plans and qualified personnel checks.

5. Hand-over

- Delivering the renovated building to the client (university).
- Often underestimated but crucial.
- Handover checklist for collecting data, user manuals, warranties.
- "As-built report" milestone with all renovation technology documents.

2.3.6. Phase 5: Post-Management



2.3.6.1. What is it? Post-Management

- This phase focusses on ensuring ongoing management and operation of the renovated building.
- Requires adjustments in behavior and management practices.

2.3.6.2. Who is involved?



Figure 16: Participants in the Post-Management phase. (Source: UNIFI)

- Researchers: Support new procedures.
- Building/energy managers: Play a central role in innovating practices.
- Students: Engaged in the new life of the renovated building.
- Public organizations: Can valorize the experience.
- Companies: Provide innovative tools for building management.

2.3.6.3. How is it implemented?

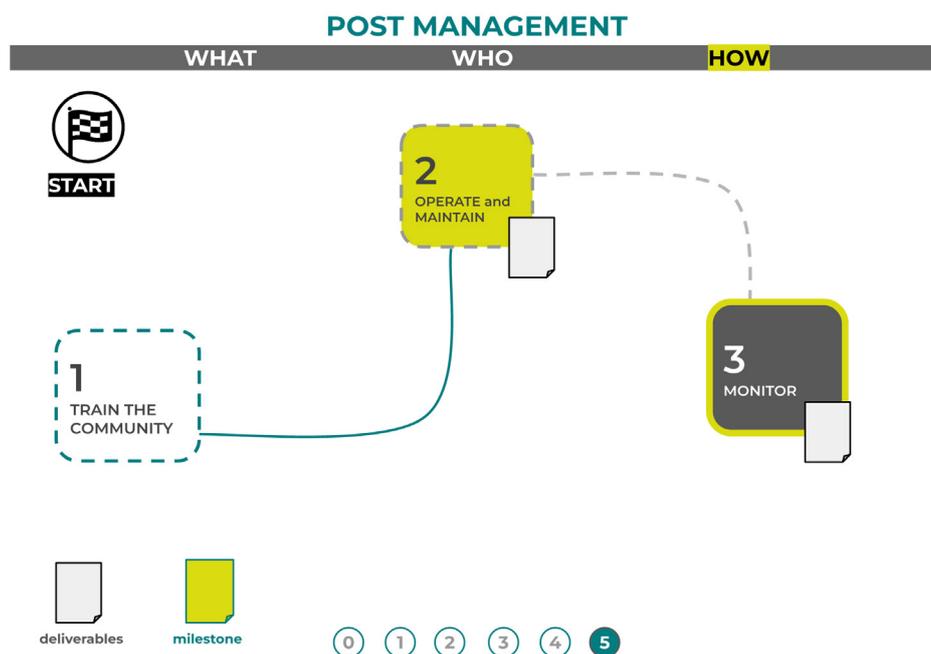


Figure 17: Steps in the Post-Management phase. (Source: UNIFI)

Activities in the Post-Management Phase

- Train the Staff
 - » Essential for maximizing performance.
 - » Staff training on new building systems and processes.
 - » Customized training programs based on needs assessment.

- Living Lab Integration
 - » Researchers and b-e managers collaborate for training.
 - » Companies providing technologies offer in-depth training.
 - » Students can be involved in post-management training.

- Monitor the Building
 - » Researchers and b-e managers collaborate for training.
 - » Companies providing technologies offer in-depth training.
 - » Students can be involved in post-management training.

- Optimize continuously
 - » Continuous improvement of building systems and processes.

3. Pilot Projects



3.1. Palestine: An-Najah National University (ANNU)

An-Najah National University consists of five campuses; namely, the New Campus, the Old Campus, Hisham Hijawi College of Technology, An-Najah National Hospital which are in Nablus, and Faculty of Agriculture and Veterinary Medicine building Campus in Tulkarem.

The pilot projects carried out at An-Najah National University (ANNU) are listed in the following table:

Site of Project	Action	Type of measure	Retrofit/New
Nablus Old Campus	Installation of a PV Generation and Distribution plant	Renewable energy generation	New project
Nablus New Campus: Faculty of Fine Arts	Construction of a PV Carport	Renewable energy generation	New project
Agriculture and Veterinary Medicine Building	Installation of a PV Generation and Distribution plant	Renewable energy generation	New project
Nablus New Campus	Construction of PV Tree	Renewable energy generation	New project
All Campus	50% Replacement of outdoor lamps to LED	Energy Efficiency	Retrofit project
All Campus	Substitution of two diesel boilers to gas	Energy Efficiency	Retrofit project

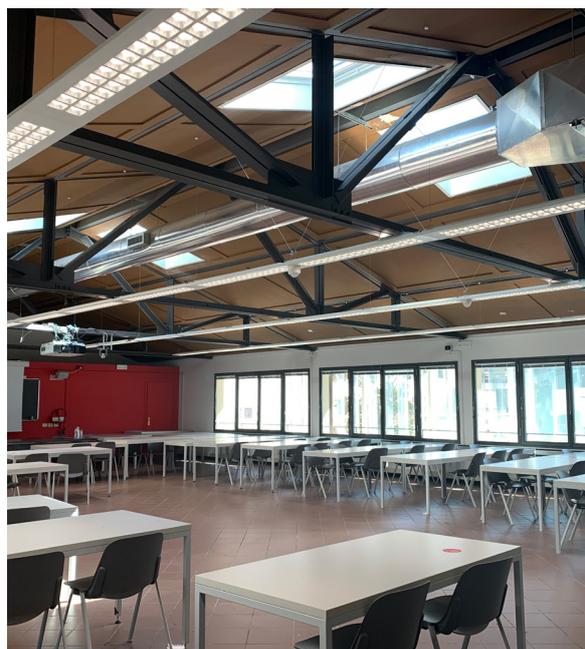


3.2. Italy: Università di Firenze (DIDA, UNIFI)

The Department of Architecture (DIDA) at the University of Florence (UNIFI) is a prestigious academic institution in Florence, Italy, dedicated to excellence in architecture education, research, and practice. Located in the heart of historic Florence, DIDA is known for its commitment to interdisciplinary, practice-oriented education and research.

The pilot projects carried out at DIDA, UNIFI are listed in the following table:

Site of Project	Action	Type of measure	Retrofit/New
School of Architecture	Pilot Project: Building Integrated PV system	Renewable energy generation and energy efficiency	New Glass-glass PV panels (90 u, ~6 kWp)
School of Architecture	Pilot Project: Structure PV panels	Renewable energy generation	New Structure with PV panels
School of Architecture	Pilot Renovation Project: Skylight system	Energy efficiency	Retrofit Opening of skylights
School of Architecture	Pilot Renovation Project: LED lamps and monitoring system	Energy efficiency	Retrofit LED lamps



3.3. Tunis: National Engineering School of Tunis (ENIT)

The National School of Engineers in Tunis, commonly known as Ecole Nationale d'Ingenieurs de Tunis (ENIT), stands as a prestigious institution at the forefront of engineering education and research in Tunisia. With a rich history dating back to its establishment, ENIT has consistently played a pivotal role in shaping the future of engineering professionals in the region. This venerable institution's commitment to excellence in both academic pursuits and innovation has earned it a well-deserved reputation as a beacon of engineering education in North Africa.

The pilot projects carried out at the National Engineering School of Tunis (ENIT) are listed in the following table:

Site of Project	Action	Type of measure	Retrofit/New
Research Unit "Qehna"	Installation of a Lab Micro-Grid equipped with an Energy Management System (SMARTNESS) Energy generation and trading	Renewable energy generation, distribution, monitoring, and exchange	New
Energy Building (Solar Lab + offices)	Renovation of windows (double glazing) Lighting (LED) Solar shading (exposed windows) Roof thermal insulation (interior)	Energy efficiency	Retrofit
Energy Building (parking + garden)	Installation of a Life-size Micro-Grid, equipped with an Energy Management System (EMS) and a Renewable Energy Certificate. PV Generation, Satellite Systems, Energy Management System, Energy Storage, Monitoring, Energy trading and Renewable Energy Certificates.	Renewable energy generation, storage, and distribution	New
Administration Building	Installation of roof thermal insulation Study for a PV generation and distribution system @ Courtyard	Energy efficiency and research	Retrofit
All school	Installation of a rooftop Solar PV generation and distribution system	Renewable energy generation and distribution	New
Teaching rooms and Energy Building	Electrification and replacement of old cooling and heating devices with high performance systems (13 units). Technical Specifications of split units: • Cooling capacity: 4950 W • Heating capacity: 5220 W	Energy efficiency	Retrofit



4. Results of Pilot Projects



4.1. Palestine: An-Najah National University (ANNU)

TUNIS: NATIONAL ENGINEERING SCHOOL OF TUNIS (ENIT)

Site of project	Description of the project	Capacity installed	Energy generated	Savings and CO ₂ emissions	Other benefits
Nablus Old Campus	Installation of a Grid-Tied PV Generation and Distribution plant. PV Generator: 145 kWp Inverters: 3x 50 kW	145 kW	200 MWh/year	<ul style="list-style-type: none"> • 11% building grid consumption • 92,5 k€/year • 170 tCO₂/year (compared to grid consumption) 	<ul style="list-style-type: none"> • Shadowed parking • Reduction of energy bills • Education and research • Reduced GHG emissions • Autonomy towards Grid • Employment generation • Available free shadow (with electricity) • Pioneering with innovative products (e.g., Solar Tree)
Nablus New Campus: Faculty of Fine Arts	Construction of a Grid-Tied PV Carport. PV Generator: 50 kWp Inverter: 50 kW (STP)	50 kW	70 MWh/year	<ul style="list-style-type: none"> • 8 k€/year • 52 t CO₂/year 	
Agriculture and Veterinary Medicine Building	Installation of a Grid-Tied PV Generation and Distribution plant. PV Generator: 77,8 kWp Inverter: 83 kW	78 kWp	105 MWh/year	<ul style="list-style-type: none"> • 60% building grid consumption • 27 k€/year • 121 t CO₂/year 	
Nablus New Campus	Construction of PV Tree	3,18 kWp	85 kWh/year		
All Campus	50% Replacement of Outdoor lamps to LED	440 u.		<ul style="list-style-type: none"> • 8 MWh/year • 5,6 t CO₂/year 	
All Campus	Substitution of two gas boilers to diesel			<ul style="list-style-type: none"> • 22,5 t CO₂/year 	
TOTAL		276 kWp 400 LED lamps 2 diesel boilers	381 MWh/year	127,5 k€ and 371,1 tCO ₂ 8 MWh	

4.2. Italy: Università di Firenze (DIDA, UNIFI)

ITALY: UNIVERSITA DI FIRENZE (UNIFI)

Site of project	Description of the project	Capacity installed	Energy generated	Savings and CO ₂ emissions	Other benefits
School of Architecture	Pilot Project: Building Integrated PV system Glass-glass PV panels (90 u., ~6 kWp)	6 kWp	7 MWh/year	3,66 t CO ₂ /year	<ul style="list-style-type: none"> • Shading and protection against solar irradiation • Education, research, and awareness raising (monitoring) • Innovation with glass-glass PV panels
School of Architecture				<ul style="list-style-type: none"> • 22,34 MWh/year • 11,67 t CO₂/year 	
School of Architecture	Pilot Project: 1. Structure PV panels 2. Skylight system 3. LED lamps and monitoring system 4. Monitoring system with more than 40 sensors to quantify environmental data (temperature, humidity, air quality, external weather, etc.) 5. App development			<ul style="list-style-type: none"> • Reduction of energy demand of the infrastructure (cooling and lighting) • 65% electricity consumption (compared to Neon) 	<ul style="list-style-type: none"> • Improvement of indoor comfort • Substitution of artificial lighting • Excellent data gathered on indoor air quality and comfort • Development of an App to visualize monitored data
School of Architecture					
TOTAL		6 kWp Skylight LED lamps Monitoring system	7 MWh/year	22,34 MWh 15,33 t CO ₂	

4.3. Tunis: National Engineering School of Tunis (ENIT)

TUNIS: NATIONAL ENGINEERING SCHOOL OF TUNIS (ENIT)

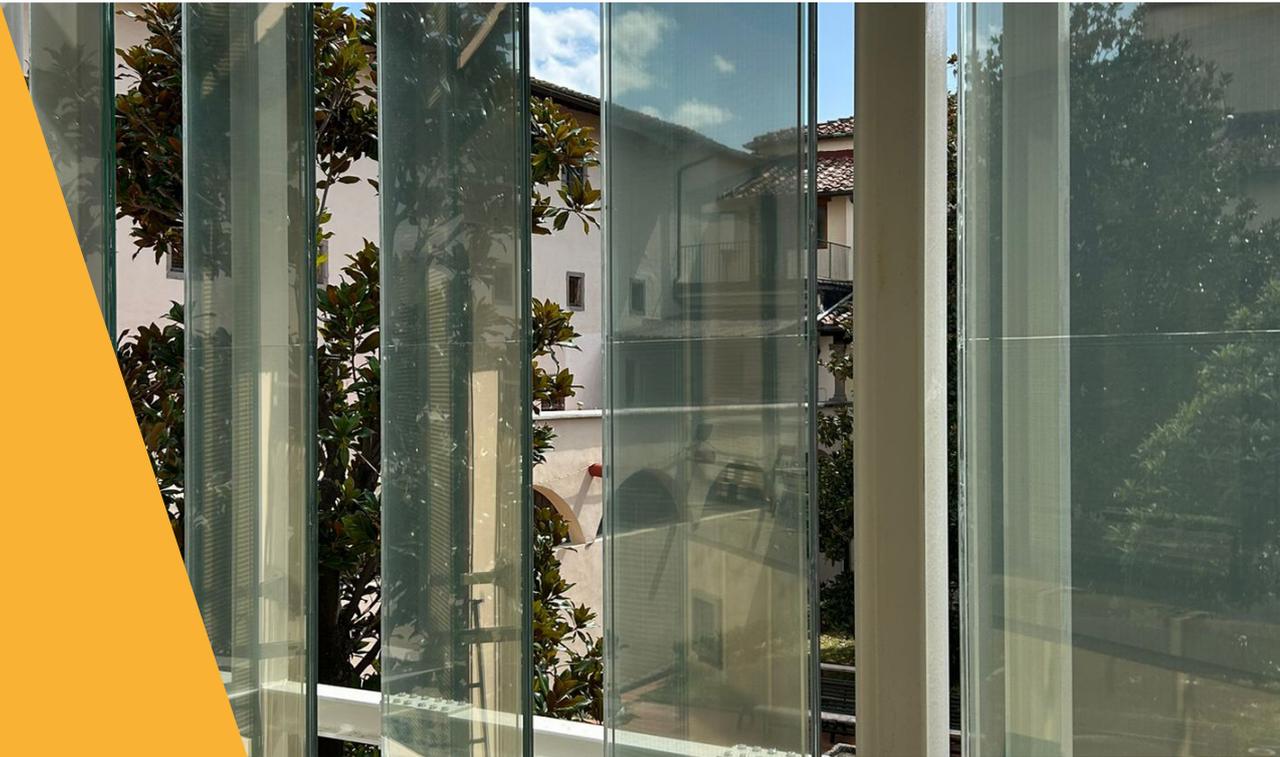
Site of project	Description of the project	Capacity installed	Energy generated	Savings and CO ₂ emissions	Other benefits
Research Unit "Qehna"	Installation of a Lab scale Micro-Grid (SMARTNESS) PV generator: 18 kWp Storage capacity: 7,2 kWh Inverter: 6kW	18 kWp	35,9 MWh/year		<ul style="list-style-type: none"> Education, research, training, and awareness raising Participation paper at the Eurosun conference 2022.
Energy Building (Solar lab + offices)	Renovation: <ul style="list-style-type: none"> Renovation of windows Lighting and solar shading space Thermal insulation in the roof 	<ul style="list-style-type: none"> Installation of 76 LED Lamps Double glazing windows (25 m²) Shading devices on the exposed windows. Thermal insulation of the roof (exterior) (100 m²) 		<ul style="list-style-type: none"> 11,76 MWh/year (LED lamps) 132 kWh/year (Windows glazing) 630 kWh/year (Shading devices) 50 kWh/year (Roof insulation) 	
Energy Building (parking + garden)	Installation of a Life scale Micro-Grid PV Generator: 21.5 kWp Storage capacity: 10 kWh Total Inverters (satellites) capacity: 21.5 kW Equipped with, Energy Management System, Monitoring	21 kWp	41,9 MWh/year	23,17 t CO ₂ /year	
Administration Building	Renovation project: <ul style="list-style-type: none"> Installation of roof thermal insulation 			Rooftop external insulation with PU 250 kWh/year	
All school	Installation of a rooftop Solar PV generation and distribution system	71,5 kWp	145,61 MWh/year	80,52 t CO ₂ /year	
Teaching Rooms	Electrification and replacement of old cooling and heating devices with high performance systems (13 units) specifications of split units: Cooling capacity: 4950 W Heating capacity: 5220 W			8,73 MWhh/year	<ul style="list-style-type: none"> Reduction of energy bills Education and research Reduced GHG emissions Autonomy towards Grid Employment generation Available free shadow (with electricity)
TOTAL		111 kWp	223,5 MWh/year	123,5 t CO ₂ /year 21,5 MWh/year 20.542 €/year	

Med-EcoSuRe Pilot Projects Results

Total installed energy generation capacity	393 kWp
Total energy generated	611,40 MWh/year
Total energy saved by implemented energy efficiency measures	56,84 saved MWh/year
Total reduction of CO ₂ emissions	509,93 t CO ₂ /year



5. Lessons Learned and Recommendations from Pilot Actions



- **Key Factors:** Follow a robust methodology, collaborate within a Living Lab, and engage local stakeholders and decision-makers from the outset.
- **Economic and Environmental Benefits:** Emphasize substantial cost savings and CO₂ reduction achieved through solar PV installations and retrofit actions.
- **Trends Driving Solar PV Adoption:** Consider factors like decreasing PV technology costs, rising electricity prices, financial incentives, carbon emission reduction, alternative financing options, air pollution concerns, and energy security priorities in project planning.
- **Achieving Energy Savings in Historical Contexts:** Demonstrate that significant energy savings and renewable energy production are achievable in historical buildings.
- **Innovative Solar Technologies:** Integrate innovative solar technologies and emphasize modularity, prefabrication, dry construction, and reversibility for sustainability and construction speed.
- **Raise Awareness:** Use events, training, and nudges to effectively raise awareness among target groups and beneficiaries for the adoption of solutions. Also, enable Real-World Experiences: Use pilot projects to stimulate discussions and provide real experiences. Enhance impact through tailored communication strategies and data visualization systems.
- **Engaging the Community:** Utilize proximity to the university to educate students and the public about innovative technologies and their benefits.
- **Engage Stakeholders:** Foster Alignment from the Start: Involve decision-makers, stakeholders, and users from the project's beginning within a Living Lab context for success.
- **Renovate Collaboratively with Excellence:** Utilize a robust methodology and acknowledge contributions from all Living Lab participants through co-design processes.
- **Knowledge Transfer:** Conduct information and capacity workshops to inspire similar strategies in other buildings.
- **Challenging Conventional Beliefs:** Be open to challenging traditional notions, such as the necessity of direct envelope interventions for energy savings.
- **Diverse Retrofit Scenarios:** Leverage extensive knowledge of existing buildings, dynamic analysis, and collaboration for innovative retrofit solutions.
- **Administrative Challenges:** Anticipate authorization procedures and public tender activation delays.
- **University Location's Significance:** Recognize the importance of a university location for catalyzing attention and engagement in public building renovations, especially in historical areas.
- **Prioritize Sustainability Beyond Efficiency:** Elevate ecological quality and sustainability, employing co-design practices and evidence-based data. Consider low-tech, high-tech, and nature-based strategies.
- **Prepare Feasibility Studies Early:** Prepare feasibility studies and tender documents at an early stage to prevent potential delays due to bureaucratic procedures.
- **Energy Manager/Building Manager:** Appoint an energy manager or building manager within the university for deployment and sustainability of implemented actions.
- **Focus on Renewable Energy (RE):** Prioritize RE measures over energy efficiency (EE) measures to reduce the electricity bill within the university effectively.
- **Smart Monitoring Devices:** Install smart monitoring devices to improve the building's performance.

